ANALYSIS OF FULL-BUILD TRAFFIC AND ENVIRONMENTAL IMPACTS MIDDLETOWN, RI

TOWN OF MIDDLETOWN R.I.
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EXECUTIVE SUMMARY

The objective of this report is to provide an analysis and evaluation of future impacts to the community as the Town of Middletown reaches a full-build scenario. This build-out analysis shows the composition and overall density of additional land development and resulting impacts if current local and State regulations remain in place. In addition to traffic, the study identifies potential impacts to surface runoff, groundwater quality and groundwater recharge. Once potential impacts are identified, recommendations are provided to address the anticipated impacts.

The Build-out analysis identified areas that are considered environmentally buildable and based upon a parcel's size, current allowed land uses and dimensional standards within the Town Zoning Code, projected the maximum potential residential housing units and commercial development. The estimated number of additional dwelling units is 1,916 and is identified in Table ES-1 by each Zoning District and Table ES-2 summarizes the projected square footage of additional commercial space. Additional scenarios are also provided in the report for development scenarios that exclude marginal lots, the potential of rezoning R-40 and R-60 Zones to R-100 and the exclusion of development within the Town's Watershed Protection District 1.

Table ES-1. Residential Dwelling Units by Zoning District with Current Zoning

Zone	Existing Dwelling Units	Additional Dwelling Units, Full-Build	Total Dwelling Units
R-10	2,724	250	2,974
R-20	1,672	226	1,898
R-30	276	247	523
R-40	878	414	1,292
R-60	267	174	441
Mobile / Transient	89	0	89
Multifamily	1,185	0	1,185
OS [1]	6	125	131
COM [2, 5]	348	423	674 [4]
P [3, 5]	354	57	411
Total	7,799	1,916	9,618

[1] OS is Open Space; Additional Dwelling Units reflect redevelopment of Wanumetonomy Country Club
[2] COM is General Business, Limited Business, Office Business, Office Park, and Light Industrial
[3] P is Public
[4] Not a direct sum. Some existing residential units in commercial zones are converted to commercial space through build-out
[5] Future development in commercial and public zones is part of mixed use development described in Commercial full-build results section

Table ES-2. Additional Commercial Space under Full-Build

Zone [1]	Full-Build with Current Zoning
Industrial	406,241
Office	936,304
Retail	1,311,497
Total	2,654,042

[1] Results for Residential development in mixed use category provided in Residential full-build results section.

Surface Water

The importance of surface water protection in Middletown is evident when it is recognized that 5,009 acres of the Town are within the Newport Water Supply Watershed. **Therefore, water quality directly impacts not only the environment but the public health of the 40,000 people that depend upon the Newport Water System as their water source**.

The evaluation of surface water quality impacts focused on the resulting change in impervious coverage and the resulting pollutant loadings in each of the Town's primary watersheds, including Upper East Passage, Lower East Passage, Sakonnet, Bailey Brook, Maidford, Paradise, Gardiner, Lower Maidford and Atlantic. Unfortunately, it was found that essentially all of the Town's watersheds are currently classified as impaired because pollutants exceed current standards. The existing impairments vary by watershed and include bacteria, nutrients, fecal coliform, lead, organic carbon, turbidity and other constituents. Therefore, even with 100% treatment of all new pollutant loadings from full-build development, watersheds will remain impaired unless improvements to existing systems are pursued.

Past national watershed studies have identified a correlation between a watershed's impervious percentage and water quality. Therefore, one aspect of this study was to compute the existing and future impervious percentage for each watershed to assess if the thresholds which indicate degradation would be exceeded. The analysis did reveal that certain watersheds would reach or exceed an impervious coverage threshold, thereby indicating noticeable degradation can be expected. The watersheds with the highest potential for impact include Lower East Passage 1, Sakonnet 1, Bailey Brook, Maidford and Paradise. The impervious coverage values are depicted in Figure ES-1.

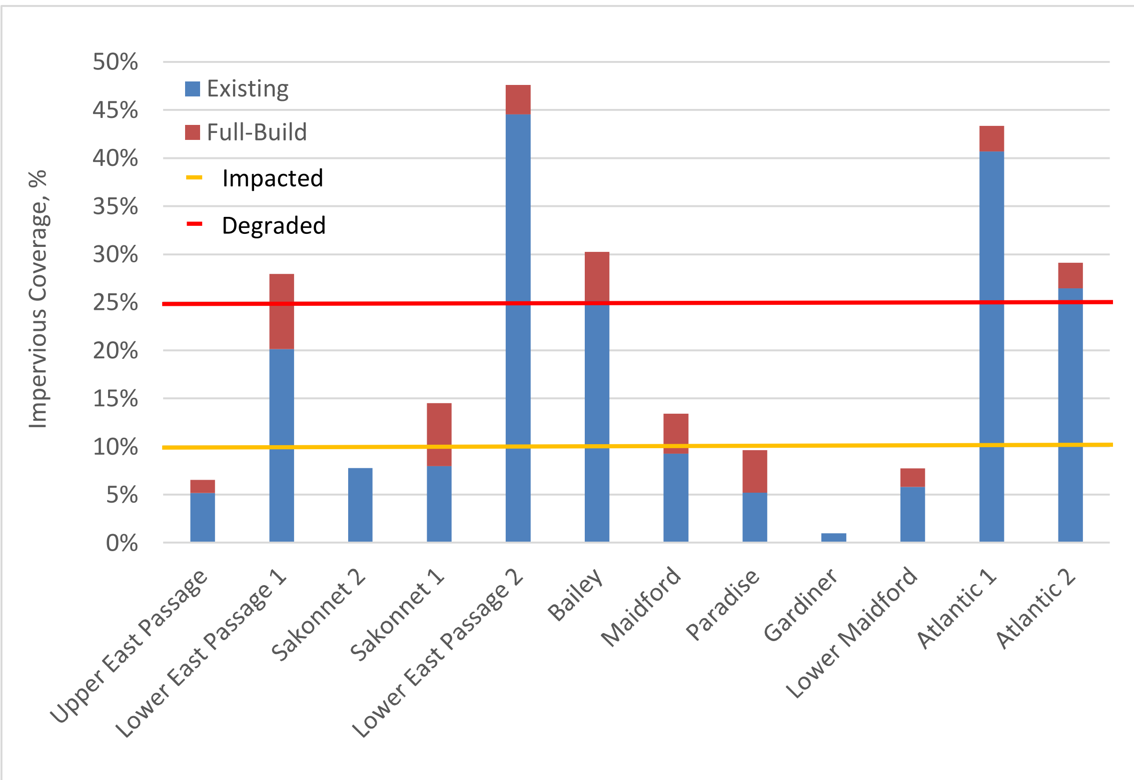


Figure ES-1. Existing and Full-build Impervious Coverage by Watershed

In addition to computing the increase in impervious coverage due to full-build, the increase in pollutant loadings per watershed were also computed for Total Nitrogen, Total Phosphorous, Total Suspended Solids, Fecal Coliform, Lead and Copper. The most dramatic increases are expected for Fecal Coliform and Lead based on runoff patterns and pollutant levels, as summarized in Table ES-3. The modeling results reflect pollutant loading not mitigated by stormwater treatment. Loads will be lower than predicted for future conditions where developers abide with the State and Town stormwater treatment requirements.

Table ES-3. Projected Increase (%) in Fecal Coliform and Lead

Watershed	Fecal Coliform	Lead
Sakonnet 1	69%	70%
Maidford	42%	35%
Paradise	84%	44%
Lower East Passage 1	31%	36%
Lower Maidford	82%	87%

For stormwater systems that are designed to conform to current RIDEM and Town Standards, the systems are expected to provide the following pollutant load reduction from new development runoff: 85% for suspended solids, 30% for nitrogen and phosphorus, and 60% for pathogens, including pathogenic bacteria. Current standards also state that stormwater systems may be required to achieve a higher pollutant removal rate for impaired receiving waters, drinking water reservoirs, bathing beaches, shell fishing grounds, Outstanding National Resource Waters, including Special Area Management Plans (SAMPs) or where TMDLs have been prepared. These more stringent design criteria need to be enforced for all new development concurrently with the implementation of strategies to improve the quality of runoff from existing development. CE provides the following specific recommendations to address stormwater concerns for the Town:

1. Develop a community outreach program to raise awareness and to gain business and public support to address existing watershed impairments.
2. Continue to encourage low impact development (LID) development strategies that minimize impervious area creation.
3. Recognize that stormwater mitigation designs based upon current standards do not fully remove pollutants of concern and identify specific target pollutant removal efficiencies that should be achieved based upon watershed specific impairments.
4. Promote source reduction (stormwater recharge/infiltration) strategies to reduce stormwater discharge from new development.
5. Establish a Fertilizer Nutrient Control Ordinance to minimize excess nitrogen and phosphorous loadings from existing lands and new developments.
6. Establish routine water quality testing of Town stormwater systems to assist in the identification of existing pollutant sources. Identify significant pollutant sources and work towards implementation of improvements.

7. Identify streams and waterways that experience erosion (sediment transport) for permanent stabilization projects.
8. Identify opportunities to improve discharge of existing development through retrofit of existing stormwater systems.
9. Evaluate the feasibility of establishing a Town Stormwater Utility for improved operations, maintenance and performance of current and future stormwater systems.
10. Work towards development of watershed hydrologic and hydraulic models to allow for more accurate evaluation of land development impacts and mitigation benefits.

Groundwater

Land development and the resulting increase in impervious coverage also has the potential to impact groundwater resources and in turn, impact drinking water wells and recharge to wetlands and streams. Currently, it is estimated that 1,000 private wells are in use today and under full-build conditions, the number will increase to 1,500. The distribution of wells across watersheds is shown in Figure ES-2.

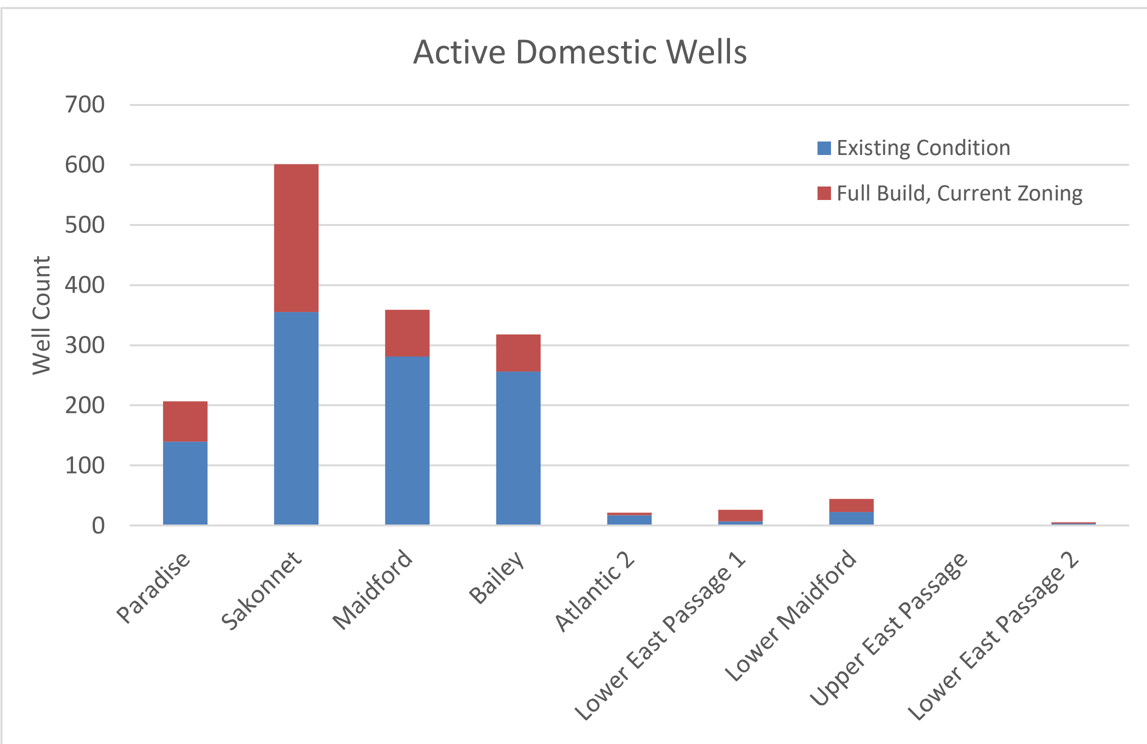


Figure ES-2. Existing and Future Domestic Well Count in Middletown by Watershed, Full-Build with Current Zoning

To assess the potential for full-build groundwater impacts, changes to the hydrologic balance, existing and future groundwater demands, and groundwater nitrate loadings were computed. The overall net decrease in groundwater recharge due to new unmitigated impervious area was highest in the Lower East Passage 1 Watershed with a 10% reduction. Figure ES-3 addresses the loss in groundwater recharge for each watershed. With stormwater systems that conform to current RIDEM and Town Standards, the groundwater recharge reductions in Figure ES-3 will be significantly reduced and will be near existing conditions on an annual basis if properly maintained and functioning.

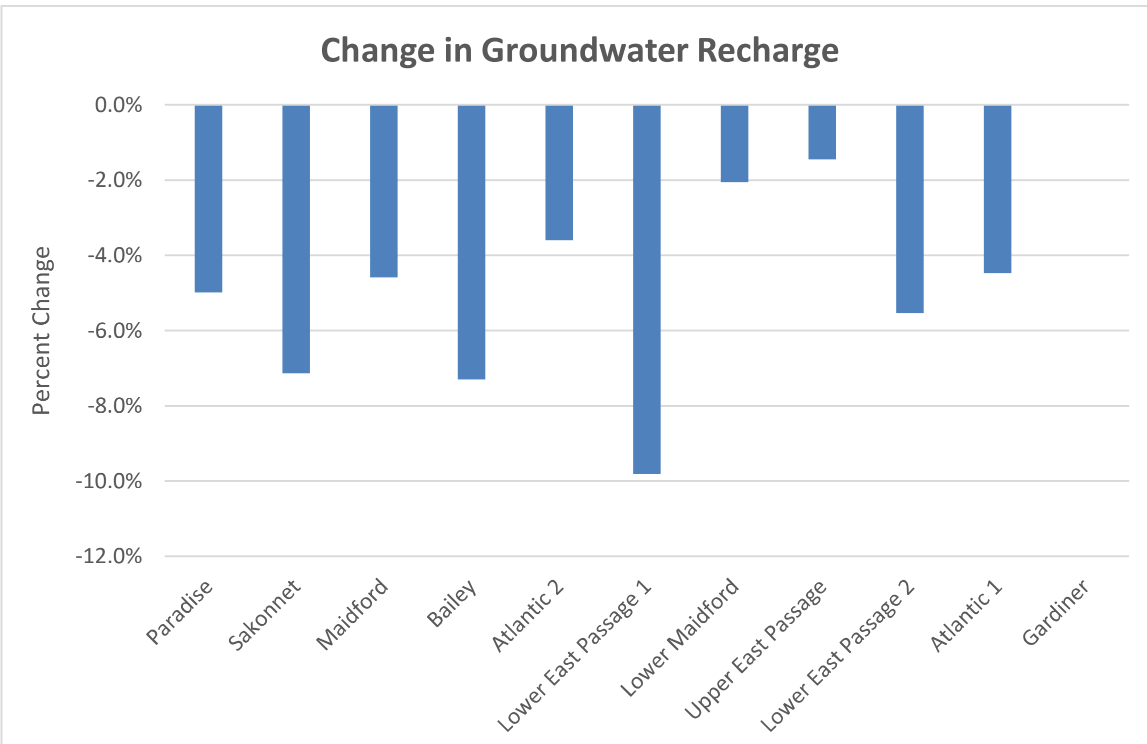


Figure ES-3. Change in Annual Groundwater Recharge per Watershed for Full-Build with Current Zoning with no Recharge Mitigation

In regards to water withdrawal within each watershed due to private wells for domestic use, Figure ES-2 clearly shows that Sakonnet 1 Watershed will experience the greatest increase in new private wells from 350 to approximately 600. This results in an additional groundwater withdrawal of approximately 44 acre-feet within the Sakonnet 1 Watershed. As shown in Figure ES-4, the additional withdrawals are significantly less in other watersheds.

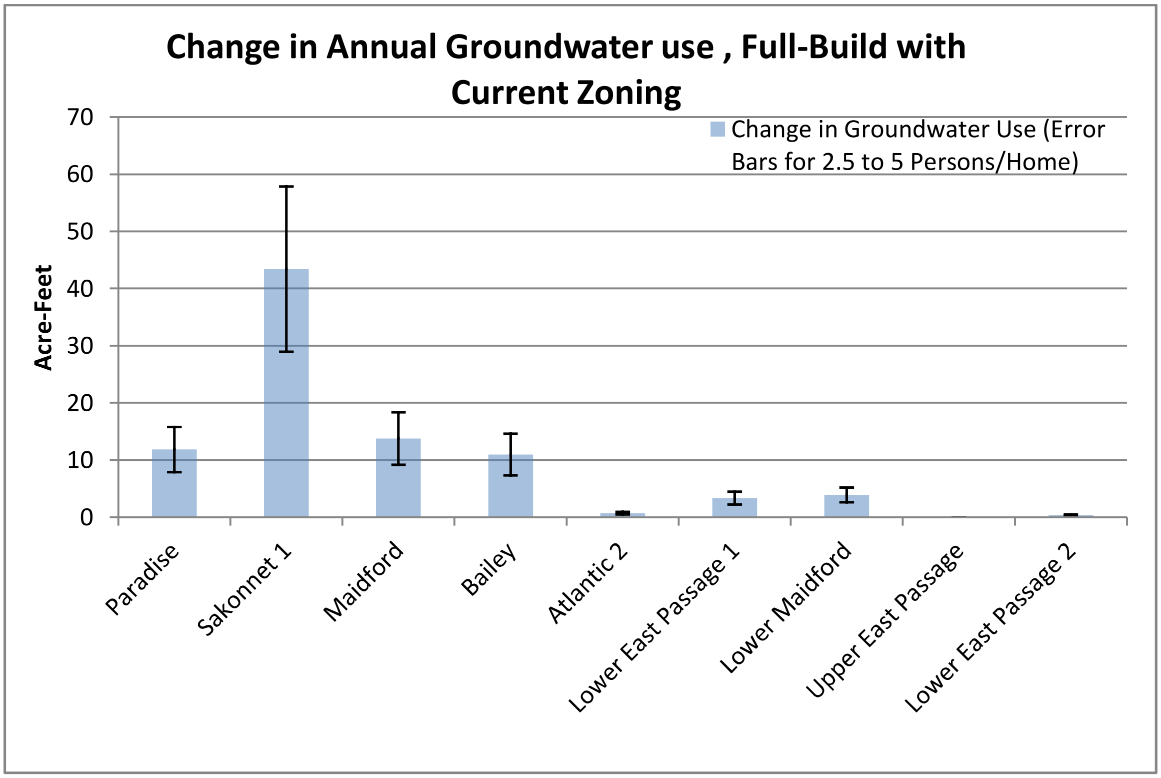


Figure ES-4. Change in Private Domestic Water Use under Full-Build, Current Zoning

The overall average annual groundwater recharge evaluation conceptually suggests that domestic water use will not exceed groundwater resources on an annual basis for an average year on a watershed basis but it must be recognized that not all water stored within bedrock fissures will be available due to lack of interconnectivity of bedrock fissures. With the clustering of homes in conservation style developments an evaluation is needed to determine the minimum lot size necessary to support a private well and an on-site septic system. Differing lot size standards should be considered for lots with and without public water and/or public sewer.

Groundwater quality is as important as groundwater supply; therefore, CE also assessed the existing and potential future number of on-site septic systems and the resulting Nitrate loading. As summarized in Figure ES-5 it is estimated that the number of on-site wastewater treatment systems will increase from 810 to 1,488 in Middletown.

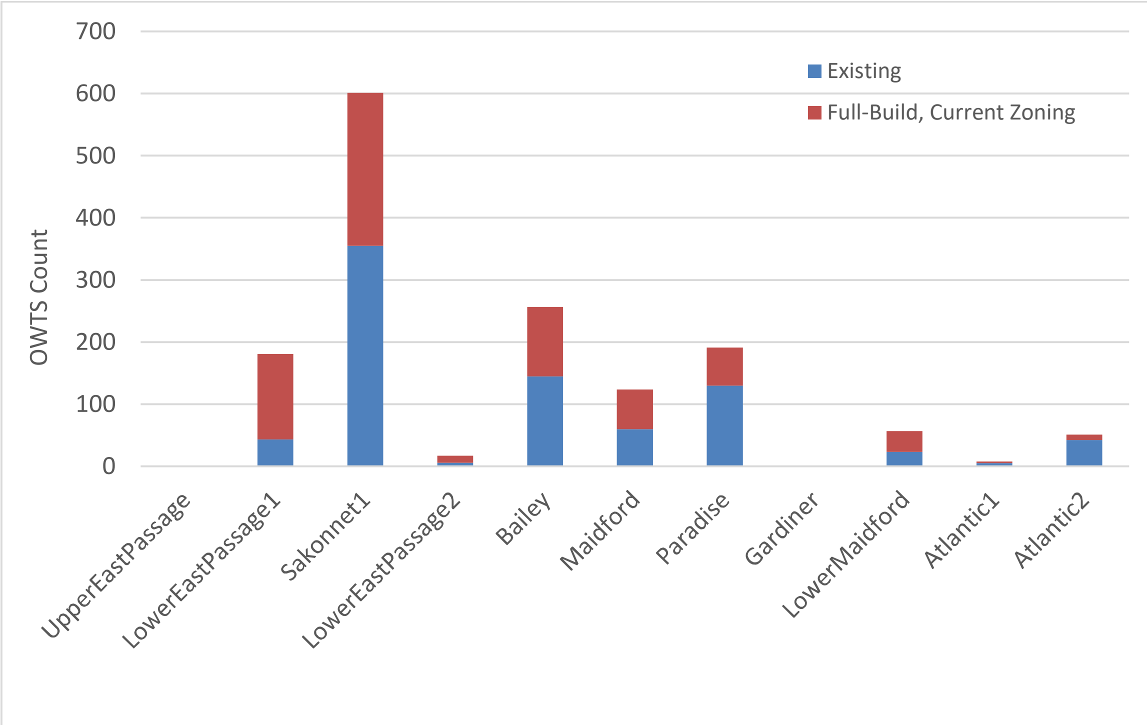


Figure ES-5. On-Site Wastewater Treatment System (OWTS) Count per Watershed

Based upon a Nitrate loading forecast and recognizing the State of Rhode Island preventative action limit of 5 mg/L, the Sakonnet 1 and Paradise watersheds have the highest potential of groundwater degradation due to septic systems. Values can be found in Figure ES-6 but it must be recognized that localized exceedances can occur. The watershed assessment represents a watershed average. The use of advanced treatment systems can reduce this potential impact.

Similar to the existing surface water quality issue that persists in Middletown watersheds, the Rhode Island Department of Health previously confirmed that segments of Town have experienced elevated levels of nitrate, potentially due to past agricultural activities. The full extent and perpetuation of elevated levels should be examined as future private wells are considered for new development.

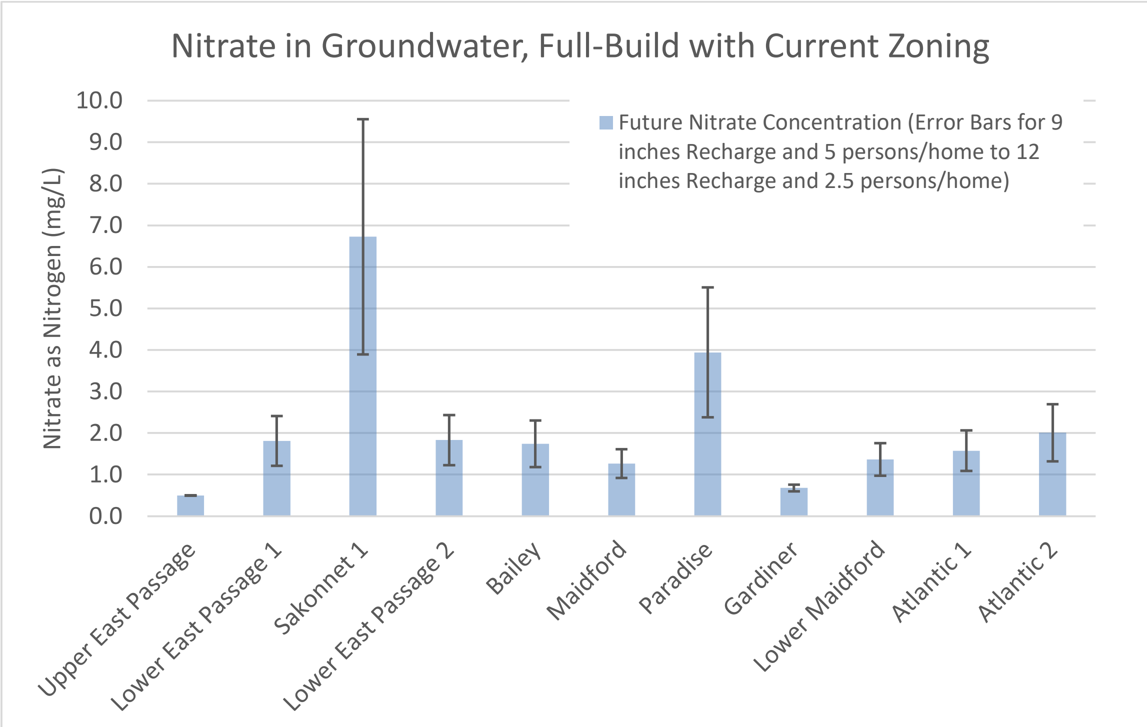


Figure ES-6. Nitrate Concentrations in Middletown by Watershed for Full-Build under Current Zoning

New development must be examined with respect to stresses on limited groundwater resources in Middletown. A significant portion of eastern Middletown depends on these resources for drinking water and agricultural use and also depends on the use of OWTS for wastewater disposal, which can contaminate groundwater if not designed and maintained properly. CE provides the following specific recommendations for improving management and protection of the Town's groundwater resources:

1. Develop a community outreach program to raise awareness and to gain business and public support to identify and address existing groundwater impairments.
2. Avoid or minimize the granting of waivers to the Town's Stormwater Standards, especially in public water supply watersheds.
3. The Stormwater design Recharge Standard is currently satisfied with a system that is sized to capture and recharge a specific volume of rainfall at the time of its installation but the Standard does not address the decrease in performance following initial installation. Performance can be significantly reduced in advance of the currently required threshold for maintenance. The Recharge Standard should be increased to address diminished performance over the life of the system.

4. 4Consider the installation of a series of groundwater monitoring wells throughout the Town to allow for long term seasonal collection of groundwater levels, quality and trends.
5. Surveys of homes with on-site wells should be taken to document private well data and the occurrence of well water supply issues and identify a point of contact for residents to inform of future well related issues.
6. Encourage water quality testing of private wells by homeowners through an educational awareness program and retain data in a Town database for future groundwater evaluations.
7. Develop an OWTS educational program for residents to ensure that the State required maintenance standards are being performed and consider enacting an Onsite Wastewater Management Ordinance with a goal of ensuring proper maintenance to elongate a system's life, minimize system failure, providing proper treatment to protect groundwater resources, and allowing residents to benefit from low-interest State loans for repairs if funds are available.
8. Evaluate the allowed lot size for new parcels with OWTS and/or wells based upon sanitary flow rate, soil conditions, and nitrate loading. This evaluation should also address the minimum lot sizes for Conservation style developments to prevent localized exceedances.
9. Consider Dimensional Zoning Requirements that address the differing needs for lots with and without public water, public sewer and both public water and sewer.
10. Perform town-wide groundwater quality testing to document conditions and needs for public water extensions.
11. Review historical records of OWTS failures or need for repair to assess future needs for public sewer extensions.
12. In future years, amend stormwater recharge and other stormwater design standards as changes in precipitation intensity and frequency occur.

Traffic

Potential traffic impacts from full-build were also analyzed with input from the Town of Middletown. After identifying representative intersections and roadways, the assessment generally involved three (3) steps and compared traffic conditions in 2019 to those projected under full-build.

- Documenting existing conditions including an inventory of roadway geometry, observed traffic volumes, and safety characteristics, including a review of available accident data.
- Forecasting of future year traffic volumes.
- Analyzing operational characteristics of primary intersections, with specific attention given to quantifying the incremental impacts of additional traffic due to development.

The primary intersections and adjacent roads of study included:

- Greene Lane / Pasture Farm Drive / West Main Road (RI 114) - ***signalized***
- Oliphant Lane / West Main Road (RI 114) - ***signalized***
- Oliphant Lane / East Main Road (RI 138) - ***signalized***
- Aquidneck Avenue / East Main Road (RI 138) - ***signalized***
- Forest Avenue / West Main Road (RI 114) - ***signalized***
- Forest Avenue / East Main Road (RI 138) - ***signalized***
- Valley Road / West Main Road (RI 114) - ***signalized***
- Valley Road / East Main Road (RI 138) - ***signalized***
- Coddington Highway / Rockwood Road / West Main Road (RI 114) - ***signalized***
- West Main Road (RI 114) / East Main Road (RI 138) - ***signalized***
- Valley Road / Miantonomi Avenue/ Green End Avenue - ***signalized***
- Valley Road / Aquidneck Avenue - ***signalized***
- Purgatory Road / Aquidneck Avenue/ Memorial Boulevard - ***signalized***
- Green End Avenue / Paradise Avenue / Berkeley Avenue – ***unsignalized – stop on Berkeley Avenue and Paradise Avenue***
- Third Beach Road / Wapping Road / Mitchell's Lane -– ***unsignalized – yield on Third Beach Road***

Based upon the projected full-build development of residential, commercial, industrial and mixed use, the increased hourly traffic volumes were determined and are summarized in Table ES-4, and in order to distribute the increased traffic volumes on the Town roadways, existing traffic counts and the Journey to Work Data from the U.S. Census Bureau was utilized as a guide. The data is provided in Table ES-5.

Table ES-4. Future Trips Resulting from Build-Out

	AM Peak hour trips*			PM Peak hour trips*		
	Total	Entering	Exiting	Total	Entering	Exiting
Residential	1,063	266	797	1,422	896	526
Industrial	164	133	31	164	34	130
Mixed Use	1,102	624	478	2,516	1,081	1,435
Office Park	152	123	29	152	32	120
Office / Business	172	148	24	170	27	143
Retail	782	485	297	3,169	1,521	1,648
Total Trips	**3,435**	**1,779**	**1,656**	**7,593**	**3,591**	**4,002**

*It should be noted that not all trips generated will be distributed along the study area streets analyzed for capacity

Table ES-5. Journey to Work Data, U.S. Census Bureau 2011-2015 American Community Survey

Where Middletown Residents Work			Where Middletown Workers Live		
Total	7,999	100.0%	Total	11,207	100.0%
Newport, RI	3,194	39.9%	Middletown, RI	2,844	25.4%
Middletown, RI	2,844	35.6%	Newport, RI	1,565	14.0%
Portsmouth, RI	353	4.4%	Portsmouth, RI	1,552	13.8%
Providence, RI	196	2.5%	Tiverton, RI	743	6.6%
North Kingstown, RI	115	1.4%	Bristol, RI	604	5.4%
South Kingstown, RI	108	1.4%	Fall River, MA	557	5.0%
Bristol, RI	99	1.2%	North Kingstown, RI	397	3.5%
Warwick, RI	68	0.9%	Warwick, RI	249	2.2%
Fall River, MA	57	0.7%	South Kingstown, RI	217	1.9%
Exeter, RI	56	0.7%	Cranston, RI	181	1.6%
Pawtucket, RI	52	0.7%	Warren, RI	175	1.6%
Tiverton, RI	48	0.6%	Jamestown, RI	159	1.4%
Jamestown, RI	46	0.6%	Johnston, RI	134	1.2%
Cranston, RI	43	0.5%	Narragansett, RI	133	1.2%
East Greenwich, RI	42	0.5%	Dartmouth, MA	118	1.1%
Dartmouth, MA	35	0.4%	Exeter, RI	115	1.0%
East Providence, RI	32	0.4%	Providence, RI	106	0.9%
Sandwich, MA	32	0.4%	East Providence, RI	74	0.7%
Westerly, RI	32	0.4%	North Attleboro, MA	69	0.6%
Other Communities	547	6.9%	New Bedford, MA	63	0.6%
			Other Communities	1,152	10.3%

Middletown Residents Work in the State of:			Middletown Workers Live in the State of:		
Rhode Island	7,445	93.1%	Rhode Island	9,821	87.6%
Massachusetts	385	4.8%	Massachusetts	1,133	10.1%
Connecticut	14	0.2%	Connecticut	182	1.6%
Other State/Country	155	1.9%	Other State/Country	71	0.6%
	7,999	100.0%		11,207	100.0%

The traffic evaluation concludes that the future build-out will have significant impacts on many of the signalized intersections. Optimizing the signal timing will provide some level of improvement but more significant mitigations such as changes in signal phasing and geometry changes, such as re-striping, road widening and conversion to roundabout at certain locations, should be considered in the future to improve capacity. The redesign of Aquidneck Avenue / Valley Road intersection from a signal to a roundabout should provide good level of service (LOS) in the future. The stop approaches of Berkeley Avenue and Paradise Avenue at Green End Avenue will need mitigation in the future and a roundabout should be considered at a later time if warranted. The unsignalized intersection of Third Beach Road / Mitchell's Lane / Wapping Road is not expected to be impacted by the future full-build scenario.

Overall, the greatest impacts on future traffic will occur during the PM Peak hour at most locations that remain signalized. Several signalized locations will deteriorate in capacity during the AM Peak as well but most will remain a good overall LOS of C or D. Tables ES-6 – ES-8 provide locations and time periods where future build-out will have the greatest impact on traffic and where improvements will be needed:

Table ES-6. Signalized Level-Of-Service Analysis Summary, High Impact Intersections, AM Peak Hour

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
W. Main Rd / Oliphant Ln	**OVERALL**	**0.70**	**15.7**	**B**	**1.07**	**92.7**	**F**	**0.99**	**64.1**	**E**
Oliphant Ln	WB	0.68	29.8	C	0.75	42.1	D	0.74	42.1	D
W. Main Rd (RI 114)	NB	0.61	16.4	B	1.03	68.4	E	0.97	49.2	D
W. Main Rd (RI 114)	SB	0.70	13.3	B	1.17	117.2	F	1.07	77.6	E
W. Main Rd / Forest Ave	**OVERALL**	**0.82**	**20.1**	**C**	**1.23**	**121.2**	**F**	**1.15**	**96.6**	**F**
Forest Ave	WB	0.74	44.9	D	0.83	50.5	D	0.82	48.9	D
W. Main Rd (RI 114)	NB	0.58	16.4	B	0.88	31.9	C	0.83	29.8	C
W. Main Rd (RI 114)	SB	0.84	18.1	B	1.35	191.5	F	1.26	148.0	F
E. Main Rd / Oliphant Ln	**OVERALL**	**0.79**	**26.6**	**C**	**1.01**	**111.2**	**F**	**0.97**	**91.8**	**F**
E. Main Rd (RI 138)	NB	0.50	6.3	A	0.61	8.9	A	0.59	8.4	A
E. Main Rd (RI 138)	SB	0.98	35.3	D	1.33	176.9	F	1.26	144.1	F

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
Oliphant Ln	SE	0.42	29.0	C	0.74	37.8	D	0.69	34.5	C
Hotel Driveway	NW	0.04	26.6	C	0.04	24.1	C	0.04	24.6	C
E. Main Rd / Forest Ave / Ramada	**OVERALL**	**0.72**	**21.2**	**C**	**0.84**	**35.1**	**D**	**0.81**	**31.1**	**C**
E. Main Rd (RI 138)	EB	0.36	8.5	A	0.43	12.5	B	0.42	14.7	B
E. Main Rd (RI 138)	WB	0.71	17.6	B	0.79	18.3	B	0.78	16.9	B
Hotel Driveway	NB	0.04	24.7	C	0.04	25.7	C	0.04	25.4	C
Forest Ave	SB	0.87	53.0	D	1.14	130.1	F	1.08	107.2	F

Table ES-7. Signalized Level-Of-Service Analysis Summary, High Impact Intersections, PM Peak Hour

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
PM PEAK HOUR										
W. Main Rd / Greene Ln / Pasture Farm Dr	**OVERALL**	**0.70**	**21.8**	**C**	**1.47**	**297.9**	**F**	**1.36**	**242.0**	**F**
Greene Ln	EB	0.67	39.8	D	0.69	39.7	D	0.68	39.6	D
Pasture Farm Dr	WB	0.01	31.9	C	0.02	31.4	C	0.02	31.4	C
W. Main Rd (RI 114)	NB	0.71	19.6	B	1.53	276.5	F	1.41	224.5	F
W. Main Rd (RI 114)	SB	0.69	21.1	C	1.73	355.5	F	1.58	290.0	F
W. Main Rd / Oliphant Ln	**OVERALL**	**0.95**	**44.2**	**D**	**1.54**	**273.7**	**F**	**1.44**	**226.3**	**F**
Oliphant Ln	WB	0.96	89.4	F	1.46	270.4	F	1.38	236.5	F
W. Main Rd (RI 114)	NB	1.00	49.4	D	1.58	296.0	F	1.49	252.2	F
W. Main Rd (RI 114)	SB	0.73	26.2	C	1.44	241.9	F	1.32	186.6	F
W. Main Rd / Forest Ave	**OVERALL**	**0.94**	**40.6**	**D**	**1.52**	**325.1**	**F**	**1.41**	**269.3**	**F**
Forest Ave	WB	0.72	44.5	D	0.86	53.7	D	0.83	50.9	D
W. Main Rd (RI 114)	NB	1.05	58.3	E	1.69	337.4	F	1.58	288.4	F
W. Main Rd (RI 114)	SB	0.85	15.6	B	1.73	347.6	F	1.57	276.7	F
W. Main Rd / Valley Rd	**OVERALL**	**0.90**	**19.3**	**B**	**1.83**	**151.6**	**F**	**1.67**	**121.1**	**F**
Valley Rd	WB	0.83	33.3	C	1.55	260.6	F	1.43	211.2	F
W. Main Rd (RI 114)	NB	0.83	24.6	C	1.28	155.5	F	1.21	121.8	F
W. Main Rd (RI 114)	SB	0.87	10.7	B	1.83	112.7	F	1.67	90.8	F
W. Main Rd / Coddington Hwy	**OVERALL**	**0.66**	**32.4**	**C**	**0.98**	**107.5**	**F**	**0.91**	**81.6**	**F**
Coddington Hwy	EB	0.72	44.7	D	1.02	74.3	E	0.96	63.3	E
Rockwood Rd	WB	0.52	54.8	D	0.52	54.8	D	0.52	54.8	D
W. Main Rd (RI 114)	NB	0.53	20.2	C	0.55	22.1	C	0.55	22.1	C
W. Main Rd (RI 114)	SB	0.77	34.2	C	1.34	163.2	F	1.24	120.4	F
W. Main Rd / E. Main Rd	**OVERALL**	**0.73**	**40.6**	**D**	**1.05**	**122.0**	**F**	**1.00**	**103.0**	**F**
E. Main Rd	EB	0.64	56.7	E	0.64	56.7	E	0.64	56.7	E
E. Main Rd (RI 138)	WB	0.69	48.1	D	0.67	42.8	D	0.66	43.0	D
W. Main Rd (RI 114)	NB	0.75	36.0	D	1.40	223.9	F	1.31	186.5	F

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
PM PEAK HOUR										
W. Main Rd (RI 114)	SB	0.83	37.6	D	1.20	66.6	E	1.09	53.8	D
E. Main Rd / Oliphant Ln	**OVERALL**	**0.89**	**30.9**	**C**	**1.27**	**174.0**	**F**	**1.20**	**145.0**	**F**
E. Main Rd (RI 138)	NB	0.95	24.7	C	1.38	189.6	F	1.30	156.8	F
E. Main Rd (RI 138)	SB	0.93	42.3	D	1.33	180.6	F	1.26	152.5	F
Oliphant Ln	SE	0.63	32.3	C	0.97	70.2	E	0.92	57.4	E
Hotel Driveway	NW	0.05	25.2	C	0.04	21.9	C	0.04	22.2	C
E. Main Rd / Aquidneck Ave	**OVERALL**	**0.86**	**30.8**	**C**	**1.35**	**120.7**	**F**	**1.26**	**100.0**	**F**
E. Main Rd (RI 138)	EB	1.00	40.9	D	1.26	141.5	F	1.22	122.0	F
E. Main Rd (RI 138)	WB	0.67	12.7	B	1.44	108.8	F	1.35	90.4	F
Aquidneck Ave	NB	0.84	37.6	D	1.23	116.6	F	1.14	90.7	F
Plaza / Bank	SB	0.14	22.0	C	0.12	18.1	B	0.11	18.1	B
E. Main Rd / Forest Ave / Ramada	**OVERALL**	**0.71**	**21.1**	**C**	**0.97**	**30.7**	**C**	**0.93**	**27.6**	**C**
E. Main Rd (RI 138)	EB	0.63	17.6	B	0.92	21.8	C	0.88	20.0	B
E. Main Rd (RI 138)	WB	0.55	12.1	B	0.73	16.1	B	0.70	13.9	B
Hotel Driveway	NB	0.08	23.7	C	0.08	23.0	C	0.08	23.0	C
Forest Ave	SB	0.90	54.9	D	1.08	101.4	F	1.05	90.8	F
E. Main Rd / Valley Rd	**OVERALL**	**0.77**	**38.0**	**D**	**1.15**	**180.3**	**F**	**1.08**	**150.1**	**F**
E. Main Rd (RI 138)	EB	0.71	31.1	C	0.88	38.6	D	0.86	37.1	D
E. Main Rd (RI 138)	WB	0.81	36.7	D	1.12	57.0	E	1.06	52.1	D
Valley Rd	NB	0.78	40.5	D	1.88	372.5	F	1.72	308.1	F
Valley Rd	SB	0.85	45.3	D	1.44	208.2	F	1.35	171.4	F
Green End Ave / Valley Rd	**OVERALL**	**1.00**	**45.5**	**D**	**1.64**	**210.7**	**F**	**1.56**	**187.9**	**F**
Green End Ave	EB	0.77	26.1	C	1.17	74.7	E	1.14	62.9	E
Green End Ave	WB	0.79	41.3	D	1.23	155.3	F	1.15	125.8	F
Valley Rd	NB	1.19	71.8	E	1.98	229.4	F	1.91	208.0	F
Valley Rd	SB	0.74	36.6	D	1.76	390.0	F	1.69	357.8	F

Table ES-8. Unsignalized Level-Of-Service Analysis Summary, High Impact Intersections

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
Green End Ave / Berkeley Ave / Paradise Ave										
Green End Ave	EB	0.02	1.2	A	0.03	1.2	A	0.03	1.2	A
Green End Ave	WB	0.05	2.4	A	0.06	1.9	A	0.05	2.0	A
Paradise Ave	NB	0.35	18.6	C	0.80	60.1	F	0.70	44.5	E
Berkeley Ave	SB	0.37	17.5	C	0.52	26.8	D	0.50	24.8	C
PM PEAK HOUR										
Green End Ave / Berkeley Ave / Paradise Ave										
Green End Ave	EB	0.04	1.5	A	0.04	1.3	A	0.04	1.3	A
Green End Ave	WB	0.03	1.6	A	0.04	1.4	A	0.04	1.4	A
Paradise Ave	NB	0.50	21.7	C	1.02	108.2	F	0.90	73.2	F
Berkeley Ave	SB	0.40	21.1	C	0.77	60.4	F	0.70	47.7	E

Based upon the traffic assessments, in order to minimize potential impacts to traffic and to enhance conditions for residents, CE provides the following traffic recommendations:

1. Optimizing the signal timing in the future should provide some capacity improvement for all signalized intersections; however, additional mitigation may be necessary to provide significant improvement at the following intersections:

    - West Main Road / Greene Lane / Pasture Farm Drive
    - West Main Road / Oliphant Lane
    - West Main Road / Forest Avenue
    - West Main Road / Valley Road
    - West Main Road / East Main Road
    - East Main Road / Oliphant Lane
    - East Main Road / Forest Avenue / Ramada Hotel Driveway
    - East Main Road / Valley Road

2. It appears that Rockwood Road could possibly be restriped with 11 ft travel lanes and minimal shoulder to provide a left/thru and right lane for a short distance to the commercial driveway curb cut. This may provide some delays and queue improvement on this side street and some improvement for the signal capacity as a whole.
3. Slightly extend the striping for the right turn lane pocket on Aquidneck Avenue at East Main Road. Since the Aquidneck Avenue northbound left/thru lane carries a small amount of traffic compared to the right turn lane, re-striping the left/thru as a left/thru/right general use lane may improve capacity for this approach.

4. For Green End Avenue at the intersection of Valley Road, it appears that using the dedicated eastbound right turn lane instead as a right/thru lane may provide some improvement to capacity eastbound.
5. The signalized intersection of Aquidneck Avenue / Valley Road will be reconstructed as a single lane roundabout. CE's analysis shows the proposed roundabout will provide good LOS for the future full-build scenario.
6. In the future the Town may want to analyze and consider the option of a roundabout to replace the signal at Aquidneck Avenue / Purgatory Road/ Memorial Boulevard.
7. For future mitigation, a proposed roundabout should be considered at Green End Avenue / Berkeley Avenue / Paradise Avenue. Analysis shows that the intersection would function well as a roundabout.
8. The LOS at Third Beach Road / Mitchell's Lane / Wapping Road remains very good for future conditions. The Town may want to consider the option of a roundabout at this location in the future should traffic conditions change.

Conclusion

The analysis found that Middletown currently experiences surface water and groundwater impairments and unmitigated new development will further degrade conditions. The analysis did find that the use of current RIDEM and Town regulations will reduce those impacts but recommendations are provided to further reduce potential negative impacts. These measures should be pursued along with a substantial effort at addressing existing impairments that are the result of development prior to modern standards. Traffic congestion is also a town-wide concern with evident deficiencies. Areas that will be most impacted by the increase in traffic are identified and can be prioritized for future upgrade.

1. INTRODUCTION

Land development can provide economic and financial opportunities for communities but land development can also create environmental impacts that may require costly mitigation and can impact the quality of life and overall public health, safety and welfare of a community. In an effort to understand those potential impacts on the community and to allow for proper planning to minimize or avoid the potential negative impacts, the Town of Middletown has embarked on this analysis of potential traffic and environmental impacts to the community upon a town-wide full-build scenario.

Land development impacts can include elements that are obvious, such as increased traffic congestion and increased flooding, and also less obvious elements, such as degraded air, water and groundwater quality, increased energy demands and an altered hydrologic cycle and wetland habitat alterations. A more comprehensive list of potential impacts associated with land development include alterations to:

Traffic Volumes	Night Sky Pollution
Air Quality	Water Quality
Energy Use	School Population
Ground/Air Temperatures	Municipal Services
Hydrology	Farmland
Runoff Volumes	Open Space
Soil Erosion	Forest
Water Usage	Wildlife Habitat
Sanitary Effluent	Flood Zones
Groundwater Quality	Groundwater Levels

Some states are also now beginning to consider reasonably foreseeable climate change impacts, such as additional greenhouse gas emissions, and assess potential "damage to the environment". The use of the term “damage to the environment” generally refers to the potential destruction, damage or impairment to any of the natural resources of the community and may include air pollution, water pollution, improper sewage disposal, pesticide pollution, excessive noise, reduction of groundwater levels, loss of flood storage, impairment of water quality, increases in flooding or storm water flows, impairment and eutrophication of rivers, streams, lakes, ponds, or other surface or subsurface water resources; destruction of seashores, dunes, marine resources, archaeological resources, wetlands, open spaces, natural areas, parks, or historic sites.

As a first step in identifying the overall environmental impacts of future development to the Town of Middletown, Crossman Engineering (CE), in conjunction with the Town Planning Department, has performed an evaluation of potential traffic impacts town-wide and the potential impacts on groundwater and surface water resources.

The Town of Middletown has previously expended significant efforts in collecting data, identifying environmental resources, and creating a geographical information system (GIS) database. These efforts provided an excellent foundation for this Town-wide assessment of full-build potential and the impact assessment. Examples of the Town's previous efforts, which exceed those of many other communities, are recent studies that were performed during consideration of a Stormwater Utility and an On-site Wastewater Management Plan. The Town's efforts in these and other past evaluations provided data on:

- Impervious Coverage Town-wide on each parcel of land
- Geologic Conditions
- Acreage Composition of Town-wide Soil Types
- Delineation of the Town's four major (Bailey Brook, Paradise Brook, Maidford River and Gardiner Pond) and two minor watersheds (eastern Narragansett Bay and eastern Little Creek Bay).
- Drinking Water Resource Areas
- Approximate Locations of Wetlands and Forested Areas
- Quantification of existing septic systems and known septic system repairs
- RIDOH Well Data from Wapping Road Area
- RIDEM and Town Documentation of TMDL and Impaired Streams and Waterbodies

The Town also maintains a geodatabase of available data in ESRI shapefile format including parcel, local boundaries, soils, utility infrastructure, roadways and other data. CE supplemented this data with publicly available data sets to assist with the analysis of impacts from potential full-build scenarios. The above only references a portion of the expanse of data that the Town has assembled over recent years and has available for use in land planning and performing impact assessments.

Land Development Potential: In order to evaluate potential impacts to traffic, surface waters and groundwater, the initial task is to quantify the town-wide full-build development potential. The Middletown Comprehensive Plan Land Use Chapter and the Town's Zoning Ordinance were used as a basis for quantifying future land uses. The Town's GIS database, field observations and RIDEM databases, were also used as a basis for assessing developable land areas and estimating future land use density. As important as the collected data, the Town Planning Department provided insight into known potential developments and land use trends.

The data and Planning Department input were used to generate an overall Plan of the Town that highlights areas expected to be developed under build-out scenarios. Once locations and land masses were identified, potential full-build density levels were forecasted based on the current allowed land uses and dimensional standards within Town Zoning Ordinance.

The results of the first Task represent essential data for performing the assessment of potential impacts to surface water, groundwater and traffic, respectively. This included:

- The identification of the current and potential full-build impervious coverages town wide. The change in impervious areas will greatly impact surface runoff, groundwater recharge, pollutant loadings and stormwater runoff rates and volumes.
- The quantification of future potential on-site wastewater systems, their locations and discharge volumes.
- The planning level quantification and location of full-build land development.

Evaluation of Surface Water and Groundwater Quality Impacts: Groundwater and surface waters of Middletown have a known history of quality degradation. Numerous streams and water bodies are currently categorized as impaired by the Rhode Island Department of Environmental Management (RIDEM) due to bacteria, phosphorous or other pollutants. Fortunately, more than half of the land in Middletown has access to public drinking water but a considerable land mass remains that must rely upon private wells. In some of these areas, groundwater quality may already be degraded due to past land use, such as the past use of fertilizer on agricultural lands. Furthermore, surface water reservoirs operated by the City of Newport receive surface runoff from the Town of Middletown and in turn provide the water supply for Middletown residents. The water quality and water treatment requirements of these surface reservoirs are directly related to the surface runoff quality.

Middletown soils are also predominately glacial till with slow permeability. Subsurface conditions commonly include a thin layer of slow permeable soils with a shallow water table depth over a dense, impervious layer. These conditions create a poor environment for septic system installations but even with these poor soil conditions, approximately 1,400 homes and businesses currently rely upon on-site septic systems in Middletown. This accounts for approximately 21% of the total number of homes and businesses in Middletown. With the build-out scenarios, this number is expected to increase.

To evaluate the potential full-build land development impact on surface and groundwater quality, the following tasks were performed:

- Identify areas that will benefit from future public sanitary and/or water system extensions.
- Collect existing groundwater well quality data.
- Review existing RIDEM surface water quality records.
- Perform evaluation of annual pollutant loading for surface water pollutants of concern to assess impacts from new impervious area.
- Assess the potential number of additional on-site septic systems per land area and the corresponding average daily and yearly volumes.
- Based upon the existing well water quality data and the future effluent, identify the groundwater pollutants of concern.
- Perform a nitrogen loading analysis for all areas serviced by on-site septic systems with consideration given to existing groundwater conditions. The analysis will also address expected impacts from the use fertilizers and agricultural activities. The use of advanced treatment and conventional septic systems will be evaluated.

For the impact evaluations, annual pollutant loading changes were assessed in order to provide a forecast as to the magnitude of potential impacts to surface water and groundwater resources from common pollutants of concern. Since groundwater patterns can be expected to generally follow the surface watershed divides, impact evaluations were performed on a "Watershed" basis, as opposed to one Town-wide scenario.

Evaluation of Groundwater Levels Impact: As previously noted, the underlying soils of Middletown are typically glacial till with low permeability and a limited thickness above a hardpan, impervious layer. These subsurface conditions limit the Town's groundwater resources, but significant tracts of land must rely upon privately owned wells due to the unavailability of public water lines.

As land is developed and surface conditions change, the overall hydrologic balance of groundwater recharge versus surface runoff can be significantly altered. To minimize the potential impacts to groundwater resources, the current State of Rhode Island Stormwater Design Manual includes a design standard that addresses groundwater recharge volumes, and the effectiveness of the manual's recharge standard will be reviewed in this analysis. Therefore, to assess if future full-build development will negatively impact Middletown's limited groundwater resources, the assessment included the following tasks:

- Performance of an overall hydrologic budget evaluation under existing and future conditions under two scenarios: (1) No waivers to the State of Rhode Island Stormwater Manual Standards and (2) assuming that the Recharge Standard within the Manual is waived for future development.

- Conceptual assessment of the impact of the hydrologic budget changes on groundwater resources including loss of recharge and increase of water withdrawals.
- Evaluation of available well and hydro-geological data within areas not served by public water and the assessment of potential impacts on existing and future wells in those areas.

Similar to the water quality assessment, the impact review is on a watershed basis in recognition that each sub-watershed in Middletown is unique and will experience differing impacts as land is developed.

Evaluation of Traffic Impacts: The Rhode Island Division of Statewide Planning and Rhode Island Department of Transportation (RIDOT) are sources of traffic planning studies statewide and maintain current traffic data and future projections for the major routes crossing through Middletown. The primary reason for obtaining these data is that a significant volume of traffic through Middletown is not generated within the Town but is through-traffic that can potentially create traffic impacts.

In regards to the future traffic due to the full-build land use density and development locations, the daily and peak trip generation were determined for each segment of Town and proceed through the following steps:

- Review of the Transportation Chapter of the Town's Comprehensive Plan and available RIDOT and Town traffic volume data.
- Working with Town Officials identified the primary road networks and intersections to analyze.
- Review of past traffic data and intersection evaluations.
- Review of recent and available past Traffic Impact Studies for previous Land Development Projects.
- Forecasted the future traffic directional distribution.
- Identified the most critical intersections in Town and perform AM and PM traffic counts during weekday periods.
- Reviewed available traffic volumes and supplemented data for primary routes.
- Reviewed available traffic accident history.
- Analyzed major intersections under existing and future development conditions and determined "Levels of Service" for each condition.
- Prepared summary of impacts and future needs of primary road segments and intersections.

During each phase of the analysis periodic meetings with the Town were held to ensure that available information was shared and that potential land development was identified. These meetings and the sharing of information throughout the process were integral to completing the build-out scenarios and the impact assessment.

2. LAND DEVELOPMENT POTENTIAL

METHODOLOGY

In order to evaluate potential impacts to traffic and water resources, the initial task was to quantify the town-wide full-build development potential. The Middletown Comprehensive Plan and the Town's Zoning Ordinance were used as the primary basis for quantifying future land use scenarios and input from Town planning staff during the scenario development provided a substantial resource of information. The Town's GIS database was also an invaluable resource, along with current aerial imagery, for assessing developable land areas and estimating future land use density.

The data were used to identify areas that were considered environmentally buildable and expected to be developed under full-build scenarios. Future development included residential, commercial and industrial land uses based upon the parcel's zoning designation. Full-build densities were forecasted based on a parcel's physical site constraints, current allowed land uses and dimensional standards as outlined within Zoning Ordinance.

Dimensional Requirements

The Middletown land use ordinances are contained primarily within Title XV, Chapter 152, Appendix A (Zoning Code) of the Middletown RI Code of Ordinances and the Rules and Regulations Regarding the Subdivision and Development of Land, as adopted by the Middletown Town Council. These documents define and frame allowable land usage and development standards within various zoning districts throughout the Town.

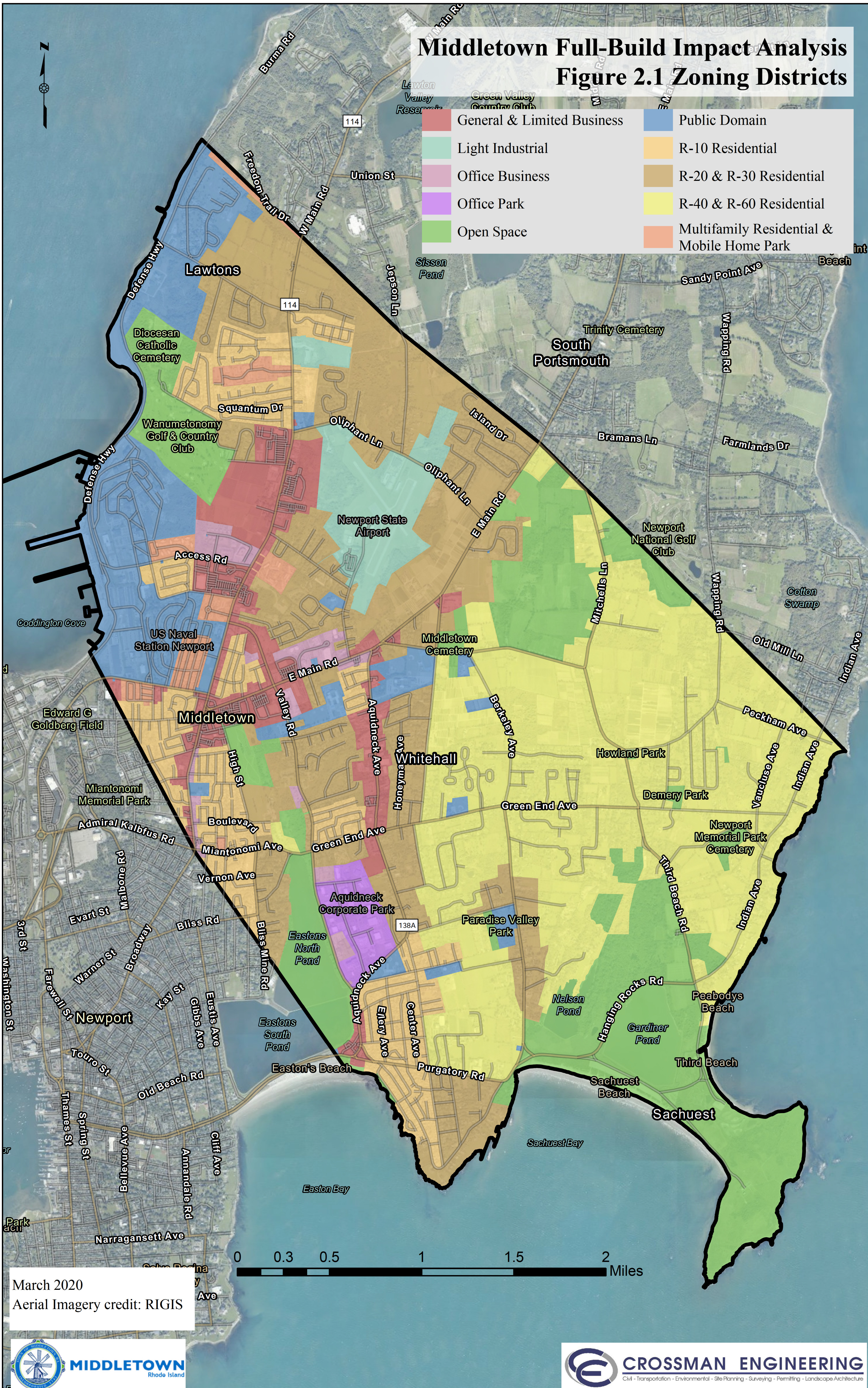
Figure 2.1 depicts the location and type of the Zoning Districts in Middletown. The lower-density residential zoning is predominantly in the eastern areas and a mix of higher-density residential and commercial development dominate the western segments of land. The Naval Station Newport (NAVSTA Newport) dominates the western coastline of Middletown and includes research facilities and residential communities for active duty Navy families.

Zoning Districts in Middletown are listed in Table 2.1. Article 6, Section 603 (Conventional Development) and Section 604 (Conservation Development) describe dimensional regulations for permitted land uses within the Town's Zoning Districts, including lot dimensions, dimensional setbacks and maximum building coverage for parcels within each zone. For determination of conceptual full-build conditions for residential development, the minimum lot size proved to be the most important variable and for determination of commercial development full-build conditions, allowable building coverage was a dominant factor. Minimum lot size and maximum building coverage for typical uses within the zoning districts are listed in the table.

Table 2.1 Lot Size Requirements, Zoning Ordinance Section 603, Conventional Development

Zone	General Use	Minimum Lot Size (Sq. Ft.)	Maximum Building-to-Lot Area Ratio	Development Type
R-60	Residential	60,000	15%	Single Family
R-40	Residential	40,000	15%	Single Family
R-30	Residential	30,000	20%	Single Family
R-20	Residential	20,000	20%	Single Family
R-10	Residential	10,000	25%	Single Family
RM	Residential Multifamily	40,000 / 5 (acres)	30% / 35%	Multifamily structure / development
MT	Residential Mobile Home	10 (acres)	20%	Mobile Home Park
GB	General Business	Varies	35%	Varies
LB	Limited Business	20,000	35%	Small-scale shopping center
OB	Office Business	40,000	35%	Non-residential
LI	Light Industrial	40,000	35%	All allowable
OP	Office Park	40,000	35%	All allowable
OS	Open Space	100,000	10%	All allowable
P	Public	N/A [1]		

[1] Public dimensional regulations were not used for the current full-build analysis.



Middletown Full-Build Impact Analysis
Figure 2.1 Zoning Districts
General & Limited Business
Light Industrial
Office Business
Office Park
Open Space
Public Domain
R-10 Residential
R-20 & R-30 Residential
R-40 & R-60 Residential
Multifamily Residential & Mobile Home Park
N
0
0.3
0.5
1
1.5
2
Miles
March 2020
Aerial Imagery credit: RIGIS
MIDDLETOWN
Rhode Island
CROSSMAN ENGINEERING
Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture
Lawtons
Middletown
Whitehall
South Portsmouth
Newport
Sachuest
Newport State Airport
US Naval Station Newport
Diocesan Catholic Cemetery
Wanumetonomy Golf & Country Club
Middletown Cemetery
Newport National Golf Club
Aquidneck Corporate Park
Paradise Valley Park
Howland Park
Demery Park
Newport Memorial Park Cemetery
Eastons North Pond
Eastons South Pond
Easton's Beach
Nelson Pond
Gardiner Pond
Peabodys Beach
Third Beach
Sachuest Beach
Sachuest Bay
Easton Bay
Coddington Cove
Sisson Pond
Cotton Swamp
Trinity Cemetery
Edward G Goldberg Field
Miantonomi Memorial Park
Defense Hwy
Freedom Trail Dr
W Main Rd
E Main Rd
Union St
Jepson Ln
Squantum Dr
Oliphant Ln
Island Dr
Access Rd
Valley Rd
Aquidneck Ave
Honeyman Ave
Berkeley Ave
Green End Ave
Mitchells Ln
Wapping Rd
Bramans Ln
Farmlands Dr
Sandy Point Ave
Old Mill Ln
Indian Ave
Peckham Ave
Vaucluse Ave
Third Beach Rd
Hanging Rocks Rd
Purgatory Rd
Ellery Ave
Center Ave
High St
Boulevard
Miantonomi Ave
Vernon Ave
Bliss Rd
Bliss Mine Rd
Admiral Kalbfus Rd
Malbone Rd
Evart St
Broadway
Warner St
Farewell St
Kay St
Gibbs Ave
Eustis Ave
Touro St
Old Beach Rd
Thames St
Spring St
Bellevue Ave
Annandale Rd
Cliff Ave
Narragansett Ave
Washington St
3rd St
Burma Rd
114
138A

For the forecasting of potential maximum commercial build-out, the determination of maximum new floor space required consideration of multiple variables, including:

- Parking Requirements (Zoning Ordinance Article 13)
- Commercial Landscaping Requirements (Code of Ordinances, Appendix A Subdivision Regulations)
- Building Coverage Allowance (Table 2.1)
- Building Height Restrictions (Zoning Code Article 6, Chapter 603)
- Non-buildable areas, such as wetlands

Each variable was considered to develop a reasonable Gross Leasable Floor Area (GLA) factor. for developable commercial land. The estimated factor was then compared to some actual, existing commercial properties in Middletown as verification of the validity of the estimated GLA values. Table 2.2 summarizes the factors that were determined to estimate future full-build commercial floor space on parcels selected for development and as noted above, the factors were confirmed by evaluation of several developed commercial parcels in Middletown and by examination of development scenarios in accordance with the Town's Zoning Ordinance.

Table 2.2 Full-Build Commercial Parcel Utilization Factors

Category	GLA [1]	Comment
Industrial [2]	0.34	Warehouse
Office	0.34	Office Building
Retail	0.30	Shopping Plaza
Mixed Use [3]	0.40	35% Residential, 35% Retail, 30% Office

[1] Gross leasable floor area as a fraction of developable land area
[2] Single-story industrial GLA factor may be closer to 0.25. Values reflect two-story office development permitted in Light Industrial zoning district.
[3] Mixed Use GLA factor reflects two-story development.

The following figures represent a sampling of actual commercial properties with calculated value.

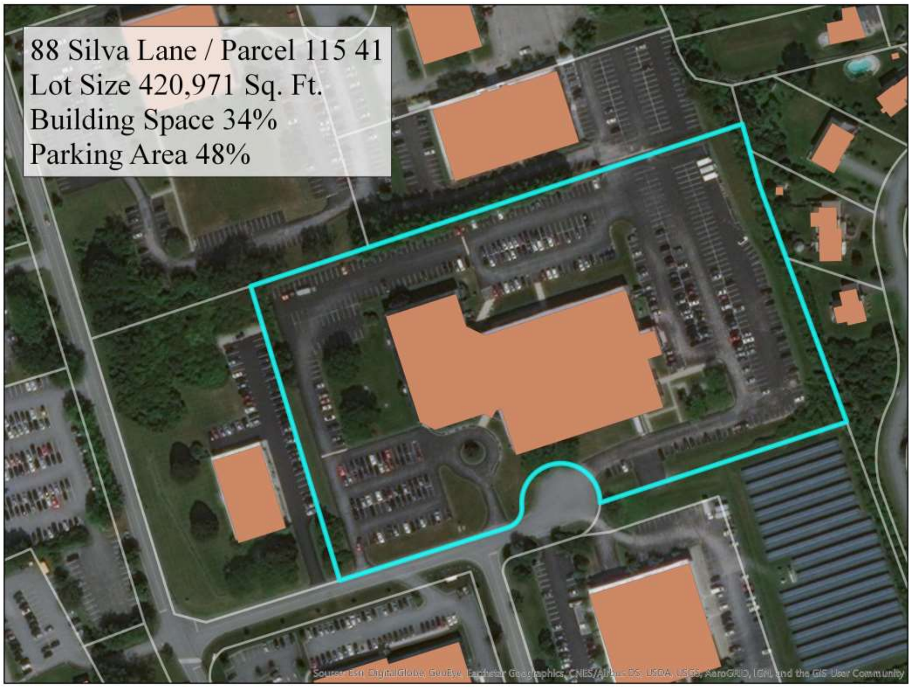


Figure 2.2 Example of Office Park Parcel Land Utilization

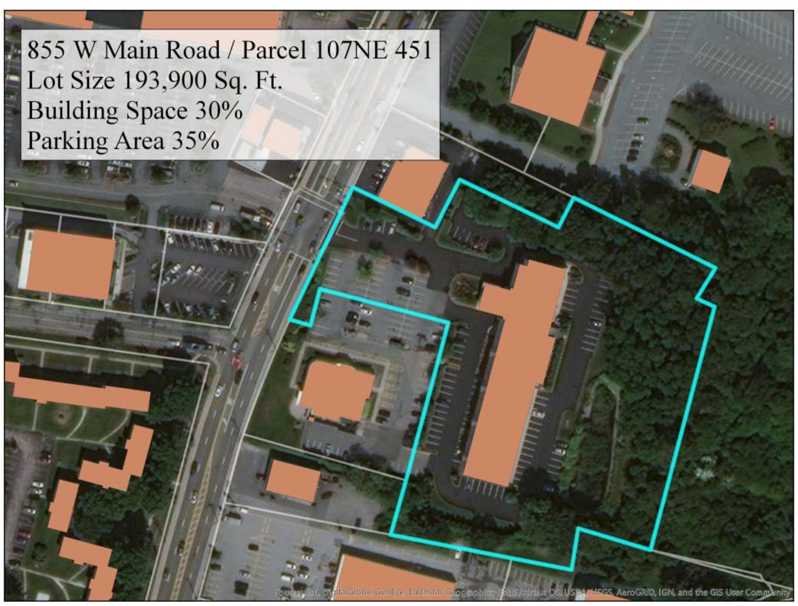


Figure 2.3 Example of Hotel Parcel Land Utilization

Wetlands Exclusion

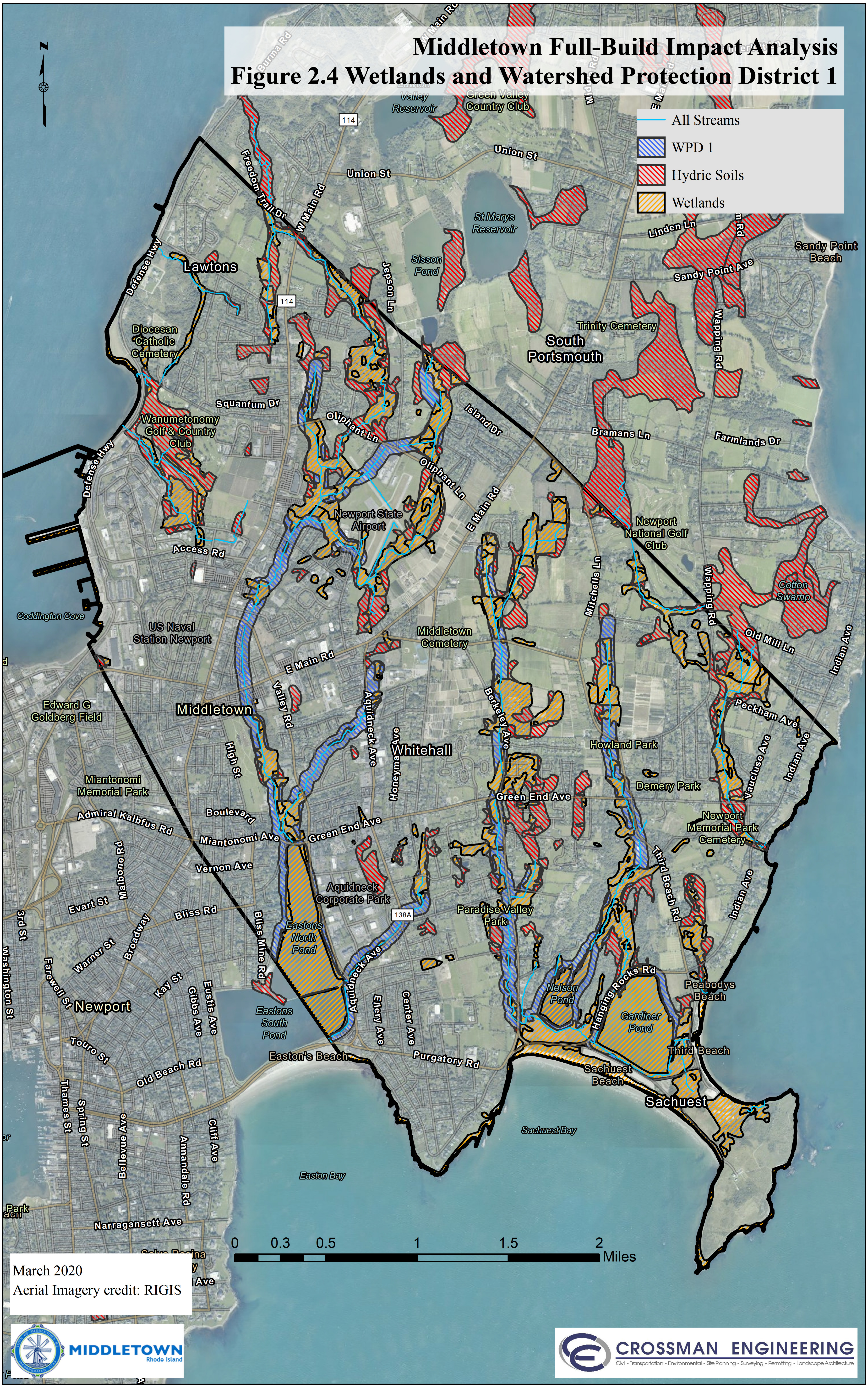
Freshwater wetlands are defined under Rhode Island General Law and the Rules and Regulations Governing Enforcement of the Freshwater Wetlands Act and generally include a bog, flood plain, pond, marsh, riverbank, swamp, river, stream, areas subject to flooding or flowage, perimeter wetlands, submergent or emergent plant communities, special aquatic sites and shrub or forested wetlands.

Wetland areas, other than perimeter and riverbank wetlands which border the wetland edges, are not considered to be developable lands and were excluded from potential developable land mass. Wetlands data were obtained from Rhode Island Geographical Information System (RIGIS) database which reflects delineation from 1988 aerial imagery using a Cowardin 16 Classification Scheme (RIGIS, 1993). The identified wetlands coverage, including coastal, inland and open water features, are depicted in Figure 2.4 and account for approximately 15% of total land area in Middletown. This excluded area totals 1,220 acres. The RIGIS wetland data are well-suited for the conceptual full-build analysis, but for site-specific development, wetland delineation in the field by a wetland scientist is required to confirm presence and exact location of wetland features and RIDEM jurisdictional limits.

In addition to regulated wetlands, development is restricted in areas designated as Town Watershed Protection Districts under the Middletown Zoning Ordinance (Article 11). The most stringent Watershed Protection District is Watershed Protection District 1 (WPD-1) which represents the following areas:

- Areas within 200 feet of the center course of streams tributary to water supply reservoirs in Middletown;
- Areas consisting of Hydric soils including Stissing silt loam (Se) and Mansfield mucky silt loam (Ma) according to soil mapping by the USDA NRCS produced in July 1981. On-site soil testing will take precedent over USDA NRCS Soil Data.

Development in WPD-1 is restricted to public utility, residential accessory, or conservation uses; however, other development may occur by special use permit issuance. Therefore, the full-build analysis created an alternative development scenario to exclude WPD-1 areas in addition to wetland areas. The baseline build-out scenario does include WPD-1 areas.



Middletown Full-Build Impact Analysis
Figure 2.4 Wetlands and Watershed Protection District 1
All Streams
WPD 1
Hydric Soils
Wetlands
0
0.3
0.5
1
1.5
2
Miles
March 2020
Aerial Imagery credit: RIGIS
MIDDLETOWN
Rhode Island
CROSSMAN ENGINEERING
Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture
Lawtons
South Portsmouth
Middletown
Whitehall
Newport
Sachuest
Newport State Airport
US Naval Station Newport
Wanumetonomy Golf & Country Club
Diocesan Catholic Cemetery
Trinity Cemetery
Newport National Golf Club
Middletown Cemetery
Howland Park
Demery Park
Newport Memorial Park Cemetery
Aquidneck Corporate Park
Paradise Valley Park
Miantonomi Memorial Park
Edward G Goldberg Field
St Marys Reservoir
Sisson Pond
Green Valley Country Club
Eastons North Pond
Eastons South Pond
Nelson Pond
Gardiner Pond
Cotton Swamp
Sandy Point Beach
Peabodys Beach
Third Beach
Sachuest Beach
Easton's Beach
Sachuest Bay
Easton Bay
Coddington Cove
Union St
Linden Ln
Sandy Point Ave
Wapping Rd
Bramans Ln
Farmlands Dr
Island Dr
Oliphant Ln
Squantum Dr
Freedom Trail Dr
W Main Rd
Jepson Ln
E Main Rd
Defense Hwy
Access Rd
Valley Rd
Aquidneck Ave
Honeyman Ave
Berkeley Ave
Mitchells Ln
Old Mill Ln
Peckham Ave
Vaucluse Ave
Indian Ave
Green End Ave
Third Beach Rd
Hanging Rocks Rd
Purgatory Rd
Ellery Ave
Center Ave
High St
Boulevard
Miantonomi Ave
Admiral Kalbfus Rd
Vernon Ave
Bliss Rd
Bliss Mine Rd
Malbone Rd
Evart St
Broadway
Warner St
Kay St
Gibbs Ave
Eustis Ave
Farewell St
Washington St
3rd St
Touro St
Old Beach Rd
Thames St
Spring St
Bellevue Ave
Annandale Rd
Cliff Ave
Narragansett Ave
114
138A

Parcel Selection

The full-build analysis utilized parcel data from the Town geodatabase as the basis for selection of developable area. Each parcel was reviewed with the Town Planning Department to confirm if there was a known reason, such as a conservation easement, for excluding a parcel from the assessment. Parcels were assigned a positive or negative value in the database indicating whether further development is feasible.

Residential parcel selection was completed independently from the commercial parcel selection. Residentially zoned parcels were screened for existing homes using the Town's geodatabase dwelling unit records. Larger parcels with existing dwelling units and sufficient lot area that would allow for future subdivision without the need for a variance from the minimum lot area requirements were considered for additional development. The residential analysis included all Zoning Districts that allowed residential uses but excluded land currently utilized for religious, school, public property, open space, conservation and cemeteries.

A quality control process for the initial screening was performed through comparison of GIS data with recent aerial imagery and site observations. This process resulted in the refinement of the parcel selection. In some cases, there are commercially developed parcels on residentially zoned land. These parcels were generally included in the selection as being suitable for redevelopment from commercial to residential, unless directly adjacent to a commercial zone. This ensures that the build-out will align with the current Zoning Ordinance.

A significant area in Middletown is reserved by conservation easement or otherwise restricted from future development. It was found that there are 72 parcels amount to 1,110 acres of land under perpetual conservation restriction or subject to Aquidneck Land Trust easement according to the Town database. The Town dataset has grouped these with other recreation, conservation, and open space (RCOS) parcels into a common dataset for planning purposes. Excluding some private RCOS parcels, including Wanumetonomy Golf Course, St Mary's Church Open Space, and several St. Georges School ancillary parcels, there are a total of 176 parcels amounting to 2,333 acres, including the 72 parcels with conservation easements or restrictions, in the dataset, representing 28% of Town's total area of 8,389 acres. The Wanumetonomy, St Mary's Church, and St Georges School parcels were not excluded from the full-build assessment, since there is no known easement or other hindrance to development on these parcels.

Selection of commercial parcels for development was based upon examination of recent aerial imagery to locate undeveloped or underdeveloped parcels. This approach does not account for significant vertical redevelopment where multistory commercial units could replace single-story units or where significant reorientation of an existing building layout could be performed to maximize parcel utilization.

It was found that there are some residentially developed parcels in commercial zones and for the full-build scenario it was assumed that they would be redeveloped to commercial use. These parcels are mainly located along main roads and in the "Atlantic Beach District" at the southern end of Aquidneck Avenue.

Full-Build Determination

Upon the selection of parcels for development, residential lot yield for single-family zoning districts was computed according to the Town's Subdivision Regulations (Section 304) as follows:

$$L = (DA \times 0.8) \div LS$$

L = New Single Family Development Lots
DA = Developable Land Area, excluding wetlands
LS = Lot Size, based upon minimum area required by Zoning

The 80 percent factor (0.80) recognizes that a portion of the land will need to be devoted to street creation and other infrastructure and that the lots are not perfectly shaped for ideal utilization.

For small parcels, parcels that could be subdivided into no more than two (2) parcels with access from existing streets, the yield was computed as follows:

$$L = DA \div LS$$

Then, the additional number of residential units per existing parcel was determined from the residential yield (L) as follows:

$$L_{New} = L - L_{Existing}$$

Where L_{New} represents additional residential units and $L_{Existing}$ represents existing lots or housing units.

In contrast to the residential yield determination process, commercial yield was determined in units of square feet of useable building space. Various types of commercial development were considered as shown in Table 2.3. These categories reflect the existing commercial zoning districts. Several parcels, including those public parcels proposed for development on West Main at Coddington Highway were selected for mixed use development for the full-build determination. These public parcels are described in the Existing Conditions discussion in the Existing Conditions section.

Table 2.3 Commercial Full-Build Use Categories

Zoning District	Development Type
GB	Retail / Mixed Use
LB	Retail / Mixed Use
LI	Industrial
OP	Office
OB	Office

Determination of gross leasable building space (GLA_{Total}) for each parcel was made as follows:

$$GLA_{Total} = (DA \times F)$$

GLA_{Total} = Gross Leasable Building Space
F = Commercial Space Utilization Factor (Table 2.2)

For cases where large parcels would likely require subdivision into commercial lots, *GLA* was computed as follows to allow space for infrastructure, street creation and lot shape:

$$GLA_{Total} = (DA \times 0.90) \times (F)$$

For Mixed Use development, retail space was set to the maximum allowed under the Town's Zoning Ordinance (Article 27A) at 35% of determined *GLA*. Residential use is required to be between 25-60% and was assumed to average 35%, and the remaining 30% was assigned to office use. The number of Residential units (*HU*) within mixed use developments were determined by assuming a two-bedroom condominium style home averages 1,000 SF / unit.

The net additional commercial space (GLA_{New}) was computed by subtracting existing commercial space, when applicable, as follows:

$$GLA_{New} = GLA_{Total} - ECS$$

ECS represents existing commercial space as determined from the Town's assessor database.

Alternative Scenarios

Three (3) alternative scenarios for the Middletown full-build analysis were selected. These alternatives stemmed from discussions with Town planning representatives during the course of the study. The alternatives accounted for various aspects of development including subdivision of existing lots, modification to residential lot size requirements and enforcement of the Town's water resources protection regulations.

Scenario 1: Preservation of Existing Lots

The Middletown Zoning Ordinance includes street frontage requirements as one criterion under dimensional standards per zoning district. For the rural R-60 residential zone, street frontage must be 200 feet, while the requirement is 100 feet for the high-density residential R-10 zone. Knowing that new roadways would be required for the development of larger lots, to determine the full-build potential of a parcel, the suitability of a large lot to be subdivided utilized parcel area exclusively. For smaller parcels with a total lot area that is sufficient to create two (2) lots but has insufficient frontage for two (2) lots, this scenario maintains Town frontage standards and considers the creation of an additional lot as not feasible. For example, parcels which have a developable area that could sustain only one additional house but insufficient frontage, are considered marginal and excluded from the build-out.

Scenario 2: Increase Rural Residential Lot Size

Under the Middletown Zoning Ordinance, the R-60 residential zoning district is the most conservative with respect to minimum lot size. In order to assess the potential benefits to traffic and environmental conditions in the Town, a zoning amendment which would create an R-100 residential zoning district was considered. For the R-100 zone scenario, the minimum lot size would be 100,000 SF; therefore a 500,000 SF parcel which could yield six (6) lots under R-60 zoning would only yield four (4) lots under R-100 zoning. For this scenario, the theoretical R-100 zoning district lot size requirement was applied to the R-40 and R-60 zoning districts.

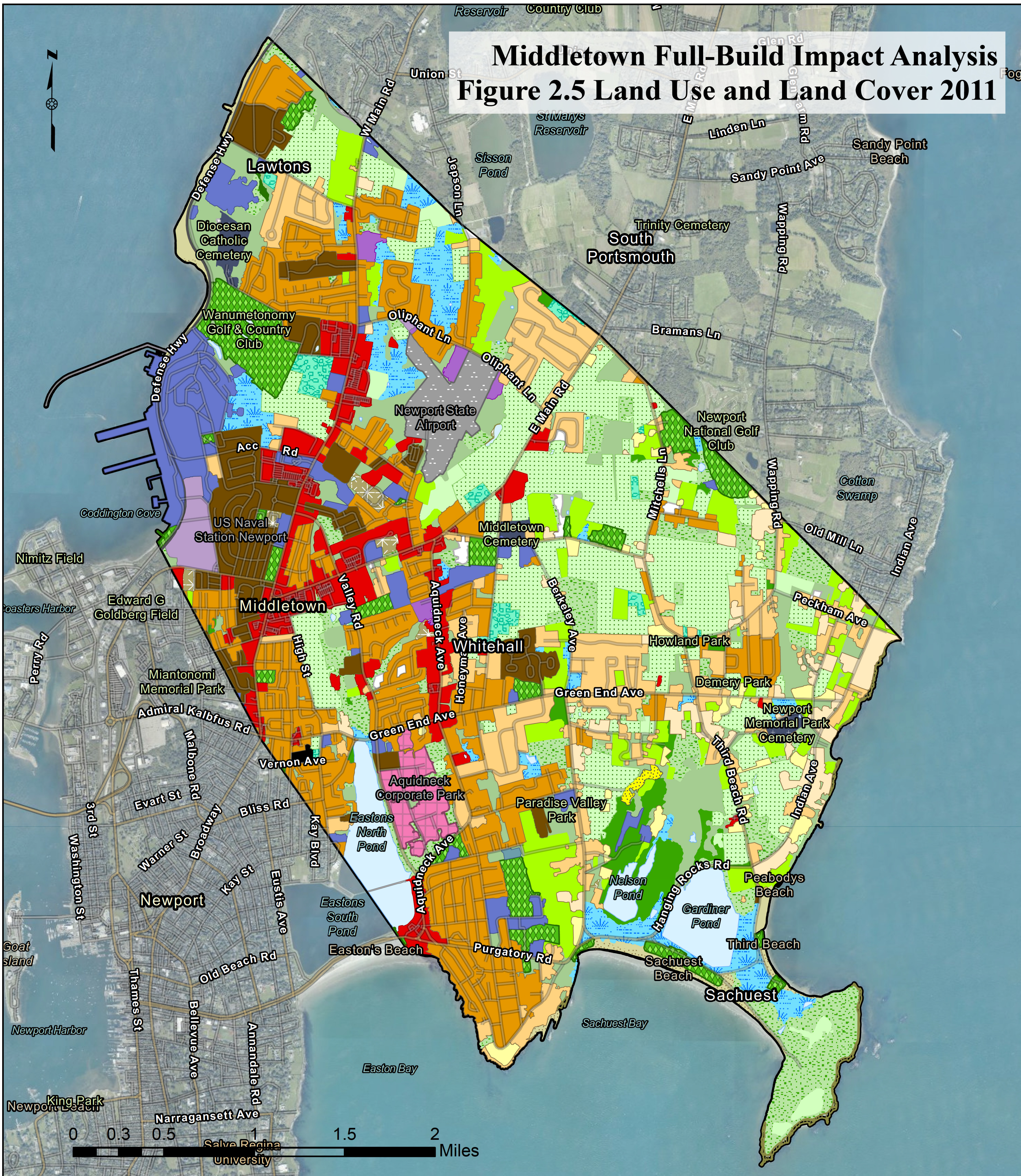
Scenario 3: Watershed Protection

As previously described, the Middletown Zoning Ordinance provides protection for lands within sensitive water resource areas including WPD-1 and WPD-2 districts. Commercial and residential development are not permitted in WPD-1 as principal uses without a special permit, therefore it was considered desirable to evaluate an alternative scenario which excludes further development in WPD-1. This scenario offers the benefit of potential pollution reduction in close proximity to important water resources, including streams and groundwater (hydric soils). WPD-1 areas were excluded from the full-build analysis similar to wetland areas, by subtracting the parcel's WPD-1 area from the parcel to determine developable area.

EXISTING CONDITIONS

This section describes the existing setting for Middletown, including commercial and industrial activities, housing supply and patterns, and public infrastructure. Figure 2.5 shows recent land use coverage for the Town based on generalized land use analysis and LIDAR imagery captured in 2011 (RIGIS, 2015).

Middletown Full-Build Impact Analysis
Figure 2.5 Land Use and Land Cover 2011



High Density Residential (<1/8 acre lots)	Institutional (schools, hospitals, churches, etc.)
Medium High Density Residential (1/4 to 1/8 acre lots)	Cemeteries
Medium Density Residential (1 to 1/4 acre lots)	Power Lines (100' or more width)
Medium Low Density Residential (1 to 2 acre lots)	Roads (divided highways > 200' plus related facilities)
Low Density Residential (>2 acre lots)	Airports (and associated facilities)
Commercial (Sale of products and services)	Railroads (and associated facilities)
Commercial/Residential Mixed	Waste Disposal (landfills, junkyards,etc.)
Commercial/Industrial Mixed	Water and Sewage Treatment
Industrial (manufacturing, design, assembly, etc.)	Other Transportation (terminals, docks, etc.)

Developed Recreation (all recreation)	Mixed Forest
Cropland (tillable)	Water
Orchards, Groves, Nurseries	Wetland
Confined Feeding Operations	Vacant Land
Pasture (agricultural not suitable for tillage)	Transitional Areas (urban open)
Idle Agriculture (abandoned fields and orchards)	Mines, Quarries and Gravel Pits
Brushland (shrub and brush areas, reforestation)	Beaches
Deciduous Forest (>80% hardwood)	Sandy Areas (not beaches)
Softwood Forest (>80% softwood)	Mixed Barren Areas
	Rock Outcrops

March 2020
RI Land Use, 2011, RIGIS
Aerial Imagery credit: RIGIS

MIDDLETOWN Rhode Island

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Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture

Industry

Middletown is home to a variety of commercial and industrial operations which include the defense industry, commercial retail operations, such as BJ's wholesale store, marine trades, the Newport State Airport and seasonal tourism.

Naval Station Newport (NAVSTA Newport) is historically and at present a large employer on Aquidneck Island. Substantial reduction in base population occurred in 1973 and the early 1990s. However, more recently the base has expanded operations including those associated with the Base Realignment and Closure (BRAC) plan, leading to a significant increase in employment on the base (Middletown, 2015). Naval Undersea Warfare Center (NUWC) Division Newport is a major employer in the Town, with approximately 2,700 employees at the Middletown location and additional funding of various contract operations throughout southern New England (Middletown, 2015). According to a recent study funded by the Commander Naval Installation Command (CNIC), base population is projected to increase from 6,470 to 7,620 due to realignment and other activities (EDAW, 2008). Limited expansion is projected for the NUWC and Coddington Cove base area in Middletown including new building construction, street / parking improvements, and wharf repairs.

There is also a significant warm-weather population and activity flux on Aquidneck Island due to attractions in and around Aquidneck Island, as well as recreational areas in Newport and Middletown. A 2001 report by the Aquidneck Island Planning Commission (AIPC, 2001) suggested there are 3,000 seasonal homes on the Island, while 2,500 of these were in Newport. U.S. Census data include information on seasonal housing, although data were not located from the 2017 Community Survey. Data included in the AIPC report demonstrated that in 1998, hospitality establishments on the Island increased occupancy from 31% in January to 92% in August.

Corporate parks in Middletown include Aquidneck Corporate Park, Newport Corporate Park, and the Enterprise Center. These developments are zoned Office Business or Office Park. Pare Corporation in conjunction with Ninigret Partners previously performed a full-build assessment of these corporate parks for the Town (Pare, 2005). At the time of the report, 613,000 SF gross building space was already developed in the Aquidneck Corporate Park. Since that preparation of that report, a solar farm was installed off Jacome Way, a new and expanded hotel facility was developed at the corner of Valley Road and Aquidneck Avenue and the parcel at 31 John Clarke Road was developed. The Newport Corporate Park is a smaller office park located near the entrance to NUWC and at the time of the full-build report it contained approximately 128,000 SF gross building space. The Enterprise Center is located off East Main Road and abuts the

Middletown Town offices and at the time of the report, approximately 201,000 SF gross building space was developed. Since preparation of the report, the vacant parcel at 75 Enterprise Drive was developed. The 2005 Study noted that at that time market conditions were not favorable for significant expansion of office and industrial space in Town.

Middletown has its history in agriculture and there remains today a presence of agriculture industry including commercial operations and Community Support Agriculture (CSA) operations (Middletown, 2015). Recent land use data show that a majority of agricultural land use in Middletown is on land zoned for residential use (Figure 2.1; Figure 2.5). According to the Middletown Zoning Ordinance, crop agriculture is permitted in most zoning districts, except residential high-density and multifamily and office park districts. Agriculture land uses account for 22% of total land area in Middletown and includes active and idle farmland (RIGIS, 2015). Although agricultural land uses are an essential part of the Middletown community, the Town's Zoning Ordinance does not reserve exclusive zones for agricultural uses, and it is assumed that these parcels could be re-developed for business or residential uses in the future, in accordance with the Zoning classification of each parcel.

Commercially zoned areas in Middletown account for 12% of total land area or 1,035 acres, including active and undeveloped parcels. According to the 2014 Update to the Comprehensive Plan for the Town of Middletown (Comprehensive Plan), there are 1.1 million square feet of existing office space and 1.3 million square feet of existing retail space (including restaurants) (Middletown, 2015). These values are less than the building areas depicted within commercially zoned areas on the Town's GIS, therefore may not account for all existing commercial (retail, office, and industrial) space in Middletown.

Housing

Residential zoned areas represent 60% of total land area in Middletown. However, existing developed residential land accounts for just 38% of town-wide land use. This percentage indicates that there is significant land area available for future residential development. Population in Middletown peaked in 1970 at 29,290, and significantly decreased to 17,216 in 1980 due to a reduction in Navy activities at NAVSTA Newport (Middletown, 2015). Since 1980, there have not been significant changes in population, with the current (2017) level at 16,100 (Census, 2019). Table 5 shows data from the U.S. Census on housing units in Middletown for the recent decadal periods. This shows that currently (2017) there are 7,798 housing units in Middletown, including multifamily and mobile home types. Figure 2.6 demonstrates the rate of home construction in Middletown which has been declining since the 1980s. Recent building permit data from the Town demonstrate a similar trend and shows the recent rate of residential construction at 26 permits per year, ranging between 14 to 40 permits.

Table 2.4. Middletown Housing Characteristics, Middletown RI; Source: Census, 2019

	2000	2010	2017 [1]
Population	17,334	16,150	16,100
Housing Units	7,603	7,622	7,798
Occupied Housing Units	6,993	6,763	6,832
Vacant Units	610	859	966
Owner-occupied	3,944	3,859	3,574
Renter-occupied	3,049	2,904	3,258

[1] 2017 data from American Community Survey

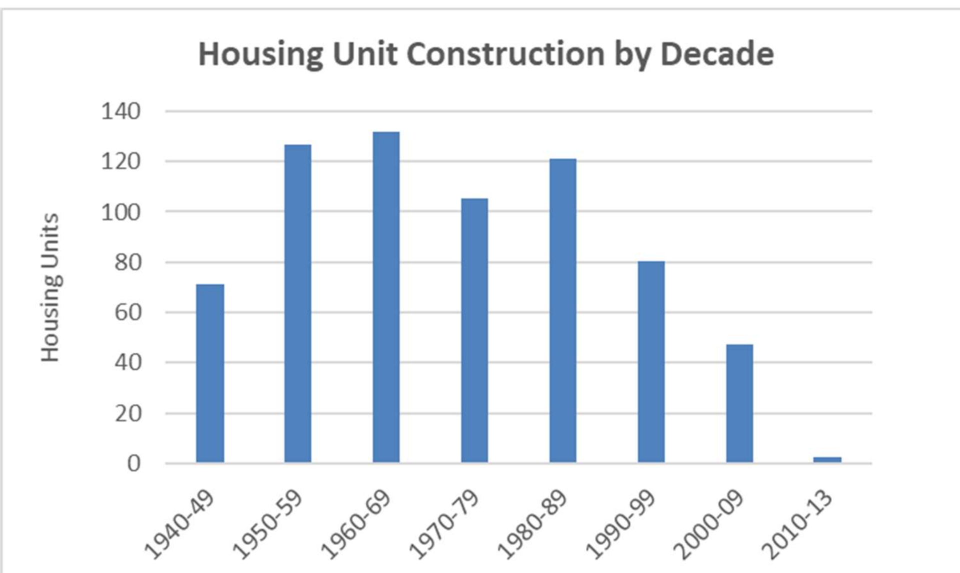


Figure 2.6 Middletown Housing Construction by Decade; Source: Census, 2019

Despite the reduced activity, there are several residential developments envisioned or under construction in Town. This includes a potential 8-lot subdivision on Prospect Avenue and a potential 11-lot subdivision on Mitchell's Lane. In addition, there are approximately 40 residential units on 9 existing parcels which were observed or reported to be in construction phase, including an estimated 32 units associated with a senior living community on West Main Road north of Oliphant Lane (Figure 2.7). Units under construction were considered existing with respect to the full-build analysis discussed in subsequent sections.

Figure 2.7 Photo of Senior Living Community Construction off of West Main Road, October 18, 2019

Article 27A of the Zoning Code was adopted recently and amended the General Business and Limited Business Zone uses to allow a mixed-use development. This would provide integrated development with a mix of residential, commercial, and restricted additional use types and promote community, land conservation, and pedestrian accessibility.

An example of this type of mixed use has been put forward by the Town for several public parcels on the west side of West Main Road just north of its intersection with East Main Road (VHB, 2011). There are current active uses on some of the public parcels. These uses would be modified with the redevelopment. The West Main / Coddington Development Center Master Plan envisions a mixed-use development with 80,000 SF retail space, 45,000 SF office space, 50,000 SF municipal space, and 175 residential multifamily units. Development of these parcels was included in the current full-build analysis.

Article 19 of the Zoning Code describes conservation development regulations which are required for major residential subdivisions and may be implemented for other developments. Conservation development encourages a layout which limits impact to the natural setting and surrounding areas. Required minimum lot sizes for residential districts are reduced from conventional development, facilitating reservation of open space and maintaining density that can be realized under the conventional approach.

Figure 2.8 Aerial photo of Residential Conservation Development

Figure 2.9 Photo of Residential Conservation Development, May 31, 2019

Public Utilities

Public Water and Sanitary Sewer

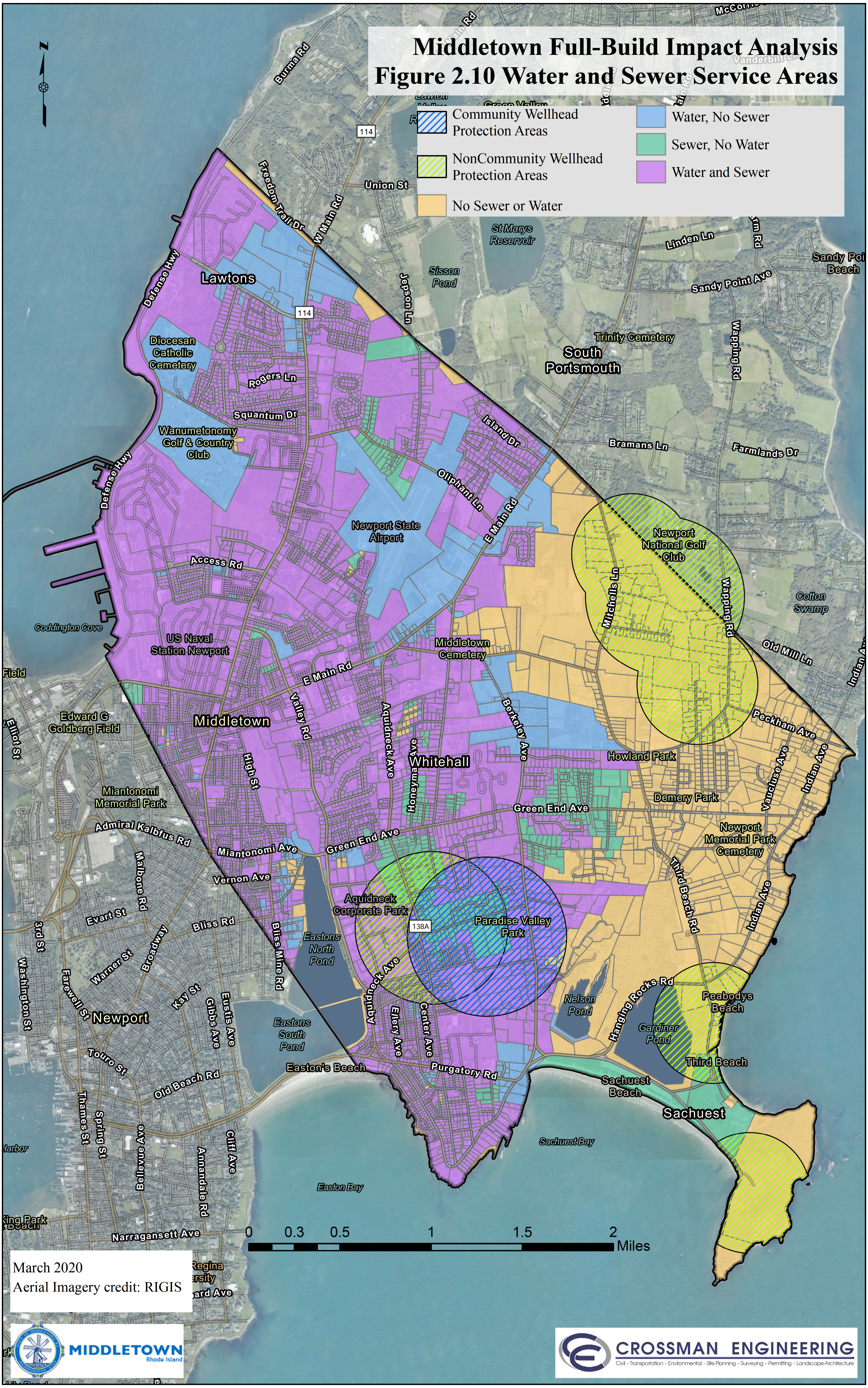
Figure 2.10 shows existing water and sewer coverage for the Town. It is evident that the sewer and water service areas are mainly on the more populated western side of Town, generally bounded by East Main and Berkley/Paradise Avenue to the east. Sewage flows from Middletown are directed to the City of Newport Wastewater Treatment Facility (WWTF) on J.T. Connell Highway. RIDEM reporting from the Newport WWTF indicates that the Newport facility serves Middletown, Newport, and NAVSTA Newport, with population of 5,200, 26,400, and 10,000 people, respectively (RIDEM, 2018). The reported average daily flow of 8.4 million gallons per day (MGD) is 79% of the reported design capacity of 10.7 MGD.

Public water service is provided by the City of Newport Water Supply which depends upon surface water supply from nine (9) surface water storage reservoirs, three (3) of which are located in

Middletown (Figure 2.10). System treatment capacity is 16 MGD, while combined reservoir safe yield is between 9.4 to 14.6 MGD, considering drought and average conditions, respectively. System production is reported for 2018 at 5.38 MGD, suggesting current use is well below system capacity (C&E, 2018). The City provides water through several connections to NAVSTA Newport and on a wholesale basis to Portsmouth Water and Fire District.

A review of parcels with frontage on a street served by sewer system indicates that 6,834 of the existing 7,799 Middletown existing residential units have access to sewer service. Since the Town reports sewer service to approximately 70% of the Town (Middletown, 2015), not all parcels with sewer access are tied into the Town system. In these areas individual on-site wastewater treatment systems (OWTS) are utilized in lieu of public sewer disposal.

A review of parcels with frontage on a street served by water system shows 6,705 of 7,799 estimated existing residential units with access to water service. Since the Town reports water service to approximately 75% of the Town (Middletown, 2015), not all parcels with water access are served by the City system. Private groundwater wells are used for domestic service in areas not connected to public water. In addition, there are seven (7) public wells listed by the RI Department of Health (RIDOH) in Middletown which are shown with a protective radius in Figure 2.10. These are facilities which have an independent water supply and serve more than 25 persons either in a transient or same-population setting (e.g., mobile home park, daycare, restaurant).


Middletown Full-Build Impact Analysis
Figure 2.10 Water and Sewer Service Areas
Community Wellhead Protection Areas
NonCommunity Wellhead Protection Areas
No Sewer or Water
Water, No Sewer
Sewer, No Water
Water and Sewer
N
0
0.3
0.5
1
1.5
2
Miles
March 2020
Aerial Imagery credit: RIGIS
MIDDLETOWN
Rhode Island
CROSSMAN ENGINEERING
Lawtons
Middletown
Whitehall
Newport
South Portsmouth
Sachuest
Newport State Airport
US Naval Station Newport
Diocesan Catholic Cemetery
Wanumetonomy Golf & Country Club
Newport National Golf Club
Middletown Cemetery
Aquidneck Corporate Park
Paradise Valley Park
Howland Park
Demery Park
Newport Memorial Park Cemetery
Eastons North Pond
Eastons South Pond
Easton's Beach
Nelson Pond
Gardiner Pond
Peabodys Beach
Third Beach
Sachuest Beach
Sachuest Bay
Easton Bay
Coddington Cove
St Marys Reservoir
Sisson Pond
Trinity Cemetery
Cotton Swamp
Sandy Point Beach
Edward G Goldberg Field
Miantonomi Memorial Park
Defense Hwy
Freedom Trail Dr
W Main Rd
E Main Rd
Union St
Jepson Ln
Burma Rd
Rogers Ln
Squantum Dr
Island Dr
Oliphant Ln
Access Rd
Valley Rd
Aquidneck Ave
Honeyman Ave
Berkeley Ave
Green End Ave
Mitchells Ln
Wapping Rd
Peckham Ave
Vaucluse Ave
Indian Ave
Third Beach Rd
Hanging Rocks Rd
Purgatory Rd
Center Ave
Ellery Ave
Bliss Mine Rd
High St
Miantonomi Ave
Vernon Ave
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Thames St
Spring St
Bellevue Ave
Annandale Rd
Cliff Ave
Narragansett Ave
Linden Ln
Sandy Point Ave
Bramans Ln
Farmlands Dr
Old Mill Ln
Elliot St
114
138A

Stormwater

Stormwater maintenance for the Town of Middletown falls under jurisdiction of the Town Public Works Department. The stormwater management is regulated by RIDEM through the Rhode Island Public Discharge Elimination System (RIPDES) Municipal Separate Storm Sewer System (MS4) permit. The Town is accountable to the RIDEM through the MS4 permit. In addition, the RI Department of Transportation (RIDOT) is required to manage stormwater via an MS4 permit associated with State highway facilities across Rhode Island, including those in Middletown. Phosphorous, fecal coliform, enterococcus, total organic carbon, dissolved oxygen and lead are known impairments of waters in the Town of Middletown. A more detailed description of water quality issues is provided in Chapter 3.

RIDOT recently published a Stormwater Control Plan (SCP) for Aquidneck Island drainage basins, including Baileys Brook and Maidford River in Middletown. The SCP was prepared in response to the Consent Decree between the RIDOT and the U.S. EPA and identifies impairments for the subject waterbodies. The studies reported 8.7 acres of impervious area in the Maidford River watershed and 40.4 acres impervious area in the Baileys Brook Watershed that are within RIDOT jurisdiction. In accordance with the Consent Decree, RIDOT will evaluate alternatives to meet the Consent Decree water quality goals (RIDOT, 2018).

Recent studies have also been published by the Town for Baileys Brook watershed (Fuss and Oneill, 2013) and the Maidford River (Fuss and Oneill, 2015) addressing stormwater management. The 2013 report examines phosphorus reduction through potential stormwater best management practices (BMP). The 2015 report provided bacteria and phosphorus sample results for wet and dry weather conditions for sites on the Maidford River and Paradise Brook in Middletown. Samples showed increase in wet weather conditions for both constituents in the streams. The past reports provide evidence that agricultural land uses have contributed to water quality impairments.

FULL-BUILD RESULTS

Residential

Residential build-out was limited to single-family residential zones, since multifamily and mobile home zones are essentially fully developed. Figure 2.11 shows the distribution of build-out by residential zoning district, including the change from existing to future full-build condition.

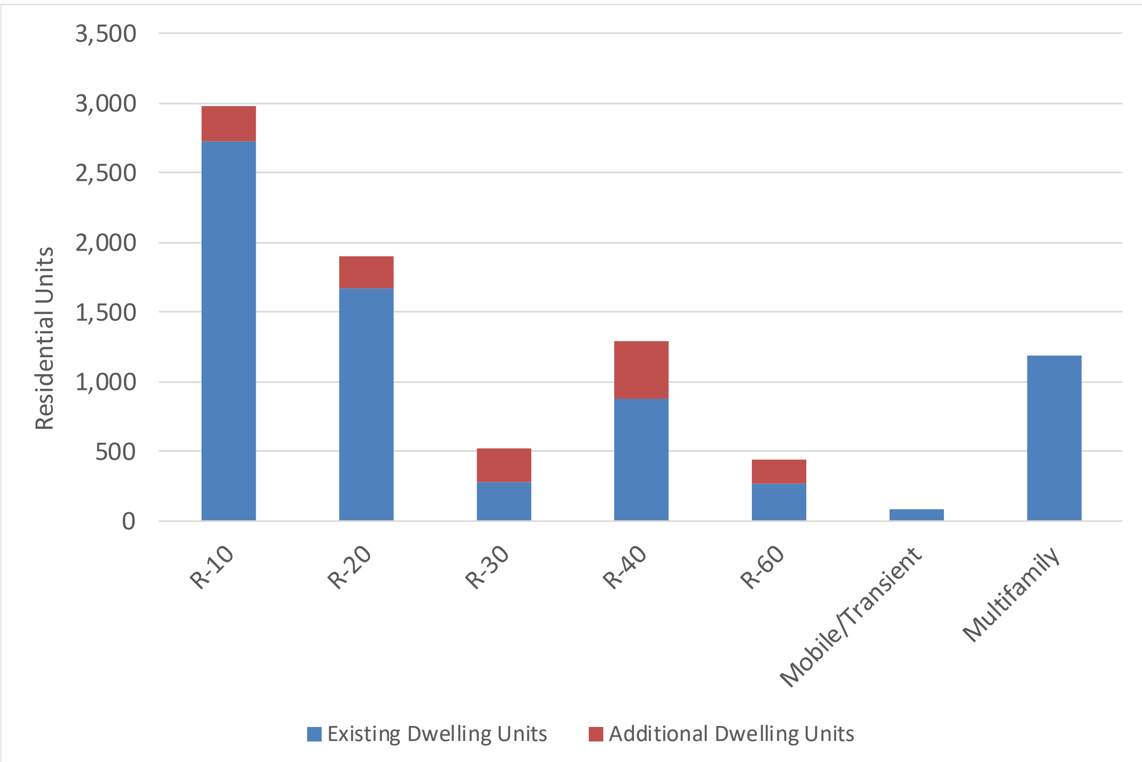


Figure 2.11 Full-Build Residential Dwelling Units by Zoning District, Full-Build with Current Zoning

It is apparent that an increase in residential units is highest in the R-40 zone. The relative increase in units within all zoning districts was higher in the R-30, R-40, and R-60 zones. This relative increase is reflective of the lower existing unit counts in these zones. It is also apparent that the build-out does not significantly affect the distribution of dwelling units across the residential zones. The total build-out adds 1,436 single-family units which includes 125 new units on the existing Wanumetonomy Country Club which is currently zoned Open Space. The values are demonstrated by zone in the Table 2.5. Results for the alternative scenarios show reduced development in Table 2.6 including the case where each alternative is implemented and the restrictions of each are realized in one scenario. The residential units in commercial zones and condominium style residential units added through the build-out are shown in Table 2.5 and Table 2.6 and are described further in the Commercial full-build results section.

Table 2.5. Residential dwelling Units by Zoning District with Current Zoning

Zone	Existing Dwelling Units	Additional Dwelling Units, Full-Build	Total Dwelling Units
R-10	2,724	250	2,974
R-20	1,672	226	1,898
R-30	276	247	523
R-40	878	414	1,292
R-60	267	174	441
Mobile / Transient	89	0	89
Multifamily	1,185	0	1,185
OS [1]	6	125	131
COM [2, 5]	348	423	674 [4]
P [3, 5]	354	57	411
Total	7,799	1,916	9,618

[1] OS is Open Space; Additional Dwelling Units reflect redevelopment of Wanumetonomy Country Club
[2] COM is General Business, Limited Business, Office Business, Office Park, and Light Industrial
[3] P is Public
[4] Not a direct sum. Some existing residential units in commercial zones are converted to commercial space through build-out
[5] Future development in commercial and public zones is part of mixed-use development described in Commercial full-build results section

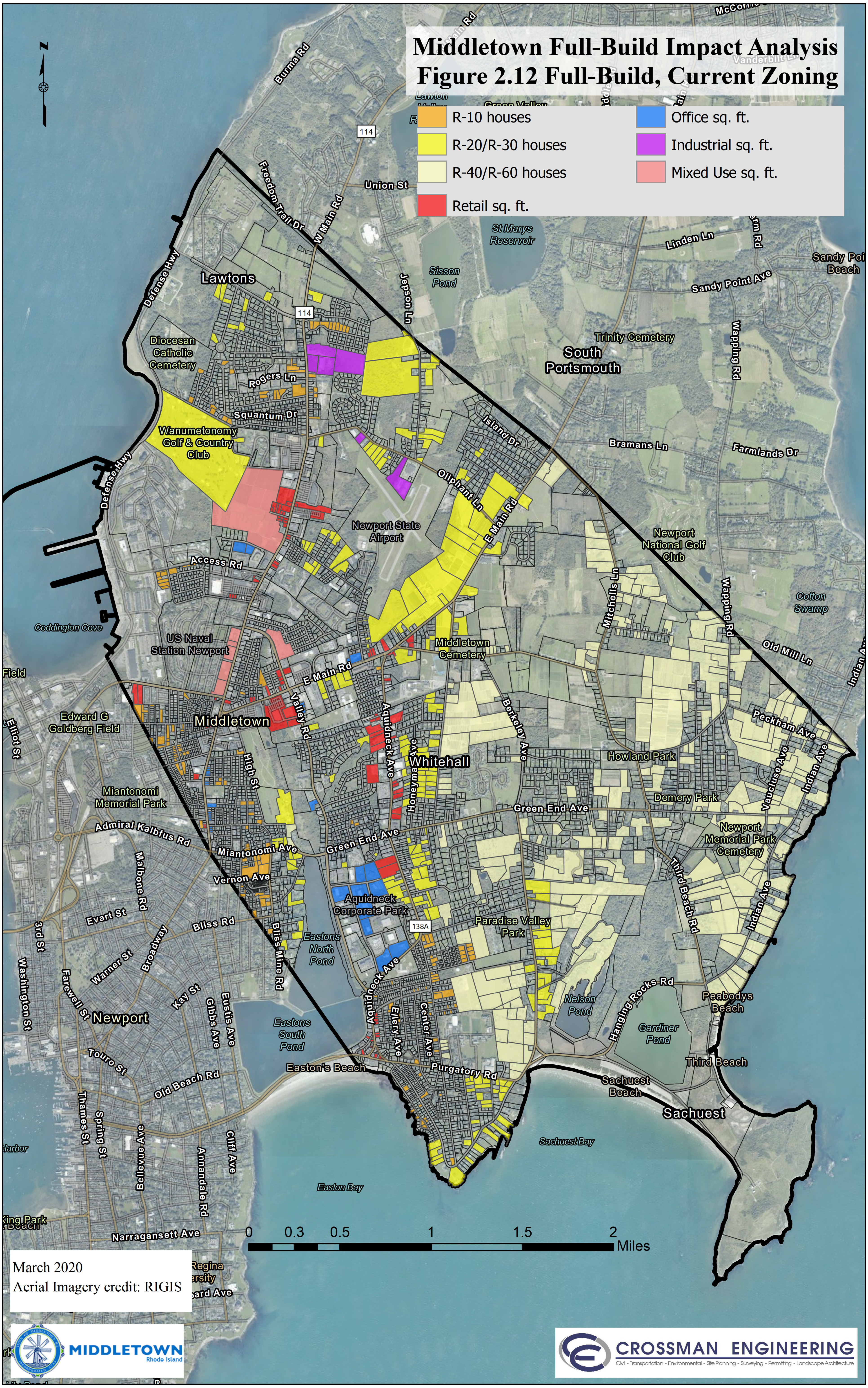
Table 2.6. Additional Residential Dwelling Units by Zoning District for Alternative Scenarios

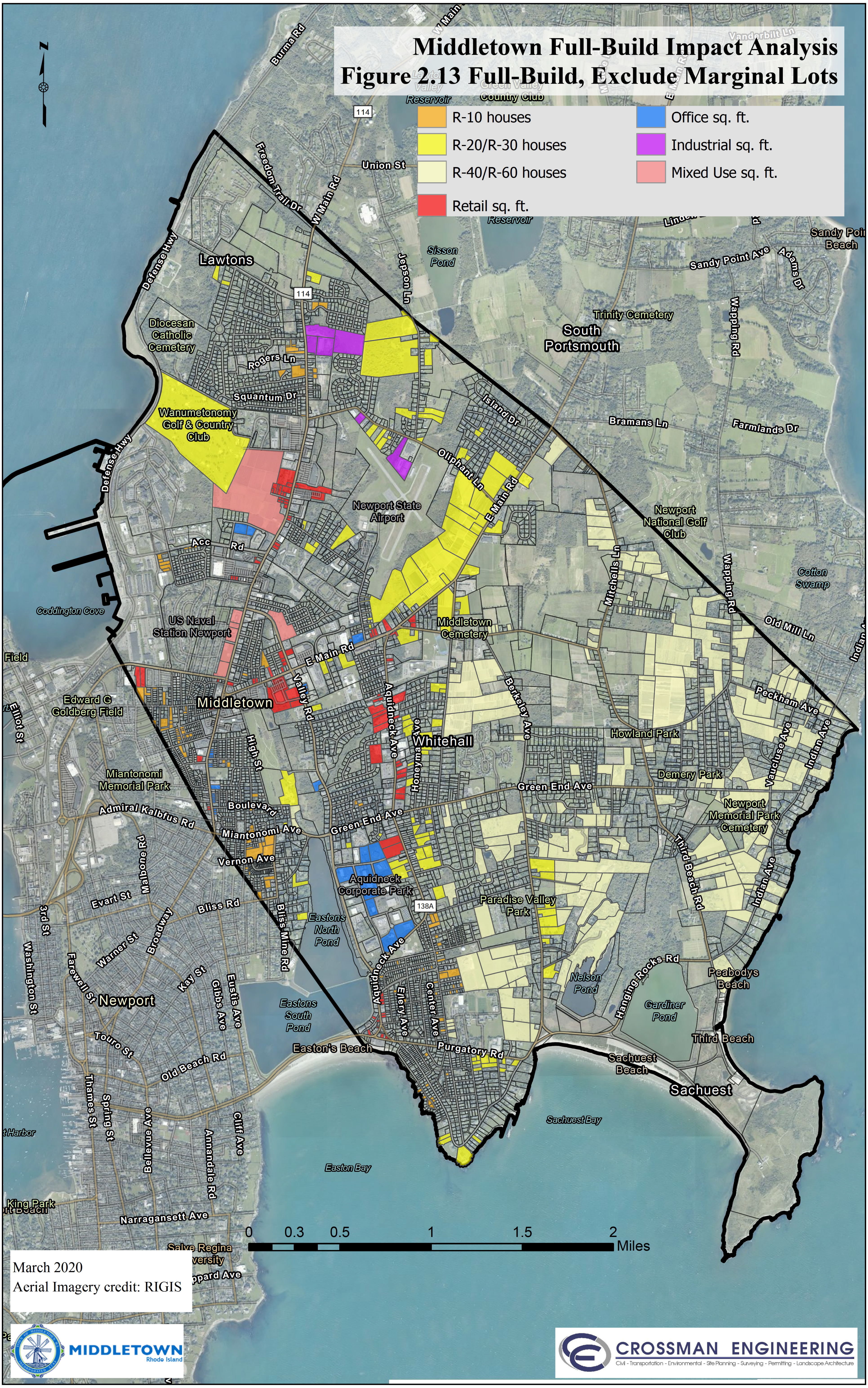
	Full-Build with Current Zoning	Alternative Scenarios [2]			
		Exclude Marginal Lots	Re-zone R-40/R-60 to R-100 Zoning	Exclude Watershed Protection District 1	Implement All Alternatives [2]
R-10	250	191 (59)	250	234 (16)	179 (71)
R-20	226	157 (69)	226	163 (63)	111 (115)
R-30	247	230 (17)	247	215 (32)	201 (46)
R-40	414	373 (41)	184 (230)	362 (52)	146 (268)
R-60	174	153 (21)	104 (70)	154 (20)	82 (92)
Mobile / Transient	0	0	0	0	0
Multifamily	0	0	0	0	0
OS	125	125	125	61 (64)	61 (64)
COM[1]	423	423	423	390 (33)	390 (33)
P[1]	57	57	57	57	57
Total	1,916	1,709 (207)	1,616 (300)	1,636 (280)	1,227 (689)

[1] Future development in commercial and public zones is part of mixed-use development described in Commercial full-build results section
[2] Values in parentheses represent the reduction in additional dwelling units from the full-build scenario

A similar study was performed by the Aquidneck Island Planning Commission (AIPC, 2011) which reported potential for 1,242 new residential lots in Middletown, on undeveloped or agricultural land. Their independent study is within reasonable agreement with the current study and concludes with similar new-lot counts by residential zone. An exception is for R-10 zones which were higher in this assessment due to inclusion of oversized existing house lots in the build-out. In addition, Wanumetonomy Country Club was not included in the previous AIPC study (2011).

Figures 2.12, 2.13, 2.14, and 2.15 are provided which show buildout maps for the base scenario and the three alternative scenarios.


Middletown Full-Build Impact Analysis
Figure 2.12 Full-Build, Current Zoning
R-10 houses
R-20/R-30 houses
R-40/R-60 houses
Retail sq. ft.
Office sq. ft.
Industrial sq. ft.
Mixed Use sq. ft.
N
Lawtons
Diocesan Catholic Cemetery
Rogers Ln
Squantum Dr
Wanumetonomy Golf & Country Club
Defense Hwy
Freedom Trail Dr
W Main Rd
Union St
Burma Rd
Jepson Ln
Sisson Pond
St Marys Reservoir
Linden Ln
Sandy Point Ave
Sandy Point Beach
Trinity Cemetery
South Portsmouth
Wapping Rd
Island Dr
Bramans Ln
Farmlands Dr
Oliphant Ln
E Main Rd
Newport State Airport
Newport National Golf Club
Access Rd
Coddington Cove
US Naval Station Newport
Mitchells Ln
Cotton Swamp
Old Mill Ln
Middletown Cemetery
E Main Rd
Edward G Goldberg Field
Middletown
Valley Rd
Aquidneck Ave
Whitehall
Berkeley Ave
Peckham Ave
Howland Park
Demery Park
Vaucluse Ave
Indian Ave
Green End Ave
Miantonomi Memorial Park
Admiral Kalbfus Rd
Miantonomi Ave
High St
Vernon Ave
Newport Memorial Park Cemetery
Third Beach Rd
Aquidneck Corporate Park
138A
Paradise Valley Park
Eastons North Pond
Bliss Mine Rd
Bliss Rd
Evart St
Malbone Rd
Broadway
Warner St
Kay St
Newport
Gibbs Ave
Eustis Ave
Eastons South Pond
Nelson Pond
Hanging Rocks Rd
Gardiner Pond
Peabodys Beach
Third Beach
Ellery Ave
Center Ave
Purgatory Rd
Easton's Beach
Sachuest Beach
Sachuest
Sachuest Bay
Easton Bay
Touro St
Old Beach Rd
Thames St
Spring St
Bellevue Ave
Annandale Rd
Cliff Ave
Narragansett Ave
Washington St
Farewell St
3rd St
0 0.3 0.5 1 1.5 2 Miles
March 2020
Aerial Imagery credit: RIGIS
MIDDLETOWN Rhode Island
CROSSMAN ENGINEERING
Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture


Middletown Full-Build Impact Analysis
Figure 2.13 Full-Build, Exclude Marginal Lots
R-10 houses
R-20/R-30 houses
R-40/R-60 houses
Retail sq. ft.
Office sq. ft.
Industrial sq. ft.
Mixed Use sq. ft.
N
Lawtons
Diocesan Catholic Cemetery
Rogers Ln
Squantum Dr
Wanumetonomy Golf & Country Club
Defense Hwy
Freedom Trail Dr
W Main Rd
Union St
Jepson Ln
Sisson Pond
114
South Portsmouth
Trinity Cemetery
Sandy Point Ave
Adams Dr
Wapping Rd
Island Dr
Bramans Ln
Farmlands Dr
Oliphant Ln
E Main Rd
Newport State Airport
Newport National Golf Club
Mitchells Ln
Cotton Swamp
Old Mill Ln
Acc Rd
Coddington Cove
US Naval Station Newport
Middletown Cemetery
E Main Rd
Peckham Ave
Edward G Goldberg Field
Middletown
Valley Rd
Aquidneck Ave
Whitehall
Berkeley Ave
Howland Park
Demery Park
Green End Ave
Miantonomi Memorial Park
High St
Boulevard
Admiral Kalbfus Rd
Miantonomi Ave
Vernon Ave
Aquidneck Corporate Park
Newport Memorial Park Cemetery
Third Beach Rd
Indian Ave
Vaucluse Ave
Paradise Valley Park
138A
Eastons North Pond
Bliss Rd
Bliss Mine Rd
Hanging Rocks Rd
Peabodys Beach
Nelson Pond
Gardiner Pond
Newport
Eastons South Pond
Ellery Ave
Center Ave
Purgatory Rd
Easton's Beach
Third Beach
Sachuest Beach
Sachuest
Sachuest Bay
Easton Bay
Old Beach Rd
Touro St
Narragansett Ave
Salve Regina University
0 0.3 0.5 1 1.5 2 Miles
March 2020
Aerial Imagery credit: RIGIS
MIDDLETOWN Rhode Island
CROSSMAN ENGINEERING
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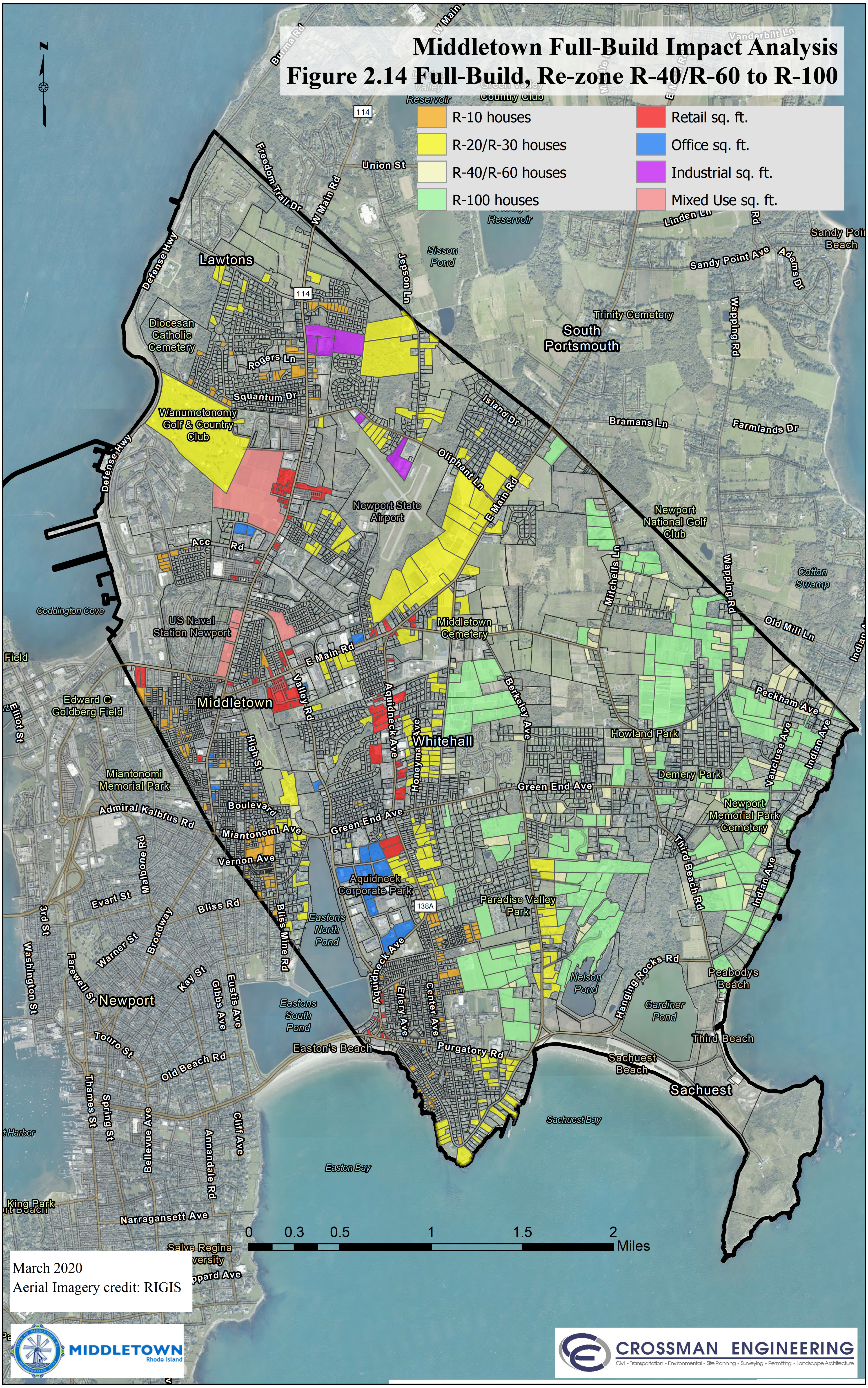
Middletown Full-Build Impact Analysis
Figure 2.14 Full-Build, Re-zone R-40/R-60 to R-100



March 2020
Aerial Imagery credit: RIGIS

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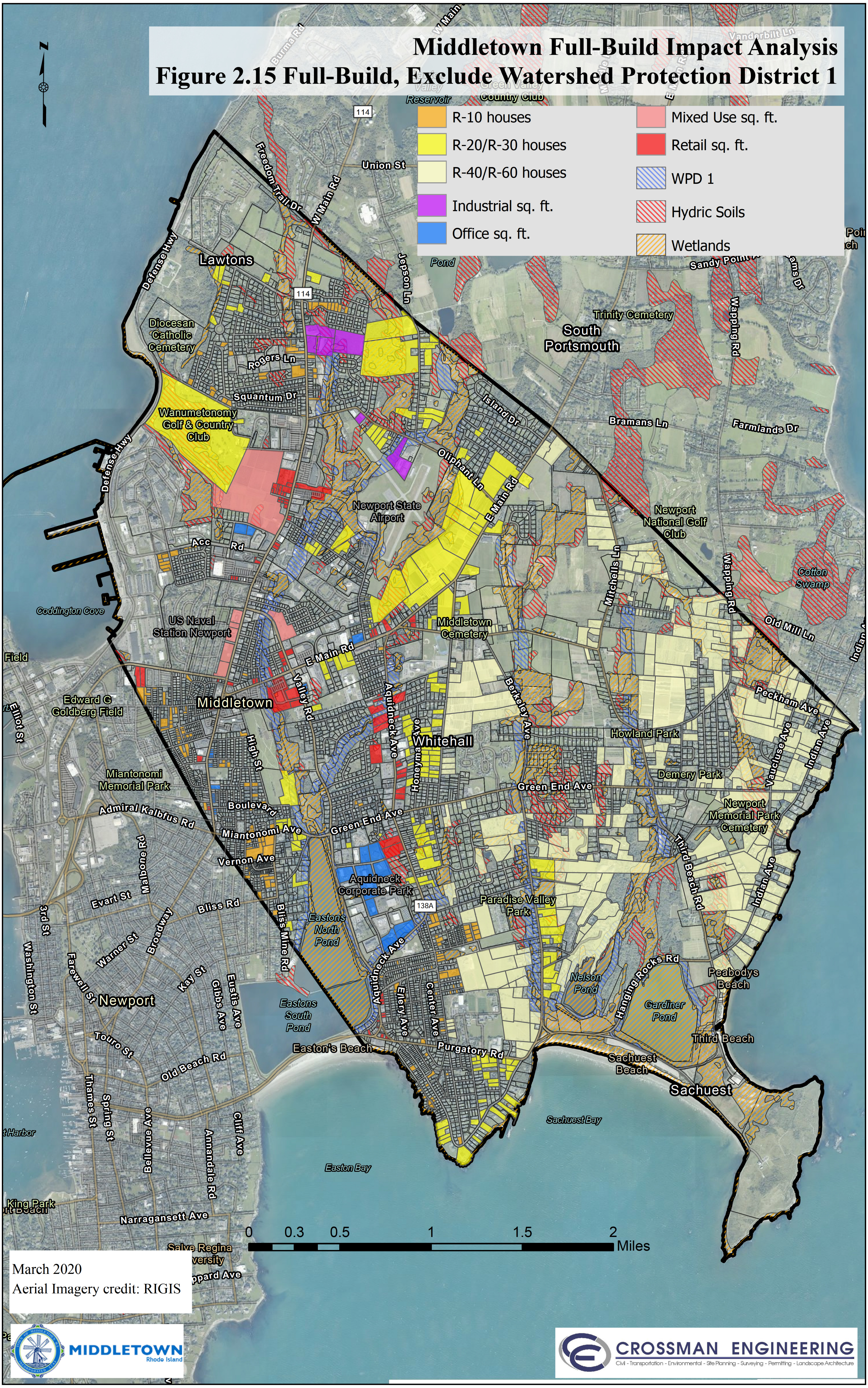

Middletown Full-Build Impact Analysis
Figure 2.15 Full-Build, Exclude Watershed Protection District 1
R-10 houses
R-20/R-30 houses
R-40/R-60 houses
Industrial sq. ft.
Office sq. ft.
Mixed Use sq. ft.
Retail sq. ft.
WPD 1
Hydric Soils
Wetlands
Lawtons
Diocesan Catholic Cemetery
Rogers Ln
Squantum Dr
Wanumetonomy Golf & Country Club
Defense Hwy
Freedom Trail Dr
W Main Rd
Union St
Jepson Ln
South Portsmouth
Trinity Cemetery
Island Dr
Bramans Ln
Farmlands Dr
Wapping Rd
Oliphant Ln
E Main Rd
Newport State Airport
Newport National Golf Club
Mitchells Ln
Cotton Swamp
Old Mill Ln
Acc Rd
Coddington Cove
US Naval Station Newport
Middletown Cemetery
E Main Rd
Valley Rd
Middletown
Edward G Goldberg Field
Aquidneck Ave
Whitehall
Honeyman Ave
Berkeley Ave
Peckham Ave
Howland Park
Demery Park
Green End Ave
Vaucluse Ave
Indian Ave
High St
Miantonomi Memorial Park
Boulevard
Admiral Kalbfus Rd
Miantonomi Ave
Vernon Ave
Green End Ave
Newport Memorial Park Cemetery
Third Beach Rd
Aquidneck Corporate Park
Paradise Valley Park
Eastons North Pond
Bliss Mine Rd
Bliss Rd
Evart St
Malbone Rd
Broadway
Warner St
Kay St
3rd St
Washington St
Farewell St
Newport
Gibbs Ave
Eustis Ave
Eastons South Pond
Nelson Pond
Hanging Rocks Rd
Gardiner Pond
Peabodys Beach
Third Beach
Ellery Ave
Center Ave
Purgatory Rd
Easton's Beach
Sachuest Beach
Sachuest
Sachuest Bay
Touro St
Old Beach Rd
Thames St
Spring St
Bellevue Ave
Annandale Rd
Cliff Ave
Easton Bay
King Park
Narragansett Ave
Salve Regina University
0 0.3 0.5 1 1.5 2 Miles
March 2020
Aerial Imagery credit: RIGIS
MIDDLETOWN Rhode Island
CROSSMAN ENGINEERING
Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture

Commercial

Table 2.7 and Figure 2.16 summarize new commercial space under the full-build condition which identifies a total of 2.65 million SF. Results showing reduced build-out for the alternative excluding Watershed Protection District 1 are also in Table 2.7. Commercial development is limited to commercial zoning districts in the western area of Town, including Aquidneck Corporate Park and the West Main corridor. Industrial development includes the "Omni" parcel located at 1747 West Main Road and adjacent parcels. The "Vanicek" property is a large agricultural parcel on the west side of West Main Road representing a significant portion of the new commercial space envisioned for the Middletown commercial full-build.

Table 2.7. Additional Commercial space in square feet by Zoning District for Alternative Scenarios

		Alternative Scenarios [3]			
Zone [1]	**Full-Build with Current Zoning**	**Exclude Marginal Lots [2]**	**Re-zone R-40/R-60 to R-100 Zoning [2]**	**Exclude Watershed Protection District 1**	**Implement All Alternatives [3]**
Industrial	406,241			249,676 (156,565)	249,676 (156,565)
Office	936,304			785,969 (150,335)	785,969 (150,335)
Retail	1,311,497			1,075,611 (235,886)	1,075,611 (235,886)
Total	2,654,042	-	-	2,111,256 (542,786)	2,111,256 (542,786)

[1] Results for Residential development in mixed use category provided in Residential full-build results section.
[2] Results for Exclude Marginal Lots and Re-zone R-40/R-60 to R-100 Zoning alternatives are unchanged for the Commercial full-build
[3] Values in parentheses represent the reduction in additional commercial space from the full-build scenario

Mixed use development areas were selected from business zone parcels which had high development potential and were along a main corridor and well-suited for the type of combination space envisioned by the Town. New development in the mixed-use category is 1.37 million SF and is allocated to office, retail, and condominium residential units. At a 35% residential utilization rate, 0.48 million SF of mixed-use space is allocated to residential units. This area is projected to equate to 480 residential units based on 1,000 SF per unit. Values in Table 2.6 reflect the office and retail portions of mixed-use development for the Middletown build-out.

There are approximately 702 existing dwelling units in commercial and public zones, which is approximately 10% of the current total housing units in Middletown. Several parcels with existing residential use are located in commercial corridors and an assumption is made that in the future, the residential uses will be changed to commercial use under the full-build condition. This assumption accounted for the loss of 97 existing dwelling units for the future commercial development.

Pare (2005) projected approximately 1.5 million SF of new office and light industrial space could be built based on analysis of three corporate parks and additional commercial parcels, including the "Omni" parcel and the "Vanicek" parcel. This included infill development of 759,000 SF at Aquidneck Corporate Park, 102,000 SF at the Newport Corporate Center, 130,500 SF at the Enterprise Center, and 27,000 SF on other commercial parcels. The total also included new construction on vacant lots, including 25,000 to 100,000 SF for the "Vanicek" parcel, 100,000 to 120,000 SF for a vacant parcel at the Enterprise Center, and 244,000 SF for the "Omni" parcel. This current full-build analysis assumed a more complete build-out of the "Vanicek" parcel, while infill development estimates are more conservative than in the Pare report as discussed previously in this Chapter.

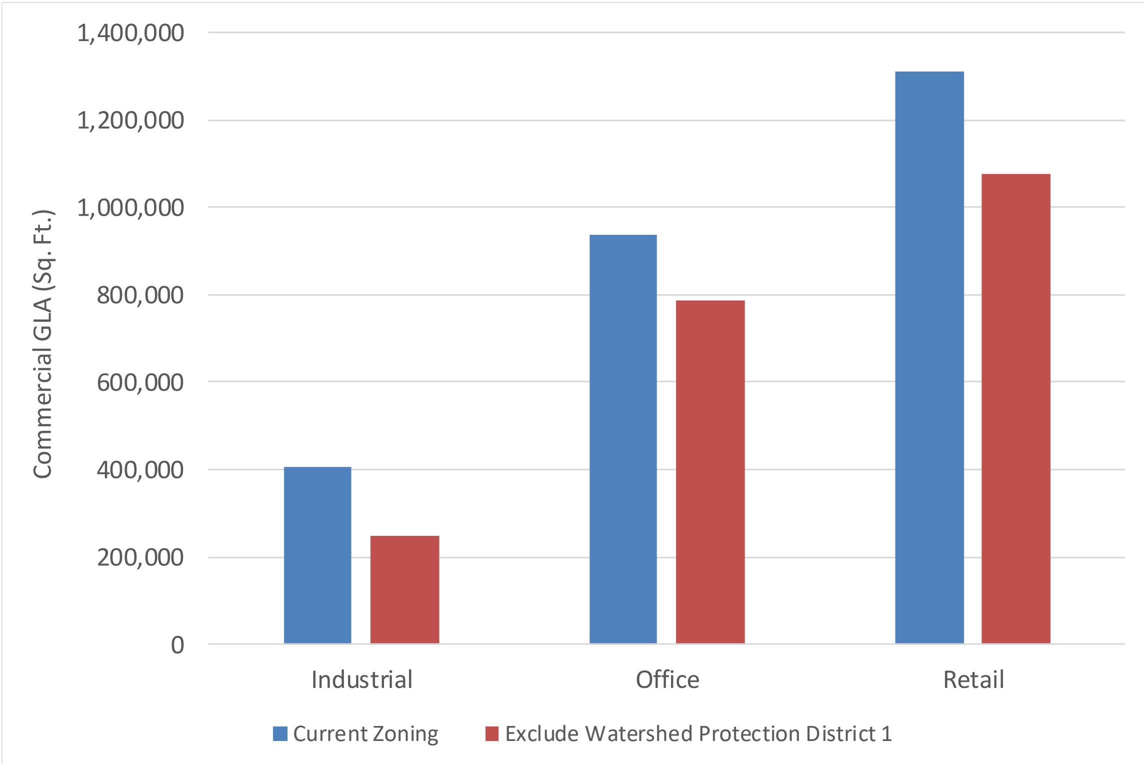


Figure 2.16 Full-Build Additional Commercial Space by development type

3. EVALUATION OF SURFACE WATER IMPACTS

MIDDLETOWN WATERSHEDS

Aquidneck Island has a land area of approximately 24,192 acres with the Town of Middletown situated in the central portion of the island between Portsmouth and Newport and with a land area of approximately 9,562 acres, Middletown represents 40% of the Aquidneck Island land mass. More importantly, 5,009 acres of Town is part of the Newport Water Supply (NWS) watershed and represents approximately 77% of the NWS watershed within Aquidneck Island. Figure 3.1 identifies the Newport Water Supply Reservoirs and tributary streams.

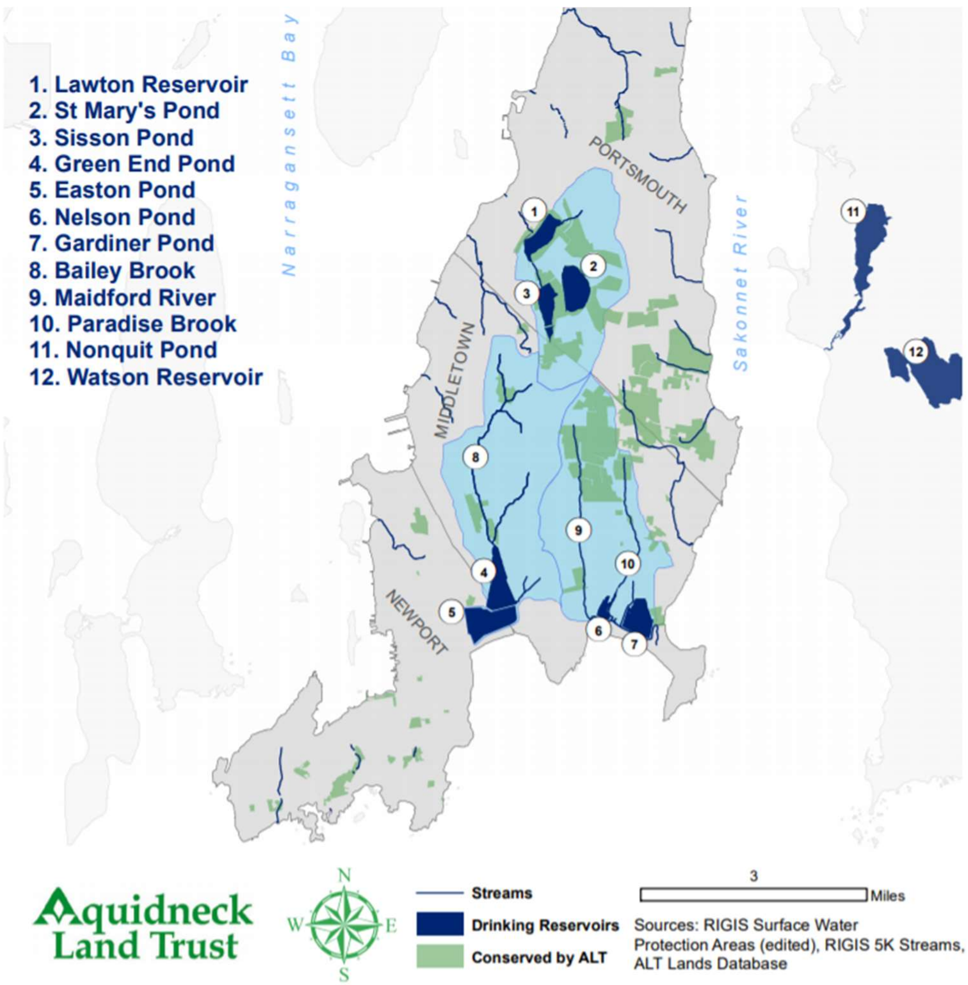


Figure 3.1 Aquidneck Island Watersheds, Source: Aquidneck Land Trust

Based upon water quality testing, RIDEM previously concluded that each stream within the entire water supply watershed within Middletown "is either threatened or impacted by non-point source pollution – namely agricultural, residential and highway runoff". RIDEM also notes that in southern Middletown, where development is most dense, conditions exhibit the worst quality.

The primary watersheds of Middletown, as identified by the United States Geological Survey (USGS) Hydrologic Unit Code (HUC) Classification, include the Lower East Passage (Narragansett Bay), Upper East Passage (Narragansett Bay), Aquidneck Island – Frontal Atlantic Ocean and Sakonnet River. For the full-build impact analysis, further subdivision of the primary USGS HUC watersheds was performed. The watershed boundaries are mapped on Figure 3.2 (USGS, 2010; RIGIS, 2002). Table 3.1 identifies the identified sub-watersheds and summarizes their present imperviousness condition. These watersheds represent portions which lie within the Middletown boundary, and include surface waters draining to Newport Water Supply reservoirs as well as those draining to coastal outlets.

Surface water protection areas (SWPA; RIGIS 2002) are watersheds of public surface water supply reservoirs and should be recognized as the first potential opportunity or line of defense to protect water quality for the future. In Middletown, Bailey Brook, Maidford River, Paradise Brook, and Gardiner Reservoir are designated SWPAs of the Newport Water Supply system. Lawton Reservoir in Portsmouth is also designated as a SWPA on Aquidneck Island but drains northwesterly, away from Middletown.

Nelson Pond is fed directly by Paradise Brook and also receives inflow from the Maidford River via a water supply diversion. Nelson Pond and Gardiner Reservoir are connected via a pipeline and together act as a reservoir with a storage volume of 526.1 million gallons. North Easton and South Easton Ponds are fed by Bailey Brook and its tributaries and together create a 685.1 million-gallon reservoir. These four reservoirs (Nelson, Gardiner, North Easton and South Easton), which essentially depend solely on runoff from Middletown lands, provide a total storage capacity of 1.211 billion gallons of drinking water and represent approximately 28% of the storage capacity of the Newport water system.

March 2020
Aerial Imagery credit: RIGIS
Watershed boundaries from RIDEM and RIGIS

Table 3.1 Surface Watersheds

Watershed Name[1]	HUC-12 Name	Area (acres)	Impervious Coverage[2] (%)
Upper East Passage	Upper East Passage	78	5.2%
Lower East Passage 1	Lower East Passage	1,455	20.1%
Sakonnet 2	Sakonnet River	2	7.7%
Sakonnet 1 (Little Creek)	Sakonnet River	880	7.9%
Lower East Passage 2	Lower East Passage	193	44.5%
Bailey (Brook)	Aquidneck Island – Frontal Atlantic Ocean	2,492	25.2%
Maidford (River)	Sakonnet River	1,498	9.2%
Paradise (Brook)	Sakonnet River	525	5.2%
Gardiner (Pond)	Sakonnet River	146	0.9%
Lower Maidford (River)	Sakonnet River	592	5.8%
Atlantic 1	Aquidneck Island – Frontal Atlantic Ocean	105	40.7%
Atlantic 2	Aquidneck Island – Frontal Atlantic Ocean	386	26.5%

[1] Watersheds highlighted blue represent Newport Water Supply watersheds.
[2] Imperviousness based upon areas for roadways, building rooftops, and driveway features from the Town of Middletown GIS.

SURFACE WATER QUALITY

The purpose of this section is to examine the potential impacts which may occur to surface water quality as a result of future residential and commercial build-out of Middletown. Consequences of unmitigated development can include an increase in runoff rates and volumes, pollutant loadings and sediment deposition, in addition to habitat degradation. Direct impacts can result from the point discharge of stormwater drainage systems and from non-point source runoff that sheet flows from lands towards surface water bodies. Both means of discharge can transport oils, greases, sediment, excess fertilizers, bacteria, nutrients and other pollutants. One commonality of both types of discharge is that scientific studies have documented a direct correlation between a watershed's impervious coverage and downstream environmental degradation. The studies indicated that once impervious coverage reaches 10% of a watershed, significant negative changes to a freshwater system becomes evident. Since all streams and wetland systems differ, the amount of imperviousness that creates evident change will vary but the 10% imperviousness value can be used as a general guideline for when evident degradation can be expected.

Upon review of the Middletown watersheds' imperviousness, Lower East Passage 1, Lower East Passage 2, Bailey Brook, Atlantic 1 and Atlantic 2 watersheds exceed the 10% threshold and would be expected to exhibit signs of environmental degradation. The Maidford River is also approaching this 10% milestone. As those past studies predicted, the expected environmental degradation was found to exist in these watersheds and is reflected in the existing water quality impairments of Bailey Brook, Paradise Brook, Maidford River, Gardiner Pond, Little Creek, North Easton Pond and South Easton Pond.

The identification of a water body as impaired is based upon actual pollutant concentrations compared to State and National standards. Common water quality parameters are summarized in Table 3.2 and Table 3.3.

Table 3.2 Surface Water Quality Standards for Freshwater Bodies

Parameter [1]	Standard	Standard Units	Comments
Enterococci	54	CFU/100ml [2]	Primary Contact Recreation/Swimming (non-designated bathing beaches), geometric mean
	33		Primary Contact Recreation/Swimming (designated bathing beaches), geometric mean
	61		Primary Contact Recreation/Swimming, instantaneous maximum (Beach swimming advisory threshold)
Fecal Coliform [4]	20 (200)	MPN/100ml [3]	Drinking water supply (Primary Contact Recreation/Swimming), geometric mean
	200 (400)		Drinking water supply (Primary Contact Recreation/Swimming), 90th percentile
Phosphorus	0.025	mg/l	Reservoir
Turbidity	5	NTU	Threshold for increase above background level; 10 NTU for Class B and C waters

[1] Toxic substances, including toxic metals, have criteria in the Water Quality Standards based on aquatic life and human consumption criteria from the EPA and are not listed in this table.
[2] CFU represents colony forming units;
[3] MPN represents most probable number, and is an equivalent unit to CFU;
[4] Primary Contact Recreation/Swimming criteria to be used if Enterococci data are not available.

Table 3.3 Surface Water Quality Standards for Saltwater Bodies

Parameter [1]	Standard	Standard Units	Comments
Enterococci	35	CFU/100mL	Geometric mean
	104		Instantaneous maximum (Beach swimming advisory threshold)
Fecal Coliform	14	MPN/100mL	Shellfishing geometric mean
	49		Shellfishing 90th percentile (31 CFU/100mL by mTec method)
Turbidity	5	NTU	Threshold for increase above background level; 10 NTU for Class SB and SC waters

[1] Toxic substances, including toxic metals, have criteria in the Water Quality Standards based on aquatic life and human consumption criteria from the EPA and not listed in this table.

State-listed impairments for waterbodies in Middletown are shown in Table 3.4. **The primary note of concern is that the majority of the Middletown watersheds are currently classified as impaired, therefore all new development and redevelopment should include the best practices available for water quality treatment of stormwater runoff**. High levels of Total Phosphorus and excessive algal growth have been identified as impairments to North Easton Pond (RIDEM, 2007) and to alleviate the impairments, RIDEM established target concentrations for the pond of 0.025 (mg/L) for Total Phosphorus, 9 µg/L for Chlorophyll-a and 2 mg/L for Dissolved Oxygen. These targeted levels would allow the pond to be utilized for its designated uses (2007 TMDL) as a reservoir. In order to reach the targeted levels, RIDEM estimated that loading to North Easton Pond which receives runoff from Bailey's Brook and its tributaries, would need to be reduced by 80% from levels measured in 2002 to achieve the 0.025 mg/l TP target. This targeted 80% pollutant loading reduction is from existing land uses and does not take into account additional loadings from full-build development.

Past studies have also demonstrated that Baileys Brook, Maidford River and Paradise Brook have bacteria levels that exceeded acceptable standards and are all recognized as impaired (RIDEM, 2011). Load reduction targets were set by RIDEM at 100% of fecal coliform for the Maidford River and Paradise Brook and 97% enterococci for Bailey's Brook. Enterococcus geometric mean values within Bailey Brook were found to range between 187-236 CFU/100mL and significantly exceed the standard of 54 CFU/100mL. For the Maidford River segment from the headwaters to the public water supply diversion, fecal coliform geometric mean values ranged between 152-746 MPN/100mL, exceeding the standard of 200 MPN/100mL. Fecal coliform samples for the Maidford River, downstream from the water supply diversion to its confluence with the Sakonnet River, ranged between 169-3,428 MPN/100mL, also exceeding in 3 of 4 cases the standard. For Paradise Brook, fecal coliform geometric mean values ranged between 38-1,200 MPN/100mL, exceeding the standard 200 MPN/100mL at 7 of 8 stations.

The TMDLs for Total Phosphorus and Total Organic Carbon that were originally scheduled for 2018 have been delayed by RIDEM and are anticipated to commence in 2020.

Table 3.4 Surface Water Quality Impairments for Waterbodies in Middletown, EPA 303d

Waterbody	Impairments [1]	TMDL Scheduled Year
Little Creek [2]	Enterococcus	2030-Ent
Gardiner Pond (Paradise Brook; Maidford River)	Total Phosphorous (TP), Total Organic Carbon (TOC), Other flow regime alterations	2018-TP, TOC
Paradise Brook	Fecal Coliform (FC), Total Phosphorous, Turbidity	2011-FC; 2018-TP, Turbidity
Nelson Pond (Paradise Brook; Maidford River)	Total Phosphorous, Total Organic Carbon, Other flow regime alterations	2018-TP,TOC
Maidord River, headwaters to water supply diversion	Benthic-Macroinvertebrate Bioassessments (MIB), Lead (Pb), Fecal Coliform, Total Phosphorus, Turbidity	2011-FC; 2018-TP, Turb; 2026-MIB, Pb
Maidford River, water supply diversion to Hanging Rock Rd	Fecal Coliform	2011-FC
Baileys Brook and tributaries	Lead, Enterococcus, Total Phosphorus	2011-FC; 2018-TP; 2026-Pb
North Easton Pond (Green End Pond) (Bailey's Brook)	Total Phosphorus, Chlorophyll-a (Chlor-A), Other flow regime alterations, Total Organic Carbon	2007-TP,Chlor-A; 2018-TOC
South Easton Pond (Bailey's Brook)	Total Phosphorus, Total Organic Carbon	2018-TP,TOC
Sisson Pond (Portsmouth)	Total Phosphorus, Total Organic Carbon, Other flow regime alterations	2018-TP,TOC
Coddington Cove, breakwater to Coddington Point [3]	Sediment Bioassays (SB) for Estuarine and Marine Waters	2028-SB

[1] RIDEM Online Database, 2019-01-25;
[2] All fresh water bodies with exception of Little Creek are designated Class AA public water supply;
[3] Coddington Cove, breakwater to Coddington Point, is Class SB designated for shellfish harvesting for controlled relay and depuration.

Impervious Coverage

To forecast potential impacts to water quality and groundwater recharge due to land development, changes in impervious area resulting from build-out were examined. Residential development typically includes new street creation, additional rooftops and driveways. Commercial development similarly adds impervious area by constructing buildings, parking lots, walkways, stormwater systems and new streets. Creation of impervious area causes a change in the runoff patterns by increasing the rate and amount of precipitation runoff. The typical impervious cover model ranks watersheds with below 10% impervious coverage as non-impacted, between 10-25% as impacted, and greater than 25% as non-supporting for water quality objectives.

Existing impervious coverage of the Town was determined using a merged dataset of impervious surfaces obtained from the Town geodatabase. Data of public roads and sidewalks, building footprints, parking lots, driveways and airport runways were merged to determine existing impervious coverage for each watershed.

In order to determine future impervious coverage for each watershed, the amount of impervious area associated with various land use types were first tabulated. For the full-build scenario, new development included residential single-family, commercial-retail, commercial-office, light industrial, and residential condominium developments, therefore the potential future impervious coverage of each land use was evaluated. Table 3.5 summarizes the values used to estimate future impervious cover for parcels to be developed in the build-out.

Table 3.5 Imperviousness per Land Use Type

Category	Lot Size (Sq. Ft.)	Zone Name	Impervious Coverage (%) Used	Impervious Coverage (%) from TR-55
R-10	10,000	Medium High Density Residential	38	38
R-20	20,000	Medium Density Residential	25	25
R-30	30,000	Medium Density Residential	25	25
R-40	40,000	Medium Low Density Residential	20	20
R-60	60,000	Medium Low Density Residential	20	20

Category	Lot Size (Sq. Ft.)	Zone Name	Impervious Coverage (%) Used	Impervious Coverage (%) from TR-55
R-100	100,000	Future Scenario – Low Density	12	12
Industrial	N/A	Light Industrial	75	72
Office	N/A	Office Business / Office Park	75	85
Retail	N/A	Commercial Retail	75	85

The Natural Resource Conservation Service (NRCS) Technical Release 55 (TR-55) provides a national standard for hydrologic modeling of runoff events (USDA, 1986) and documents impervious coverage based on various land use type. This study compared actual existing residential and commercial development impervious coverage values in Middletown to the NRCS TR-55 data and the results generally showed slightly lower actual impervious coverage in Middletown than the values prescribed in TR-55. It was also found that new development does not always build to the maximum allowed impervious coverage. Values in NRCS TR-55 are more reflective of the maximum allowed impervious coverages. For commercial land use, NRCS TR-55 assigns a higher rate of imperviousness to office and retail types. For this full-build study, a value of 75% was selected for all commercial development types to reflect the Town's 25% landscaping requirement.

Future impervious area coverages in each watershed were calculated by subtracting existing impervious area from the total maximum impervious area for each parcel with the full-build scenario. This determination of additional impervious area was summed for all parcels on a watershed basis to quantify the full-build change in impervious area. Figure 3.3 provides the existing and future impervious coverage in each watershed. In addition, Figure 3.4A and Figure 3.4B show the map of watersheds categorized for impervious coverage for existing and full-build results, respectively.

Under current conditions, five (5) of twelve (12) watersheds exceed 10% impervious coverage representing potential impacted conditions. Under the full-build condition, seven (7) of twelve (12) watersheds are projected to exceed the 10% threshold. Under current conditions, four (4) of twelve (12) watersheds exceed 25% impervious coverage, which represents potential non-supporting conditions. Under the full-build condition, five (5) of twelve (12) watersheds will exceed the 25% threshold. Lower East Passage 1 increases from the impacted to the non-supporting category, and Maidford and Sakonnet 1 (Little Creek) increase from the non-impacted to the impacted category.

Therefore, it is anticipated that without proper mitigation, noticeable additional degradation can be expected.

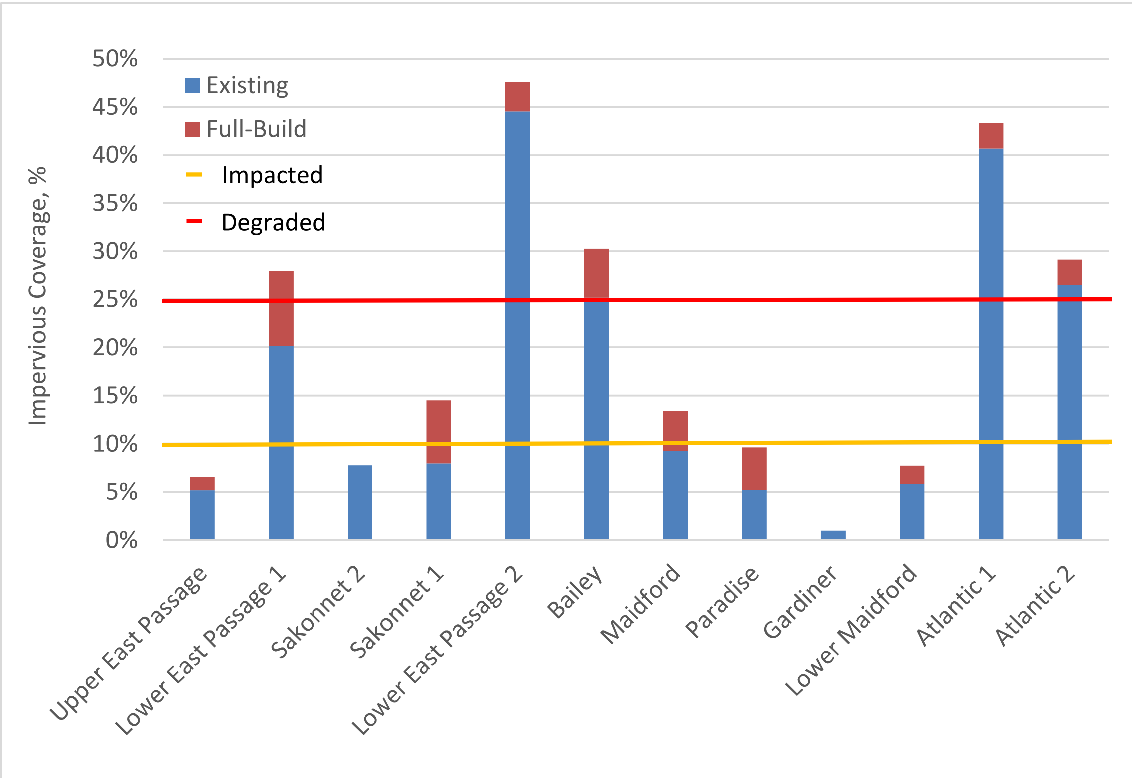
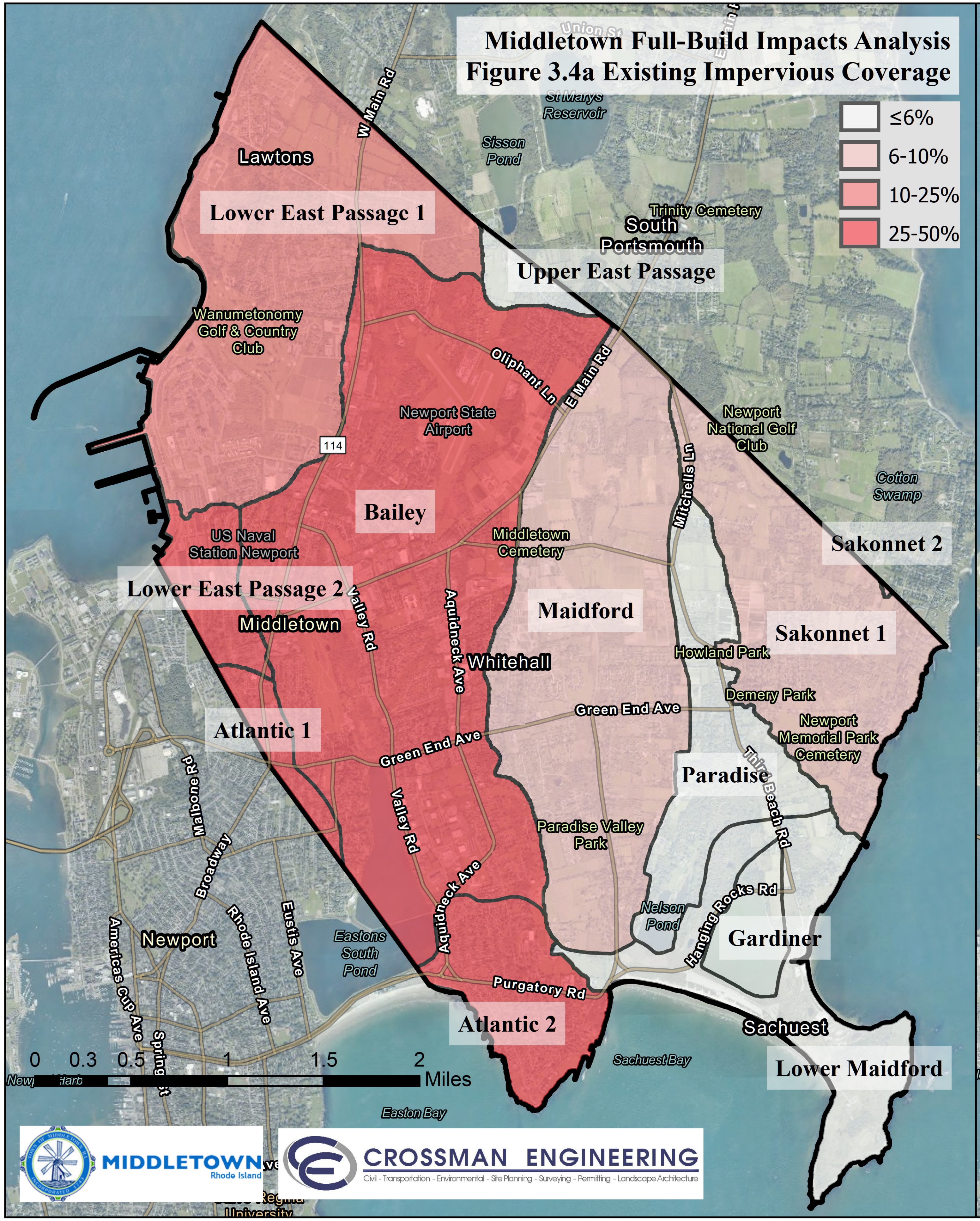


Figure 3.3 Existing and Full-build Impervious Coverage by Watershed

The degree of change in impervious coverage resulting from the build-out is depicted in Figure 3.5A and Figure 3.5B, showing absolute and relative change, respectively. Relative changes to existing imperviousness were highest for Paradise and Sakonnet 1 watersheds. The change in impervious coverage for the three (3) alternative full-build scenarios was also evaluated and indicates that for the rural eastern watersheds, the change to R-100 zoning reduced the full-build impervious impact by approximately 50%. For the Lower East Passage 1, the Watershed Protection Alternative reduced impervious area impacts by approximately 25%. Alternatives results for impervious coverage are shown in Appendix B.



Middletown Full-Build Impacts Analysis
Figure 3.4a Existing Impervious Coverage

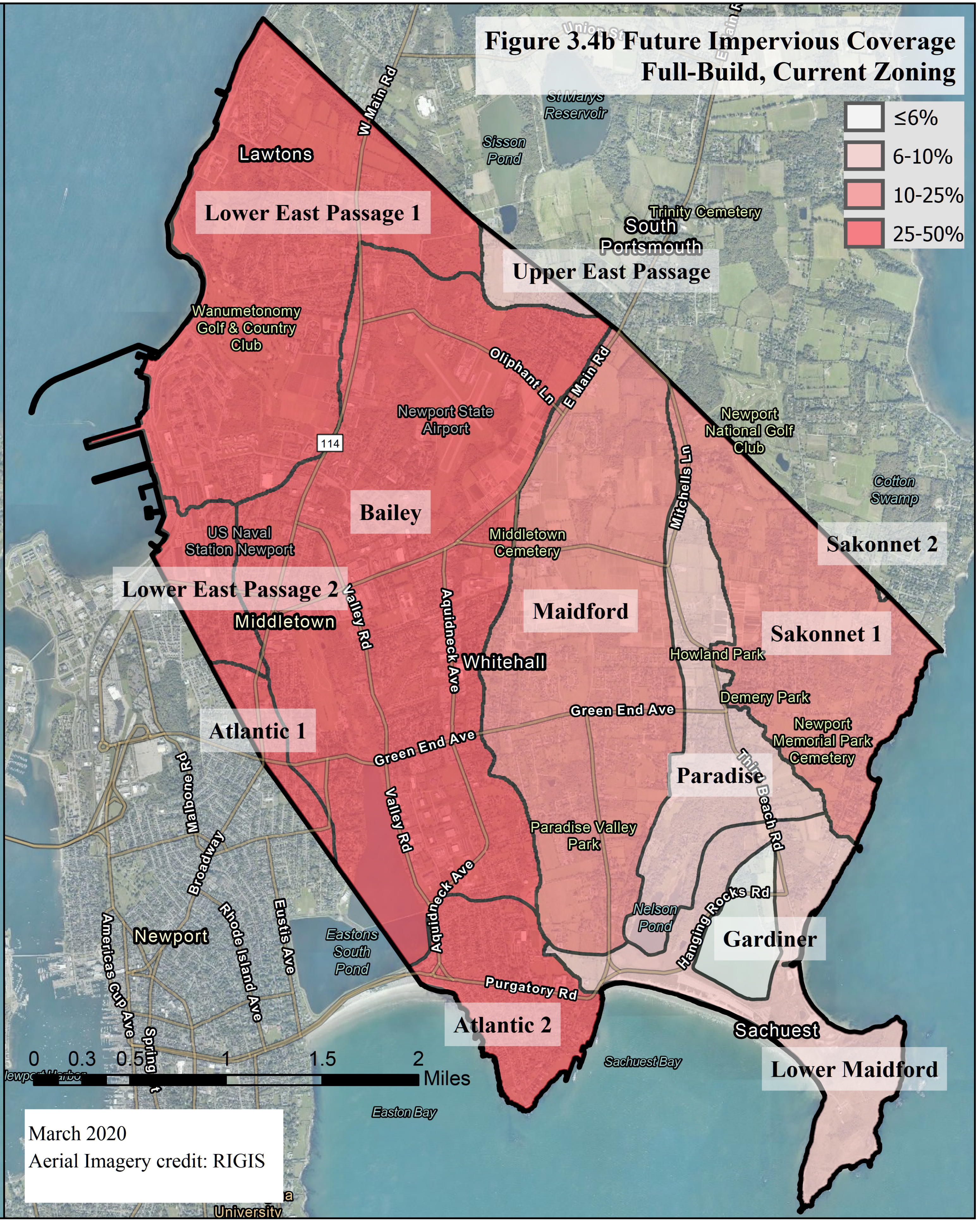
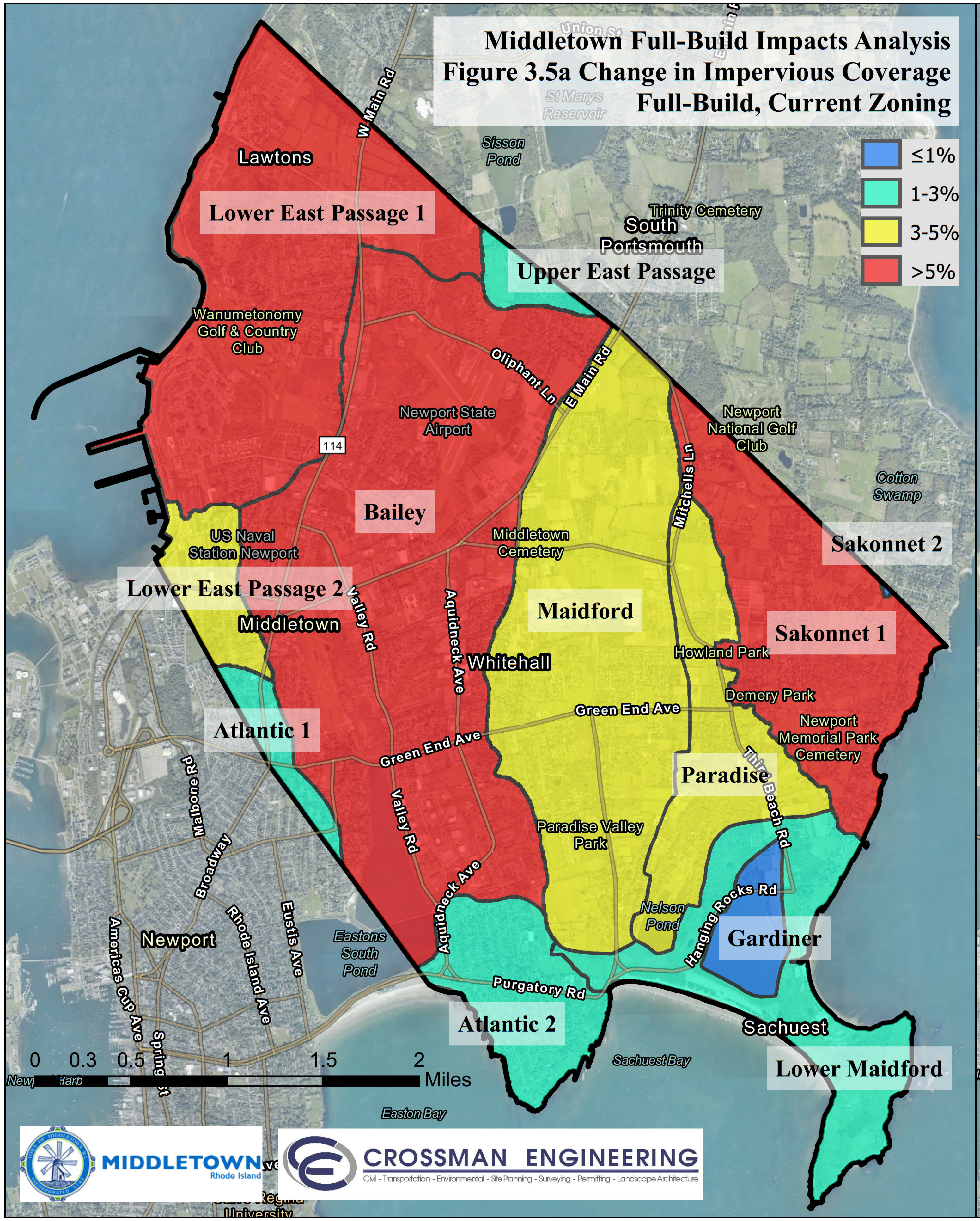


Figure 3.4b Future Impervious Coverage
Full-Build, Current Zoning


Middletown Full-Build Impacts Analysis
Figure 3.5a Change in Impervious Coverage
Full-Build, Current Zoning
≤1%
1-3%
3-5%
>5%
Lawtons
Lower East Passage 1
Upper East Passage
South Portsmouth
Trinity Cemetery
Sisson Pond
St Marys Reservoir
W Main Rd
Wanumetonomy Golf & Country Club
Newport State Airport
Oliphant Ln
E Main Rd
114
Bailey
Newport National Golf Club
Mitchells Ln
Cotton Swamp
Sakonnet 2
US Naval Station Newport
Middletown Cemetery
Lower East Passage 2
Middletown
Valley Rd
Aquidneck Ave
Maidford
Whitehall
Sakonnet 1
Howland Park
Demery Park
Green End Ave
Newport Memorial Park Cemetery
Atlantic 1
Paradise
Third Beach Rd
Malbone Rd
Broadway
Paradise Valley Park
Nelson Pond
Hanging Rocks Rd
Gardiner
Newport
Rhode Island Ave
Eustis Ave
Eastons South Pond
Americas Cup Ave
Purgatory Rd
Atlantic 2
Sachuest
Sachuest Bay
Lower Maidford
Easton Bay
0 0.3 0.5 1 1.5 2 Miles
MIDDLETOWN Rhode Island
CROSSMAN ENGINEERING
Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture

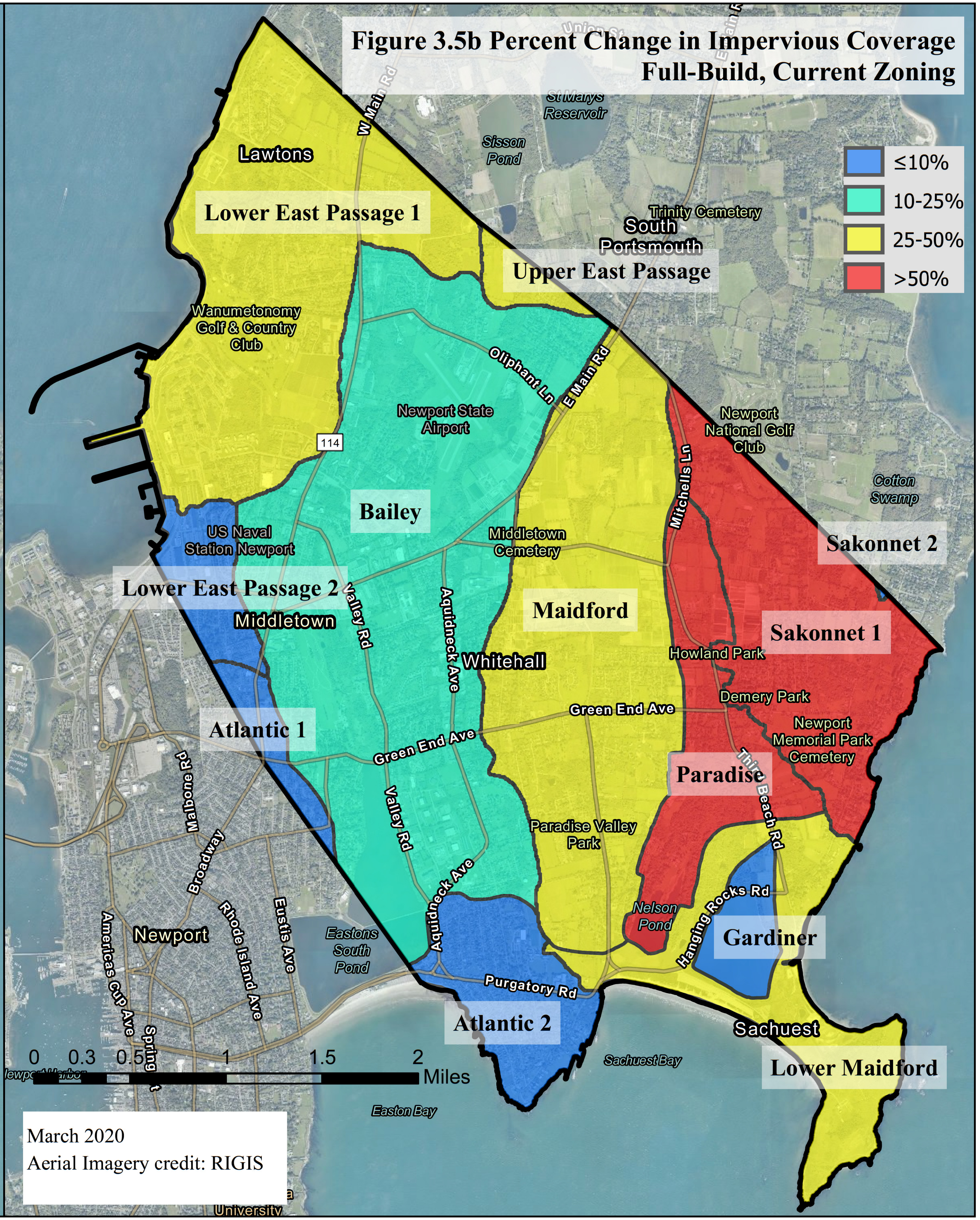


Figure 3.5b Percent Change in Impervious Coverage
Full-Build, Current Zoning
≤10%
10-25%
25-50%
>50%
Lawtons
Lower East Passage 1
Upper East Passage
South Portsmouth
Trinity Cemetery
Sisson Pond
St Marys Reservoir
W Main Rd
Wanumetonomy Golf & Country Club
Newport State Airport
Oliphant Ln
E Main Rd
114
Bailey
Newport National Golf Club
Mitchells Ln
Cotton Swamp
Sakonnet 2
US Naval Station Newport
Middletown Cemetery
Lower East Passage 2
Middletown
Valley Rd
Aquidneck Ave
Maidford
Whitehall
Sakonnet 1
Howland Park
Demery Park
Green End Ave
Newport Memorial Park Cemetery
Atlantic 1
Paradise
Third Beach Rd
Malbone Rd
Broadway
Paradise Valley Park
Nelson Pond
Hanging Rocks Rd
Gardiner
Newport
Rhode Island Ave
Eustis Ave
Eastons South Pond
Americas Cup Ave
Purgatory Rd
Atlantic 2
Sachuest
Sachuest Bay
Lower Maidford
Easton Bay
0 0.3 0.5 1 1.5 2 Miles
March 2020
Aerial Imagery credit: RIGIS

STORMWATER POLLUTANT LOADING

In order to assess the relative impact of build-out on water quality, the potential increase in Total Nitrogen, Total Phosphorous, Total Suspended Solids, Fecal Coliform, Lead and Copper were estimated based on the Simple Method, a recommended approach as outlined in the State of Rhode Island Stormwater Design and Installation Standards Manual (Stormwater Manual; RIDEM, 2015). The Simple Method is an empirical model which is useful for the prediction of pollutant loads for urban runoff scenarios. The model utilizes event mean concentrations (EMC) for pollutants which characterize the average concentration of a pollutant during rainfall runoff events. The model predicts loading on an annual basis; therefore, the model parameters must represent annual average values for the various land use types (i.e., residential, commercial, agricultural, and undeveloped).

The Simple Method is a two-part model which predicts pollutant load (L) in pounds as follows:

$$L = F \text{ x } R \text{ x } C \text{ x } A$$

F = Conversion Factor = 0.2267 for concentrations in (mg/L) and 1.03E-3 for pollutant density in colonies per 100 milliliters (CFU/100mL),
R = Annual Runoff (inches)
C = Pollutant Concentration (mg/l) or density (CFU/100mL)
A = Drainage Area (acres)

$$R = P \text{ x } P_j \text{ x } R_v,$$

P = Annual Precipitation (inches)
P_j = Fraction of Annual Precipitation converted to Runoff
R_v = Runoff Coefficient.

$$R_v = 0.05 + 0.009 \text{ x } I$$

I = Impervious Cover (%)

Typical impervious coverage values for the land use categories are shown in Table 3.6. Values are broken down further for each land use or land cover (LULC) type in Appendix A.

Table 3.6 Impervious Cover (%) by Land Use Category

Land Use Category	Imperviousness (%)
High Density Residential (<1/8 acre lots)	44
Medium High Density Residential (1/4 to 1/8 acre lots)	38
Medium Density Residential (1 to 1/4 acre lots)	25
Medium Low Density Residential (1 to 2 acre lots)	20
Low Density Residential (>2 acre lots)	12
Commercial [1]	75
Industrial [1]	75
Transportation [2]	80
Institutional [2]	34
Open Urban [2]	9
Agricultural [3]	19
Undeveloped	0

[1] Value utilized in this report for commercial and industrial build-out in Middletown;
[2] Watershed Treatment Model default values (Caraco, 2013)
[3] Value reflects turf grass land cover.

Pollutant EMC values for this study are primarily based upon the RI Stormwater Manual and are shown by land use category in Table 3.7. The values represent the order of magnitude expected for pollutants in runoff and are intended to be representative of a specific land use, e.g., residential, commercial, forested, etc. Therefore, the annual loading results will be useful for understanding relative water quality impacts to be expected from future land development. The EMC values broken down for each LULC type are shown in Appendix A.

Table 3.7 Pollutant Event Mean Concentration (mg/l) by Land Use Category

	Total Nitrogen	Total Phosphorus [2]	Total Suspended Solids	Fecal Coliform	Lead	Copper
Residential	2.1 [1]	0.30	100	7,000	0.012	0.005
Commercial	2.1	0.20	75	4,600	0.018	0.096

	Total Nitrogen	**Total Phosphorus** [2]	**Total Suspended Solids**	**Fecal Coliform**	**Lead**	**Copper**
Industrial	2.1	0.25	75	2,400	0.026	0.002
Transportation	2.3	0.25	150	1,700	0.035	0.001
Agricultural	2.85 [3]	0.50	100	300 [4]	0	0
Mining	2.1	0.25	150 [5]	2,400 [6]	0.035 [7]	0.096 [7]
Undeveloped	1.7	0.10	50	300	0	0

[1] Values for all parameters in mg/L except Fecal Coliform (colonies / 100 mL);
[2] Values for phosphorus from RIDEM (2015) and from EPA (2014) for Charles River TMDL study, Massachusetts;
[3] Nitrate value for agricultural land use estimated from general literature review
[4] Fecal Coliform value for agricultural land use based on agricultural study in Texas; value reflects crop agriculture use
[5] Value estimated for mining land use based on assumption of moderate losses from exposed soils.
[6] Fecal Coliform value for mining land use assumed equivalent to industrial land use;
[7] Lead and Copper values for mining land use assumed equivalent to highest value for other land uses assuming exposure of metals in mined material.

Pollutant Loading Results

As previously noted, the Simple Method was utilized to estimate pollutant loads for each watershed under existing and full-build conditions. All lands, developed and undeveloped, contribute to pollutant loadings and the intent of the model is to assess how pollutant loadings change as land use varies and intensifies.

Middletown's existing residential land use fraction is approximately 33% of the Town's area and will increase to near 50% in the full-build condition. Residential land use fraction varies by watershed and the primary increase is in the eastern part of the Town which includes the Maidford, Paradise, and Sakonnet 1 watersheds.

Overall, in the full-build scenario there is a slight decrease in the commercial / industrial / other developed land fraction from 23% to 22% with mild gains in commercial land area and some losses in areas such as developed recreation land. The full-build projection also estimates Agricultural land use, which is currently concentrated in the more rural eastern part of the Town including

Maidford, Paradise, and Sakonnet 1 watersheds, decreases from 23% to 12%. Losses will also occur in the natural land area which decrease from 21% to 17% of Town land area.

Commercial development and, to a lesser extent, moderate and high-density residential development will increase impervious coverage above agricultural or undeveloped land cover. Therefore, these developments, if unmitigated, will decrease groundwater recharge and produce more stormwater runoff than the existing conditions. Runoff increases in most watersheds are minor to moderate owing to limited future development or to development which is comparable in intensity to existing land use (e.g., agriculture and moderate to low-density residential). Across the Town, the estimated stormwater runoff increases by approximately 8% with the Lower East Passage 1 watershed experiencing the largest runoff increase at approximately 19%. More significant increases in Lower East Passage 1 owe to residential and commercial development.

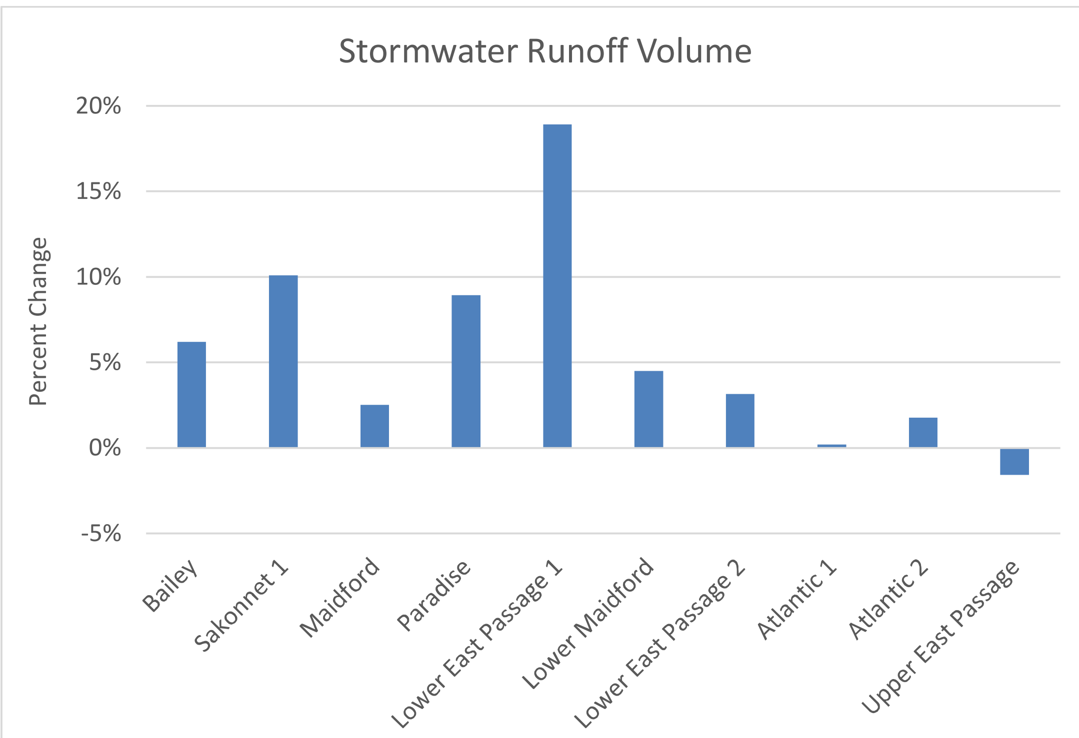


Figure 3.6 Stormwater Runoff Increase per Watershed

In addition to modeling the percentage increase in surface runoff, the percentage change in common pollutants associated with land development were determined. The modeled constituents included nitrogen, phosphorous, sediment, bacteria, copper and lead. Modeled changes in pollutant loading with full-build conditions are varied, as shown in Figures 3.7 – 3.12. Changes should also be understood in light of existing loading, where more developed watersheds generally have higher existing loading. This can be understood when examining the impervious coverage existing and future values in Figure 3.3. Furthermore, the modeling results reflect pollutant loading not mitigated by stormwater treatment both for existing and future conditions. Loads will be lower than predicted for future conditions where developers abide with the State and Town stormwater treatment requirements.

Nutrient levels do not increase significantly except on the order of 15% in Lower East Passage 1 watershed, which reflects the full-build development and associated runoff increases (Figure 3.7, Figure 3.8). Reductions in nutrient loading for watersheds, including Maidford, reflect relatively small changes in runoff patterns and estimated lower nutrient concentrations for residential land use (Table 3.7). Suspended solid or sediment loading increases are minor to moderate and reflect fairly consistently the increases in runoff (Figure 3.9). Bacteria loading increases are significant for some watersheds including the eastern watersheds with significant residential development, with impacts ranging from 42% to 84% (Figure 3.10). Agriculture may contribute to existing bacteria loading where livestock are managed but this land use was modeled to reflect minor bacteria loading as the majority of agriculture activities in Middletown are crop-related. Lead and Copper show moderate to significant increases in some watersheds, including the eastern watersheds with significant residential development, and Lower East Passage 1 with residential and commercial development (Figure 3.11, Figure 3.12). Decreases in Copper for Paradise and Maidford watersheds reflect limited transition of existing commercial use to residential use (on land zoned for residential use) and reflect the high EMC value for commercial land use.

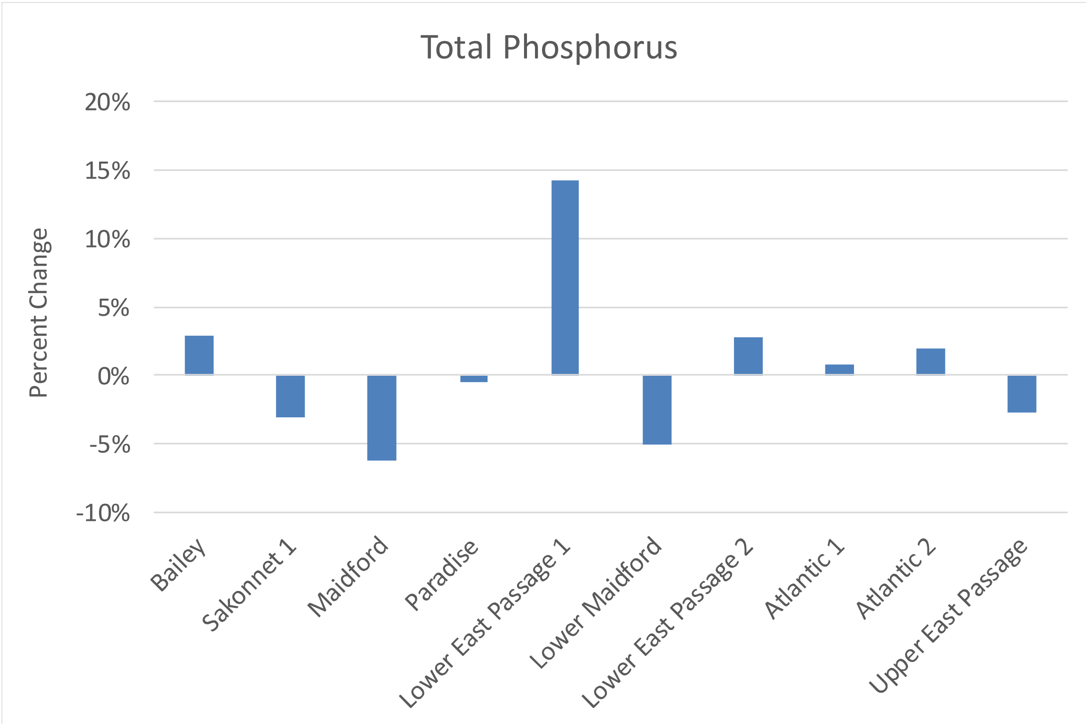


Figure 3.7 Change in Phosphorus Loads

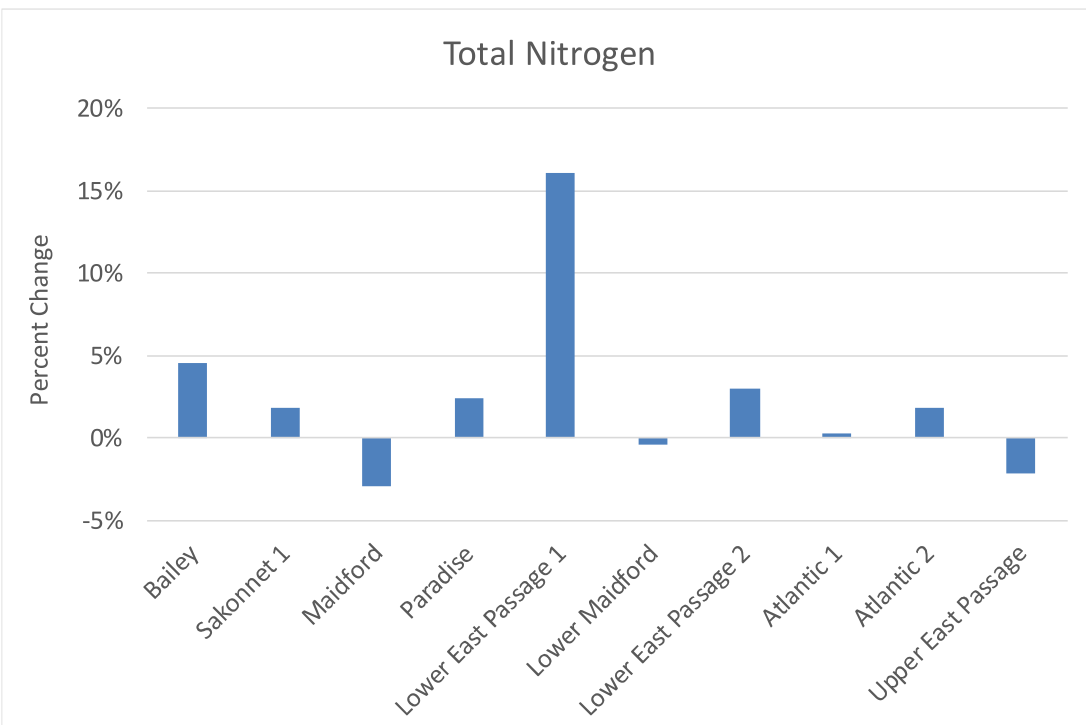


Figure 3.8 Change in Nitrogen Loads

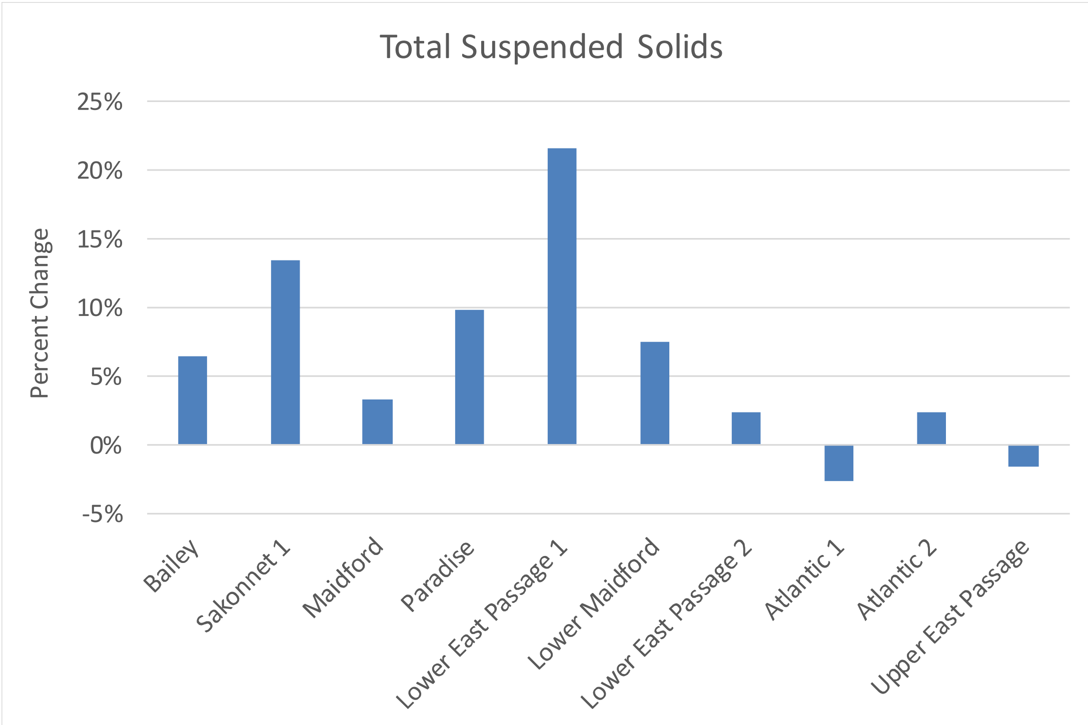


Figure 3.9 Change in Total Suspended Solids Loads

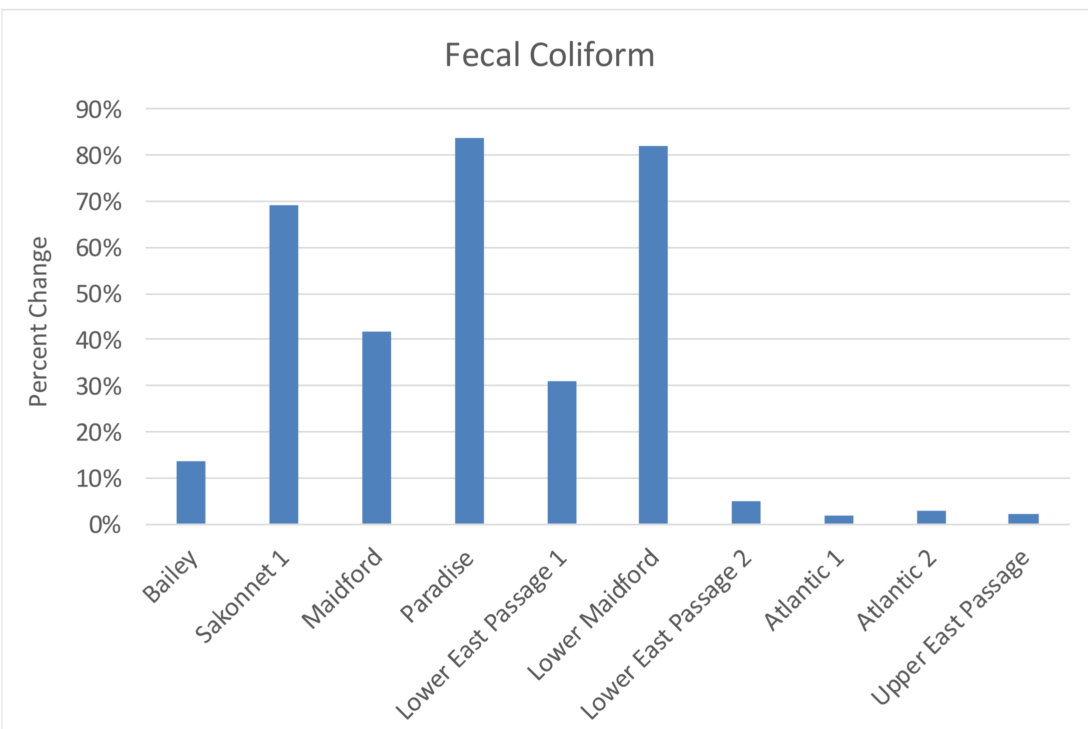


Figure 3.10 Change in Fecal Coliform Loads

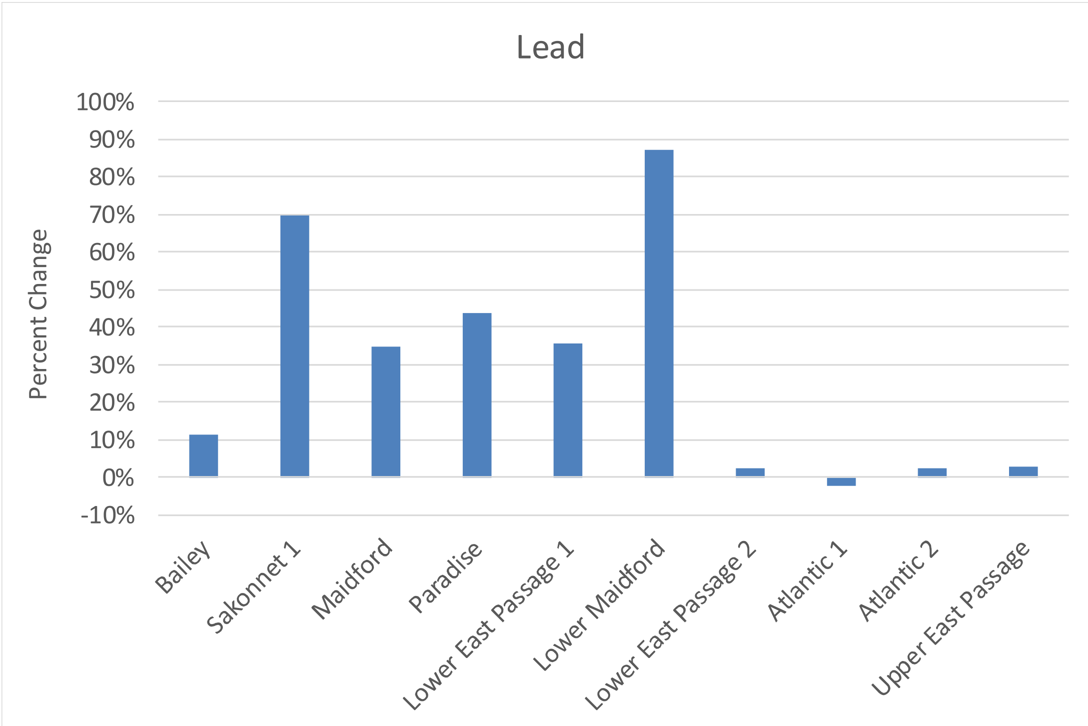


Figure 3.11 Change in Lead Loads

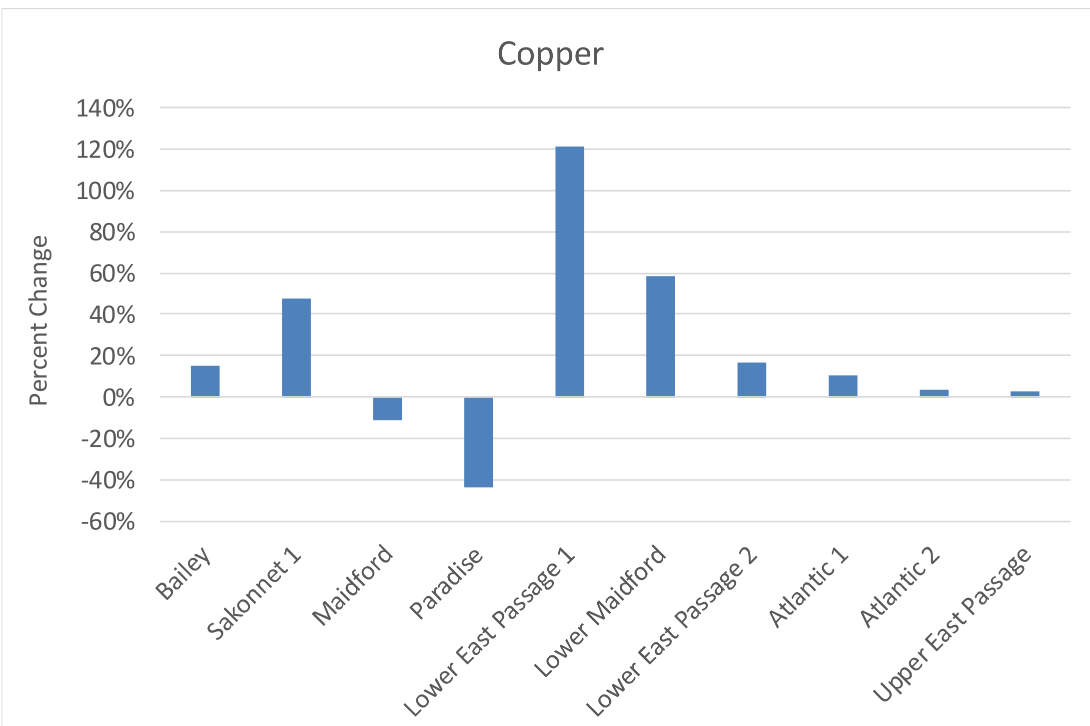


Figure 3.12 Change in Copper Loads

SURFACE WATER IMPACTS CONCLUSIONS

Existing water quality impairments currently exist for most of the surface water bodies in Middletown. Primarily, existing impairments include exceedances of phosphorus and bacteria standards, and lead exceedances are also recorded for the Maidford River and Bailey's Brook. The mass loading modeling results of the full-build study are beneficial in identifying if unmitigated development can be expected to degrade existing conditions. **Overall, modeling indicates that increases in bacteria and metals loadings will increase with build-out unless measures are taken to reduce runoff or mitigate the runoff quality from developed areas**. For sub-watersheds that currently have livestock agricultural land uses, localized reductions in bacteria levels may occur.

Looking at the alternative scenarios which restrict build-out for Sakonnet 1, Maidford, Paradise, and Lower Maidford watersheds, loads decrease rather than increase with R-100 re-zoning scenario, for nutrient and sediment loading. Moderate increases are still observed although less than the full-build scenario, for bacteria and metals loading. Load impacts are unchanged for Bailey and Lower East Passage 1 watersheds, partially due to imprecision of the model data inputs to capture land use changes. The Watershed Protection District (WPD) 1 exclusion scenario is expected to provide a slight impact reduction from the full-build scenario. Alternatives results for the water quality analysis including mass loading and percentage change in loading are provided in Appendix B.

The Town currently enforces a Stormwater Management Ordinance (Title XV, Chapter 153), which requires preparation of a Stormwater Management Plan and implementation of stormwater controls for land development. Water quality treatment is required for the first one (1) inch of runoff over impervious areas and the Town Stormwater Ordinance requires conformance with the RI Stormwater Manual. Enforcement of these standards provides partial mitigation to stormwater impacts of new developments in Middletown. The Stormwater Manual provides tabulation of expected pollutant removal percentages for various stormwater mechanisms.

Structural stormwater treatment systems are generally required (RIDEM, 2015) to provide the following pollutant load reduction from new development runoff: 85% for suspended solids, 30% for nitrogen and phosphorus, and 60% for pathogens, including pathogenic bacteria. A stormwater design that conforms to the RI Stormwater Manual is assumed to meet the above targets but it should be noted that the targets do not remove 100% of any pollutant. The Manual does state that stormwater systems may be required to achieve a higher pollutant removal rate for impaired receiving waters, drinking water reservoirs, bathing beaches, shell fishing grounds, Outstanding

National Resource Waters, including Special Area Management Plans (SAMPs) or where TMDLs have been prepared.

Past studies of the Middletown watersheds clearly demonstrated that bacteria and phosphorus concentrations increase during wet weather events and are directly related to stormwater runoff and as outlined in Table 3.4, Middletown Watersheds are already identified as impaired with numerous pollutants. Therefore, there are existing concerns with water quality due to surface water runoff, which creates concern for new developments and associated future contributions to already-impaired waters.

Surface Water Quality Recommendations

Independent of new development, historical data of Middletown waterways clearly demonstrate that source reduction and stormwater controls should be pursued to mitigate past land development and new development must address not only current standards but implement stormwater systems that specifically treat the individual watershed's pollutant of concern. Recommendations to mitigate surface water quality include:

3.1 Develop a community outreach program to raise awareness and to gain business and public support to address existing watershed impairments.

3.2 Continue to encourage low impact development (LID) development strategies that minimize impervious area creation.

3.3 Recognize that stormwater mitigation designs based upon current standards do not fully remove pollutants of concern and identify specific target pollutant removal efficiencies that should be achieved based upon watershed specific impairments.

3.4 Promote source reduction (stormwater recharge/infiltration) strategies to reduce stormwater discharge from new development.

3.5 Establish a Fertilizer Nutrient Control Ordinance to minimize excess nitrogen and phosphorous loadings from existing lands and new developments.

3.6 Establish routine water quality testing of Town stormwater systems to assist in the identification of existing pollutant sources. Identify significant pollutant sources and work towards implementation of improvements.

3.7 Identify streams and waterways that experience erosion (sediment transport) for permanent stabilization projects.

3.8 Identify opportunities to improve discharge of existing development through retrofit of existing stormwater systems.

3.9 Evaluate the feasibility of establishing a Town Stormwater Utility for improved operations, maintenance and performance of current and future stormwater systems.

3.10 Work towards development of watershed hydrologic and hydraulic models to allow for more accurate evaluation of land development impacts and mitigation benefits.

4. EVALUATION OF GROUNDWATER IMPACTS

INTRODUCTION

In addition to impacts to surface waters, unmitigated land development has the potential of impacting groundwater resources which supply drinking water to wells and provide recharge to streams and wetlands. The first step in assessing potential groundwater impacts is an evaluation of changes to the hydrologic cycle and the corresponding change in the volume of rainfall that recharges groundwater versus the volume that becomes surface runoff.

Precipitation

Annual precipitation in Middletown has averaged 41.7 inches per year from 1999 to 2018. (Northeast Regional Climate Center http://climod2.nrcc.cornell.edu/). The same period averaged 48.5 inches in Providence, RI, while the long-term record from 1933 to 2018 for Providence averaged 45.1 inches. Climate data for Newport, RI for the years 1961 – 1990 indicate an annual precipitation average of 45.97 inches per year. For this analysis, an average of 46 inches per year will be used.

Geologic Setting

The surface geology of Middletown is covered by glacial till. The "till [overburden], commonly referred to as 'hardpan', is composed of boulders, gravel, sand, silt, and clay mixed in various proportions, and is usually compact, stony, and difficult to dig." (Flanagan et al., 1999). According to Trench (1991), the till in the Narragansett Basin averages approximately 20 feet in depth above bedrock. When compared to stratified drift glacial deposits, which are common in other areas of New England, till deposits are less permeable and less prolific as water-yielding formations (Trench, 1991).

Middletown is in the southern section of the Narragansett Basin and the bedrock geology consists mainly of sedimentary and metamorphosed sedimentary rock, including conglomerate, sandstone, shale, and some coal, graphite, and slate (Trench, 1991). The Rhode Island Formation comprises most of Middletown, which is shown in a purple shade in Figure 4.1, with intervening Purgatory Conglomerate, which is shown as narrow blue bands extending north to south (RIDEM http://www.dem.ri.gov/maps/). Due to the differing formation process of sedimentary, igneous and metamorphic rocks, metamorphosed sedimentary rock typically provides less access to water than sedimentary rock but more access to water sources via fissures than igneous formations.

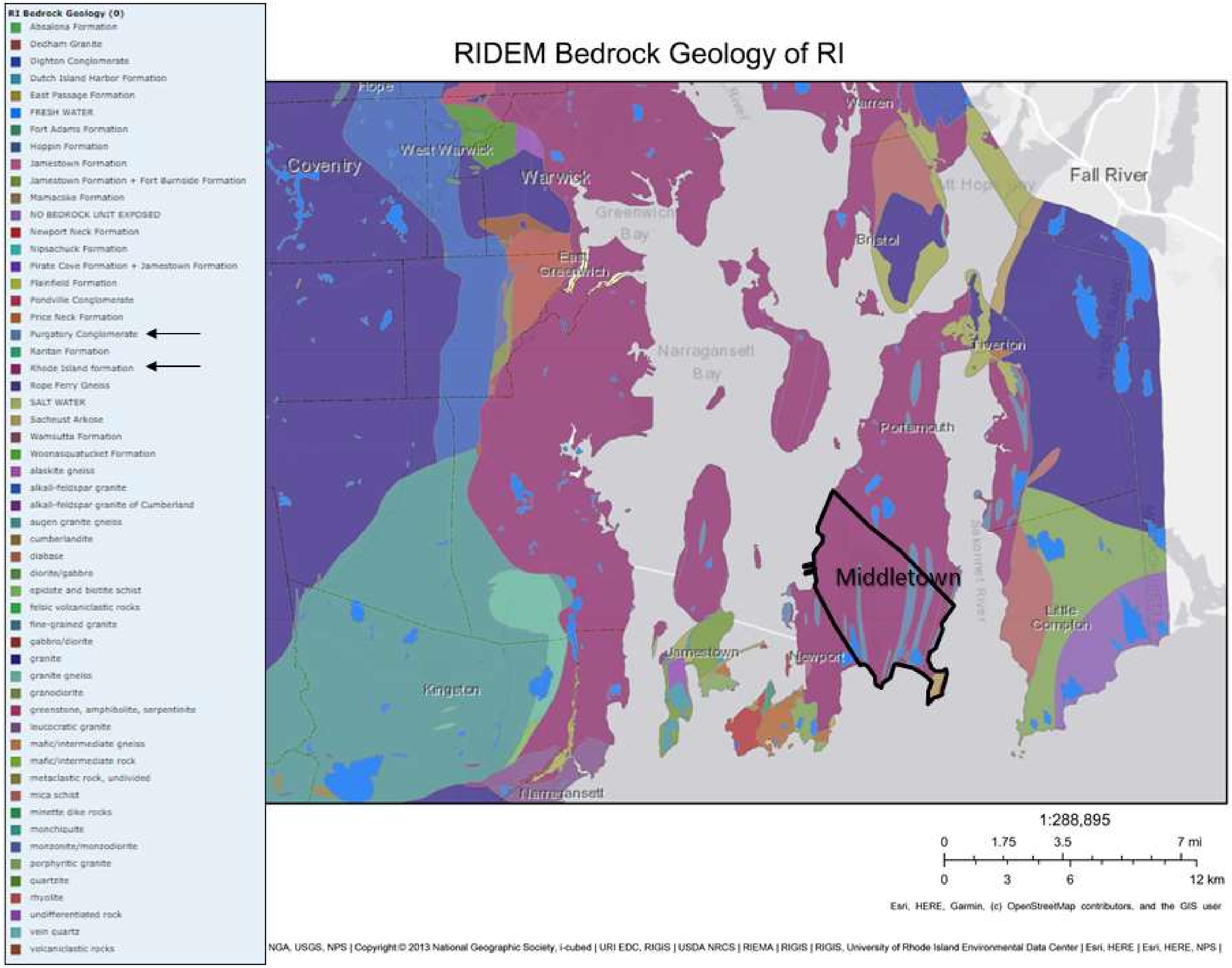


Figure 4.1 Bedrock geology for eastern Rhode Island

Groundwater recharge occurs via infiltration and the groundwater flow direction can be reflective of surface topography, moving from higher elevations downward towards the coast (Trench, 1991). With low permeable till soils, groundwater movement is slow and commonly varies from 0.1 to 5 feet/day. As precipitation infiltrates the volume is stormed temporarily in the till layer until it ultimately discharges laterally to surface water or further recharges to the underlying bedrock through fractures at the till-bedrock interface (Trench, 1991; Flanagan et al., 1999). This bedrock recharge provides a water supply to approximately 1,000 private wells in Middletown.

Bedrock wells are considered to be a dependable water source for homes with moderate demands but the dependence on water movement through fissures and the randomness of fissures create a degree of uncertainty in regard to the potential impact of development on a specific well. The performance of each well will vary and depend upon the interconnection and number of fissures, bedrock weathering and the drilled well depth. Typically, shallower wells have a higher probability of seasonal supply deficiencies but bedrock wells in general are a reliable water source for low volume users. In regards to well depths, once a well reaches a depth of 500 feet in the metamorphic sedimentary bedrock, fissures become less available due to subsurface pressures, with minimal benefit of drilling deeper than 500 feet (Trench, 1991).

Available well records for Middletown were researched and it was found that 100 records were available for wells installed between 1972 to 2018. Based on these records, average depth to bedrock is 18 feet with a range from 4 feet to 60 feet. The 90th percentile of well depth is 522 feet, indicating that most wells are less than 500 feet. This corresponds well with the indication that the productive fracture zone for metamorphosed sedimentary rocks is 500 feet (Trench, 1991). Average well depth was found to be 340 feet. Data for 85 wells provided yield data; 1 well was dry, 4 wells yielded less than 1 GPM and the average yield is 7.8 GPM. The yield data are based on driller’s reports and may not reflect long-term yields.

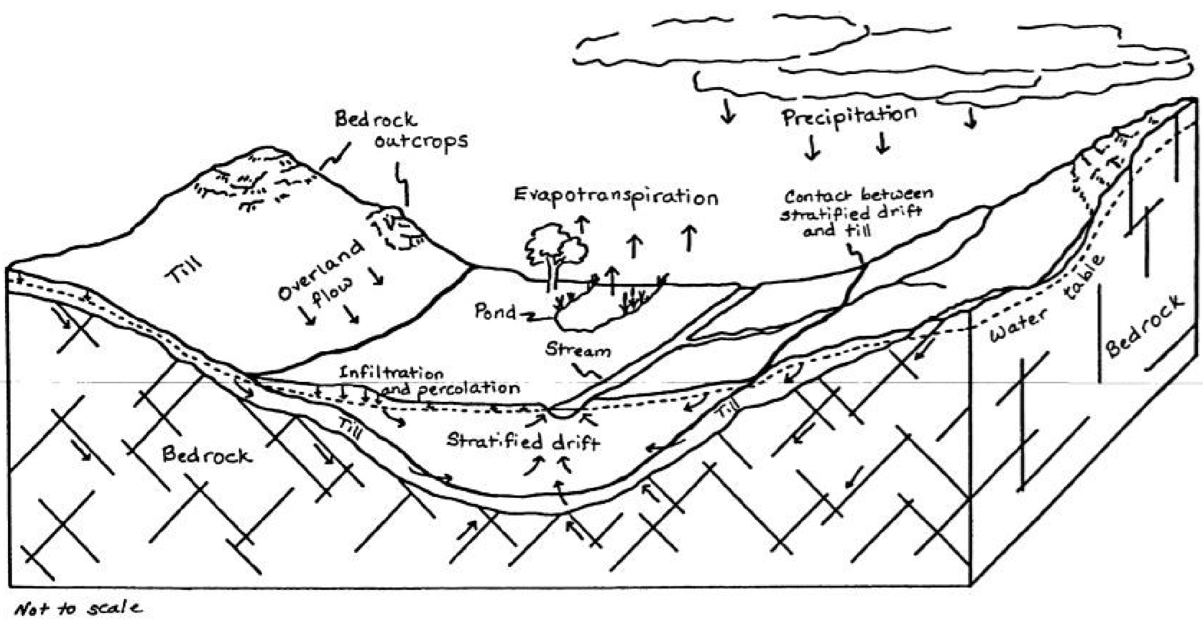


Figure 4.2 Geologic Setting for Glaciated Terrain (Trench, 1991)

GROUNDWATER RECHARGE

The exact location of ground surface area that contributes to the recharge of a bedrock well depends upon the fissure connectivity and degree of bedrock weathering but based on the region's rolling terrain, it is reasonable to conclude that a significant surface recharge area is in close proximity to the well itself and not from an extended distance. To assess the potential impact on the groundwater / bedrock water supply, a water budget was prepared to assess the annual inflow and recharge into the aquifer. Essentially, the water budget starts with quantifying precipitation and partitioning the precipitation into the various components of the budget, including evapotranspiration, shallow subsurface flow, runoff, and recharge.

Water Budget

A simple water budget equation can be expressed as:

$$P = Q + ET + R + \Delta S$$

With, P = Annual Precipitation = 46 inches

Q	=	Surface Discharge from Watershed
ET	=	Annual Evapotranspiration = 20.5 inches
R	=	Recharge = 9 to 12 inches into till
ΔS	=	Change in Storage volume

The average annual evapotranspiration rate is based upon Northeast Regional Climate Center at Cornell University for Providence, RI. For annual water balance it is customary to assume negligible change in storage volume or soil moisture, so that the water balance equation becomes;

$$P = Q + ET + R$$

In regards to recharge, the till overburden is generally much less permeable than stratified drift surface formations also found in New England. A study completed in western Connecticut with similar glacial surface geology reported calibrated model results between 3.6 to 7.9 inches of groundwater recharge annually, while considering the effects of surface geology and impervious coverage (Mullaney, 2004). The higher value is considered typical of sub-basins with less impervious area. A summary of groundwater resources for Rhode Island described characteristics of the Narragansett basin and reported average annual recharge to stratified drift formations at 25 inches and recharge to till formations at 9 inches (Trench, 1991). Other reports tend to validate the use of 9 inches for annual recharge into till. For this analysis, it is reasonable to assume 9 inches and 12 inches as lower and upper limits for expected annual recharge into the upper till layer. From this value, the next step is estimation of the amount of water from the till recharge that will eventually recharge the bedrock fissures.

Recharge into the till overburden may eventually discharge horizontally to local surface waterbodies, be removed via evapotranspiration from the soil surface and vegetation or recharge to the underlying bedrock formation. Since base flow within perennial streams is commonly via groundwater discharge and since there are numerous perennial streams in Middletown, it is reasonable to assume that less than 100% of till recharge will eventually recharge into bedrock fissures. Bedrock recharge depends on factors including bedrock formation, land slope, overburden thickness and overburden permeability (Nielsen, 2002). Literature values were compiled and data collection was performed by Nielsen (2002) for estimation of recharge to bedrock formations in New England. Annual recharge values cited ranged from lower estimates of 1 to 4 inches, moderate estimates from modeling of 2 to 8 inches, to higher estimates of 9 to 11 inches. Flanagan et al. (1999) indicated expected bedrock recharge of 3 to 5 inches for crystalline bedrock in New England, but this was from the same study reporting 1 to 4 inches in Nielsen (2002). It is recognized that the metamorphosed sedimentary bedrock in southern Narragansett Basin will have a higher degree of fissures, water recharge and water movement than igneous formations in other areas of New England but it is clear that the actual recharge to metamorphosed sedimentary bedrock in southern New England is not well quantified. For water recharge into Middletown bedrock, a range was assumed to be between 30% to 60% of the till recharge into bedrock. Therefore, low and high estimates of annual bedrock recharge are:

Low annual bedrock recharge = 30% x 9 inches = **3 inches**

High annual bedrock recharge = 60% x 12 inches = **7 inches**

For the following impact evaluations, the assumption is made that any decrease in recharge into the till overburden will result in the same percentage reduction of recharge into bedrock fissures.

Recharge Standard

In 2010, the State of Rhode Island improved stormwater design standards and recognized that maintaining groundwater recharge rates are necessary to maintain a hydrologic balance and to minimize environmental impacts from land development. These new standards are identified in the RI Stormwater Manual (RIDEM, 2015). The Recharge Standard as stated in the Stormwater Manual is:

$$Re = (1 \text{ inch} \times F \times \mathrm{I})/12$$

With,	Re	=	Required Recharge Volume (acre-feet)
	F	=	Recharge factor based on soils
	I	=	New Impervious Surface Area (acres)

The value of one (1) refers to the runoff in inches from a storm with 1.2 inches of precipitation, referred to as the Water Quality storm. The value for *F* with soils of hydrologic group C (poor infiltration) is 0.25. Group C Soils are typical of till-derived soils in Middletown (USDA SSURGO soil database for Rhode Island). Therefore, for new impervious surfaces in Middletown recharge mitigation typically provides up to 0.25 inches of rainfall for each rain event.

With till recharge being 9 to 12 inches per year in pervious areas, an assessment was performed to determine if the 0.25-inch recharge standard is reasonable for impervious surfaces. For this evaluation, a 15.5-year period of hourly rainfall data were analyzed. During this period there was a total precipitation of 743 inches with an annual average precipitation of 47.9 inches per year. During rain events, excluding trace and minor events that were considered insufficient to generate measurable runoff, a total of approximately 677 inches of precipitation occurred. Since numerous single storm events exceed 0.25 inches of rainfall, the approximate number of actual events is approximately 542. Based on an evaluation of each of the rain events, when the first 0.25 inches of each rain event from an impervious surface is infiltrated, approximately 160 inches would be recharged during this period. On average, this recharge is computed to be approximately 10.3 inches per year, which is within the range of the expected natural recharge into till for predevelopment conditions.

Based upon the above calculations, the RI Stormwater Manual Recharge Standard appears to mitigate the loss of recharge due to the creation of new impervious surfaces but two (2) concerns remain. First, the granting of waivers to this standard should be avoided in undeveloped areas, especially within water supply watersheds. Secondly, the RI Stormwater Manual design process assumes that an infiltration system operates at 100% efficiency for its life. In actuality, the infiltration capacity will tend to decrease over time; therefore, the actual long-term infiltration volume is anticipated to be below the intended target.

Bedrock Recharge Results

Estimates of existing annual recharge into bedrock fissures were computed on a watershed basis and are shown in Figure 4.3. The range of the low and high bounds for each watershed are depicted. Individual watershed values differ significantly due to differing watershed size and surface features. The highest annual recharge volume is reported for the Bailey Brook watershed, which is also the largest watershed by area. The bedrock recharge for Bailey Brook watershed is estimated to range from a low of 391 acre-feet to 1,042 acre-feet (1.9 to 5.0 inches).

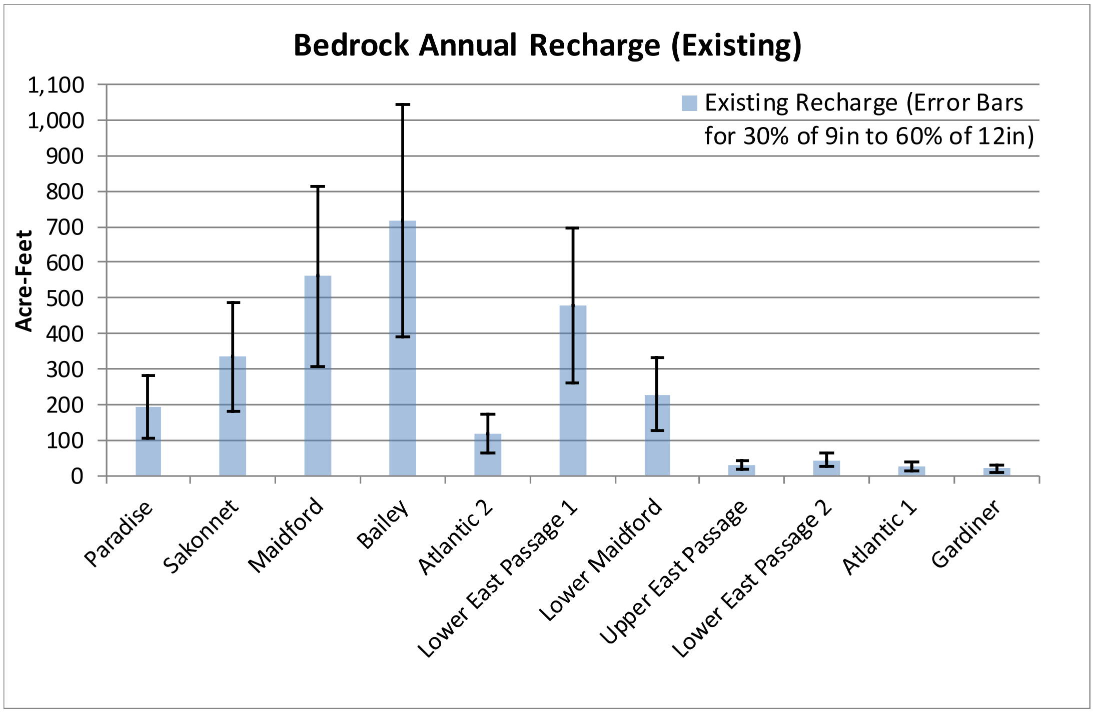


Figure 4.3 Existing Annual Bedrock Recharge to Pervious Areas per Watershed

Future recharge volumes were computed for each watershed for the full-build condition with no recharge mitigation. This represents the maximum potential impact to the Town. Future recharge values for this worst-case scenario are shown in Figure 4.4 and the change in recharge is shown in Figure 4.5. In addition, Figure 4.6 depicts the locations and change in recharge for each watershed. The findings were that impacts to recharge due to increases in impervious surfaces range from -1.5% for the Upper East Passage watershed to -10% for the Lower East Passage 1 watershed. Change in recharge for Gardiner watershed shows no significant change. Results in Figures 4.4 – 4.6 reflect the build-out under current zoning regulations. Results for alternative scenarios are shown in Appendix B; highlighted improvements include the R-100 zoning alternative reduced impacts by approximately 50% for the Sakonnet 1 Watershed and the WPD-1 alternative reduced impacts by approximately 25% for the Lower East Passage 1 Watershed.

Current and future developments in Town are required to conform to the State Recharge Standard described previously, unless a waiver is granted, and as previously described, the rainfall/recharge analysis suggests that conformance to the Recharge Standard will result in an infiltration volume that is near the existing recharge volume that occurs within pervious areas in Middletown. Therefore, CE concludes that development with fully compliant mitigation will not significantly alter the groundwater recharge pattern for the Town.

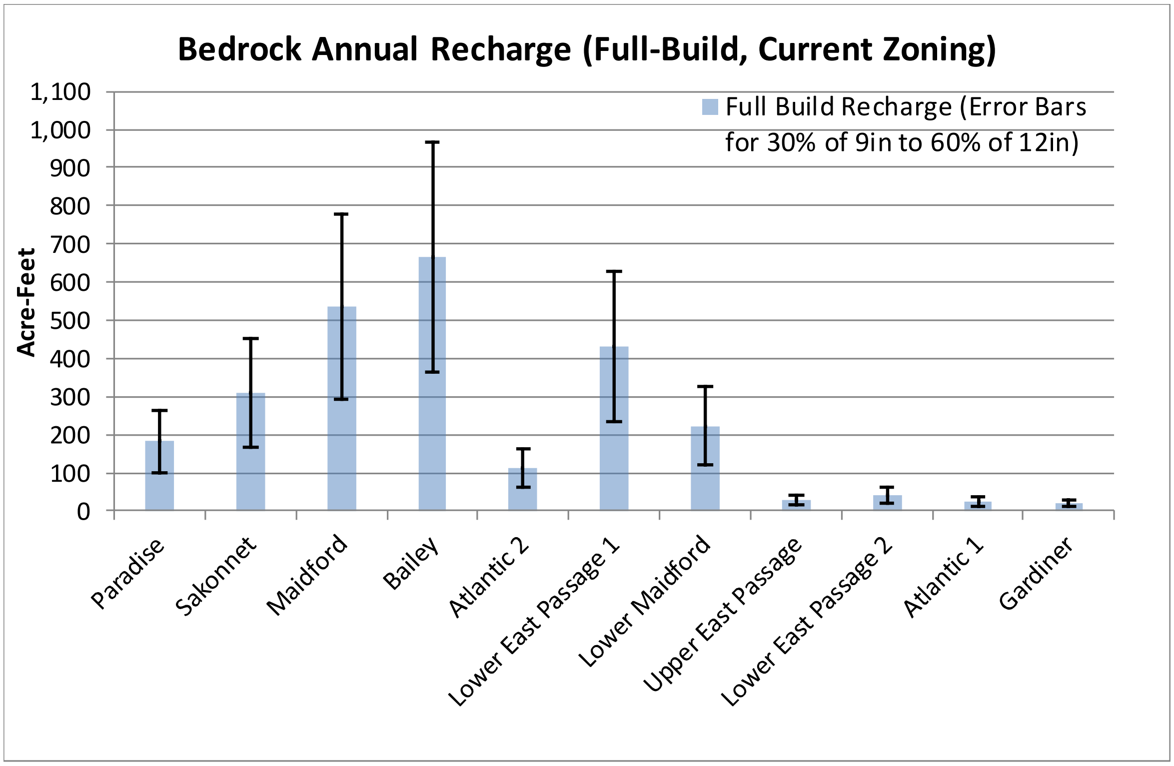


Figure 4.4 Future Annual Bedrock Recharge to Pervious Areas per Watershed

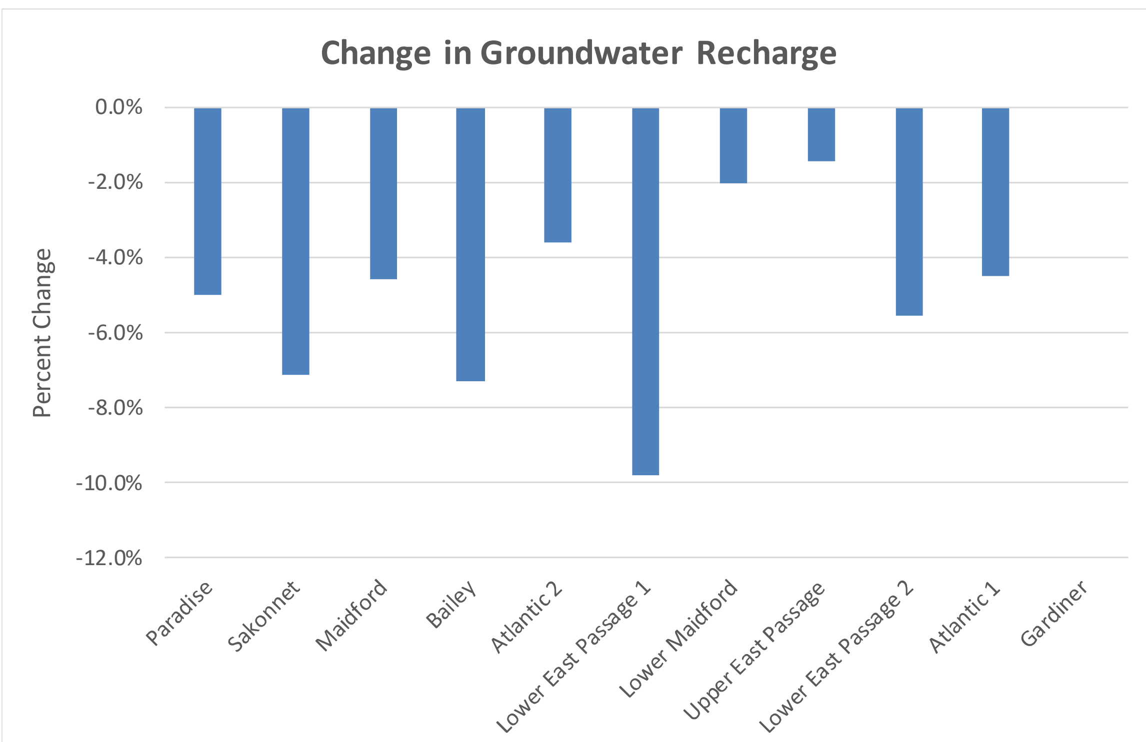
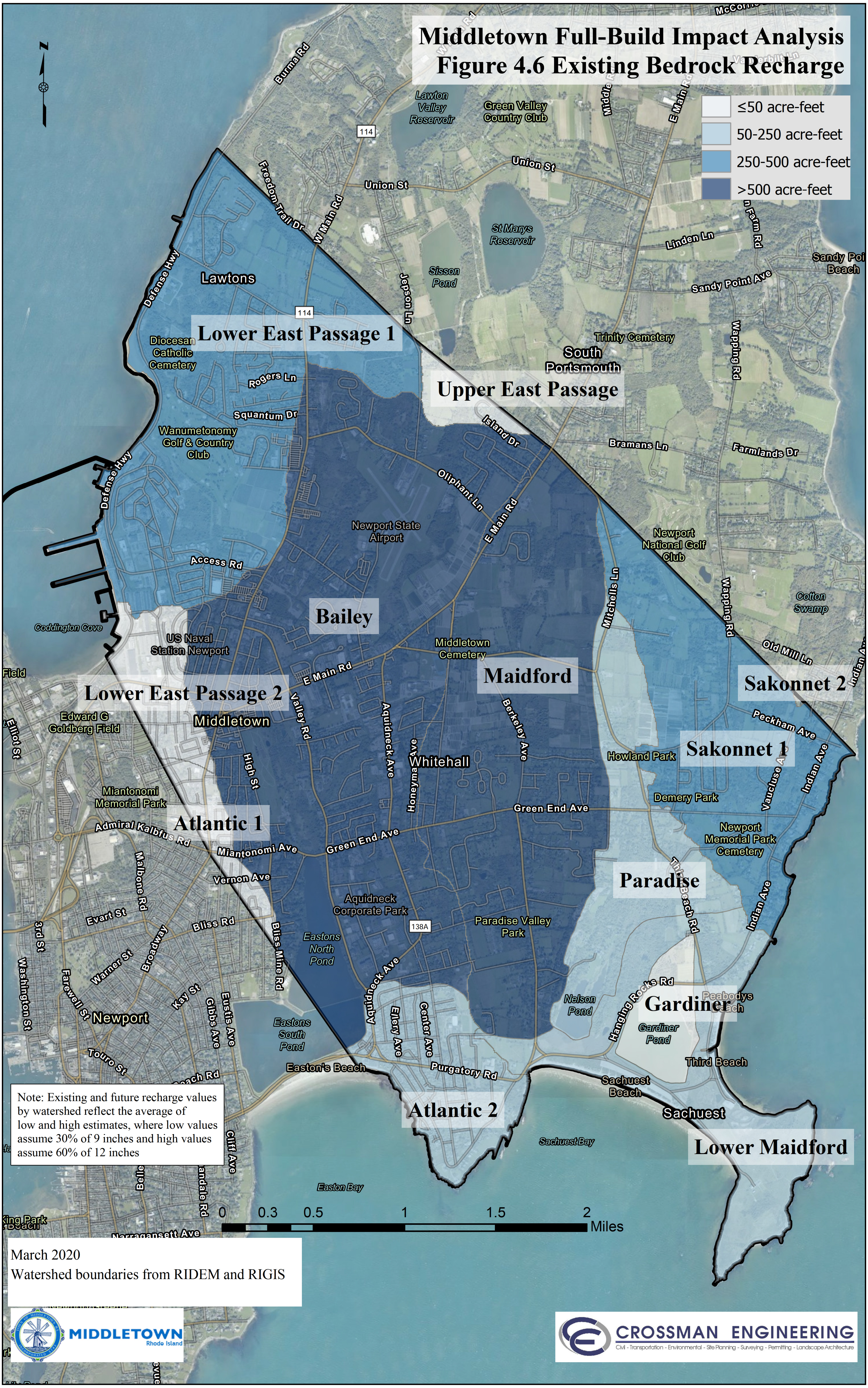


Figure 4.5 Change in Annual Groundwater Recharge per Watershed for Full-Build with Current Zoning with no Recharge Mitigation



Note: Existing and future recharge values by watershed reflect the average of low and high estimates, where low values assume 30% of 9 inches and high values assume 60% of 12 inches

March 2020
Watershed boundaries from RIDEM and RIGIS

MIDDLETOWN Rhode Island

CROSSMAN ENGINEERING
Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture

ESTIMATING GROUNDWATER USE

The Newport Water System serves 40,000 people, including approximately 75% of the Middletown population. According to the recent update to the Water Supply System Management Plan (WSSMP; C&E, 2018), the generalized average water use in the Newport System is 134 gallons per capita per day (GPCD) with domestic water use averaging 42 GPCD. Compared to other communities, the 42 GPCD represents a low domestic usage rate. A water use value near 65 GPCD is more common.

Areas of Middletown not served by Newport Water must rely upon groundwater supply wells. The existing wells include small non-municipal public wells serving community and commercial uses (RIDOH database) and numerous private residential wells. In addition, some golf courses and farms in Middletown source water from wells for irrigation purposes.

In order to estimate water use, it is common to utilize typical water use rates and population values and utilizing the full-build residential unit count and actual average per capita water use rates from the recent Newport WSSMP, the full-build domestic water use consumption can be estimated. Average household size in Middletown, as reported in the last decennial U.S. Census is 2.39 persons per household. However, this figure reflects all housing types whereas households served by wells are more likely single-family homes and would be expected to have a higher person-per-home rate than the Town average. In order to account for this variation, low and high estimates of residential water use per housing unit were determined:

Low annual water use = 2.5 persons x 42 GPCD x 365 days per year = **38,325 gallons/residence**

High annual water use = 5 persons x 42 GPCD x 365 days per year = **76,650 gallons/residence**

Commercial water use rates vary based on the size and facility use and since the full-build commercial growth predominately occurs in areas with public water, commercial demand was not included in this analysis.

Coverage of the water distribution network in Middletown was obtained from the Town geodatabase and an assumption was made that parcels with frontage on a street with public water service would connect into the public system. Parcels without access to public water (based on the current distribution network) are assumed to be served by new bedrock groundwater wells and the additional domestic withdrawal from bedrock wells was determined based on the above household water demand and the full-build unit projections.

Water Use Results

Based on data for existing residential units and the water service area, 1,081 existing active domestic wells are estimated to be in operation in Middletown. This includes the assumption that one well serves one residential unit. This value does not take into account units with frontage on a road with public water but instead of a public water connection use a private well. Figure 4.7 summarizes the estimated existing domestic well count for each watershed. The findings indicate that the wells are primarily in the Maidford, Paradise, Bailey, and Sakonnet 1 watersheds. The corresponding estimated annual water use for the existing private, residential wells ranges from close to null in Upper East Passage to 33 – 66 acre-feet (10.8 – 21.5 million gallons) in Sakonnet 1 watershed. The range is for estimates of 2.5 and 5 persons per home, respectively. These estimates do not account for irrigation and agricultural uses. Figure 4.8 through Figure 4.11a provide the estimated current well water use for each watershed, in chart and map format, respectively.

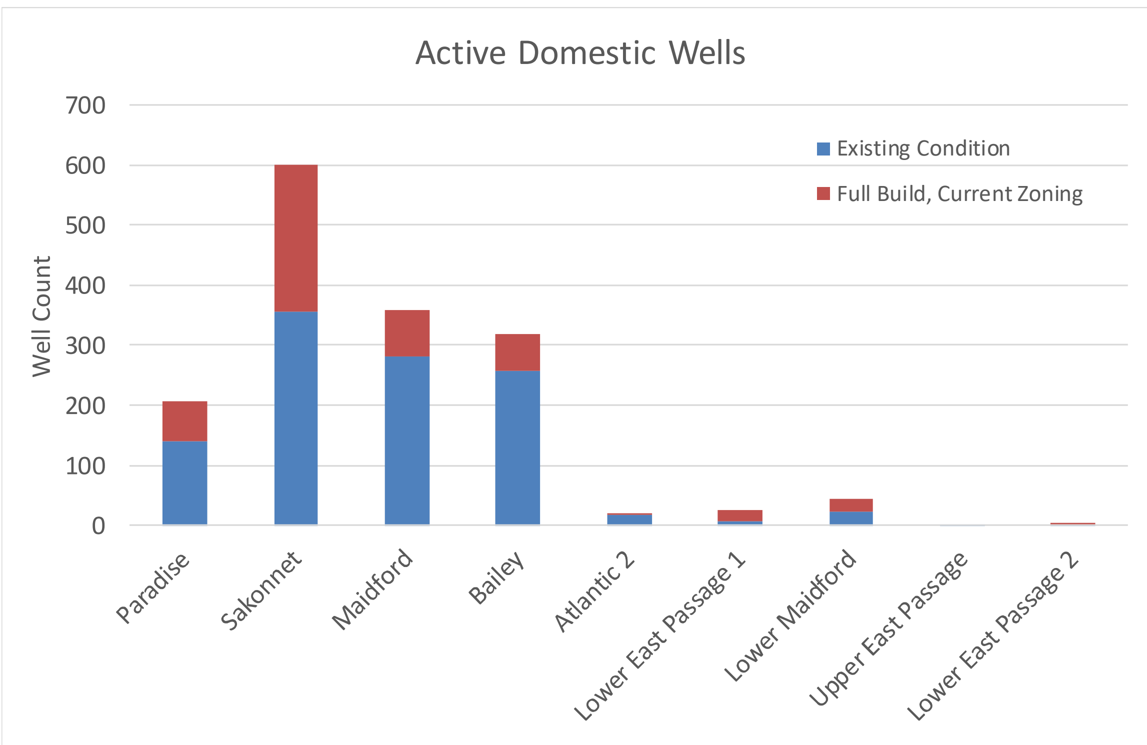


Figure 4.7 Existing and Future Domestic Well Count in Middletown by Watershed, Full-Build with Current Zoning

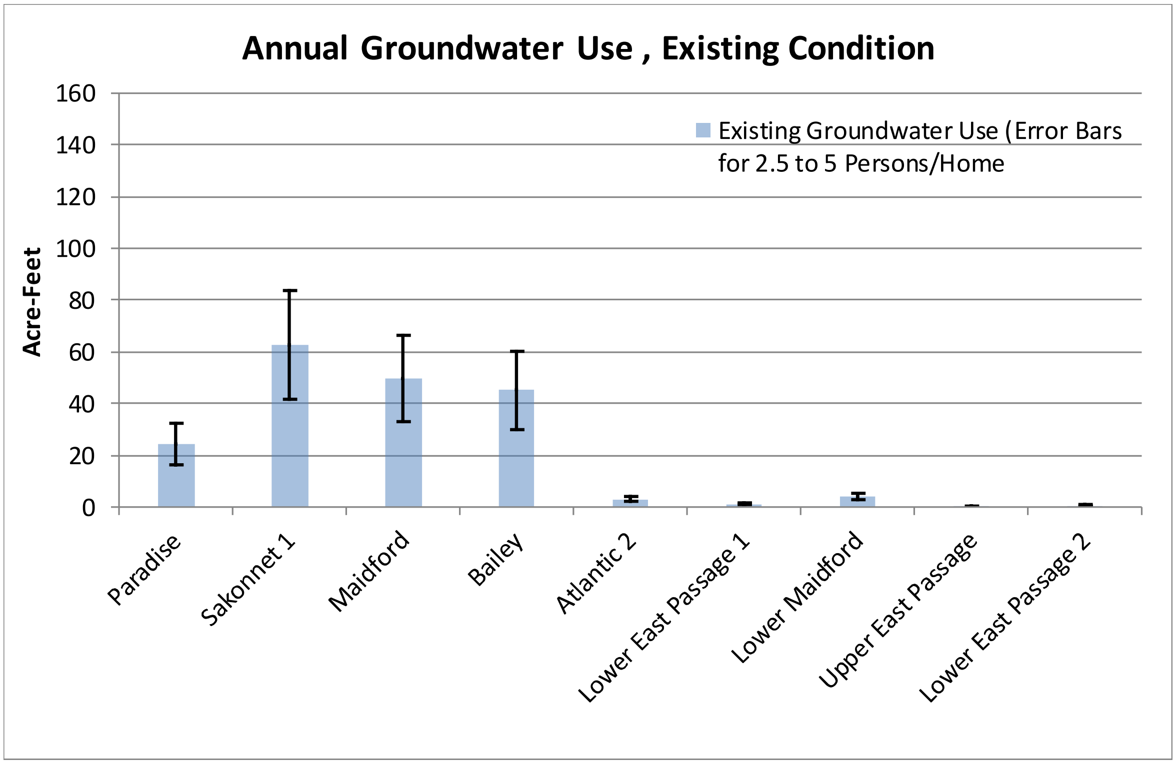


Figure 4.8 Existing Private Domestic Water Use from Wells in Middletown by Watershed

An increase of 500 domestic wells is expected under the build-out for areas without access to Newport water supply. Figure 4.7 also shows, in addition to existing well counts, the increased number of wells and future total well counts for each watershed. Sakonnet 1 (Little Creek) watershed has the highest existing count and largest increase in number of new wells for the Town. Figure 4.9 and Figure 4.11b provide the estimated future well water use for each watershed, in chart and map format, respectively. Change in groundwater use is shown in Figure 4.10. Corresponding future annual water use for private wells is estimated to increase by approximately 50% across Middletown. For Sakonnet 1 watershed, the increase is 69%, up to 42 – 85 acre-feet (13.8 – 27.5 million gallons), for estimates of 2.5 and 5 persons per home, respectively. Increases are less significant for the other watersheds. These results reflect the build-out under current zoning regulations. Results for alternative scenarios are shown in Appendix B. For Sakonnet 1, Paradise, and Maidford watersheds, the R-100 zoning alternative reduced impacts on the order of 50%. For Bailey watershed, the WPD-1 alternative reduced impacts by approximately 34%.

The watersheds showing significant increases in domestic well water use in Figure 4.10 also have significant existing agricultural land use which will be redeveloped under full-build scenarios Assuming the agricultural properties currently rely on well water for irrigation and other purposes, existing water use will be higher than the estimates, and in turn, the projected increase in water use will be less than anticipated.

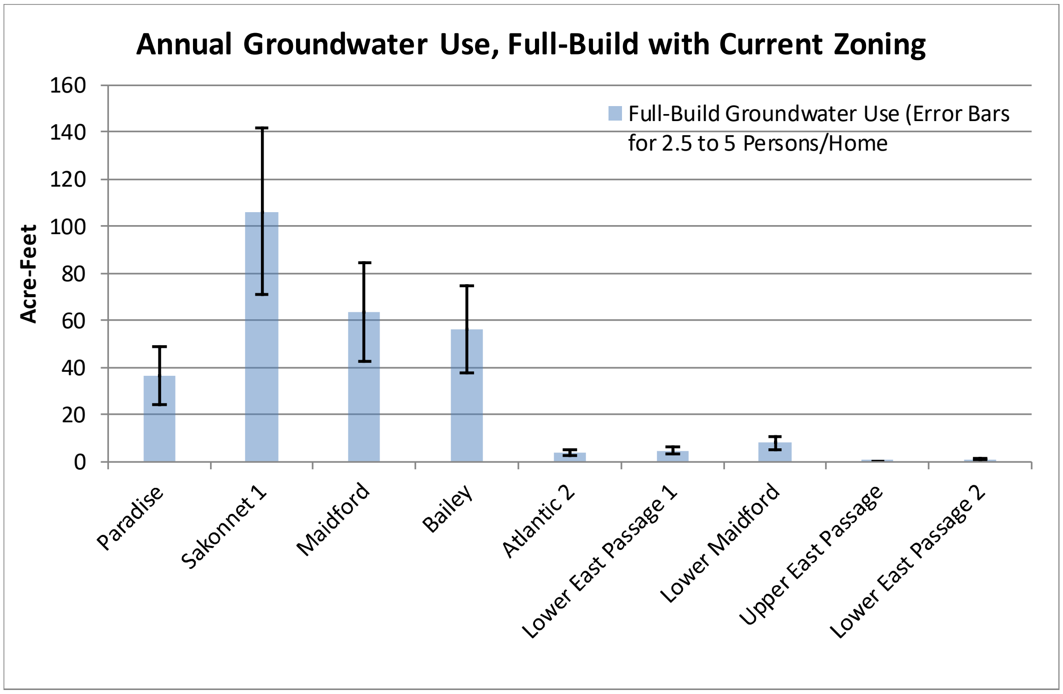


Figure 4.9 Future Private Domestic Water Use from Wells, Full-Build with Current Zoning

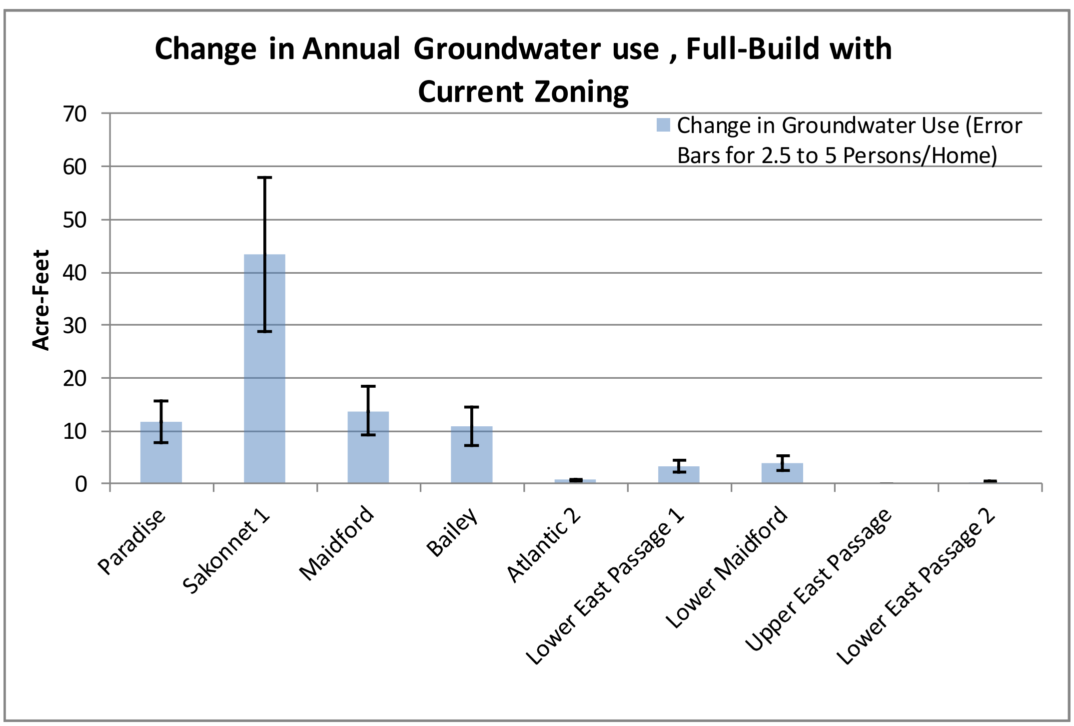
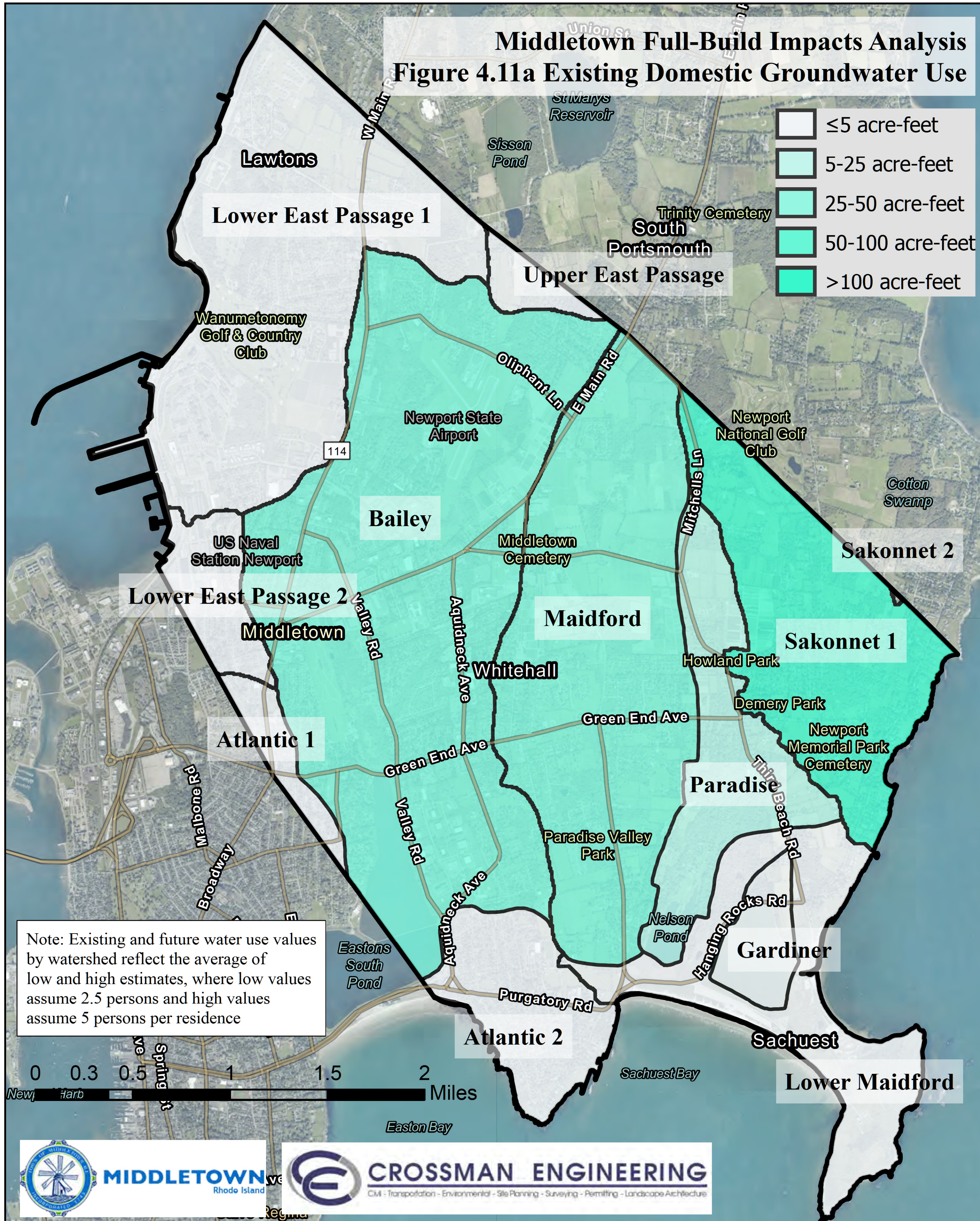


Figure 4.10 Change in Private Domestic Water Use under Full-Build, Current Zoning


Middletown Full-Build Impacts Analysis
Figure 4.11a Existing Domestic Groundwater Use
≤5 acre-feet
5-25 acre-feet
25-50 acre-feet
50-100 acre-feet
>100 acre-feet
Lawtons
Lower East Passage 1
Upper East Passage
South Portsmouth
Trinity Cemetery
St Marys Reservoir
Sisson Pond
Wanumetonomy Golf & Country Club
Newport State Airport
Oliphant Ln
E Main Rd
W Main Rd
114
Newport National Golf Club
Cotton Swamp
Bailey
Mitchells Ln
Sakonnet 2
US Naval Station Newport
Middletown Cemetery
Lower East Passage 2
Middletown
Valley Rd
Aquidneck Ave
Maidford
Whitehall
Sakonnet 1
Howland Park
Demery Park
Green End Ave
Newport Memorial Park Cemetery
Atlantic 1
Paradise
Third Beach Rd
Malbone Rd
Broadway
Paradise Valley Park
Hanging Rocks Rd
Nelson Pond
Gardiner
Eastons South Pond
Purgatory Rd
Note: Existing and future water use values by watershed reflect the average of low and high estimates, where low values assume 2.5 persons and high values assume 5 persons per residence
Atlantic 2
Sachuest
Sachuest Bay
Lower Maidford
0 0.3 0.5 1 1.5 2 Miles
Easton Bay
MIDDLETOWN Rhode Island
CROSSMAN ENGINEERING
Civil · Transportation · Environmental · Site Planning · Surveying · Permitting · Landscape Architecture

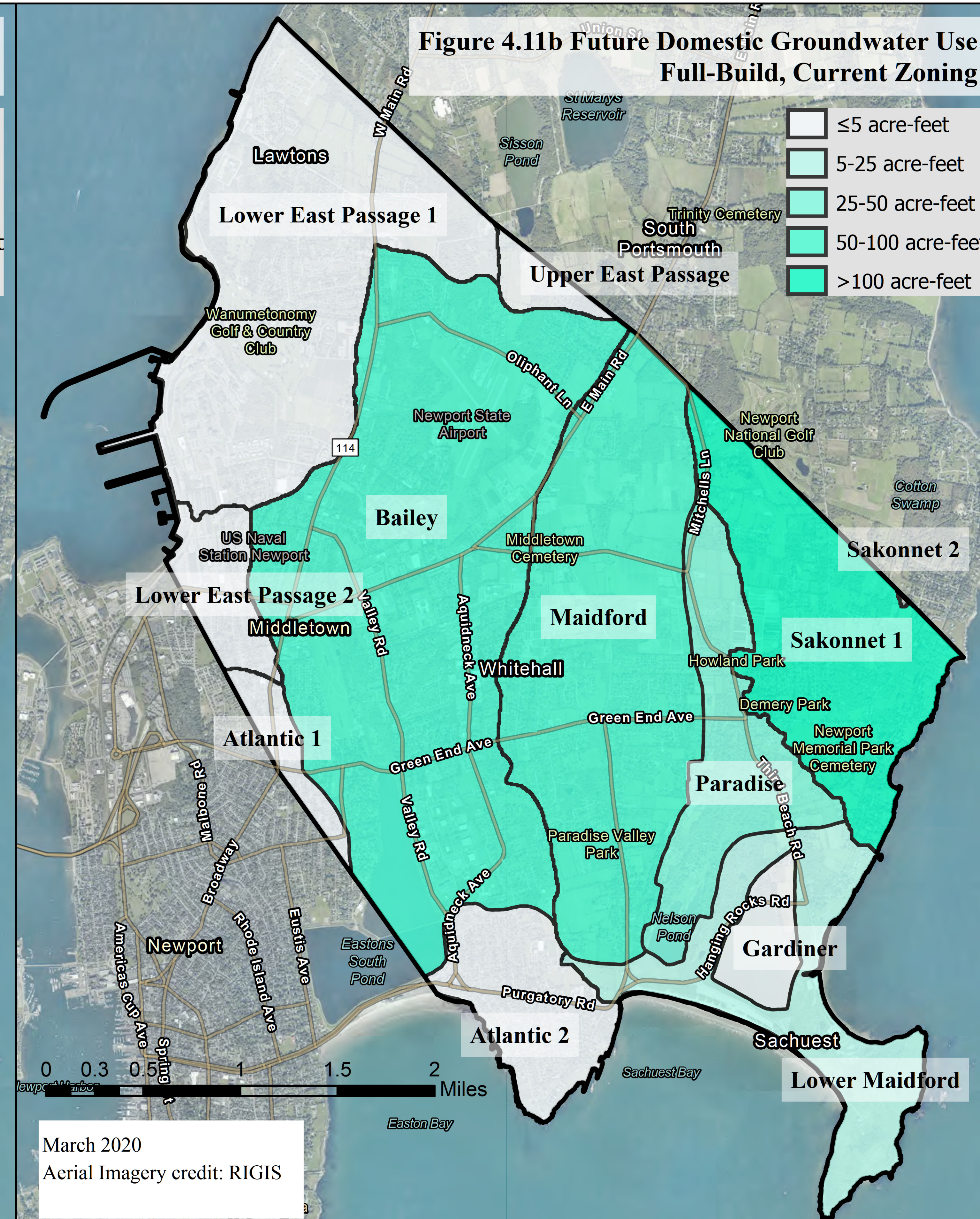


Figure 4.11b Future Domestic Groundwater Use
Full-Build, Current Zoning
≤5 acre-feet
5-25 acre-feet
25-50 acre-feet
50-100 acre-feet
>100 acre-feet
Lawtons
Lower East Passage 1
Upper East Passage
South Portsmouth
Trinity Cemetery
St Marys Reservoir
Sisson Pond
Wanumetonomy Golf & Country Club
Newport State Airport
Oliphant Ln
E Main Rd
W Main Rd
114
Newport National Golf Club
Cotton Swamp
Bailey
Mitchells Ln
Sakonnet 2
US Naval Station Newport
Middletown Cemetery
Lower East Passage 2
Middletown
Valley Rd
Aquidneck Ave
Maidford
Whitehall
Sakonnet 1
Howland Park
Demery Park
Green End Ave
Newport Memorial Park Cemetery
Atlantic 1
Paradise
Third Beach Rd
Malbone Rd
Broadway
Newport
Rhode Island Ave
Eustis Ave
Americas Cup Ave
Paradise Valley Park
Hanging Rocks Rd
Nelson Pond
Gardiner
Eastons South Pond
Purgatory Rd
Atlantic 2
Sachuest
Sachuest Bay
Lower Maidford
0 0.3 0.5 1 1.5 2 Miles
Easton Bay
March 2020
Aerial Imagery credit: RIGIS

GROUNDWATER BUDGET

An examination of the bedrock fissure recharge and water withdrawal demands results can provide an indication of stress on any on the groundwater supply of each watershed. The results show a range of future estimated recharge from 1,400 acre-feet to 3,740 acre-feet, while domestic well water use is estimated to range from 190 to 370 acre-feet. **These values conceptually suggest that domestic water use will not exceed groundwater resources on an annual basis for an average year** but it must be recognized that not all water stored within bedrock fissures will be available due to interconnectivity or lack of interconnectivity of bedrock fissures.

When each watershed is examined independently, recharge values are estimated to exceed water demand values for each watershed. Sakonnet 1 (Little Creek) watershed with 170 to 450 acre-feet recharge and 70 to 140 acre-feet water demand has the highest demand-recharge ratio in Middletown but the projected demand still does not exceed the annual recharge on average. Seasonal variations in rainfall and demand can be expected to cause temporal shortfalls when rainfall is lower in summer months. Seasonal shortfalls will draw on available storage in the connected bedrock fissure system. In this study CE has not examined the storage (or available storage) in the bedrock aquifer, but wells drilled deeper into the bedrock aquifer will be less susceptible to “going dry” during drought conditions.

In areas without access to public sewers, partial recharge credit from on-site wastewater treatment systems (OWTS) effluent will occur but the exact value that will reach bedrock fissures can vary significantly. Therefore, credit was not taken in this analysis. This additional source of recharge to the aquifer may partially mitigate the impacts of additional groundwater withdrawals in the eastern watersheds.

It must also be noted that non-domestic water use, including farm and irrigation water use, has not been included in the water budget. **Non-domestic water uses would contribute to withdrawals from the aquifer and may result in shortfalls where demands are competing in the aquifer**. The agricultural and golf course irrigation withdrawals would be reduced under the full-build future condition as some of the land developed to residential uses will replace land currently developed for agriculture.

A conceptual unit water budget for residential land use was performed in order to estimate the lot size required to sustain water use for a home. Lot size requirements vary based on water demand (size of home or number of household members) and the range of annual recharge into the bedrock aquifer. The lot size requirements depicted in Table 4.1 represent the lot area required to recharge an amount of water equal to the domestic water demand into the bedrock. These lot size requirements incorporate an allowance for impervious acreage based on Table 3.5 and assume that the required development recharge occurs off-site. In addition, return flow from an OWTS is not considered to contribute to the annual bedrock recharge. Therefore, the lot areas should be viewed as a conceptual estimate.

Table 4.1 Conceptual Lot Size Required to Sustain Groundwater Domestic Water Supply

House Size	Annual Water Demand (acre-feet)	Lot size (square feet)	
		60% of 12" Till Recharge	30% of 9" Till Recharge
2 Persons/Home [1]	0.09	10,000	20,000
5 Persons/Home [1]	0.24	20,000	60,000
3-Bedroom Home [2]	0.39	40,000	90,000
4-Bedroom Home [2]	0.52	50,000	110,000

[1] Water use modeled at 42 gallons per person per day (GPCD) (low estimate)
[2] Water use modeled at 115 gallons per bedroom per day (high estimate)

GROUNDWATER QUALITY

On-site wastewater treatment systems (OWTS) provide a treatment mechanism for domestic wastewater but can represent a threat to groundwater quality where limiting conditions exist in the soils, groundwater levels are high, systems are not maintained or system density exceeds the capacity of the basin to adequately dilute wastewater constituents. In conventional treatment, decomposition of solids occurs in the septic tank by anaerobic bacteria while grease and lighter solids are also collected in the septic tank. Organic content, microorganisms, bacteria and the remaining effluent flow through a distribution box into a leach field and are partially captured or broken down in the underlying bio-mat that forms beneath the leach field or in the unsaturated aerobic zone below the dispersal lines. The general treatment mechanism occurs via filtration, absorption and aerobic digestion. Also, in the underlying aerobic soil zone, ammonium nitrogen is converted to nitrate nitrogen. Further breakdown of nitrogen requires anaerobic conditions and a carbon source which is not common in a conventional system (Heger, 2017).

Naturally occurring nitrogen is expected to be low or negligible in Middletown's groundwater, but significant contributions may come from the infiltration of lawn or crop fertilizer and stormwater runoff. To assess the potential impact of future residential development on groundwater quality, a nitrogen loading analysis was performed. The nitrogen levels are of primarily of concern in the eastern part of Middletown which relies on well water supply.

Nitrogen groundwater concentrations (C_{GW}) can be estimated based on the mixing of precipitation recharge and OWTS discharge as follows (Nielsen, 2002):

$$C_{GW} = [\ (1-d)*Q_W*C_W + (Q_P-Q_W)*C_P\ ] / Q_P$$

Where,

d	=	Denitrification Percentage (5%)
Q_W	=	Septic System Discharge Rate
C_W	=	Septic System Nitrate Concentration
Q_P	=	Natural Recharge
C_P	=	Natural Recharge Nitrate Concentration

For a long-term analysis, this formulation was used to account for well water withdrawals which negate the OWTS contributions in the long term, assuming a connection between the subsurface soils and bedrock aquifer (Nielsen, 2002). A value of 0.05 was estimated for *d* in the Nielsen (2002) study, assuming denitrification is not significant in soils beneath typical septic systems. This assumption is in line with discussions in Heger (2017). Nitrate concentration in OWTS effluent can vary depending on the waste source and functioning of the OWTS system. For example, a value of 35 mg/L is reflective of residential wastewater and was used for planning purposes by the Cape Cod Commission Water Resources Office (Cape Cod, 1992). A value of 46 mg/L was used by URI (2003) for the Town of Jamestown for residential wastewater, based on field data collected for southern Rhode Island. For this analysis, a value of 46 mg/L for C_W and 0.05 for *d* have been utilized.

OWTS discharge is estimated to be 90% of water use, which was computed using the same low and high estimates as described in the previous section. The total wastewater flow for a watershed was estimated as follows:

$$Q_W = 0.9 * N_W * q_W$$

Where, Q_W = Watershed Total Wastewater Flow
N_W = Count of Homes with OWTS
q_W = Home Water Use

Annual recharge rates into the till layer were estimated to range between 9 inches and 12 inches, based on the previous discussion concerning recharge to the till layer and Recharge values were maintained at existing condition levels for modeling the nitrate budget under full-build conditions in order to reflect implementation of the stormwater Recharge Standard with future development.

Atmospheric nitrogen loading from precipitation is estimated to be approximately 0.5 mg/L, based on Cape Cod (1992), although that study considered a negligible amount would reach the groundwater. For this study, a value of 0.5 mg/L was assumed for Nitrate in natural recharge.

The prevalence of agricultural land in eastern Middletown suggests that crop fertilization and pesticide application may be threats to groundwater quality in this area. The Rhode Island Department of Health (RIDOH) conducted a study in 2014 and demonstrated severely elevated Nitrate concentrations in wells serving properties adjacent to the agricultural property north and west of Wapping Road (RIDOH, 2014). Average levels were elevated in the vicinity of Wapping Road, Peckham Lane and Riverview Avenue. Average Nitrate values for samples on these roads ranged between 7.6 and 12.0 mg/L versus the drinking water standard of 10 mg/L. One reason for federal Nitrate standard is to protect infants from over-exposure to nitrates in drinking water. Overexposure by infants can cause methemoglobinemia, or "blue baby" disease. Elevated levels also raise concern for the potential for elevated bacteria or pesticides. The RIDOH study investigated several sources of Nitrates in the groundwater and agricultural fertilization appeared to be a significant contributor. Shallow or poorly constructed groundwater wells in the area may be prone to impacts from the leaching Nitrate.

Lawn fertilization of residential and commercial properties can be a source of nitrate in groundwater in Middletown. Two studies demonstrate a possible range of values for nitrate leaching to groundwater from fertilization. The Cape Cod Commission estimates 131 lbs of Nitrate nitrogen per acre would be applied to lawns and that 25% of the application would leach to groundwater (Cape Cod, 1992). This assumption would lead to Nitrate concentration of 16.1 mg/L in the water leaching below the lawn surface, assuming 9 inches of recharge annually. For modeling in the Town of Jamestown (URI, 2003) values of 175 lbs per acre Nitrate nitrogen and 6% leaching were assumed. This assumption leads to Nitrate concentration of 5.1 mg/L in the water leaching below the lawn surface. This provides an approximate range of the potential contribution of lawn fertilization to groundwater Nitrate concentrations; however, proper fertilization and lawn watering should result in minimal leaching of Nitrate to the groundwater. Furthermore, the lawn area relative to the total property size will affect the impact of lawn fertilization on the groundwater; if the fertilized lawn area is relatively large, there will be less dilution of the fertilizer-impacted drainage.

Water Quality Results

Based on data for existing residential units and the current sewer service area, 810 existing OWTS are estimated to be active in Middletown. This value assumes that one OWTS serves one residential unit. Homes that are within the Middletown sewer system service area may also be served by a private OWTS but would not be included in the count of 810 systems. Figure 4.12 depicts the estimated existing OWTS count for each watershed. The OWTSs are primarily in the Paradise, Bailey, and Sakonnet 1 watersheds. An increase of 678 OWTS is expected under the full-build scenario for areas without access to Middletown sewer service and reflects an increase of approximately 85% in OWTS across the Town. Figure 4.12 identifies the increase and future total OWTS counts for each watershed. Sakonnet 1 (Little Creek) watershed has the highest existing and increase in OWTS count for the Town.

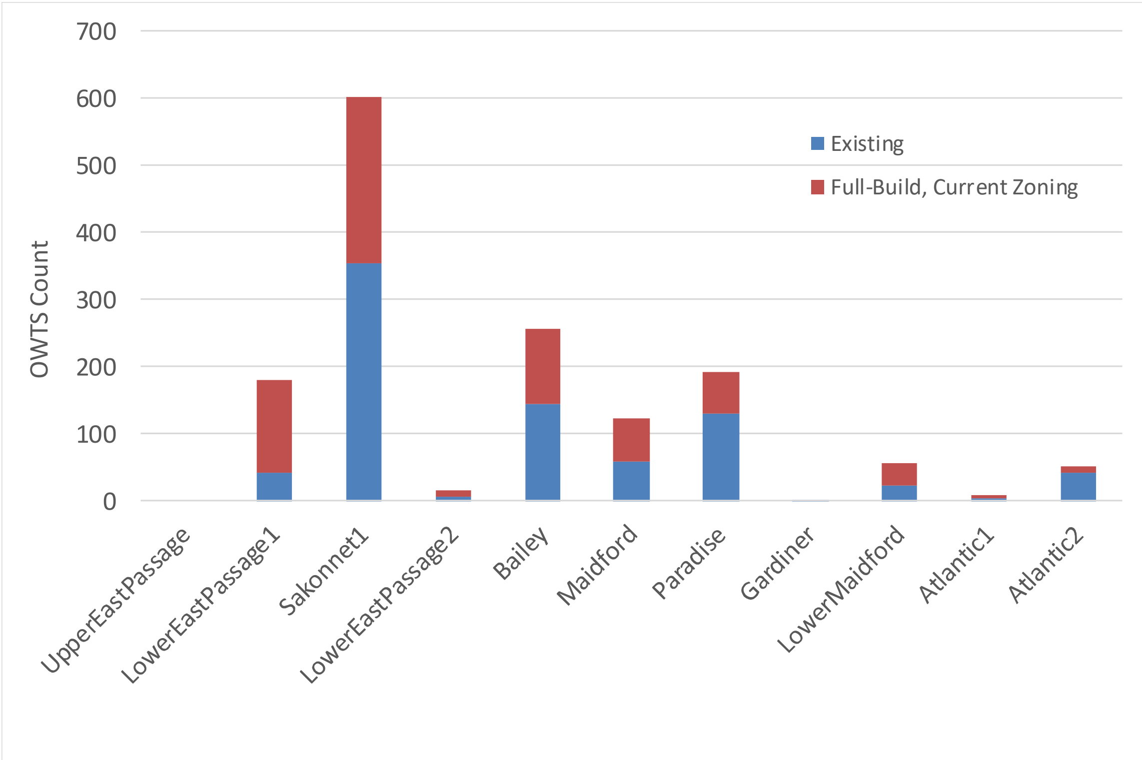


Figure 4.12 On-Site Wastewater Treatment System (OWTS) Count per Watershed

Existing modeled Nitrate concentrations by watershed are shown in Figure 4.13, showing concentrations greater than 1.0 mg/L in Sakonnet 1, Paradise, and Atlantic 2 watersheds. URI (2003) indicates that values above 1.0 mg/L are considered elevated in Rhode Island. Upper error bars reflect water use with 5 persons per home and recharge of 9 inches to the till layer. Low error bars reflect water use with 2.5 persons per home and recharge of 12 inches to the till layer. The highest future Nitrate concentration in groundwater reflects the additional OWTS discharge and is estimated to range between 3.9 to 9.6 mg/L for Sakonnet 1 watershed. The results for each watershed are shown in Figure 4.14. Values are as low as 0.5 mg/L for Upper East Passage watershed, which has no reported OWTS, present or future. The Rhode Island groundwater quality standard for Nitrate is 10 mg/L, but Rhode Island has a "preventative action limit" threshold of 5 mg/L. In comparison, the upper limit values for Paradise and Sakonnet 1 watersheds exceed 5 mg/L, signaling a call for attention to the constituent levels. These results reflect the build-out under current zoning regulations. Results for alternative scenarios are provided in Appendix B. For Paradise and Sakonnet 1 watersheds, the R-100 zoning alternative reduced impacts on the order of 50%. The Paradise watershed upper limit value would be just below 5 mg/L, but the Sakonnet 1 watershed upper limit value would remain above 5 mg/L at 7.5 mg/L.

The results indicate the influence of OWTS discharge on groundwater nitrate concentrations and can be corroborated by similar findings for the community of Jamestown. Although soil conditions differ, the net impact is expected to be similar. The Town of Jamestown has reported elevated nitrate levels in the more densely developed Jamestown Shores neighborhood. Well samples in Jamestown Shores with lots less than 1 acre averaged 3.2 mg/L Nitrate as Nitrogen (URI, 2003). Furthermore, elevated nitrate levels were correlated with bacteria presence in groundwater.

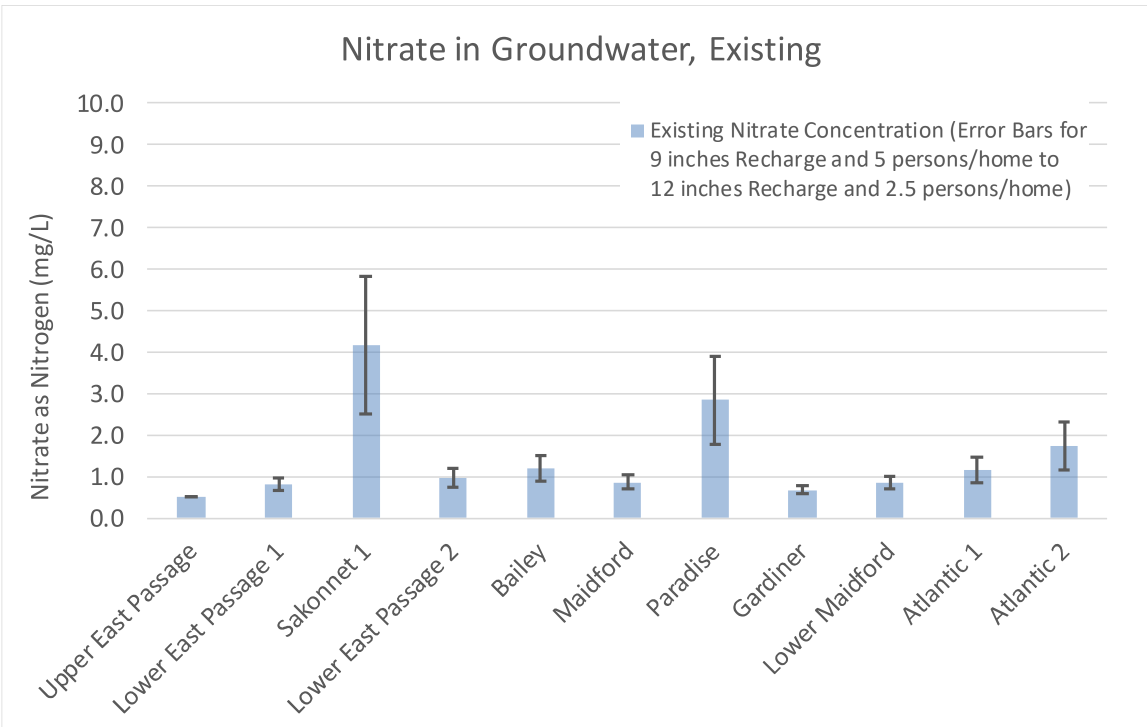


Figure 4.13 Existing Estimated Nitrate Concentrations in Middletown by Watershed

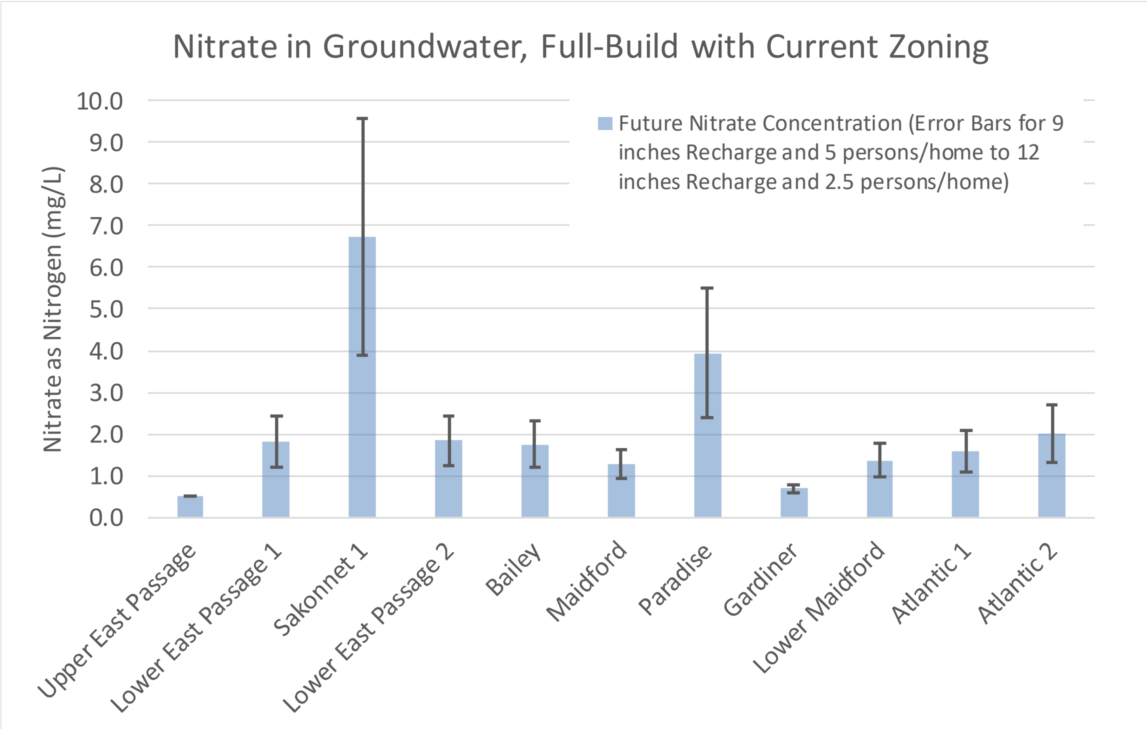


Figure 4.14 Nitrate Concentrations in Middletown by Watershed for Full-Build under Current Zoning

GROUNDWATER IMPACTS CONCLUSIONS

Groundwater quantity and groundwater quality are critical to maintain long term public health, safety and welfare as land development reaches the Town's full build condition. Mitigation strategies are necessary to prevent negative impacts to groundwater. As previously described, the loss of groundwater recharge can be mitigated through a requirement to recharge runoff from new impervious areas.

In regards to groundwater quality, RIDOH documentation clearly indicates that sections of Middletown experience elevated levels of nitrate and future development can increase nitrogen input into groundwater resources via septic system effluent and household fertilization. Coinciding with the development of agricultural lands into housing, a potential localized decrease in nitrogen and phosphorous nutrients can result if a net decrease in fertilization occurs. A significant reduction in bacteria entering streams and groundwater can also occur if uncontrolled animal livestock facilities are redeveloped. New development housing lot size and density controls are necessary to minimize long term groundwater degradation. For example, Conservation style developments that allow for more open space in exchange for the clustering of smaller lot size can create localized groundwater concerns for developments on private wells and septic systems.

On-site wastewater treatment regulations for Rhode Island put forth a discharge limit of 345 gallons per day per 20,000 square feet lot size when the site is served by a water supply well or when one is located within 200 feet (250-RICR-150-10-6.45). **This suggests that at minimum, R-20 zoning is required for lots served by drinking water wells and OWTS**. The flow per lot size ratio can be exceeded if nitrogen reducing technologies are provided by the OWTS.

Groundwater Recommendations

Based upon the groundwater and water quality assessments, in order to minimize potential impacts to groundwater quality and to enhance conditions for residents, CE provides the following recommendations:

4.1 Develop a community outreach program to raise awareness and to gain business and public support to identify and address existing groundwater impairments

4.2 Avoid or minimize the granting of waivers to the Town's Stormwater Standards, especially in public water supply watersheds.

4.3 The Stormwater design Recharge Standard is currently satisfied with a system that is sized to capture and recharge a specific volume of rainfall at the time of its installation but the Standard does not address the decrease in performance following initial installation. Performance can be significantly reduced in advance of the currently required threshold for maintenance. The Recharge Standard should be increased to address diminished performance over the life of the system.

4.4 Consider the installation of a series of groundwater monitoring wells throughout the Town to allow for long term seasonal collection of groundwater levels, quality and trends.

4.5 Surveys of homes with on-site wells should be taken to document private well data and the occurrence of well water supply issues and identify a point of contact for residents to inform of future well related issues.

4.6 Encourage water quality testing of private wells by homeowners through an educational awareness program and retain data in a Town database for future groundwater evaluations.

4.7 Develop an OWTS educational program for residents to ensure that the State required maintenance standards are being performed and consider enacting an Onsite Wastewater Management Ordinance with a goal of ensuring proper maintenance to elongate a system's life, minimize system failure, providing proper treatment to protect groundwater resources, and allowing residents to benefit from low-interest State loans for repairs if funds are available.

4.8 Evaluate the allowed lot size for new parcels with OWTS and/or wells based upon sanitary flow rate, soil conditions, and nitrate loading. This evaluation should also address the minimum lot sizes for Conservation style developments to prevent localized exceedances.

4.9 Consider Dimensional Zoning Requirements that address the differing needs for lots with and without public water, public sewer and both public water and sewer.

4.10 Perform town-wide groundwater quality testing to document conditions and needs for public water extensions.

4.11 Review historical records of OWTS failures or need for repair to assess future needs for public sewer extensions.

4.12 In future years, amend stormwater recharge and other stormwater design standards as changes in precipitation intensity and frequency occur.

5. EVALUATION OF TRAFFIC IMPACTS

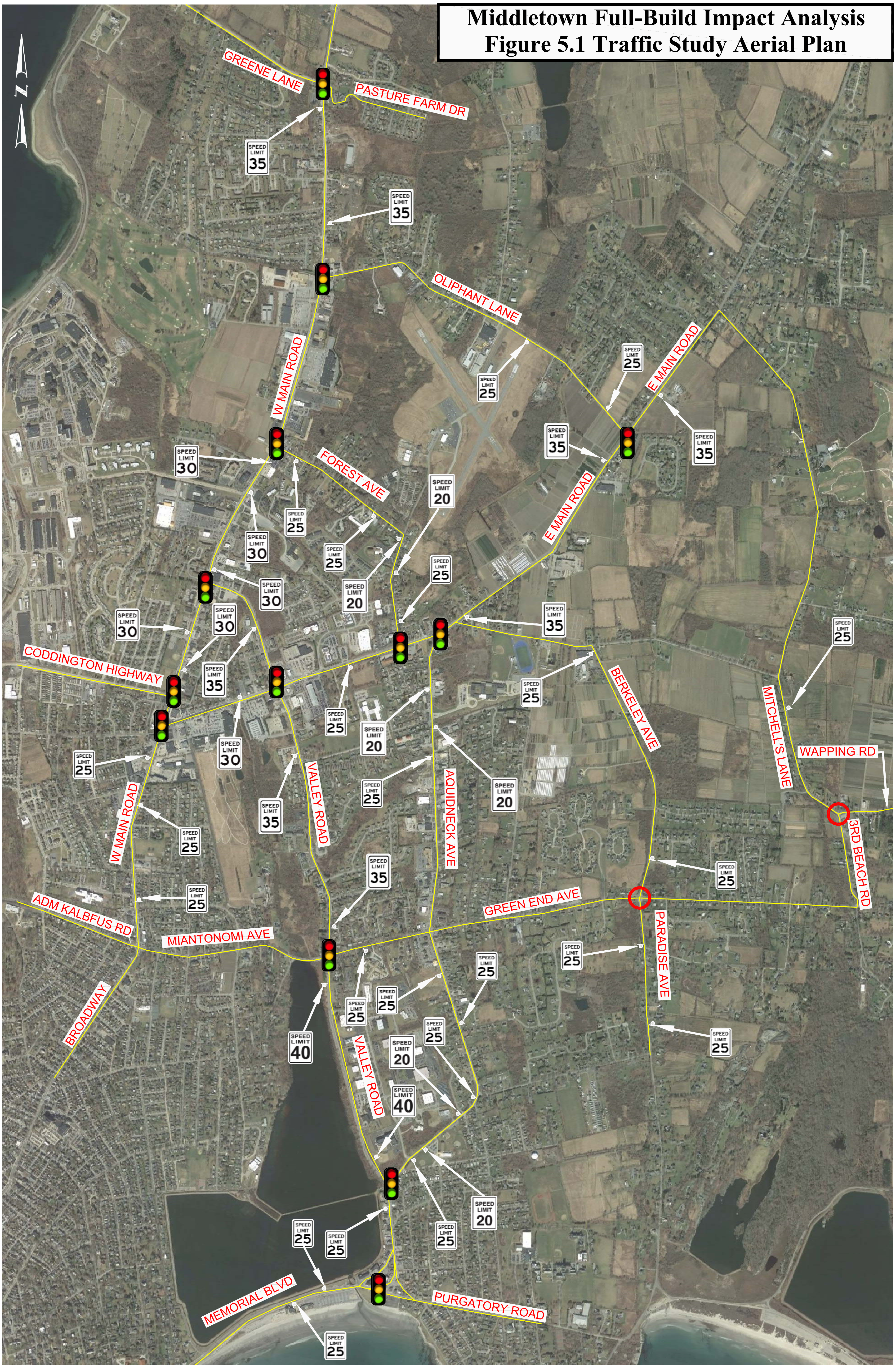
INTRODUCTION

A Traffic Impact Study was performed to assess the potential impact of a full build-out of the entire Town of Middletown in future years. Crossman Engineering (CE) examined locations within the Town which are expected to be the most impacted by the traffic added by future development. The locations, determined by CE and the Town, in the study area to be analyzed include the following intersections:

- Greene Lane / Pasture Farm Drive / West Main Road (RI 114)
- Oliphant Lane / West Main Road (RI 114)
- Oliphant Lane / East Main Road (RI 138)
- Aquidneck Avenue / East Main Road (RI 138)
- Forest Avenue / West Main Road (RI 114)
- Forest Avenue / East Main Road (RI 138)
- Valley Road / West Main Road (RI 114)
- Valley Road / East Main Road (RI 138)
- Coddington Highway / Rockwood Road / West Main Road (RI 114)
- West Main Road (RI 114) / East Main Road (RI 138)
- Valley Road / Miantonomi Avenue/ Green End Avenue
- Valley Road / Aquidneck Avenue
- Purgatory Road / Aquidneck Avenue/ Memorial Boulevard
- Green End Avenue / Paradise Avenue/ Berkeley Avenue
- Third Beach Road / Wapping Road / Mitchell's Lane

The locations of the study area intersections are shown on Figure 5.1. For aid in assigning future trip distribution, the study areas were sub-divided into the following seven areas (Figure 5.2):

Middletown Full-Build Impact Analysis
Figure 5.1 Traffic Study Aerial Plan



SIGNALIZED LOCATION INCLUDED IN TRAFFIC STUDY

UNSIGNALIZED LOCATION INCLUDED IN TRAFFIC STUDY

CROSSMAN ENGINEERING

Civil - Transportation - Environmental - Site Planning - Surveying - Permitting - Landscape Architecture

Middletown Full-Build Impact Analysis
Figure 5.2 Traffic Areas in Middletown

West Main – This northwest corner of the Town is generally bordered by the Portsmouth town line to the north, East Main Road to the east, Valley Road and Coddington Highway to the south and Narragansett Bay to the west.

East Main / West Main - This section of the Town is generally bordered by Valley Road, Coddington Highway and Wyatt Road to the north, Berkeley Avenue to the east, Miantonomi Avenue and Green End Avenue to the south, and to the north and the town line of Newport to the west.

Aquidneck - This section of the Town is generally bordered by Miantonomi Avenue and Green End Avenue to the north, Paradise Avenue to the east, Reservoir Road and Aquidneck Avenue to the south, and the town line of Newport to the west.

St. George - This section of the Town is generally bordered by Reservoir Road and Aquidneck Avenue to the north, Paradise Avenue to the east, Purgatory Road to the south, and Aquidneck Avenue to the west.

Wapping Road - This northeast corner of the Town is generally bordered by the Portsmouth town line to the north, the Sakonnet River to the east, Green End Avenue to the south, and Berkeley Avenue to the west.

Third Beach - This southeast corner of the Town is generally bordered by Green End Avenue to the north, the Sakonnet River to the east, Sachuest Bay to the south, and Paradise Avenue to the west.

Atlantic - This section of the Town is generally bordered by Purgatory Road to the north, Sachuest Bay to the east, Easton Point to the south, and Easton Bay to the west.

The location and square footage of the future full-build developments are as follows:

Table 5.1 Full-Build Results by Traffic Area

	W Main	**E.Main/ W.Main**	**Aquidneck**	**St George**	**Wapping**	**Third Beach**	**Atlantic**	**Total**
Residential (# of units)	452	186	156	115	279	200	48	1,436
Industrial	406,241	0	0	0	0	0	0	406,241
Mixed Use	1,210,142	161,577	0	0	0	0	0	1,371,719
Office Park	0	0	378,220	0	0	0	0	378,220
Office/ Business	76,784	69,786	0	0	0	0	0	146,570
Retail	200,625	488,045	89,565	36,038	17,411	0	0	831,684

METHODOLOGY

This study was prepared with input from the Town of Middletown and conducted in three stages. The first stage documents existing conditions in the transportation study area including an inventory of roadway geometry, observed traffic volumes, and safety characteristics. Next, future year traffic conditions are forecast that account for other average area traffic growth and project-related traffic increases. The third step quantifies operating characteristics of primary study intersections, with specific attention given to quantifying the incremental impacts of the proposed development.

This traffic study examines existing conditions in 2019, proposed development conditions 20 years in the future and our subsequent conclusions/recommendations. The existing conditions consist of geometric data gathered from an on-site visit and existing traffic volume data collected for AM and PM peak hours. The proposed development section examines the proposed future land uses, resulting traffic generated and distributed throughout town roads, and capacity analysis of existing and future conditions. Our conclusions and recommendations are prepared following a comprehensive review of the capacity analysis.

EXISTING CONDITIONS

As previously stated, this report examines the potential impacts of a full build-out of the entire Town of Middletown in future years. The locations, determined by CE and the Town, in the study area to be analyzed include the following intersections:

- Greene Lane / Pasture Farm Drive / West Main Road (RI 114) - ***signalized***
- Oliphant Lane / West Main Road (RI 114) - ***signalized***
- Oliphant Lane / East Main Road (RI 138) - ***signalized***
- Aquidneck Avenue / East Main Road (RI 138) - ***signalized***
- Forest Avenue / West Main Road (RI 114) - ***signalized***
- Forest Avenue / East Main Road (RI 138) - ***signalized***
- Valley Road / West Main Road (RI 114) - ***signalized***
- Valley Road / East Main Road (RI 138) - ***signalized***
- Coddington Highway / Rockwood Road / West Main Road (RI 114) - ***signalized***
- West Main Road (RI 114) / East Main Road (RI 138) - ***signalized***
- Valley Road / Miantonomi Avenue/ Green End Avenue - ***signalized***
- Valley Road / Aquidneck Avenue - ***signalized***
- Purgatory Road / Aquidneck Avenue/ Memorial Boulevard - ***signalized***
- Green End Avenue / Paradise Avenue / Berkeley Avenue – ***unsignalized – stop on Berkeley Avenue and Paradise Avenue***
- Third Beach Road / Wapping Road / Mitchell’s Lane -– ***unsignalized – yield on Third Beach Road***

A comprehensive field inventory of existing conditions within the study area was conducted in June 2019. Functional classifications were taken from the State of Rhode Island Existing Highway Functional Classification inventory map dated 3/22/16. The field investigation consisted of an inventory of existing roadway geometrics, traffic volumes and operating characteristics. Existing roadway and traffic conditions within the study area are described as follows.

Roadways

West Main Road (RI 114)

West Main Road is functionally classified as an urban principal arterial and is maintained by the State. It generally runs north-south from Bristol Ferry Road in Portsmouth to Broadway in Middletown. The land uses along this road in the study area are primarily commercial with some residential areas. West Main Road generally consists of two travel lanes in each direction.

East Main Road (RI 138)

East Main Road is functionally classified as an urban principal arterial and is maintained by the State. It generally runs northeast-southwest from Boyds Lane in Portsmouth to West Main Road in Middletown. The land uses along this road in the study area are residential and farmland north of Enterprise Drive and commercial use to the south. East Main Road generally consists of two travel lanes in each direction.

Greene Lane

Greene Lane is functionally classified as an urban major collector and is maintained by the State. It generally runs east – west from West Main Road to Burma Road (Defense Highway). The land uses along this road are residential and farmland. Greene Lane generally consists of one travel lane in each direction.

Pasture Farm Drive

Pasture Farm Drive is a local residential road. It generally runs east – west from Busher Drive to West Main Road. Pasture Farm Drive generally consists of one travel lane in each direction.

Oliphant Lane

Oliphant Lane is functionally classified as an urban major collector. It generally runs east – west from East Main Road to West Main Road. The land uses along this road include residential, farmland, a small airport (with no public access) and an industrial complex. Oliphant Lane generally consists of one travel lane in each direction.

Aquidneck Avenue

Aquidneck Avenue is functionally classified as an urban principal arterial and is maintained by the State. It generally runs north - south from East Main Road to Purgatory Road. The land uses along this road are a mix of residential and commercial. Aquidneck Avenue generally consists of one travel lane in each direction.

Forest Avenue

Forest Avenue is functionally classified as an urban major collector. It generally runs northwest - southeast from West Main Road to East Main Road. The land use along this road is residential. Forest Avenue consists of one travel lane in each direction.

Valley Road

Valley Road is functionally classified as an urban minor arterial maintained by the State. It generally runs northwest - southeast connecting West Main Road to East Main Road and continues south to Aquidneck Avenue. The land use along this road is commercial. Valley Road consists of one travel lane in each direction.

Coddington Highway

Coddington Highway is functionally classified as an urban principal arterial maintained by the State. It generally runs east – west connecting West Main Road to J.T. Connell Highway in Newport. The land use along this road is primarily commercial with some residential. Coddington Highway consists of one travel lane in each direction with a central two-way left turn lane.

Rockwood Road

Rockwood Road is a local road with commercial land use. It generally runs east – west from Ridgewood Road to West Main Road. There are no centerline pavement markings but the road consists of one travel lane in each direction.

Green End Avenue

Green End Avenue is functionally classified as a residential urban minor arterial. It runs east – west from Indian Avenue to Valley Road. Green End Avenue consists of one travel lane in each direction.

Purgatory Road

Purgatory Road is functionally classified as an urban minor arterial. It generally runs east – west from Paradise Avenue to Memorial Boulevard. The land use along this road is primarily residential. Purgatory Road consists of one travel lane in each direction.

Paradise Avenue

Paradise Avenue is functionally classified as an urban principal arterial. It generally runs north-south from Green End Avenue to Purgatory Road. The land use along this road is residential. Paradise Avenue consists of one travel lane in each direction.

Berkeley Avenue

Berkeley Avenue is functionally classified as an urban major collector. It generally runs north-south from Wyatt Road to Green End Avenue. The land use along this road is residential and farmland. Berkeley Avenue consists of one travel lane in each direction.

Third Beach Road

Third Beach Road is functionally classified as an urban major collector. It generally runs north-south from Wapping Road to Third Beach. The land use along this road is residential, farmland and open space with a bird sanctuary. Third Beach Road consists of one travel lane in each direction.

Wapping Road

Wapping Road is functionally classified as an urban major collector. In the vicinity of the study area it runs northeast-southwest from Sandy Point Avenue in Portsmouth to Third Beach Road. The land use along this road is residential and farmland. Wapping Road consists of one travel lane in each direction.

Mitchell's Lane

Mitchell's Lane is functionally classified as an urban major collector. In the vicinity of the study area it runs northwest-southeast from East Main Road at the Portsmouth town line to Third Beach Road. The land use along this road is primarily farmland and residential. Mitchell's Lane consists of one travel lane in each direction.

Intersections

Greene Lane / Pasture Farm Drive / West Main Road (RI 114)

Greene Ln facing EB toward West Main Rd

West Main Rd NB toward Greene Ln and Pasture Farm Dr

The intersection of Greene Lane / Pasture Farm Drive / West Main Road is located approximately a ½ mile south of the Portsmouth / Middletown town line. It is a four-legged, signalized intersection. Both the northbound and southbound West Main Road approaches consist of a thru / left turn lane, thru / right turn lane and shoulder. The Pasture Farm Drive westbound approach consists of a multi-use lane. The Greene Lane eastbound approach consists of a left turn lane, a thru / right turn lane and shoulder. There are pedestrian crosswalks with pedestrian signals at each approach except the northbound approach. There are continuous sidewalks on both sides of West Main Road. The speed limits at the intersection are as follows:

- 35 mph northbound and southbound
- 40 mph eastbound
- 20 mph westbound

Oliphant Lane / West Main Road (RI 114)

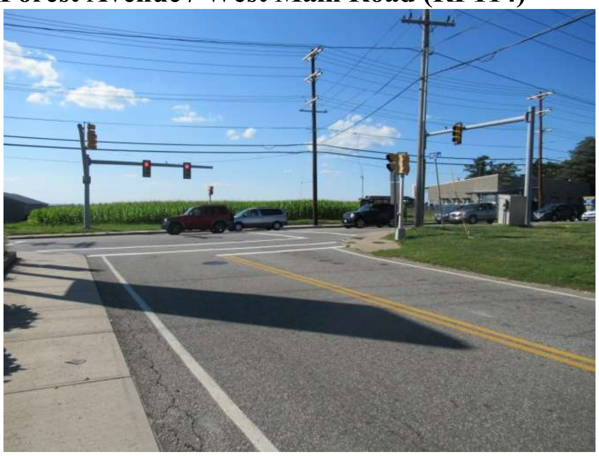
Oliphant Ln facing WB toward West Main Rd

West Main Rd facing NB toward Oliphant Ln

The intersection of Oliphant Lane / West Main Road is a three-legged, signalized intersection located approximately 3,500 ft south of Greene Lane. The northbound approach consists of a thru lane, a thru / right turn lane and shoulder. The southbound approach consists of a thru / left turn lane, a thru lane and shoulder. The Oliphant Lane westbound approach consists of a multi-use lane. There are continuous sidewalks on both sides of West Main Road. The speed limits at the intersection are as follows:

- 35 mph northbound and southbound
- 25 mph westbound

Forest Avenue / West Main Road (RI 114)



Forest Ave facing WB toward West Main Rd

West Main Rd facing NB toward Forest Ave

The intersection of Forest Ave / West Main Road is a three-legged, signalized intersection located approximately 3,000 ft south of Oliphant Lane. The West Main Road northbound approach consists of a thru lane, a thru/ right turn lane and shoulder. The West Main Road southbound approach consists of a thru / left lane, a thru lane and shoulder. The Forest Avenue westbound approach consists of a single multi-use lane. Continuous sidewalks exist on both sides of West Main Road. There is a crosswalk and pedestrian signal with push buttons at the southbound and westbound approaches. The speed limits at the intersection are as follows:

- 30 mph northbound and southbound
- 25 mph westbound

Valley Road / West Main Road (RI 114)

Valley Rd facing WB toward West Main Rd

West Main Rd facing SB toward Valley Rd

The intersection of West Main Road / Valley Road is approximately ½ mile southwest of the Forest Ave / West Main Road signal. This is a signalized, 3-legged intersection. The West Main Road northbound approach consists of a thru lane, a thru/ right lane and shoulder. The West Main Road southbound approach consists of a left turn lane, two thru lanes and shoulder. Valley Road westbound approach prohibits right turns on red and consists of a left turn lane and a right turn lane and shoulder. The speed limits at the intersection are as follows:

- 30 mph northbound and southbound
- 35 mph westbound

Coddington Highway / Rockwood Road / West Main Road (RI 114)

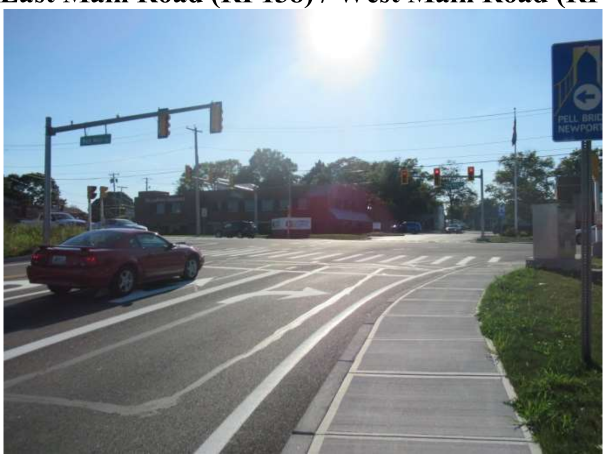
Coddington Hwy facing EB toward West Main Rd

West Main Rd facing NB toward Coddington Hwy

The intersection of Coddington Highway / Rockwood Road / West Main Road is approximately 2,150 feet southwest of the Valley Road / West Main Road intersection. It is a signalized, 4-legged intersection. The Coddington Highway eastbound approach consists of two left turn lanes, a thru / right turn lane and shoulder. The Rockwood Road westbound approach consists of a single multi-use lane. The West Main Road northbound approach provides a left turn lane, two multi-use lanes and shoulder. The southbound West Main Road approach provides two multi-use lanes, a right turn lane and shoulder. There are pedestrian crosswalks with pedestrian signals at each approach. There are continuous sidewalks on both sides of West Main Road. The speed limits at the intersection are as follows:

- 25 mph northbound
- 30 mph southbound
- 25 mph eastbound
- 25 mph westbound

East Main Road (RI 138) / West Main Road (RI 114)



East Main St facing SW toward West Main Rd

West Main Rd facing NB toward East Main St

The East Main Road / West Main Road intersection is approximately 450 ft southwest of the Coddington Highway / Rockwood Road / West Main Road intersection. This is a signalized, 4-legged intersection. The westbound East Main Road approach consists of a left turn lane, left/thru lane, right turn lane and shoulder; the eastbound approach consists of a single multi-use lane. Both approaches on West Main Road consists of a left turn lane, a thru/left lane, a thru/right lane and shoulder. There are pedestrian crosswalks with pedestrian signals at each approach except the southbound direction. There are continuous sidewalks on both sides of West Main Road and on the north side of East Main Road. The speed limits at the intersection are as follows:

- 25 mph northbound
- 30 mph southbound
- 25 mph eastbound
- 30 mph westbound

Oliphant Lane / East Main Road (RI 138)

Oliphant Ln facing SE toward East Main Rd

East Main Rd facing NB toward Oliphant Ln

The Oliphant Lane / East Main Road intersection is approximately ½ mile southwest of the Portsmouth / Middletown town line. This is a signalized, 4-legged intersection. The northwest bound approach from the East Island Reserve Hotel driveway consists of a left turn lane and thru/right lane. The southeast bound approach from Oliphant Lane consists of a single multi-use lane. Both approaches on East Main Road consist of a thru/left lane, a thru/right lane and shoulder. There is a pedestrian crosswalk with pedestrian signals at the northeast bound approach along East Main Road. There are no sidewalks at this intersection. The speed limits at the intersection are as follows:

- 25 mph northwest bound
- 35 mph northeast bound
- 25 mph southeast bound
- 35 mph southwest bound

Aquidneck Avenue / East Main Road (RI 138)

Aquidneck Ave facing NB toward East Main Rd

East Main Rd facing NE toward Aquidneck Ave

The Aquidneck Avenue / East Main Road intersection is approximately a mile southwest of the Oliphant Lane / East Main Road intersection. This is a signalized, 4-legged intersection. Both approaches on East Main Road consist of a thru/left lane, a thru/right lane and shoulder. The northbound Aquidneck Avenue approach consists of a left/thru lane, right lane and shoulder. The southbound approach from the retail driveway consists of a left/thru lane and right lane. There is a pedestrian crosswalk with pedestrian signals at each approach. There are continuous sidewalks on both sides of East Main Road. The speed limits at the intersection are as follows:

- 25 mph northbound
- 25 mph southbound
- 35 mph eastbound
- 35 mph westbound

Forest Avenue / East Main Road (RI 138)

Forest Ave facing SB toward East Main Rd

East Main Rd facing WB toward Forest Ave

The Forest Avenue / East Main Road intersection is approximately 675 ft southwest of the Aquidneck Avenue / East Main Road intersection. This is a signalized, 4-legged intersection. The southbound Forest Avenue and northbound Ramada Inn driveway approach both consist of a multi-use lane. Both approaches on East Main Road consist of a thru/left lane, a thru/right lane and shoulder. There is a pedestrian crosswalk with pedestrian signals at each approach. There are sidewalks on both sides of the road at each approach. The speed limits at the intersection are as follows:

- 25 mph northbound
- 35 mph eastbound
- 25 mph southbound
- 35 mph westbound

Valley Road / East Main Road (RI 138)


Valley Rd facing EB toward East Main Rd


East Main Rd facing NB toward Valley Rd

The Valley Road / East Main Road intersection is approximately a ½ mile southwest of the Forest Avenue / East Main Road intersection. This is a signalized, 4-legged intersection. The Valley Road northbound and southbound approaches both consist of a left turn lane and thru/right lane. Both approaches on East Main Road consist of a left turn lane, a thru lane, a thru/right lane and shoulder. There is a pedestrian crosswalk with pedestrian signals at each approach. There are continuous sidewalks on both sides of the road along each approach at this intersection.
The speed limits at the intersection are as follows:

- 35 mph northbound
- 35 mph southbound
- 35 mph eastbound
- 35 mph westbound

Valley Road / Miantonomi Avenue / Green End Avenue


Miantonomi Ave EB toward Valley Rd / Green End Ave


Valley Rd NB toward Miantonomi Ave / Green End Ave

The Valley Road / Miantonomi Avenue / Green End Avenue intersection is approximately a mile south of the Valley Road / East Main Road intersection. This is a signalized, 4-legged intersection. The Valley Road northbound approach consists of a left turn lane, thru/right lane, shoulder and sidewalk along the east side of the road. The southbound Valley Road approach consists of a left/thru lane, thru/right lane and shoulder. The Miantonomi Avenue eastbound approach consists of a left turn lane, a thru lane, a right lane and shoulder. The Green End Avenue westbound approach consists of a left lane, thru/right lane, shoulder and sidewalk. There is a pedestrian crosswalk with pedestrian signals at each approach. There is a continuous sidewalk on the northbound side of Valley Road. The speed limits at the intersection are as follows:

- 35 mph northbound
- 35 mph southbound
- 25 mph eastbound
- 25 mph westbound

Valley Road / Aquidneck Avenue

Aquidneck Ave WB facing Valley Rd

Valley Rd SB facing Aquidneck Ave

The Valley Road / Aquidneck Avenue intersection is approximately ¾ mile south of the Valley Road / Miantonomi Avenue / Green End Avenue intersection. This is a signalized, 3-legged intersection. The Aquidneck Avenue northbound approach which is controlled by the signal, consists of a thru lane with shoulder and sidewalk along the east side of the road. From the northbound approach there is also a yield controlled right turn channelized lane. The southbound Valley Road approach consists of a left turn lane, thru lane, shoulder and sidewalk along the east side of the road. The westbound Aquidneck Avenue approach consists of a left turn lane controlled by the signal. Off this approach, there is also a yield controlled right turn channelized lane. There are pedestrian crosswalks along the westbound approach. The speed limits at the intersection are as follows:

- 25 mph eastbound
- 25 mph southbound
- 25 mph westbound

Aquidneck Avenue / Purgatory Road/ Memorial Boulevard

Purgatory Rd facing WB toward Aquidneck Ave

Memorial Blvd facing NE toward Aquidneck Ave

The Aquidneck Avenue / Purgatory Road / Memorial Boulevard intersection is approximately 1,925 ft south of the Valley Road / Aquidneck Avenue intersection. This is a signalized, 3-legged intersection. The Memorial Boulevard northeast bound approach which is controlled by the signal, consists of a thru lane and right turn lane with a shoulder and sidewalks on both sides of the road. From the northbound approach there is also a yield controlled right turn channelized lane. The southbound Aquidneck Avenue approach consists of a single lane, shoulder and sidewalks on both sides of the road. The westbound Purgatory Road approach consists of a left turn lane and right turn lane controlled by the signal. The speed limits at the intersection are as follows:

- 25 mph northbound
- 40 mph southbound
- 25 mph westbound

Berkeley Avenue / Paradise Avenue / Green End Avenue

Green End Ave facing EB toward Berkeley Ave/Paradise Ave

Paradise Ave facing NB toward Green End Ave/Berkeley Ave

The intersection of Berkeley Avenue / Paradise Avenue / Green End Avenue is approximately 1 mile northeast of the signalized Valley Road / Miantonomi Avenue / Green End Avenue intersection. The eastbound and westbound approaches both consist of a single multi-use lane and shoulder with no traffic control. The Paradise Avenue northbound approach and Berkeley Avenue southbound approach both consist of a single multi-use lane and shoulder which are stop-controlled. There are no sidewalks or pedestrian crosswalks at this intersection. The speed limits at the intersection are as follows:

- 25 mph northbound
- 25 mph southbound
- 25 mph eastbound
- 25 mph westbound

Third Beach Road / Wapping Road / Mitchell's Lane

Third Beach Rd NB facing Wapping Rd/Mitchell's Ln

Wapping Rd facing WB toward Third Beach Rd/Mitchell's Ln

The intersection of Third Beach Road / Wapping Road / Mitchell's Lane is approximately 1 mile northeast of the Berkeley Avenue / Paradise Avenue / Green End Avenue intersection. Each of the approaches consists of a single multi-use lane and shoulder. The northbound approach is yield controlled and there are no other traffic controls. There are no existing sidewalks or pedestrian crosswalks at this intersection. The speed limits at the intersection are as follows:

- 25 mph northbound
- 25 mph southeast bound
- 25 mph westbound

Existing Traffic Volumes

To evaluate peak hour traffic conditions, manual turning movement counts (TMCs) were conducted at the study area intersections during the weekday morning and afternoon peak periods. TMCs were performed from 7-9 AM and 4-6 PM on Wednesday June 19 and Thursday June 20, 2019 while Middletown public schools were still in session. Based on these counts, the weekday AM and PM peak hours in the study area were determined to be 8-9 AM and 4:15-5:15 PM, respectively. The overall approach direction of traffic in the TMC counts are summarized in Table 5.2 and all traffic data are included in Appendix C.

Table 5.2 – Existing Turning Movement Counts – Overall Approach Direction

Location	AM Peak (8-9 AM)				PM Peak (4:15-5:15 PM)			
	SB	WB	NB	EB	SB	WB	NB	EB
W. Main Rd / Greene Ln / Pasture Farm Dr	1,005	35	604	65	914	14	1,354	169
W. Main Rd / Oliphant Ln	1,290	162	793	-	1,104	192	1,710	-
W. Main Rd / Forest Ave	1,362	160	824	-	1,227	218	1,729	-
W. Main Rd / Valley Rd	1,321	351	987	-	1,590	509	1,231	-
W. Main Rd / Coddington Hwy / Rockwood Rd	1,000	19	672	576	1,220	62	951	636
W. Main Rd / E. Main Rd	599	525	897	76	756	628	968	98
E. Main Rd / Oliphant Ln	1,376	4	609	219	806	2	1,464	214
E. Main Rd / Aquidneck Ave	27	1,426	337	480	55	983	702	830
E. Main Rd / Forest Ave	239	1,091	8	469	250	715	14	928
E. Main Rd / Valley Rd	357	883	424	602	527	752	668	676
Green End Ave / Valley Rd	637	373	448	789	595	431	773	765
Valley Rd / Aquidneck Ave	386	497	572	-	454	341	681	-
Aquidneck Ave / Purgatory Rd	641	188	709	-	619	167	959	-
Green End Ave / Berkeley Ave / Paradise Ave	128	231	117	157	101	173	184	242
Third Beach Rd / Mitchell's Ln / Wapping Rd	91	123	86	-	141	105	129	-

Seasonal Adjustment

The TMC data gathered as part of this study was collected during the month of June 2019 while public schools were still in session. In working with the Statewide Planning Program, we received from the State of Rhode Island Department of Transportation (RIDOT) the latest seasonal adjustment factors from 2018. The data were not specific to certain municipalities of the State but rather categorized by month, day of the week as well as interstate, rural, urban, other and recreation areas. For Wednesdays and Thursdays (when counts were performed) in June, seasonal adjustment factors ranged from 0.885 on Thursdays in Other Rural (OR) areas to 0.994 on Wednesdays in Interstate Rural (IR) areas. This implies that based on this general data for the entire State, the raw counts we performed are slightly higher than the average month condition. Using this adjustment means multiplying the raw volume by the rate, which in this case reduces the raw volumes, to reflect average conditions. To provide a conservative analysis, and since the RI seasonal adjustment data are not specific to Middletown traffic, we used the raw unadjusted volumes. The 2019 Existing Peak Weekday traffic volumes are graphically depicted in Figures 5.3 and 5.4.

Crash Data

In April 2019, CE wrote a formal request to RIDOT for the most recent three years of accidents at the intersections included in this study. This request was denied by RIDOT under Rhode Island General Law, Section 38-2-2 (A) II (S): Records, reports, opinions, information and statements required to be kept confidential by federal law or regulation or state law, or rule of court.

The Top Ten Crash Locations in Middletown with the highest crash frequencies (as published in Table T-3 of the 2014 Middletown Comprehensive Community Plan) is provided in Table 5.3 below.

Table 5.3 – Top Ten Crash Locations in Middletown

Rank	**Road**	**Intersecting Road**	**Total # of Crashes (2006-2008)**	**Severity Index (Total Cost)**
1*	East Main Road	West Main Road	57	$1,282,200
2*	Valley Road**	East Main Road	55	$1,047,400
3*	Forest Avenue	West Main Road	51	$688,200
4*	West Main Road	Coddington Hwy	45	$646,200
5*	East Main Road	Turner Road	40	$666,400
6	West Main Road	Smythe Road	30	$541,200
7	Browns Lane	West Main Road	29	$644,600
8	Aquidneck Ave	East Main Road	29	$534,200
9	West Main Road	Woolsey Road	27	$465,000
10	Broadway	West Main Road	27	$465,000

Source: RIDOT 2006-2008 Crash Database
*Denotes high severity locations
**Crash data at East Main Road and Valley Road do not account for recent intersection improvements.

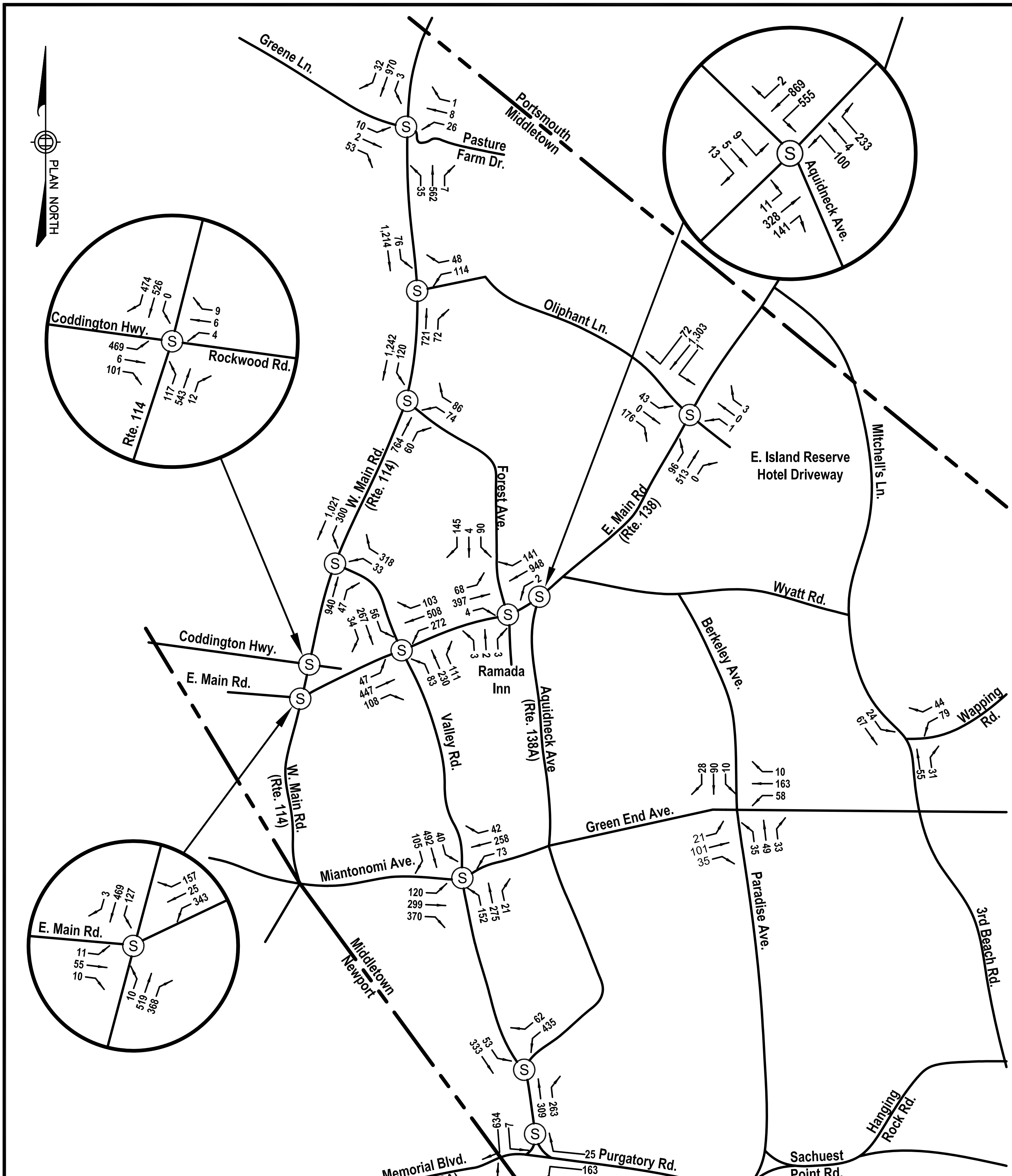


FIGURE 5.3

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- Environmental
- Site Planning
- Surveying
- Permitting
- Landscape Architecture

TRAFFIC IMPACT ANALYSIS
EXISTING AM PEAK HOUR 8 - 9 AM

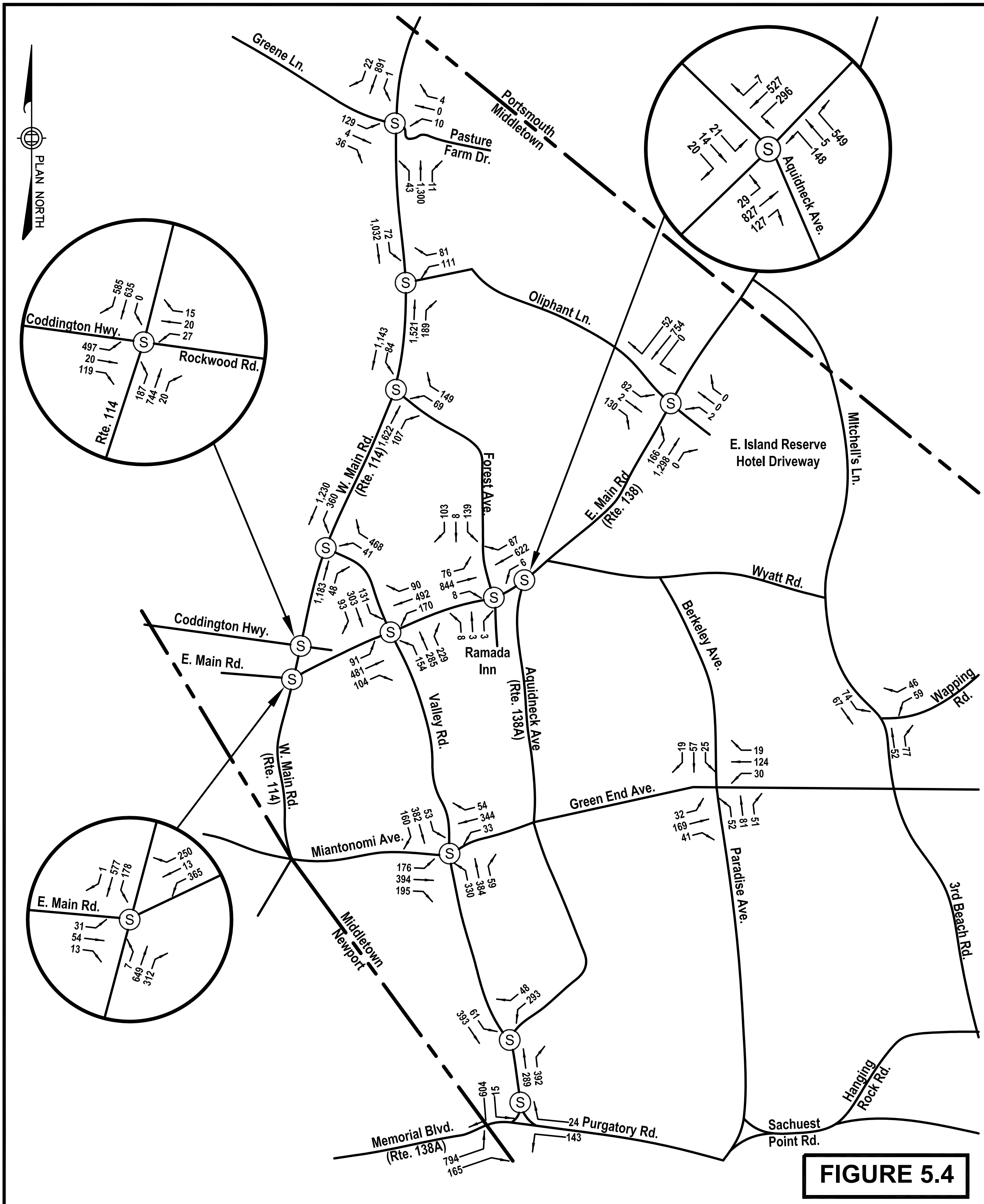

FIGURE 5.4

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- Permitting
- Landscape Architecture

TRAFFIC IMPACT ANALYSIS
EXISTING PM PEAK HOUR 4:15 - 5:15

FUTURE CONDITIONS

Generally, future traffic forecasts are developed for two scenarios: future No-Build Conditions (without proposed project in place) and future Build Conditions (with proposed project in place).

No-Build Conditions include existing traffic plus all additional traffic unrelated to the development due to future growth including:

1. Historic annual traffic growth
2. Specific Planned Development by Others
3. Relevant Roadway improvement projects

Build Conditions generally represents traffic conditions with a proposed development in place. It is generally determined by adding the expected vehicle trips generated by the proposed development to the future No-Build volumes.

This study does not examine just one development but instead examines all long-term development (over an approximate 25-year period) to completely build out the Town of Middletown. Therefore, in this case, the last two (2) No-Build Conditions categories listed above are already included as part of the build-out "Build Condition", rather than as part of the No-Build condition. To determine the historic annual growth for No-Build, we contacted Statewide Planning. Their findings were that in recent years the annual growth in Middletown has actually been a negative growth rate. To be conservative, Statewide Planning agrees with CE that a 0% annual growth rate is reasonable to use for our purposes, versus a negative annual growth. As such, we will present Existing Conditions from June 2019 and add the anticipated traffic generated by the build-out to attain future Build Conditions. In addition, we will also present future Optimized Build conditions as an option where improvement may be needed.

Future Build Conditions

Future Build Conditions represent traffic conditions with the proposed full build-out in place. Build volumes were determined by adding the expected vehicle trips generated by the full build-out to the 2019 Existing volumes.

Proposed Trip Generation

The proposed full build-out consists of the following developments:

- 1,436 units - Residential (single-unit houses) Units
- 406,241 square feet - Industrial
- 1,371,719 square feet - Mixed Use
- 378, 220 square feet - Office Park
- 146,570 square feet - Office Space
- 831,684 square feet - Retail

The location and square footage of the future full build-out developments are to be in the following sections of Middletown as delineated in Figure 5.2:

	W Main	E.Main/ W.Main	Aquidneck	St George	Wapping	Third Beach	Atlantic	Total
Residential (# of units)	452	186	156	115	279	200	48	1436
Industrial	406,241	0	0	0	0	0	0	406,241
Mixed Use	1,210,142	161,577	0	0	0	0	0	1,371,719
Office Park	0	0	378,220	0	0	0	0	378,220
Office/ Business	76,784	69,786	0	0	0	0	0	146,570
Retail	200,625	488,045	89,565	36,038	17,411	0	0	831,684

Daily and peak hour vehicle trip generation estimates for the proposed development were determined using trip generation rates published by the Institute of Transportation Engineers (ITE, 2017). The trip generation calculations for the following Land Use Code (LUCs) were used for the proposed developments.

- Residential - LUC 210 (Single-Family Detached Housing)
- Industrial – LUC 130 (Industrial Park)
- Mixed Use - Assume 35% residential, 35% retail, and 30% office
    - Mixed Use Residential - LUC 221 (Multifamily Housing – Mid Rise). Assumes 1,000 SF per unit
    - Mixed Use Retail – LUC 820 (Shopping Center)
    - Mixed Use – Office / Business - LUC 710 (General Office Building)
- Office Park – LUC 130 (Industrial Park)
- Office / Business – LUC 710 (General Office Building)
- Retail – LUC 820 (Shopping Center)

The estimated trip generation for the proposed project is summarized in Table 5.4. These ITE land use code rates are included in Appendix C and the land use zoning for the build-out is shown on a map also included in Appendix C.

Table 5.4 – Future Trips Resulting from Build-Out

	AM Peak hour trips*			PM Peak hour trips*		
	Total	Entering	Exiting	Total	Entering	Exiting
Residential	1,063	266	797	1,422	896	526
Industrial	164	133	31	164	34	130
Mixed Use	1,102	624	478	2,516	1,081	1,435
Office Park	152	123	29	152	32	120
Office / Business	172	148	24	170	27	143
Retail	782	485	297	3,169	1,521	1,648
Total Trips	**3,435**	**1,779**	**1,656**	**7,593**	**3,591**	**4,002**

*It should be noted that not all trips generated will be distributed along the study area streets analyzed for capacity

Trip Distribution

The distribution / route assignment for the proposed build-out trips is based on the existing traffic patterns in the study area as well as data from the Census Bureau's 2011 – 2015 American Community Survey, Rhode Island Commuting Patterns which provided journey to work statistics for Middletown and other Rhode Island municipalities (RIDLT, 2019). Generally, CE used *Where Middletown Residents Work* data to determine trips for proposed residences and retail; *Where Middletown Workers Live* data were used to determine distribution for proposed office, business and industrial uses. The journey to work percentages are shown in Table 5.5 on the following page. The expected vehicle trips generated by the proposed project were assigned on the study area roadway network as shown on Figures 5.5 and 5.6. In addition, a map of the trip generation densities for the build-out is included in Appendix C.

Build Traffic Volumes

To establish the Build peak hour traffic volumes, the project-related traffic was assigned to the surrounding roadway network based on the project distribution pattern. These project trips were then added to the Existing peak hour traffic volumes to represent the Build peak hour traffic volumes. The resulting Build weekday morning and weekday afternoon peak hour traffic volumes are presented in Figure 5.7 and Figure 5.8, respectively.

In addition to the Full-Build scenario, CE also examined one of the build-out alternatives which provided the lowest build out, or the most reduction in site generated traffic compared to the Full-Build scenario. This particular alternative chosen excludes Watershed Protection District 1 (WPD-1) from future development. This scenario is presented in Figures 5.9 through 5.12.

Table 5.5 – Journey to Work Data, U.S. Census Bureau 2011-2015 American Community Survey

Where Middletown Residents Work			Where Middletown Workers Live		
Total	7,999	100.0%	Total	11,207	100.0%
Newport, RI	3,194	39.9%	Middletown, RI	2,844	25.4%
Middletown, RI	2,844	35.6%	Newport, RI	1,565	14.0%
Portsmouth, RI	353	4.4%	Portsmouth, RI	1,552	13.8%
Providence, RI	196	2.5%	Tiverton, RI	743	6.6%
North Kingstown, RI	115	1.4%	Bristol, RI	604	5.4%
South Kingstown, RI	108	1.4%	Fall River, MA	557	5.0%
Bristol, RI	99	1.2%	North Kingstown, RI	397	3.5%
Warwick, RI	68	0.9%	Warwick, RI	249	2.2%
Fall River, MA	57	0.7%	South Kingstown, RI	217	1.9%
Exeter, RI	56	0.7%	Cranston, RI	181	1.6%
Pawtucket, RI	52	0.7%	Warren, RI	175	1.6%
Tiverton, RI	48	0.6%	Jamestown, RI	159	1.4%
Jamestown, RI	46	0.6%	Johnston, RI	134	1.2%
Cranston, RI	43	0.5%	Narragansett, RI	133	1.2%
East Greenwich, RI	42	0.5%	Dartmouth, MA	118	1.1%
Dartmouth, MA	35	0.4%	Exeter, RI	115	1.0%
East Providence, RI	32	0.4%	Providence, RI	106	0.9%
Sandwich, MA	32	0.4%	East Providence, RI	74	0.7%
Westerly, RI	32	0.4%	North Attleboro, MA	69	0.6%
Other Communities	547	6.9%	New Bedford, MA	63	0.6%
			Other Communities	1,152	10.3%
Middletown Residents Work in the State of:			Middletown Workers Live in the State of:		
Rhode Island	7,445	93.1%	Rhode Island	9,821	87.6%
Massachusetts	385	4.8%	Massachusetts	1,133	10.1%
Connecticut	14	0.2%	Connecticut	182	1.6%
Other State/Country	155	1.9%	Other State/Country	71	0.6%
	7,999	100.0%		11,207	100.0%

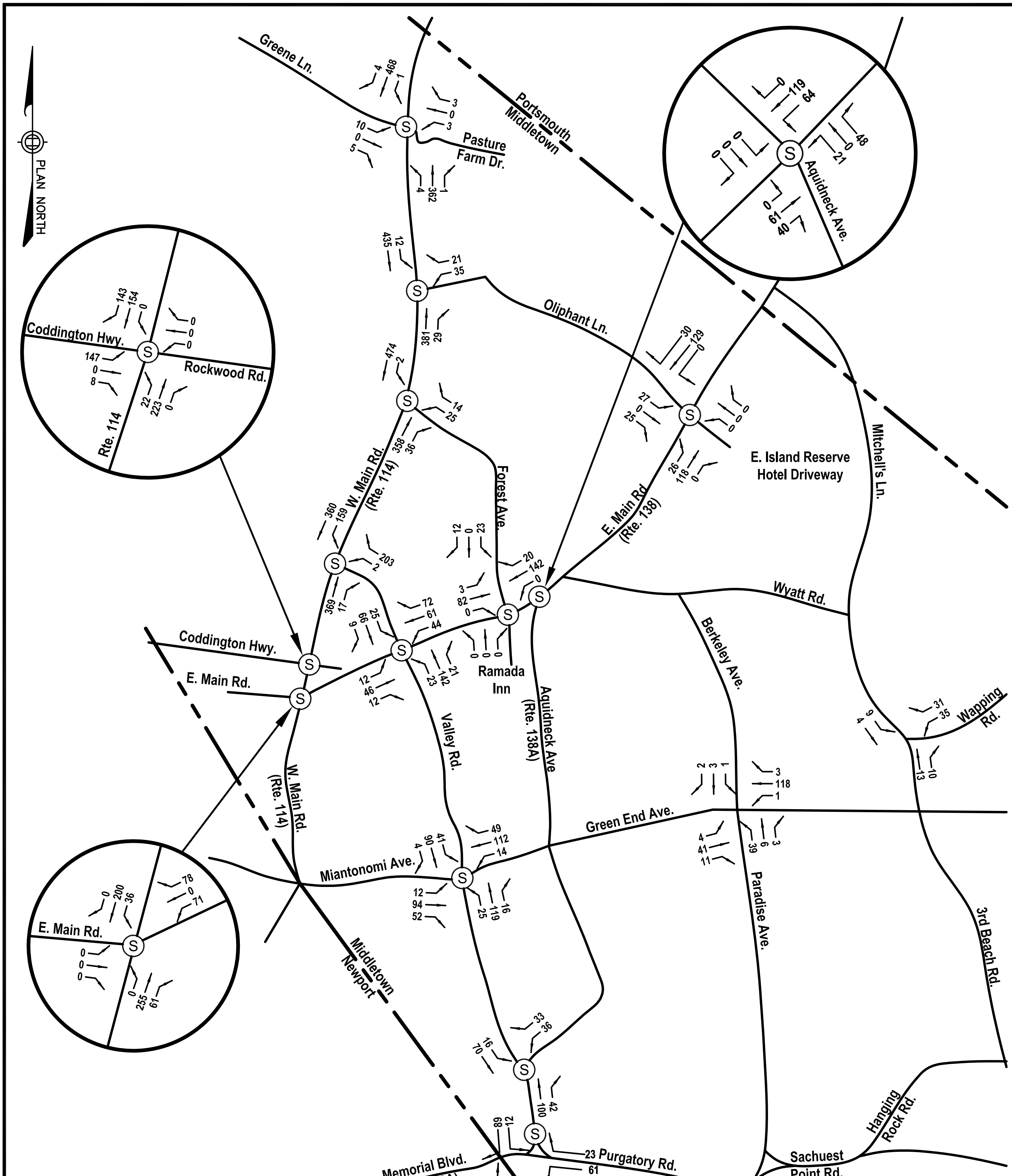

FIGURE 5.5

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MIDDLETOWN FULL BUILD SITE GENERATED TRAFFIC AM PEAK HOUR

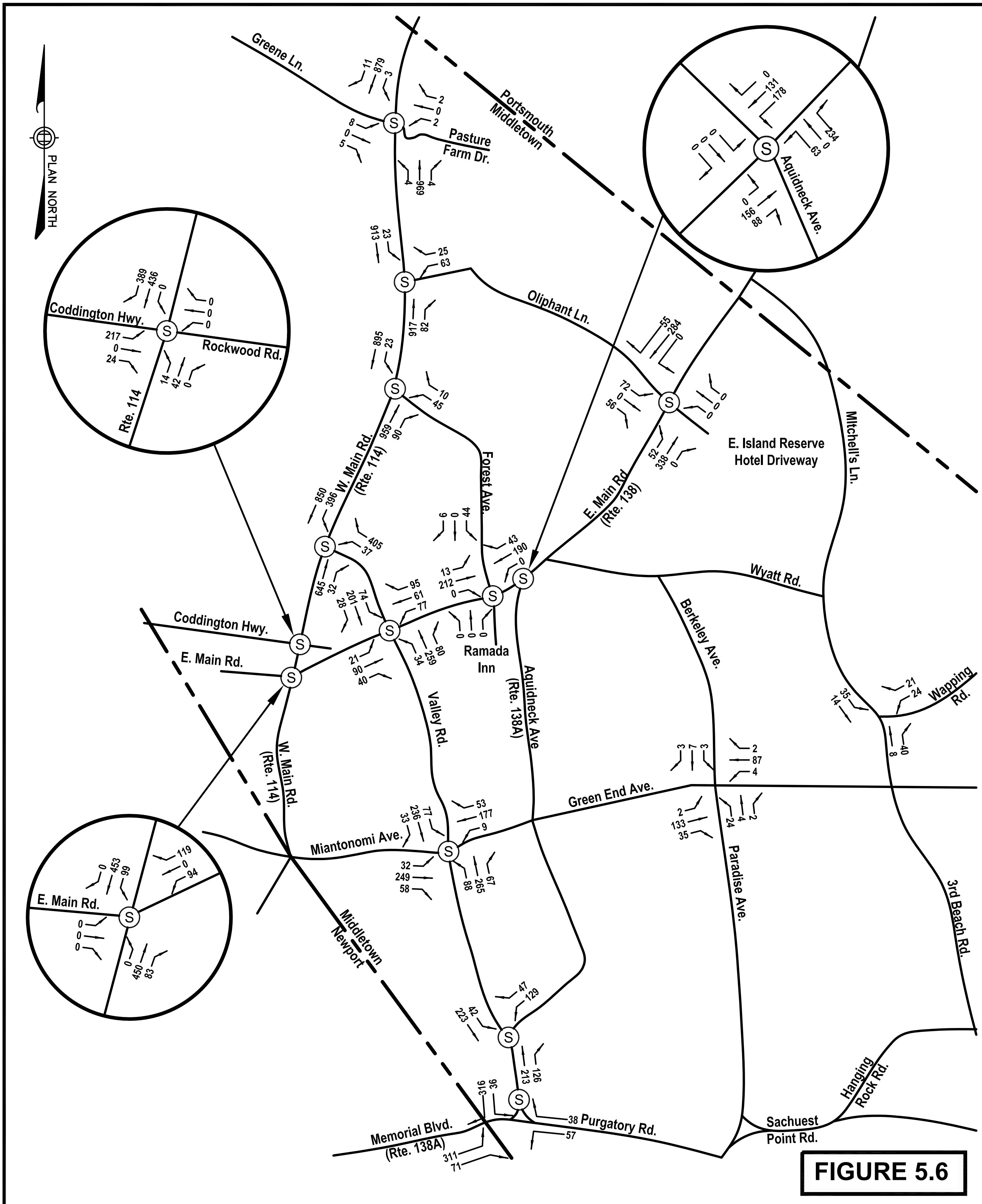

FIGURE 5.6

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MIDDLETOWN FULL BUILD SITE GENERATED TRAFFIC PM PEAK HOUR

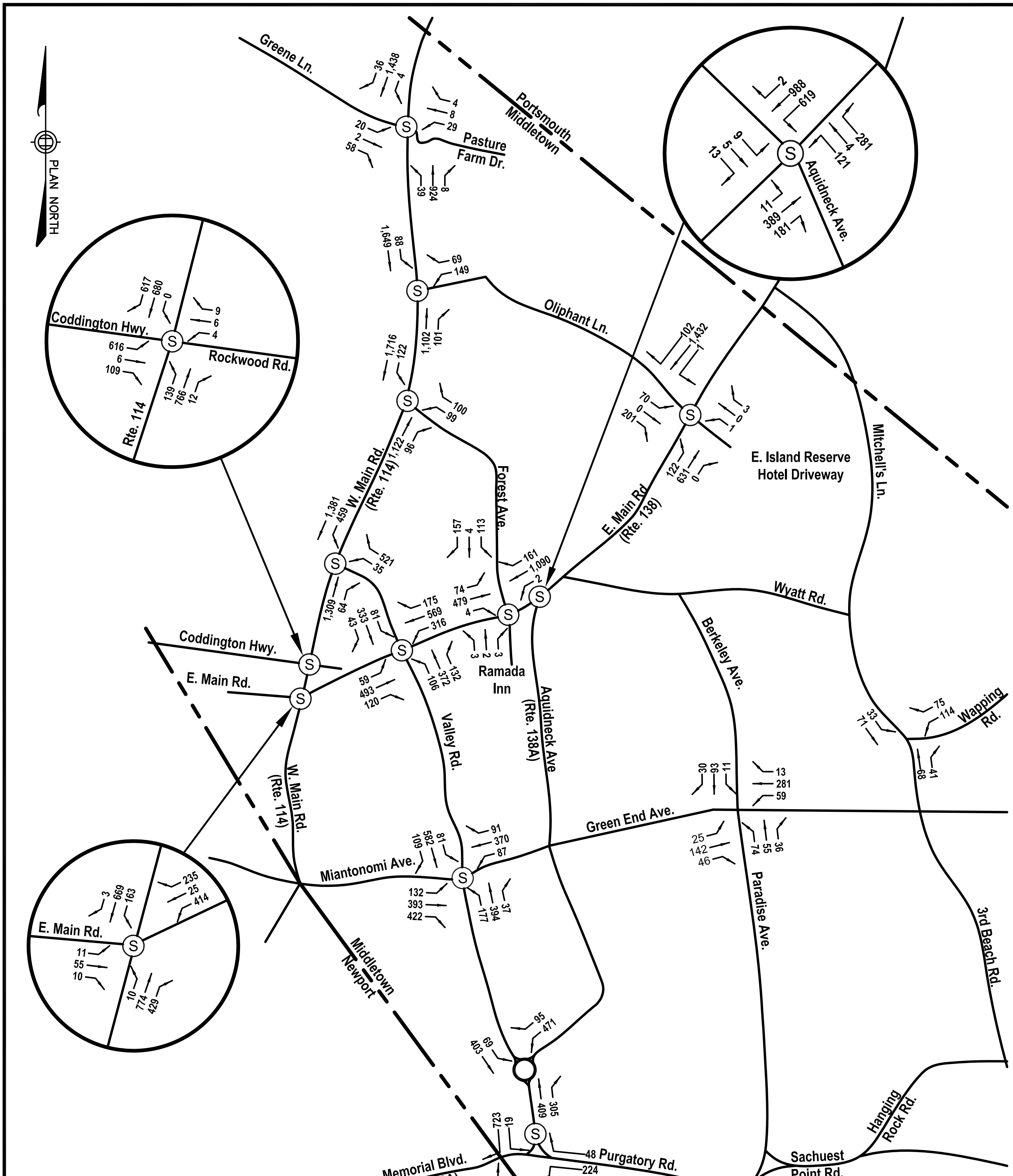

FIGURE 5.7

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MIDDLETOWN FULL BUILD TRAFFIC IMPACT ANALYSIS BUILD AM PEAK HOUR 8 - 9 AM

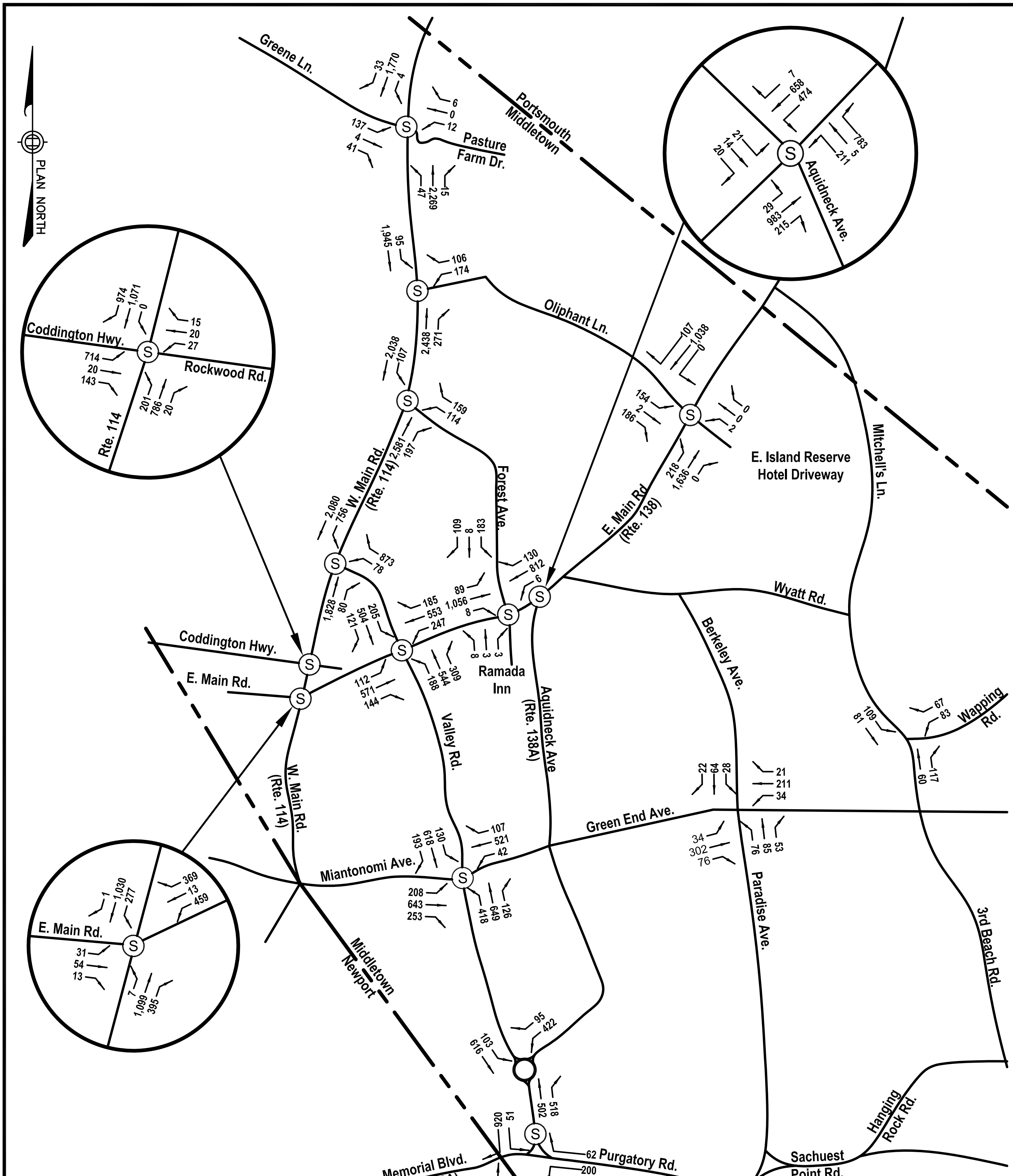

FIGURE 5.8

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MIDDLETOWN FULL BUILD
TRAFFIC IMPACT ANALYSIS
BUILD PM PEAK HOUR 4:15 - 5:15 PM

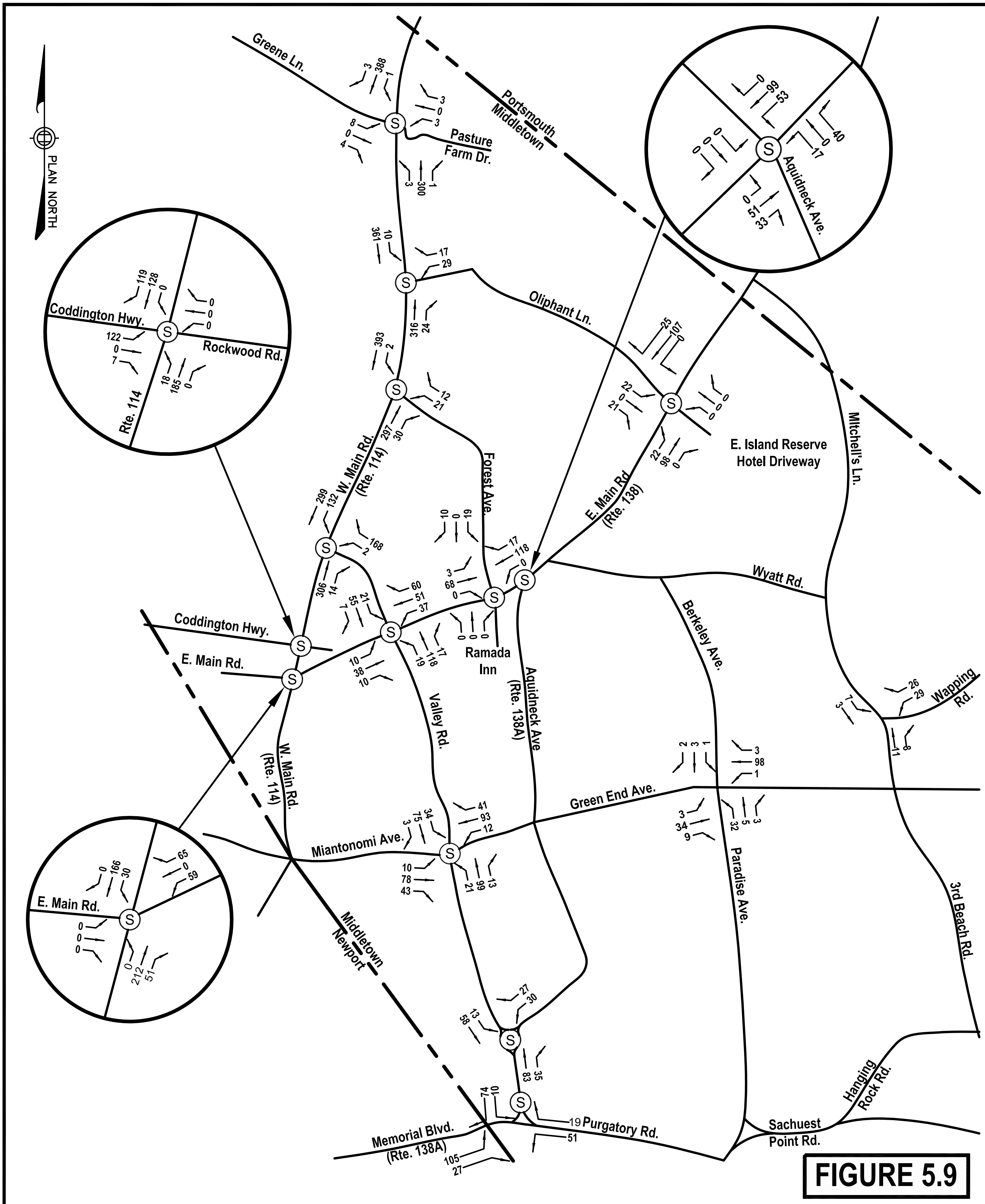

FIGURE 5.9

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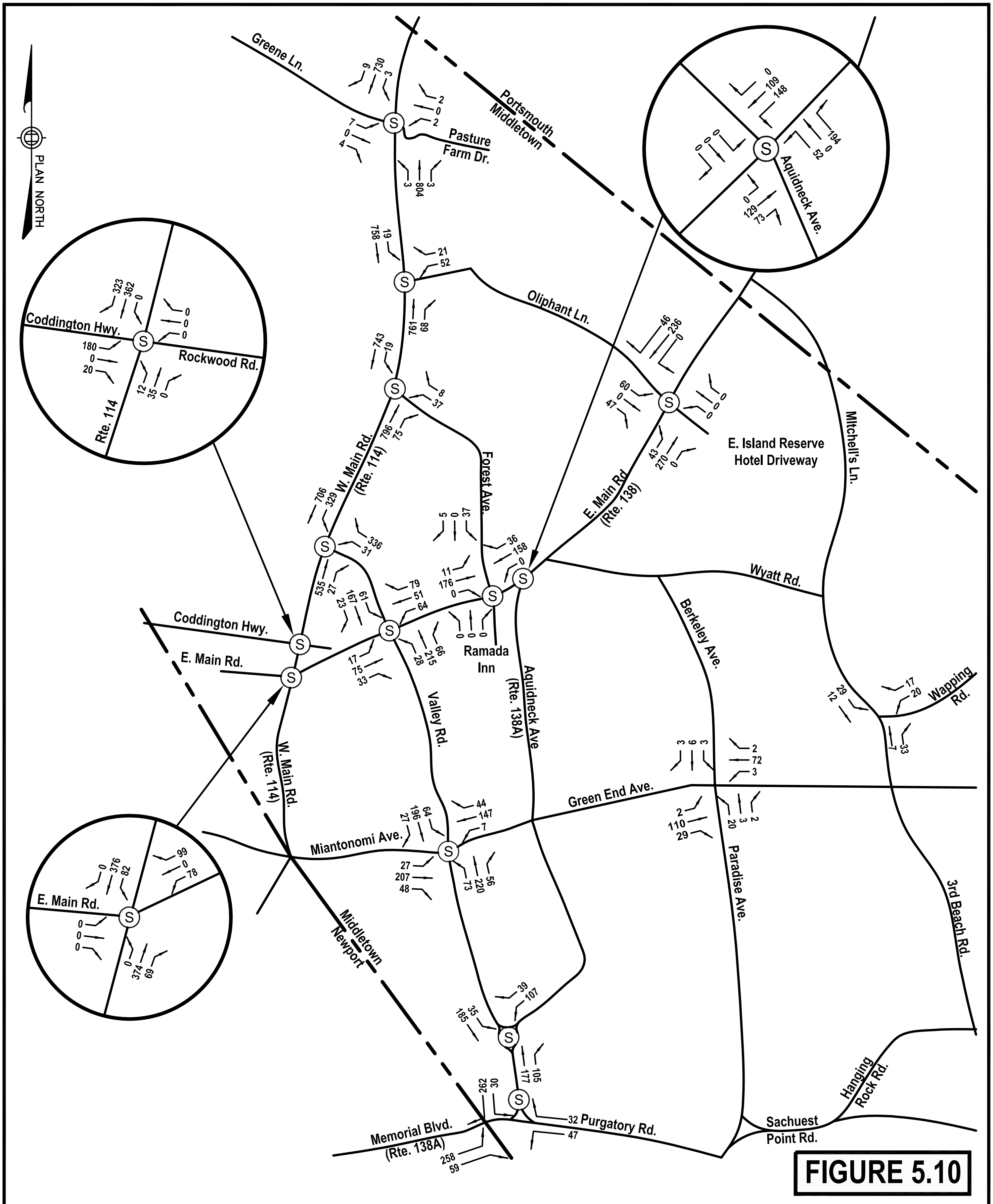
MIDDLETOWN ALTERNATIVE (WPD1)
SITE GENERATED TRAFFIC
AM PEAK HOUR



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MIDDLETOWN ALTERNATIVE (WPD1)
SITE GENERATED TRAFFIC
PM PEAK HOUR

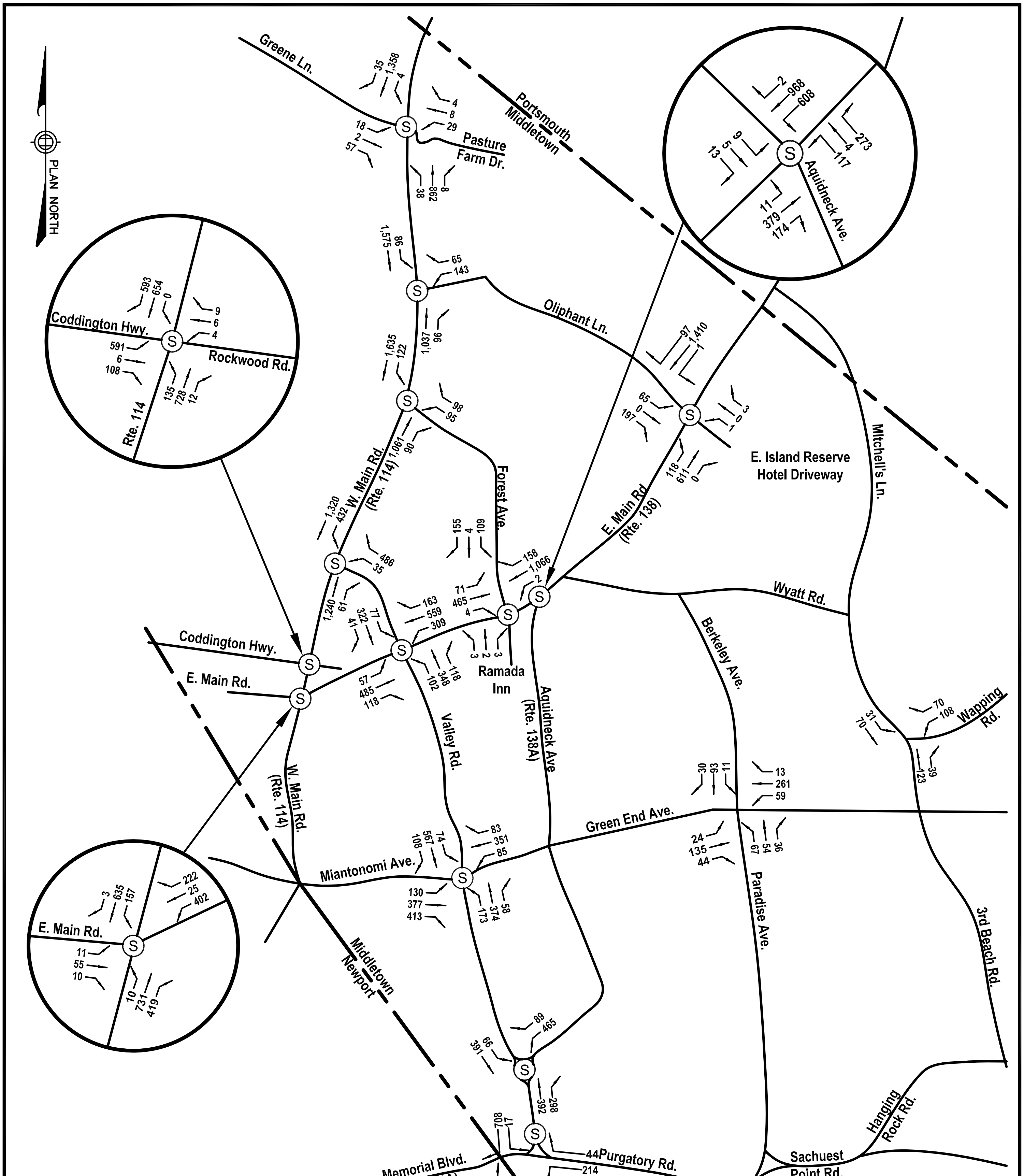

FIGURE 5.11

CROSSMAN ENGINEERING

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MIDDLETOWN ALTERNATIVE (WPD1)
TRAFFIC IMPACT ANALYSIS
BUILD AM PEAK HOUR 8 - 9 AM

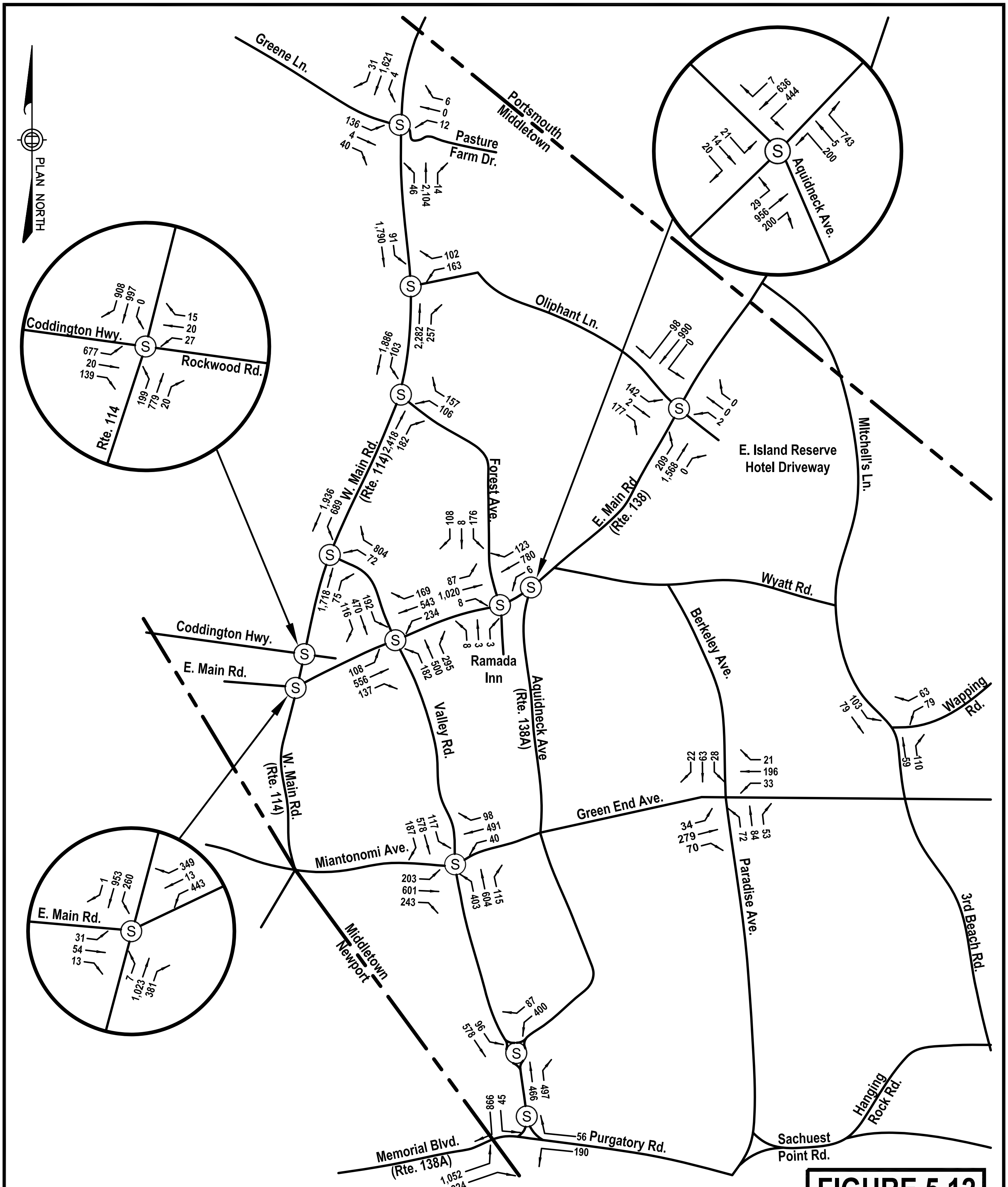

FIGURE 5.12

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MIDDLETOWN ALTERNATIVE (WPD1)
TRAFFIC IMPACT ANALYSIS
PM PEAK HOUR 4:15 - 5:15 PM

Traffic Operations Analysis

Traffic operations analysis describes the quality of traffic flow at the study intersections for the traffic demands. As a basis for this assessment, intersection capacity analyses were conducted using Synchro capacity analysis software for the study area intersections for the 2019 Existing, Future Build peak hour traffic conditions. This analysis is based on procedures contained in the 2010 Highway Capacity Manual (TRB, 2010). A discussion of the evaluation criteria and a summary of the results of the capacity analyses are presented below.

Level-Of-Service Criteria

The analyses result in a Level of Service (LOS) being assigned to the intersection. LOS is defined as a qualitative measure describing operational conditions based on vehicular delay. There are six levels of service ranging from LOS A (little or no delay) to LOS F (worst operating conditions – high delays) with LOS D being considered acceptable for peak hour conditions at signalized intersections.

Signalized Intersections

The levels of service at signalized intersections are determined by a procedure described in the 2010 Highway Capacity Manual and as shown in Table 5.6.

Table 5.6 – Level of Service Criteria for Signalized Intersections

LOS	Control Delay (seconds/vehicle)	General Description
A	≤10	Free Flow
B	>10.0 to 20.0	Stable Flow (slight delays)
C	>20.0 to 35.0	Stable Flow (acceptable delays)
D	>35.0 to 55.0	Approaching Unstable Flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	>55.0 to 80.0	Unstable Flow (operating at capacity)
F	>80.0	Forced Flow (congested and queues fail to clear)

Unsignalized Intersections

The levels of service at unsignalized intersections are determined by a procedure described in the 2010 Highway Capacity Manual. The level of service criteria for unsignalized intersections is described in Table 5.7.

Table 5.7 - Level of Service Criteria for Unsignalized Intersections

LOS	Control Delay (seconds/vehicle)
A	≤10.
B	>10.0 to 15.0
C	>15.0 to 25.0
D	>25.0 to 35.0
E	>35.0 to 50.0
F	>50.0

Volume to Capacity Ratio (v/c)

The v/c ratio, also referred to as degree of saturation, represents the sufficiency of an intersection to accommodate the vehicular demand. A v/c ratio less than 0.85 generally indicates that adequate capacity is available and vehicles are not expected to experience significant queues and delays. As the v/c ratio approaches 1.0, traffic flow may become unstable, and delay and queuing conditions may occur. Once the demand exceeds the capacity (a v/c ratio greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected. Under these conditions, vehicles may require more than one signal cycle to pass through the intersection.

Capacity Analysis Results

The capacity analyses indicated volume to capacity ratios, average vehicle delay (in seconds), and the levels of service shown in Table 5.8 (Table 5.8A and 5.8B) and Table 5.9 for signalized intersections and unsignalized intersections, respectively, in the study area. We have presented three scenarios:

- 2019 Existing Conditions
- "Build" Full-Build Conditions based on current zoning
- "Build Alternative" Conditions which excludes Watershed Protection District 1

Several alternative conditions were considered; however, this specific alternative which excludes Watershed Protection District 1 was analyzed because it resulted in the largest reduction in site generated traffic compared to the full-build scenario.

It should be noted that there are future plans to re-design the signalized intersection of Aquidneck Avenue / Valley Road as a roundabout. At the request of the Town, we have provided future analysis results for both the roundabout re-design as well as for future conditions with the existing signal control.

For Tables 5.8A and 5.8B, the intersections most impacted by traffic in the future are highlighted in yellow.

Table 5.8A- Signalized Level-Of-Service Analysis Summary for AM Peak

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
W. Main Rd / Greene Ln / Pasture Farm Dr	**OVERALL**	**0.56**	**17.5**	**B**	**0.84**	**54.9**	**D**	**0.79**	**42.3**	**D**
Greene Ln	EB	0.10	38.5	D	0.20	38.3	D	0.18	38.3	D
Pasture Farm Dr	WB	0.49	41.9	D	0.52	42.1	D	0.52	42.1	D
W. Main Rd (RI 114)	NB	0.29	3.6	A	0.52	22.4	C	0.48	20.2	C
W. Main Rd (RI 114)	SB	0.74	23.3	C	1.10	78.6	E	1.04	57.5	E
W. Main Rd / Oliphant Ln	**OVERALL**	**0.70**	**15.7**	**B**	**1.07**	**92.7**	**F**	**0.99**	**64.1**	**E**
Oliphant Ln	WB	0.68	29.8	C	0.75	42.1	D	0.74	42.1	D
W. Main Rd (RI 114)	NB	0.61	16.4	B	1.03	68.4	E	0.97	49.2	D
W. Main Rd (RI 114)	SB	0.70	13.3	B	1.17	117.2	F	1.07	77.6	E
W. Main Rd / Forest Ave	**OVERALL**	**0.82**	**20.1**	**C**	**1.23**	**121.2**	**F**	**1.15**	**96.6**	**F**
Forest Ave	WB	0.74	44.9	D	0.83	50.5	D	0.82	48.9	D
W. Main Rd (RI 114)	NB	0.58	16.4	B	0.88	31.9	C	0.83	29.8	C
W. Main Rd (RI 114)	SB	0.84	18.1	B	1.35	191.5	F	1.26	148.0	F
W. Main Rd / Valley Rd	**OVERALL**	**0.65**	**13.0**	**B**	**1.05**	**28.6**	**C**	**0.99**	**22.7**	**C**
Valley Rd	WB	0.52	19.4	B	0.83	30.2	C	0.78	26.6	C
W. Main Rd (RI 114)	NB	0.67	20.8	C	0.96	40.1	D	0.91	33.2	C
W. Main Rd (RI 114)	SB	0.64	5.4	A	1.08	19.7	B	1.02	13.8	B
W. Main Rd / Coddington Hwy	**OVERALL**	**0.51**	**28.2**	**C**	**0.65**	**31.8**	**C**	**0.63**	**30.3**	**C**
Coddington Hwy	EB	0.70	43.7	D	0.86	49.1	D	0.83	47.2	D
Rockwood Rd	WB	0.25	56.1	E	0.25	56.1	E	0.25	56.1	E
W. Main Rd (RI 114)	NB	0.61	26.3	C	0.62	28.4	C	0.62	25.9	C
W. Main Rd (RI 114)	SB	0.41	18.9	B	0.58	23.1	C	0.55	22.3	C
W. Main Rd / E. Main Rd	**OVERALL**	**0.63**	**34.1**	**C**	**0.82**	**43.0**	**D**	**0.78**	**38.8**	**D**
E. Main Rd	EB	0.57	55.7	E	0.57	55.7	E	0.57	55.7	E
E. Main Rd (RI 138)	WB	0.70	49.4	D	0.66	43.8	D	0.66	44.7	D
W. Main Rd (RI 114)	NB	0.59	28.1	C	0.96	54.4	D	0.89	44.2	D
W. Main Rd (RI 114)	SB	0.72	25.9	C	0.82	25.0	C	0.81	24.3	C
E. Main Rd / Oliphant Ln	**OVERALL**	**0.79**	**26.6**	**C**	**1.01**	**111.2**	**F**	**0.97**	**91.8**	**F**
E. Main Rd (RI 138)	NB	0.50	6.3	A	0.61	8.9	A	0.59	8.4	A
E. Main Rd (RI 138)	SB	0.98	35.3	D	1.33	176.9	F	1.26	144.1	F
Oliphant Ln	SE	0.42	29.0	C	0.74	37.8	D	0.69	34.5	C
Hotel Driveway	NW	0.04	26.6	C	0.04	24.1	C	0.04	24.6	C
E. Main Rd / Aquidneck Ave	**OVERALL**	**0.75**	**17.9**	**B**	**0.87**	**26.6**	**C**	**0.85**	**24.1**	**C**
E. Main Rd (RI 138)	EB	0.72	26.3	C	0.87	32.7	C	0.85	30.4	C
E. Main Rd (RI 138)	WB	0.78	11.4	B	0.95	23.3	C	0.92	20.1	C
Aquidneck Ave	NB	0.57	31.3	C	0.60	30.2	C	0.60	30.6	C
Plaza / Bank	SB	0.12	29.3	C	0.10	27.8	C	0.11	28.2	C

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
E. Main Rd / Forest Ave / Ramada	**OVERALL**	**0.72**	**21.2**	**C**	**0.84**	**35.1**	**D**	**0.81**	**31.1**	**C**
E. Main Rd (RI 138)	EB	0.36	8.5	A	0.43	12.5	B	0.42	14.7	B
E. Main Rd (RI 138)	WB	0.71	17.6	B	0.79	18.3	B	0.78	16.9	B
Hotel Driveway	NB	0.04	24.7	C	0.04	25.7	C	0.04	25.4	C
Forest Ave	SB	0.87	53.0	D	1.14	130.1	F	1.08	107.2	F
E. Main Rd / Valley Rd	**OVERALL**	**0.69**	**28.1**	**C**	**0.86**	**34.4**	**C**	**0.83**	**33.0**	**C**
E. Main Rd (RI 138)	EB	0.58	26.7	C	0.79	35.2	D	0.75	33.1	C
E. Main Rd (RI 138)	WB	0.86	21.1	C	0.94	26.6	C	0.95	27.6	C
Valley Rd	NB	0.65	35.8	D	0.87	43.5	D	0.81	38.8	D
Valley Rd	SB	0.71	37.1	D	0.75	37.8	D	0.73	36.9	D
Green End Ave / Valley Rd	**OVERALL**	**0.66**	**25.7**	**C**	**0.87**	**37.2**	**D**	**0.83**	**34.2**	**C**
Green End Ave	EB	0.48	20.8	C	0.73	27.8	C	0.67	26.4	C
Green End Ave	WB	0.64	33.5	C	0.90	53.5	D	0.86	47.4	D
Valley Rd	NB	0.57	17.6	B	0.77	24.5	C	0.73	22.8	C
Valley Rd	SB	0.74	33.7	C	0.91	48.8	D	0.87	44.7	D
Aquidneck Ave / Valley Rd	**OVERALL**	**0.79**	**14.3**	**B**	**PROPOSED ROUNDABOUT***			**PROPOSED ROUNDABOUT***		
Aquidneck Ave	WB	0.80	16.0	B	0.70	17.0	C	0.67	15.0	B/C
Aquidneck Ave	NB	0.79	15.9	B	0.61	10.0	A/B	0.58	10.0	A/B
Valley Rd	SE	0.60	9.9	A	0.63	15.0	B/C	0.60	14.0	B
Aquidneck Ave / Valley Rd (w/SIGNAL)	**OVERALL**	**0.79**	**14.3**	**B**	**0.92**	**25.8**	**C**	**0.90**	**22.8**	**C**
Aquidneck Ave	WB	0.80	16.0	B	0.90	24.0	C	0.88	21.6	C
Aquidneck Ave	NB	0.79	15.9	B	0.94	30.4	C	0.92	27.4	C
Valley Rd	SE	0.60	9.9	A	0.92	21.7	C	0.86	17.9	B
Aquidneck Ave / Purgatory Rd	**OVERALL**	**0.60**	**9.4**	**A**	**0.75**	**14.0**	**B**	**0.73**	**13.2**	**B**
Aquidneck Ave	SB	0.63	8.7	A	0.80	15.0	B	0.78	13.8	B
Memorial Blvd	NW	0.48	17.4	B	0.62	21.6	C	0.59	20.6	C
Purgatory Rd	NE	0.64	8.0	A	0.76	10.9	B	0.74	10.4	B

*Proposed roundabout at Aquidneck Avenue / Valley Road follows unsignalized LOS criteria

Table 5.8B- Signalized Level-Of-Service Analysis Summary for PM Peak

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
PM PEAK HOUR										
W. Main Rd / Greene Ln / Pasture Farm Dr	**OVERALL**	**0.70**	**21.8**	**C**	**1.47**	**297.9**	**F**	**1.36**	**242.0**	**F**
Greene Ln	EB	0.67	39.8	D	0.69	39.7	D	0.68	39.6	D
Pasture Farm Dr	WB	0.01	31.9	C	0.02	31.4	C	0.02	31.4	C
W. Main Rd (RI 114)	NB	0.71	19.6	B	1.53	276.5	F	1.41	224.5	F
W. Main Rd (RI 114)	SB	0.69	21.1	C	1.73	355.5	F	1.58	290.0	F
W. Main Rd / Oliphant Ln	**OVERALL**	**0.95**	**44.2**	**D**	**1.54**	**273.7**	**F**	**1.44**	**226.3**	**F**
Oliphant Ln	WB	0.96	89.4	F	1.46	270.4	F	1.38	236.5	F
W. Main Rd (RI 114)	NB	1.00	49.4	D	1.58	296.0	F	1.49	252.2	F
W. Main Rd (RI 114)	SB	0.73	26.2	C	1.44	241.9	F	1.32	186.6	F
W. Main Rd / Forest Ave	**OVERALL**	**0.94**	**40.6**	**D**	**1.52**	**325.1**	**F**	**1.41**	**269.3**	**F**
Forest Ave	WB	0.72	44.5	D	0.86	53.7	D	0.83	50.9	D
W. Main Rd (RI 114)	NB	1.05	58.3	E	1.69	337.4	F	1.58	288.4	F
W. Main Rd (RI 114)	SB	0.85	15.6	B	1.73	347.6	F	1.57	276.7	F
W. Main Rd / Valley Rd	**OVERALL**	**0.90**	**19.3**	**B**	**1.83**	**151.6**	**F**	**1.67**	**121.1**	**F**
Valley Rd	WB	0.83	33.3	C	1.55	260.6	F	1.43	211.2	F
W. Main Rd (RI 114)	NB	0.83	24.6	C	1.28	155.5	F	1.21	121.8	F
W. Main Rd (RI 114)	SB	0.87	10.7	B	1.83	112.7	F	1.67	90.8	F
W. Main Rd / Coddington Hwy	**OVERALL**	**0.66**	**32.4**	**C**	**0.98**	**107.5**	**F**	**0.91**	**81.6**	**F**
Coddington Hwy	EB	0.72	44.7	D	1.02	74.3	E	0.96	63.3	E
Rockwood Rd	WB	0.52	54.8	D	0.52	54.8	D	0.52	54.8	D
W. Main Rd (RI 114)	NB	0.53	20.2	C	0.55	22.1	C	0.55	22.1	C
W. Main Rd (RI 114)	SB	0.77	34.2	C	1.34	163.2	F	1.24	120.4	F
W. Main Rd / E. Main Rd	**OVERALL**	**0.73**	**40.6**	**D**	**1.05**	**122.0**	**F**	**1.00**	**103.0**	**F**
E. Main Rd	EB	0.64	56.7	E	0.64	56.7	E	0.64	56.7	E
E. Main Rd (RI 138)	WB	0.69	48.1	D	0.67	42.8	D	0.66	43.0	D
W. Main Rd (RI 114)	NB	0.75	36.0	D	1.40	223.9	F	1.31	186.5	F
W. Main Rd (RI 114)	SB	0.83	37.6	D	1.20	66.6	E	1.09	53.8	D
E. Main Rd / Oliphant Ln	**OVERALL**	**0.89**	**30.9**	**C**	**1.27**	**174.0**	**F**	**1.20**	**145.0**	**F**
E. Main Rd (RI 138)	NB	0.95	24.7	C	1.38	189.6	F	1.30	156.8	F
E. Main Rd (RI 138)	SB	0.93	42.3	D	1.33	180.6	F	1.26	152.5	F
Oliphant Ln	SE	0.63	32.3	C	0.97	70.2	E	0.92	57.4	E
Hotel Driveway	NW	0.05	25.2	C	0.04	21.9	C	0.04	22.2	C
E. Main Rd / Aquidneck Ave	**OVERALL**	**0.86**	**30.8**	**C**	**1.35**	**120.7**	**F**	**1.26**	**100.0**	**F**
E. Main Rd (RI 138)	EB	1.00	40.9	D	1.26	141.5	F	1.22	122.0	F
E. Main Rd (RI 138)	WB	0.67	12.7	B	1.44	108.8	F	1.35	90.4	F
Aquidneck Ave	NB	0.84	37.6	D	1.23	116.6	F	1.14	90.7	F
Plaza / Bank	SB	0.14	22.0	C	0.12	18.1	B	0.11	18.1	B

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
PM PEAK HOUR										
E. Main Rd / Forest Ave / Ramada	**OVERALL**	**0.71**	**21.1**	**C**	**0.97**	**30.7**	**C**	**0.93**	**27.6**	**C**
E. Main Rd (RI 138)	EB	0.63	17.6	B	0.92	21.8	C	0.88	20.0	B
E. Main Rd (RI 138)	WB	0.55	12.1	B	0.73	16.1	B	0.70	13.9	B
Hotel Driveway	NB	0.08	23.7	C	0.08	23.0	C	0.08	23.0	C
Forest Ave	SB	0.90	54.9	D	1.08	101.4	F	1.05	90.8	F
E. Main Rd / Valley Rd	**OVERALL**	**0.77**	**38.0**	**D**	**1.15**	**180.3**	**F**	**1.08**	**150.1**	**F**
E. Main Rd (RI 138)	EB	0.71	31.1	C	0.88	38.6	D	0.86	37.1	D
E. Main Rd (RI 138)	WB	0.81	36.7	D	1.12	57.0	E	1.06	52.1	D
Valley Rd	NB	0.78	40.5	D	1.88	372.5	F	1.72	308.1	F
Valley Rd	SB	0.85	45.3	D	1.44	208.2	F	1.35	171.4	F
Green End Ave / Valley Rd	**OVERALL**	**1.00**	**45.5**	**D**	**1.64**	**210.7**	**F**	**1.56**	**187.9**	**F**
Green End Ave	EB	0.77	26.1	C	1.17	74.7	E	1.14	62.9	E
Green End Ave	WB	0.79	41.3	D	1.23	155.3	F	1.15	125.8	F
Valley Rd	NB	1.19	71.8	E	1.98	229.4	F	1.91	208.0	F
Valley Rd	SB	0.74	36.6	D	1.76	390.0	F	1.69	357.8	F
Aquidneck Ave / Valley Rd	**OVERALL**	**0.74**	**12.1**	**B**	**PROPOSED ROUNDABOUT***			**PROPOSED ROUNDABOUT***		
Aquidneck Ave	WB	0.68	14.2	B	0.71	18.0	C	0.64	15.0	B/C
Aquidneck Ave	NB	0.78	13.4	B	0.90	26.0	D	0.84	20.0	C
Valley Rd	SE	0.66	8.6	A	0.90	34.0	D	0.83	24.0	C
Aquidneck Ave / Valley Rd (w/SIGNAL)	**OVERALL**	**0.74**	**12.1**	**B**	1.15	91.8	F	1.08	71.6	E
Aquidneck Ave	WB	0.68	14.2	B	0.85	19.5	B	0.81	17.8	B
Aquidneck Ave	NB	0.78	13.4	B	1.30	158.3	F	1.21	120.1	F
Valley Rd	SE	0.66	8.6	A	1.36	59.6	E	1.27	48.6	D
Aquidneck Ave / Purgatory Rd	**OVERALL**	**0.71**	**8.6**	**A**	**0.98**	**49.3**	**D**	**0.93**	**32.8**	**C**
Aquidneck Ave	SB	0.51	5.2	A	1.02	47.1	D	0.93	26.5	C
Memorial Blvd	NW	0.62	26.7	C	0.62	24.1	C	0.61	24.1	C
Purgatory Rd	NE	0.73	7.6	A	1.09	55.8	E	1.03	39.1	D

*Proposed roundabout at Aquidneck Avenue / Valley Road follows unsignalized LOS criteria

Table 5.9 - Unsignalized Level-Of-Service Analysis Summary

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
Green End Ave / Berkeley Ave / Paradise Ave										
Green End Ave	EB	0.02	1.2	A	0.03	1.2	A	0.03	1.2	A
Green End Ave	WB	0.05	2.4	A	0.06	1.9	A	0.05	2.0	A
Paradise Ave	NB	0.35	18.6	C	0.80	60.1	F	0.70	44.5	E
Berkeley Ave	SB	0.37	17.5	C	0.52	26.8	D	0.50	24.8	C
Green End Ave / Berkeley Ave / Paradise Ave					**PROPOSED ROUNDABOUT***			**PROPOSED ROUNDABOUT***		
Green End Ave	EB				0.27	6.0	A	0.26	6.0	A
Green End Ave	WB				0.34	7.0	A	0.32	6.0	A
Paradise Ave	NB				0.19	5.0	A	0.17	5.0	A
Berkeley Ave	SB				0.19	6.0	A	0.19	6.0	A
Third Beach Rd / Mitchell's Ln / Wapping Rd										
Wapping Rd	WB	0.07	5.4	A	0.10	5.4	A	0.09	5.4	A
Third Beach Rd	NB	0.21	11.6	B	0.31	13.9	B	0.29	13.5	B
Mitchell's Ln	SE	0.09	0.0	A	0.10	0.0	A	0.10	0.0	A
PM PEAK HOUR										
Green End Ave / Berkeley Ave / Paradise Ave										
Green End Ave	EB	0.04	1.5	A	0.04	1.3	A	0.04	1.3	A
Green End Ave	WB	0.03	1.6	A	0.04	1.4	A	0.04	1.4	A
Paradise Ave	NB	0.50	21.7	C	1.02	108.2	F	0.90	73.2	F
Berkeley Ave	SB	0.40	21.1	C	0.77	60.4	F	0.70	47.7	E
Green End Ave / Berkeley Ave / Paradise Ave					**PROPOSED ROUNDABOUT***			**PROPOSED ROUNDABOUT***		
Green End Ave	EB				0.42	7.0	A	0.39	7.0	A
Green End Ave	WB				0.31	6.0	A	0.29	6.0	A
Paradise Ave	NB				0.29	7.0	A	0.27	7.0	A
Berkeley Ave	SB				0.18	6.0	A	0.17	5.0	A
Third Beach Rd / Mitchell's Ln / Wapping Rd										
Wapping Rd	WB	0.05	4.3	A	0.08	4.5	A	0.07	4.4	A
Third Beach Rd	NB	0.22	11.3	B	0.34	13.3	B	0.32	12.9	B
Mitchell's Ln	SE	0.12	0.0	A	0.16	0.0	A	0.15	0.0	A

*Proposed roundabout at Green End Ave / Berkeley Ave / Paradise Ave follows unsignalized LOS criteria

Signalized Intersections

West Main Road / Greene Lane / Pasture Farm Drive

As a result of the full-build development, the overall signal LOS will change from LOS B during the 2019 Existing AM Peak Hour to LOS D during the Build AM Peak Hour. Overall delay at the intersection will increase from 17.5 seconds to 54.9 seconds. With the exception of the West Main Road southbound approach, all the approaches will have LOS D or better, as experienced in existing conditions. The southbound approach experiences LOS C during Existing AM Peak and will be operating at capacity (LOS E) by Future Build conditions.

As a result of the full-build development, the overall signal LOS will change from LOS C during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 21.8 seconds to 297.9 seconds. With the exception of the West Main Road approaches, the minor road approaches will have LOS D or better, unchanged LOS from existing conditions. The northbound West Main Road approach experiences LOS B during Existing PM Peak and will be operating at LOS F by Future Build conditions. The southbound West Main Road approach experiences LOS C during Existing PM Peak and will be operating at LOS F by Future Build conditions.

The Build Alternative provides a slight decrease in delay compared to the full-build scenario. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

We examined Greene Lane and Pasture Farm Drive to determine if there are any changes to striping which could improve capacity on these side streets at the approach to West Main Road. Greene Lane measures 43 ft in width at the intersection of West Main Road, consisting of a 10 ft thru/right lane and 11 ft left lane eastbound and a 15 ft westbound travel lane with 7 ft shoulder. The eastbound left turn lane is approximately 140 ft long. The length of the left turn lane can be further extended; however, queuing does not seem to be an issue at this location and extending the lane should not have significant impact on the capacity. Pasture Farm Drive has a width of only 23.5 ft and cannot be restriped or widened to improve capacity.

Facing west toward Greene Lane at West Main Rd

Facing east along Pasture Farm Drive

West Main Road / Oliphant Lane

As a result of the full-build development, the overall signal LOS will change from LOS B during the 2019 Existing AM Peak Hour to LOS F during the Build AM Peak Hour. Overall delay at the intersection will increase from 15.7 seconds to 92.7 seconds. During the AM Existing conditions, westbound, northbound and southbound approaches are LOS C, B and B, respectively. Future Build conditions will change LOS along the westbound, northbound and southbound approaches to LOS D, E and F, respectively.

As a result of the full-build development, the overall signal LOS will change from LOS D during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 44.2 seconds to 273.7 seconds. During the PM Existing conditions, westbound, northbound and southbound approaches are LOS F, D and C, respectively. Future Build conditions will change to LOS F for all approaches.

The Build Alternative provides a decrease in delay compared to Full Buildout, particularly for the mainline during AM Peak. During the AM Peak, the Build Alternative experiences LOS E compared to LOS F for Full Buildout. For PM Peak there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

We examined Oliphant Lane to determine if there are any changes to striping which could improve capacity on this side street at the approach to West Main Road. Oliphant Lane measures only 25 ft in width at the intersection of West Main Road. With this narrow width, it appears that Oliphant Lane cannot be restriped to improve capacity, unless the road is widened. Even if the roadway is widened, it will provide some improvement to queuing and delays on Oliphant Lane but it will not have significant impact on the signal as a whole, especially during the PM Peak Full Buildout when all approaches are LOS F.

Facing east on Oliphant Ln from W. Main Rd

<u>West Main Road / Forest Avenue</u>

As a result of the full-build development, the overall signal LOS will change from LOS C during the 2019 Existing AM Peak Hour to LOS F during the Build AM Peak Hour. Overall delay at the intersection will increase from 20.1 seconds to 121.2 seconds. During the AM Existing conditions, westbound, northbound and southbound approaches are LOS D, B and B, respectively. Future Build conditions will change LOS along the westbound, northbound and southbound approaches to LOS D, C and F, respectively.

As a result of the full-build development, the overall signal LOS will change from LOS D during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 40.6 seconds to 325.1 seconds. During the PM Existing conditions, westbound, northbound and southbound approaches are LOS D, E and B, respectively. Future Build conditions will change LOS along the westbound, northbound and southbound approaches to LOS D, F and F, respectively.

The Build Alternative provides a decrease in delay compared to Full Buildout. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

We examined Forest Avenue to determine if there are any changes to striping which could improve capacity on this side street at the approach to West Main Road. Forest Avenue measures approximately 27 ft in width at the intersection of West Main Road. With this narrow width, it appears that Forest Avenue cannot be restriped to improve capacity. Even widening Forest Avenue will not have significant impact on improving the signal capacity as a whole since the mainline experiences LOS F with the full-build scenario.

Forest Ave facing east

Forest Ave facing west toward W. Main Rd

West Main Road / Valley Road

As a result of the full-build development, the overall signal LOS will change from LOS B during the 2019 Existing AM Peak Hour to LOS C during the Build AM Peak Hour. Overall delay at the intersection will increase from 13 seconds to 28.6 seconds. During the AM Existing conditions, westbound, northbound and southbound approaches are LOS B, C and A, respectively. Future Build conditions will change LOS along the westbound, northbound and southbound approaches to LOS C, D and B, respectively. This is a very minor change in delay and capacity from existing conditions and shows that LOS will be good at D or better.

As a result of the full-build development, the overall signal LOS will change from LOS B during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 19.3 seconds to 151.6 seconds. During the PM Existing conditions, westbound, northbound and southbound approaches are LOS C, C and B, respectively. Future Build conditions will change to LOS F for all approaches.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

We examined Valley Road to determine if there are any changes to striping which could improve capacity on this side street at the approach to West Main Road. Valley Road measures approximately 46 ft in width at the intersection of West Main Road. It consists of a left turn lane, thru/right lane with shoulder westbound and an eastbound travel lane and shoulder. With this width, it appears that Valley Road could possibly be restriped with 11 ft travel lanes and minimal shoulder to improve delays and queues on this side street. Even widening Valley Road will probably not have significant impact on improving the signal capacity as a whole since the mainline experiences LOS F with the Full-Build scenario.

Valley Rd facing east

Valley Rd facing west toward W. Main Rd

<u>West Main Road / Coddington Highway / Rockwood Road</u>

As a result of the full-build development, there will be no overall change from LOS C during 2019 Existing AM Peak Hour to Build AM Peak Hour. Overall delay at the intersection will increase by only 3.6 seconds. Future Build conditions maintain existing LOS along the eastbound, westbound and northbound approaches at LOS D, E and C, respectively. The southbound approach will change from LOS B to LOS C. This is a very minor change in delay and capacity from existing conditions.

As a result of the full-build development, the overall signal LOS will change from LOS C during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 32.4 seconds to 107.5 seconds. During the PM Build conditions, westbound and northbound approaches will remain LOS D and C, respectively. Future Build conditions will change the eastbound approach from LOS D to E; the southbound approach will change from LOS C to F.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

We examined Coddington Highway and Rockwood Road to determine if there are any changes to striping which could improve capacity on these side streets at the approach to West Main Road. Coddington Highway measures approximately 53 ft in width at the intersection of West Main Road. It consists of two left turn lanes, a thru / right turn lane with shoulder eastbound and travel lane with shoulder westbound. It does not appear that the roadway could be restriped to improve delay and queues. Rockwood Road measures approximately 37.5 ft in width at the intersection and narrows to 23.5 ft wide away from the intersection. With this width, it appears that Rockwood Road could possibly be restriped with 11 ft travel lanes and minimal shoulder to provide a left/thru and right lane for a short distance to the commercial driveway curb cut. This may provide some delays and queue improvement on this side street and some improvement for the signal capacity as a whole.


Coddington Hwy facing east toward W. Main Rd


Rockwood Rd facing west toward W. Main Rd

West Main Road / East Main Road

As a result of the full-build development, the overall LOS will change from C to D during 2019 Existing AM Peak Hour to Build AM Peak Hour. Overall delay at the intersection will increase by only 9 seconds. Future Build conditions maintain existing LOS along the eastbound, westbound and southbound approaches at LOS E, D and C, respectively. The northbound approach will change from LOS C to LOS D. This is a very minor change in delay and capacity from existing conditions.

As a result of the full-build development, the overall signal LOS will change from LOS D during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 40.6 seconds to 122 seconds. During the PM Build conditions, westbound and eastbound approaches will remain LOS D and E, respectively. Future Build conditions will change the northbound approach from LOS D to F; the southbound approach will change from LOS D to E.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

This intersection of two major routes in Town has recently been redesigned with new geometry, new paving and signal updates. Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

East Main Road / Oliphant Lane

As a result of the full-build development, the overall signal LOS will change from C to F during 2019 Existing AM Peak Hour to Build AM Peak Hour. Overall delay at the intersection will increase from 26.6 seconds to 111.2 seconds. Future Build conditions maintain existing LOS along the northbound and northwest bound approaches at LOS A and C, respectively. The southbound approach will change from LOS D to LOS F; the southeast bound approach will change from LOS C to D.

As a result of the full-build development, the overall signal LOS will change from LOS C during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 30.9 seconds to 174 seconds. During the PM Build conditions, the northwest bound approach will remain LOS C. Future Build conditions will change the northbound, southbound and southeast bound approaches from LOS C, D, C, respectively, to LOS F, F, E, respectively.

The Build Alternative provides a decrease in delay compared to Full Buildout. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

We examined Oliphant Lane to determine if there are any changes to striping which could improve capacity on this side street at the approach to East Main Road. Oliphant Lane measures only 22 ft in width at the intersection of East Main Road. With this narrow width, Oliphant Lane cannot be restriped to improve capacity, unless the road is widened. If the roadway is able to be widened to allow for a thru/left and thru/right lane eastbound, it may provide some improvement to queuing and delays on Oliphant Lane and provide some improved capacity for the signalized intersection as a whole.

Oliphant Lane facing west from East Main Road

<u>East Main Road / Aquidneck Avenue</u>

As a result of the full-build development, the LOS will change from B to C overall during 2019 Existing AM Peak Hour to Build AM Peak Hour. Overall delay at the intersection will increase from 17.9 seconds to 26.6 seconds. During the AM Build conditions, the eastbound, northbound and southbound approaches will all remain at LOS C. Future Build conditions will change the westbound approach from LOS B to LOS C. This is a very minor change in delay and capacity from existing conditions and shows that LOS will remain good at LOS C for all approaches.

As a result of the full-build development, the overall signal LOS will change from LOS C during the 2019 Existing PM Peak Hour to LOS F during the Build PM Peak Hour. Overall delay at the intersection will increase from 30.8 seconds to 120.7 seconds. During the Existing PM Peak Hour, the eastbound, westbound, northbound and southbound approaches experience LOS D, B, D and C, respectively. During the PM Build conditions, the eastbound, westbound, northbound and southbound approaches change to LOS F, F, F and B, respectively.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement.

We examined Aquidneck Avenue to determine if there are any changes to striping which could improve capacity on this side street at the approach to East Main Road. Aquidneck Avenue measures approximately 74 ft curb to curb at the flared intersection of East Main Road. This consists of a thru/left lane, a right turn pocket with shoulder northbound, a median island and a southbound lane and shoulder. Farther back from the intersection the road narrows to approximately 32 ft in width consisting of a travel lane and shoulder in both directions. It may be possible to extend slightly the striping for the right turn lane pocket. Since the Aquidneck Avenue northbound left/thru lane carries a small amount of traffic compared to the right turn lane, re-striping the left/thru as a left/thru/right general use lane may improve capacity for this approach.

Aquidneck Ave facing south

Aquidneck Ave facing north toward E. Main Rd

East Main Road / Forest Avenue / Ramada Hotel Driveway

As a result of the full-build development, the overall signal LOS will change from C to D overall during 2019 Existing AM Peak Hour to Build AM Peak Hour. Overall delay at the intersection will only increase from 21.2 seconds to 35.1 seconds. During the AM Build conditions, the westbound and northbound approaches will all remain at LOS B and C, respectively. Future Build conditions will change the eastbound approach from LOS A to LOS B; the southbound approach from LOS D to LOS F. While LOS D is generally considered an acceptable level of service for a signal, the southbound approach is beyond capacity during AM Peak Hour Build condition and should be improved a bit through optimized signal timing.

As a result of the full-build development, the overall signal LOS will remain at LOS C for 2019 Existing PM Peak Hour and future Build PM Peak Hour. Overall delay at the intersection will only increase from 21.1 seconds to 30.7 seconds. During the PM Build conditions, the westbound and northbound approaches will all remain at LOS B and C, respectively. Future Build conditions will change the eastbound approach from LOS B to LOS C; the southbound approach from LOS D to LOS F. While LOS D is generally considered an acceptable level of service for a signal, the southbound approach is beyond capacity during AM Peak Hour Build condition and should be improved a bit through optimized signal timing.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM Peak a 4-second decrease in delay results in a LOS C for the Build Alternative versus a LOS D during the Full Buildout. During the PM Peak there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future should provide some capacity improvement, particularly for the southbound approach; however, additional mitigation may be necessary to provide significant improvement.

We examined Forest Avenue to determine if there are any changes to striping which could improve capacity on this side street at the approach to East Main Road. Forest Avenue measures approximately 24 ft in width at the intersection of East Main Road. With this narrow width, Forest Avenue cannot be restriped to improve capacity unless the road is widened. If widening is possible to allow for a southbound right/thru and left/thru lane then this should provide improved capacity for Forest Avenue which will otherwise experience LOS F during Full Buildout peak hours.

Forest Ave facing north

Forest Ave facing south toward East Main Rd

East Main Road / Valley Road

As a result of the full-build development, the overall LOS at this signal will remain LOS C for 2019 Existing AM Peak Hour and Build AM Peak Hour. Overall delay at the intersection will only increase from 28.1 seconds to 34.4 seconds. During the AM Build conditions, the westbound, northbound and southbound approaches will all remain at LOS C, D and D, respectively. Future Build conditions will change the eastbound approach from LOS C to LOS D. This is a minor change in delay and capacity from existing conditions and shows that LOS at each approach will be good at LOS D or better.

As a result of the full-build development, the overall signal LOS will change from LOS D to LOS F from 2019 Existing PM Peak Hour to future Build PM Peak Hour conditions. Overall delay at the intersection will increase from 38 seconds to 179 seconds. During the PM Existing conditions, the eastbound, westbound, northbound and southbound approaches experience LOS C, D, D and D, respectively. During the PM Build conditions, the eastbound, westbound, northbound and southbound approaches experience LOS D, E, F and F, respectively.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM and PM Peaks there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future may provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement particularly for the PM Peak hour.

We examined Valley Road to determine if there are any changes to striping which could improve capacity on this side street at the approach to East Main Road. Valley Road measures approximately 38 ft in width at the approaches to East Main Road. This generally consists of a 12.5 ft travel lane and 7 ft shoulder northbound and a 12.5 ft travel lane and 6 ft shoulder southbound. At the intersection, the road widens allowing for 5 lanes with minimal shoulders. Each intersection approach is 3 approach lanes including a left turn lane and 2 departure lanes. It does not appear Valley Road can be restriped to improve capacity unless the road is widened.

Valley Rd facing north toward E. Main Rd

Valley Rd facing south toward E. Main Rd

Green End Avenue / Valley Road

As a result of the full-build development, the overall LOS at this signal will change from LOS C to LOS D from 2019 Existing AM Peak Hour to Build AM Peak Hour. Overall delay at the intersection will only increase from 25.7 seconds to 37.2 seconds. During the AM Build conditions, the eastbound approach will remain at LOS C. Future Build conditions will change the westbound, northbound and southbound approaches from LOS C, B and C, respectively, to LOS D, C and D, respectively. This is a minor change in delay and capacity from existing conditions and shows that LOS at each approach will be good at LOS D or better.

As a result of the full-build development, the overall signal LOS will change from LOS D to LOS F from 2019 Existing PM Peak Hour to future Build PM Peak Hour conditions. Overall delay at the intersection will increase from 45.5 seconds to 210.7 seconds. During the PM Existing conditions, the eastbound, westbound, northbound and southbound approaches experience LOS C, D, E and D, respectively. During the PM Build conditions, the eastbound, westbound, northbound and southbound approaches experience LOS E, F, F and F, respectively.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM Peak a 3-second decrease in delay results in a LOS C for the Build Alternative versus a LOS D during the Full Buildout. During the PM Peak there are no changes in overall LOS compared to the full-build scenario.

Optimizing the signal timing in the future may provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement particularly for the PM Peak hour.

We examined Green End Avenue and Valley Road to determine if there are any changes to striping which could improve capacity on these streets. Valley Road measures approximately 38 ft and 48 ft in width at the southbound and northbound approaches, respectively. Restriping alone will not improve capacity along this road without widening the road at least 6 ft to 7 ft. Green End Avenue generally measures between 27 ft to 30 ft in width. Eastbound it widens to approximately 50 ft to provide a single westbound departure lane and 3 eastbound lanes (left, thru and right lanes). It appears that using the dedicated eastbound right turn lane instead as a right/thru lane may provide some improvement to capacity eastbound; however, this would require widening the westbound approach to provide an additional departure lane east of the signal. Westbound Green End Avenue widens to three lanes (one eastbound departure lane, a left lane and thru/right lane westbound) beginning about 100 ft from intersection. It does not appear Green End Avenue westbound can be restriped to improve capacity unless the road is widened along that approach.

Valley Road northbound

Valley Rd facing south toward Green End Ave

Green End Ave facing east toward Valley Rd

Green End Ave facing west toward Valley Rd

<u>Aquidneck Avenue / Valley Road</u>

By the time the future Build condition is completed, this existing signal will be reconstructed as a single lane roundabout. The Build analysis reflects this future condition.

The Existing AM Peak Hour condition at this signalized intersection is LOS B, B and A for the westbound, northbound and southeast bound approaches, respectively. As a result of the future Full Buildout and roundabout construction, the approach LOS will change to LOS C, A/B and B/C for the westbound, northbound and southeast bound approaches, respectively. The approach delays at the intersection will increase by 1 second westbound, decrease by 5.9 seconds northbound and increase by 5.1 seconds southeast bound. This is a minor change in delay and capacity from existing conditions and shows that LOS at each approach will be good at LOS C or better. The future proposed roundabout is an improvement over the future condition if the signal were to stay in place.

The Existing PM Peak Hour condition at this signalized intersection is LOS B, B and A for the westbound, northbound and southeast bound approaches, respectively. As a result of the future Full Buildout and roundabout construction, the approach LOS at this intersection will change to LOS C, D and D for the westbound, northbound and southeast bound approaches, respectively. The approach delays at the intersection will increase by 3.8 seconds westbound, 12.6 seconds northbound and 25.4 seconds southeast bound. The LOS at each approach will be good at LOS D or better. The future proposed roundabout is an improvement over the future condition if the signal were to stay in place.

The Build Alternative provides a slight decrease in delay and improved LOS compared to the full-build scenario for both AM and PM Peaks.

This intersection redesigned as a roundabout in the future will provide good LOS for the full-build scenario.

<u>Aquidneck Avenue / Purgatory Road/ Memorial Boulevard</u>

As a result of the full-build development, the overall LOS at this signal will change from LOS A to LOS B from 2019 Existing AM Peak Hour to Build AM Peak Hour. Overall delay at the intersection will only increase from 9.4 seconds to 14 seconds. During Existing AM Peak Hour conditions, the southbound, northwest bound and northeast bound approaches are LOS A, B and A, respectively. Future Build conditions will change the southbound, northwest bound and northeast bound approaches to LOS B, C and B, respectively. This is a minor change in delay and capacity from existing conditions and shows that LOS at each approach will be good at LOS C or better.

As a result of the full-build development, the overall signal LOS will change from LOS A to LOS D from 2019 Existing PM Peak Hour to future Build PM Peak Hour conditions. Overall delay at the intersection will increase from 8.6 seconds to 49.3 seconds. During the PM Existing conditions, the southbound, northwest bound and northeast bound approaches experience LOS A, C and A, respectively. During the PM Build conditions, the southbound, northwest bound and northeast bound approaches experience LOS D, C and E, respectively.

The Build Alternative provides a slight decrease in delay compared to Full Buildout. During the AM Peak there is no change in LOS from Full Buildout versus Build Alternative. During the PM Peak the Build Alternative is an overall LOS C versus a LOS D with the full-build scenario.

Optimizing the signal timing in the future will provide some capacity improvement; however, additional mitigation may be necessary to provide significant improvement particularly for the PM Peak hour. The Town may want to consider the option of a roundabout at this location in the future.

We examined the approaches at this signal to determine if there are any changes to striping which could improve capacity on these streets. Memorial Boulevard measures approximately 38 ft in width and consists of 2 eastbound lanes including a dedicated right turn lane as well as a westbound departure lane. It does not appear this approach can be restriped to improve capacity unless the road is widened. The LOS along this approach is a good LOS C for future conditions. Aquidneck Avenue measures approximately 36 ft in width and consists of a 12.5 ft travel lane and 5.5 ft shoulder/bike lane in each direction. Restriping the lanes to allow for two southbound approach lanes could improve capacity along this road if the bike lane / shoulders were removed. Purgatory Road generally measures 28 ft in width and widens to approximately 61 ft at the intersection (15 ft westbound departure lane with 5 ft shoulder, 11 ft median island, 25 ft for 2 travel lanes and a 5 ft shoulder eastbound). Restriping this approach will not significantly affect capacity along this road unless the road is widened.

Facing west toward Aquidneck Ave from Memorial Blvd


Facing east from Purgatory Rd toward Aquidneck Ave


Aquidneck Ave SB toward Purgatory Rd

Unsignalized Intersections

Green End Avenue / Berkeley Avenue / Paradise Avenue

During the AM Peak Hour Build condition, the eastbound and westbound approach LOS will remain at the existing LOS A. The northbound and southbound approaches will both change from existing LOS C to LOS F and D, respectively.

During the PM Peak Hour Build condition, the eastbound and westbound approach LOS will remain at the existing LOS A. The northbound and southbound approaches will both change from existing LOS C to LOS F.

The Build Alternative provides a decrease in delay compared to Full Buildout. During the AM Peak the LOS improved for the Build Alternative versus the full-build scenario. During the PM Peak, there is no change in LOS except for the southbound approach with a LOS E during the Build Alternative versus a LOS F with the full-build scenario.

For future mitigation, a proposed roundabout should be considered at this location. Analysis shows that the intersection would function well as a roundabout.

Green End Ave facing west

Berkeley Ave facing north


Green End Ave facing east


Paradise Ave facing south

Third Beach Road / Mitchell's Lane / Wapping Road

For both the AM and PM Peak hour conditions, there is no change in approach LOS from existing to future Build conditions and negligible change in delay. The LOS remains very good at LOS A or B for each approach.

The Build Alternative provides virtually no change in delay and no changes in overall LOS compared to the full-build scenario.

We examined the approaches at this intersection to determine if there are any changes to striping which could improve capacity on these streets. All of these roadways have pavement in poor condition and are narrow in width measuring 22.5 ft to 25 ft wide. They would not have improved capacity just from restriping unless the roads were widened by approximately 10 ft. The LOS at this intersection is good even for future conditions; however, the Town may want to consider the option of a roundabout at this location in the future should traffic conditions change.


Mitchell's Lane facing west


Wapping Rd facing east

Third Beach Rd facing south

TRAFFIC EVALUATION CONCLUSIONS

After reviewing several major intersections in the Town, we conclude that the future build-out will have significant impacts on many of the signalized intersections. Overall, reducing the buildout to the Alternative Build (which excludes Watershed Protection District 1) will not provide significant improvement over the Full-Build scenario. Optimizing the signal timing will provide some level of improvement but more significant mitigations such as changes in signal phasing and geometry changes, such as re-striping, road widening and conversion to roundabout at certain locations, should be considered in the future to improve capacity. The redesign of Aquidneck Avenue / Valley Road intersection from a signal to a roundabout should provide good LOS in the future and is an improvement in delay and LOS versus maintaining the signal control in the future. The stop approaches of Berkeley Avenue and Paradise Avenue at Green End Avenue will need mitigation in the future and a roundabout should be considered at a later time if warranted. The unsignalized intersection of Third Beach Road / Mitchell's Lane / Wapping Road is not expected to be impacted by the future full-build scenario.

Overall, the greatest impacts on future traffic will occur during the PM Peak hour at most locations that remain signalized. Several signalized locations will deteriorate in capacity during the AM Peak as well but most will remain a good overall LOS of C or D. The following tables show locations and time periods where future build-out will have the greatest impact on traffic and where improvements will be needed:

Table 5.10A Signalized Level-Of-Service Analysis Summary AM Peak, High Impact Intersections

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
W. Main Rd / Oliphant Ln	**OVERALL**	**0.70**	**15.7**	**B**	**1.07**	**92.7**	**F**	**0.99**	**64.1**	**E**
Oliphant Ln	WB	0.68	29.8	C	0.75	42.1	D	0.74	42.1	D
W. Main Rd (RI 114)	NB	0.61	16.4	B	1.03	68.4	E	0.97	49.2	D
W. Main Rd (RI 114)	SB	0.70	13.3	B	1.17	117.2	F	1.07	77.6	E
W. Main Rd / Forest Ave	**OVERALL**	**0.82**	**20.1**	**C**	**1.23**	**121.2**	**F**	**1.15**	**96.6**	**F**
Forest Ave	WB	0.74	44.9	D	0.83	50.5	D	0.82	48.9	D
W. Main Rd (RI 114)	NB	0.58	16.4	B	0.88	31.9	C	0.83	29.8	C
W. Main Rd (RI 114)	SB	0.84	18.1	B	1.35	191.5	F	1.26	148.0	F
E. Main Rd / Oliphant Ln	**OVERALL**	**0.79**	**26.6**	**C**	**1.01**	**111.2**	**F**	**0.97**	**91.8**	**F**
E. Main Rd (RI 138)	NB	0.50	6.3	A	0.61	8.9	A	0.59	8.4	A
E. Main Rd (RI 138)	SB	0.98	35.3	D	1.33	176.9	F	1.26	144.1	F
Oliphant Ln	SE	0.42	29.0	C	0.74	37.8	D	0.69	34.5	C
Hotel Driveway	NW	0.04	26.6	C	0.04	24.1	C	0.04	24.6	C
E. Main Rd / Forest Ave / Ramada	**OVERALL**	**0.72**	**21.2**	**C**	**0.84**	**35.1**	**D**	**0.81**	**31.1**	**C**
E. Main Rd (RI 138)	EB	0.36	8.5	A	0.43	12.5	B	0.42	14.7	B
E. Main Rd (RI 138)	WB	0.71	17.6	B	0.79	18.3	B	0.78	16.9	B
Hotel Driveway	NB	0.04	24.7	C	0.04	25.7	C	0.04	25.4	C
Forest Ave	SB	0.87	53.0	D	1.14	130.1	F	1.08	107.2	F

Table 5.10B Signalized Level-Of-Service Analysis Summary PM Peak, High Impact Intersections

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
PM PEAK HOUR										
W. Main Rd / Greene Ln / Pasture Farm Dr	**OVERALL**	**0.70**	**21.8**	**C**	**1.47**	**297.9**	**F**	**1.36**	**242.0**	**F**
Greene Ln	EB	0.67	39.8	D	0.69	39.7	D	0.68	39.6	D
Pasture Farm Dr	WB	0.01	31.9	C	0.02	31.4	C	0.02	31.4	C
W. Main Rd (RI 114)	NB	0.71	19.6	B	1.53	276.5	F	1.41	224.5	F
W. Main Rd (RI 114)	SB	0.69	21.1	C	1.73	355.5	F	1.58	290.0	F
W. Main Rd / Oliphant Ln	**OVERALL**	**0.95**	**44.2**	**D**	**1.54**	**273.7**	**F**	**1.44**	**226.3**	**F**
Oliphant Ln	WB	0.96	89.4	F	1.46	270.4	F	1.38	236.5	F
W. Main Rd (RI 114)	NB	1.00	49.4	D	1.58	296.0	F	1.49	252.2	F
W. Main Rd (RI 114)	SB	0.73	26.2	C	1.44	241.9	F	1.32	186.6	F
W. Main Rd / Forest Ave	**OVERALL**	**0.94**	**40.6**	**D**	**1.52**	**325.1**	**F**	**1.41**	**269.3**	**F**
Forest Ave	WB	0.72	44.5	D	0.86	53.7	D	0.83	50.9	D
W. Main Rd (RI 114)	NB	1.05	58.3	E	1.69	337.4	F	1.58	288.4	F
W. Main Rd (RI 114)	SB	0.85	15.6	B	1.73	347.6	F	1.57	276.7	F
W. Main Rd / Valley Rd	**OVERALL**	**0.90**	**19.3**	**B**	**1.83**	**151.6**	**F**	**1.67**	**121.1**	**F**
Valley Rd	WB	0.83	33.3	C	1.55	260.6	F	1.43	211.2	F
W. Main Rd (RI 114)	NB	0.83	24.6	C	1.28	155.5	F	1.21	121.8	F
W. Main Rd (RI 114)	SB	0.87	10.7	B	1.83	112.7	F	1.67	90.8	F
W. Main Rd / Coddington Hwy	**OVERALL**	**0.66**	**32.4**	**C**	**0.98**	**107.5**	**F**	**0.91**	**81.6**	**F**
Coddington Hwy	EB	0.72	44.7	D	1.02	74.3	E	0.96	63.3	E
Rockwood Rd	WB	0.52	54.8	D	0.52	54.8	D	0.52	54.8	D
W. Main Rd (RI 114)	NB	0.53	20.2	C	0.55	22.1	C	0.55	22.1	C
W. Main Rd (RI 114)	SB	0.77	34.2	C	1.34	163.2	F	1.24	120.4	F
W. Main Rd / E. Main Rd	**OVERALL**	**0.73**	**40.6**	**D**	**1.05**	**122.0**	**F**	**1.00**	**103.0**	**F**
E. Main Rd	EB	0.64	56.7	E	0.64	56.7	E	0.64	56.7	E
E. Main Rd (RI 138)	WB	0.69	48.1	D	0.67	42.8	D	0.66	43.0	D
W. Main Rd (RI 114)	NB	0.75	36.0	D	1.40	223.9	F	1.31	186.5	F
W. Main Rd (RI 114)	SB	0.83	37.6	D	1.20	66.6	E	1.09	53.8	D
E. Main Rd / Oliphant Ln	**OVERALL**	**0.89**	**30.9**	**C**	**1.27**	**174.0**	**F**	**1.20**	**145.0**	**F**
E. Main Rd (RI 138)	NB	0.95	24.7	C	1.38	189.6	F	1.30	156.8	F
E. Main Rd (RI 138)	SB	0.93	42.3	D	1.33	180.6	F	1.26	152.5	F
Oliphant Ln	SE	0.63	32.3	C	0.97	70.2	E	0.92	57.4	E
Hotel Driveway	NW	0.05	25.2	C	0.04	21.9	C	0.04	22.2	C
E. Main Rd / Aquidneck Ave	**OVERALL**	**0.86**	**30.8**	**C**	**1.35**	**120.7**	**F**	**1.26**	**100.0**	**F**
E. Main Rd (RI 138)	EB	1.00	40.9	D	1.26	141.5	F	1.22	122.0	F
E. Main Rd (RI 138)	WB	0.67	12.7	B	1.44	108.8	F	1.35	90.4	F
Aquidneck Ave	NB	0.84	37.6	D	1.23	116.6	F	1.14	90.7	F
Plaza / Bank	SB	0.14	22.0	C	0.12	18.1	B	0.11	18.1	B

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
PM PEAK HOUR										
E. Main Rd / Forest Ave / Ramada	**OVERALL**	**0.71**	**21.1**	**C**	**0.97**	**30.7**	**C**	**0.93**	**27.6**	**C**
E. Main Rd (RI 138)	EB	0.63	17.6	B	0.92	21.8	C	0.88	20.0	B
E. Main Rd (RI 138)	WB	0.55	12.1	B	0.73	16.1	B	0.70	13.9	B
Hotel Driveway	NB	0.08	23.7	C	0.08	23.0	C	0.08	23.0	C
Forest Ave	SB	0.90	54.9	D	1.08	101.4	F	1.05	90.8	F
E. Main Rd / Valley Rd	**OVERALL**	**0.77**	**38.0**	**D**	**1.15**	**180.3**	**F**	**1.08**	**150.1**	**F**
E. Main Rd (RI 138)	EB	0.71	31.1	C	0.88	38.6	D	0.86	37.1	D
E. Main Rd (RI 138)	WB	0.81	36.7	D	1.12	57.0	E	1.06	52.1	D
Valley Rd	NB	0.78	40.5	D	1.88	372.5	F	1.72	308.1	F
Valley Rd	SB	0.85	45.3	D	1.44	208.2	F	1.35	171.4	F
Green End Ave / Valley Rd	**OVERALL**	**1.00**	**45.5**	**D**	**1.64**	**210.7**	**F**	**1.56**	**187.9**	**F**
Green End Ave	EB	0.77	26.1	C	1.17	74.7	E	1.14	62.9	E
Green End Ave	WB	0.79	41.3	D	1.23	155.3	F	1.15	125.8	F
Valley Rd	NB	1.19	71.8	E	1.98	229.4	F	1.91	208.0	F
Valley Rd	SB	0.74	36.6	D	1.76	390.0	F	1.69	357.8	F

Table 5.11 Unsignalized Level-Of-Service Analysis Summary, High Impact Intersections

Location	Movement	2019 Existing			Build			Build Alternative		
		v/c	Delay	LOS	v/c	Delay	LOS	v/c	Delay	LOS
AM PEAK HOUR										
Green End Ave / Berkeley Ave / Paradise Ave										
Green End Ave	EB	0.02	1.2	A	0.03	1.2	A	0.03	1.2	A
Green End Ave	WB	0.05	2.4	A	0.06	1.9	A	0.05	2.0	A
Paradise Ave	NB	0.35	18.6	C	0.80	60.1	F	0.70	44.5	E
Berkeley Ave	SB	0.37	17.5	C	0.52	26.8	D	0.50	24.8	C
PM PEAK HOUR										
Green End Ave / Berkeley Ave / Paradise Ave										
Green End Ave	EB	0.04	1.5	A	0.04	1.3	A	0.04	1.3	A
Green End Ave	WB	0.03	1.6	A	0.04	1.4	A	0.04	1.4	A
Paradise Ave	NB	0.50	21.7	C	1.02	108.2	F	0.90	73.2	F
Berkeley Ave	SB	0.40	21.1	C	0.77	60.4	F	0.70	47.7	E

Recommendations

Based upon the traffic assessments, in order to minimize potential impacts to traffic and to enhance conditions for residents, CE provides the following recommendations:

5.1 Optimizing the signal timing in the future should provide some capacity improvement for all signalized intersections; however, additional mitigation may be necessary to provide significant improvement at the following intersections:

- West Main Road / Greene Lane / Pasture Farm Drive
- West Main Road / Oliphant Lane
- West Main Road / Forest Avenue
- West Main Road / Valley Road
- West Main Road / East Main Road
- East Main Road / Oliphant Lane
- East Main Road / Forest Avenue / Ramada Hotel Driveway
- East Main Road / Valley Road

5.2 It appears that Rockwood Road could possibly be restriped with 11 ft travel lanes and minimal shoulder to provide a left/thru and right lane for a short distance to the commercial driveway curb cut. This may provide some delays and queue improvement on this side street and some improvement for the signal capacity as a whole.

5.3 Slightly extend the striping for the right turn lane pocket on Aquidneck Avenue at East Main Road. Since the Aquidneck Avenue northbound left/thru lane carries a small amount of traffic compared to the right turn lane, re-striping the left/thru as a left/thru/right general use lane may improve capacity for this approach.

5.4 For Green End Avenue at the intersection of Valley Road, it appears that using the dedicated eastbound right turn lane instead as a right/thru lane may provide some improvement to capacity eastbound; however, this would require widening the westbound approach to provide an additional departure lane east of the signal.

5.5 The signalized intersection of Aquidneck Avenue / Valley Road will be reconstructed as a single lane roundabout. CE's analysis shows the proposed roundabout will provide good LOS for the future full-build scenario.

5.6 In the future the Town may want to analyze and consider the option of a roundabout to replace the signal at Aquidneck Avenue / Purgatory Road/ Memorial Boulevard.

5.7 For future mitigation, a proposed roundabout should be considered at Green End Avenue / Berkeley Avenue / Paradise Avenue. Analysis shows that the intersection would function well as a roundabout.

5.8 The LOS at Third Beach Road / Mitchell's Lane / Wapping Road remains very good for future conditions. The Town may want to consider the option of a roundabout at this location in the future should traffic conditions change.

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