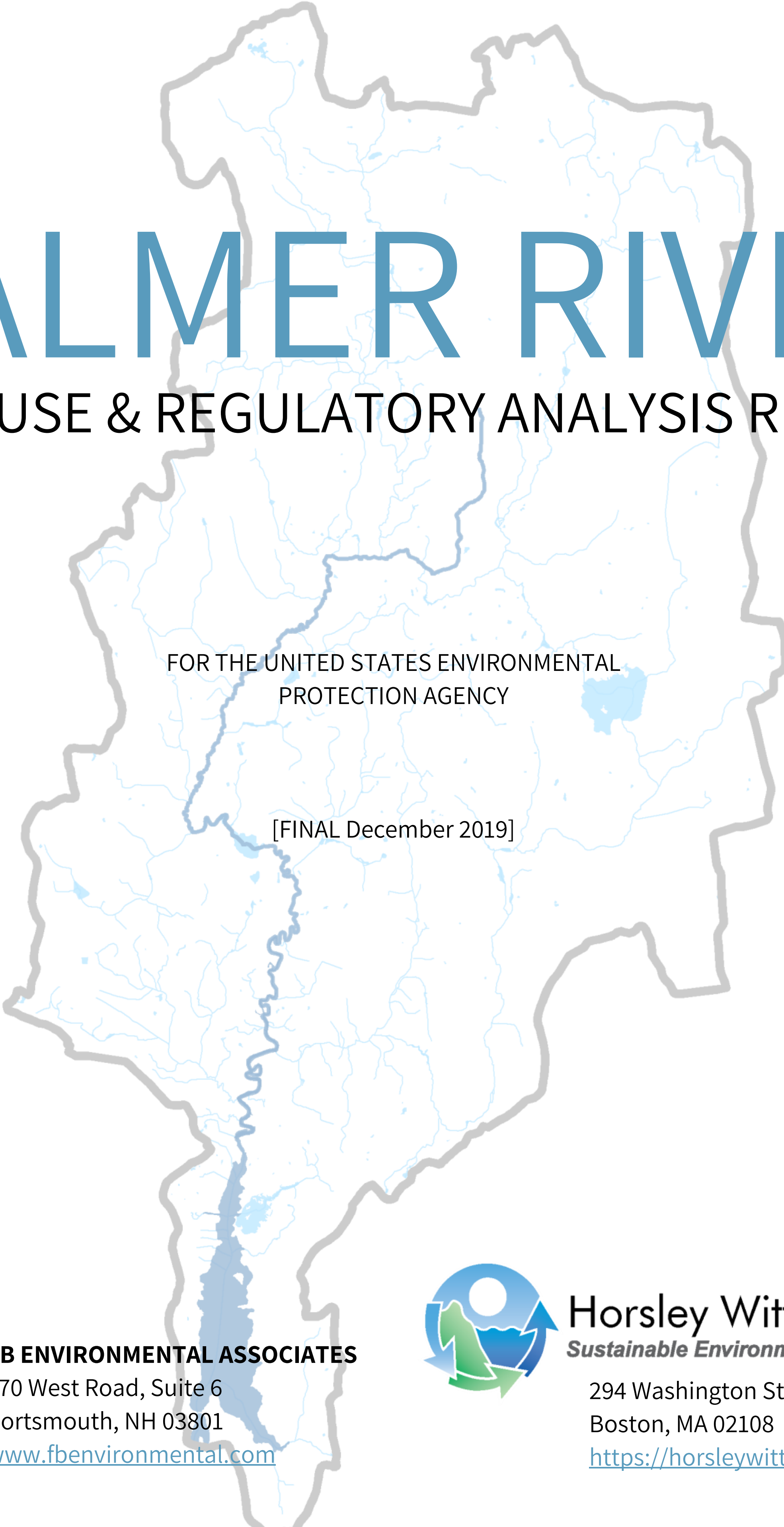

PALMER RIVER

LAND USE & REGULATORY ANALYSIS REPORT

FOR THE UNITED STATES ENVIRONMENTAL
PROTECTION AGENCY

[FINAL December 2019]

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EXECUTIVE SUMMARY

As part of Palmer River Source Tracking, Water Quality Trends Summary, and Watershed Plan project to address pathogen pollution sources to the Palmer River, we assessed land use change and development patterns in the Palmer River watershed and provided recommendations for regulatory amendments that support best land use practices for water quality protection. We focused on the five towns that make up most of the developed portion of the watershed: Rehoboth, Seekonk, and Swansea, MA and Warren and Barrington, RI. A summary of our findings is presented as follows:

- Significant development has occurred over the last 25 years in the Palmer River watershed; the most rapid development occurred between 1995-2001 when forest and agricultural land was converted to urban development.
- Development in the watershed has increased pollutant loading to the Palmer River and will continue to do so under business-as-usual development strategies allowed by local land use regulations.
- Not all development types have equal impact to water quality, suggesting that the towns can develop in a manner or select certain types of development that minimize their impact to water quality.
- While the five towns have implemented some low impact development strategies to their land use regulations, all five towns have room for improvement in requiring best practices for development projects and may need to re-envision how their long-term development goals can be translated into code and ultimately practice to curtail the pace and/or conventional type of development in their community.
- Communities support the concept of low impact development and generally have or plan to complete code revisions, but it can be challenging to implement best practices in lieu of conventional development when the data suggest that a paradigm shift in community values and acceptable best practices is needed. Our preliminary discussions with these towns showed that code revisions involving best practices have been challenging to implement because of lack of staff experience, capacity, community education, and/or funding.
- As an initial step, we recommend that existing resources within the towns be pooled and a series of in-person meetings with the staff be conducted to review current land use regulations, identify specific challenges and solutions to incorporating code revisions, and develop a more thorough list of recommendations for improving codes and land use practices. It is likely that significant amendments to town master plans are needed to ensure that resources such as agricultural lands are more strategically, sustainably, and resiliently aligned with land use trends and policy.
- There are several tools that exist for communities to conduct self-evaluations and provide a process for updating regulations. For example, the Mass Audubon Local Land Use Regulations Analysis Tool and online collection of supporting materials part of the Commonwealth of Massachusetts' Smart Growth/Smart Energy Toolkit are tremendous resources for assisting towns with bylaw review and updates. Mass Audubon indicated that they are eager to be a resource to towns for improving bylaws. There are also grant opportunities that the towns can pursue to hire consultants to assist them through the review and update process.

BACKGROUND

The Palmer River, which flows across the Massachusetts (MA) and Rhode Island (RI) state border, is a major tributary in the Narragansett Bay watershed. The upper freshwater reaches of the Palmer River begin in Rehoboth, MA with the east and west branches of the river extending into Seekonk and Swansea, MA. Head of tide for the Palmer River is at the outlet of the Shad Factory Pond Dam, downstream of which the Palmer River joins with the Barrington River at Tyler Point in RI to form the Warren River before emptying into the Narragansett Bay. While still dominated by forest, the Palmer River watershed contains significant agriculture and urban development and faces increasing development pressure. In 1992, the Rhode Island Department of Environmental Management (RIDEM) listed its portion of the Palmer River as impaired for recreation and shellfish consumption due to elevated levels of fecal coliform and as impaired for fish and wildlife habitat due to low dissolved oxygen levels, with a total nitrogen impairment listing added in 1998. The Massachusetts Department of Environmental Protection (Mass DEP) listed its portion of the Palmer River as impaired due to elevated levels of fecal coliform beginning in 2002 (segment 53-03 from the Route 6 bridge to the state line was first listed in 1998), along with nutrient and flow alteration impairment listings. In 2002 and 2004, a total maximum daily load (TMDL) was approved for the Palmer River watershed in RI (fecal coliform) and MA (*E. coli*), respectively (RIDEM, 2002; ESS Group Inc, 2004). The 2004 MA TMDL study found that 33 out of 88 sampling stations along the Palmer River violated state criteria for fecal indicator bacteria. The Palmer River also exhibited elevated levels of total suspended solids (TSS) and nutrients (nitrogen and phosphorus). A watershed management plan for the Barrington-Palmer-Warren Rivers was developed by RIDEM and FB Environmental Associates (FBE) for the US Environmental Protection Agency (US EPA) Region 1 in 2012 (FBE, 2012).

In 2012, the Palmer River watershed was included in the National Water Quality Initiative (NWQI) to abate fecal contamination through the installation of agricultural conservation practices or best management practices (BMPs). In the same year, Mass DEP, RIDEM, and US EPA Region 1 began a joint project to further investigate water pollution sources to the Palmer River. By 2015, agricultural BMPs were being installed throughout the southern portion of the watershed and have continued to be installed up to present day. Beginning in 2016, MassDEP, RIDEM, and US EPA Region 1 have collected monthly water quality samples at twelve fixed stations or "core" sites within the lower Palmer River watershed to determine the effectiveness of remediation efforts with agricultural BMP installations. The "core" sites included four saline and eight freshwater stations, with three stations on Clear Run sampled for *E. coli*, three stations on the main stem sampled for Enterococci, and the remaining six stations sampled for both parameters. All sites were also sampled for TSS and nutrients. Beginning in 2017, samples were collected for ribonucleic acid (RNA) microarray analysis using PhyloChip[1]. It is important to note that Barrington, Warren, and most of Swansea discharge to the Palmer River downstream of the agricultural BMPs, though this downstream, tidally influenced section of the Palmer River may transport pollutant sources upstream to sampling locations.

This report examined several objectives of the Palmer River Source Tracking, Water Quality Trends Summary, and Watershed Plan project (HWG & FBE, 2019a), including 1) assessing land use change and development patterns in the Palmer River watershed, and 2) providing recommendations for regulatory amendments that support best land use practices for water quality protection.

STUDY AREA

The 32,670-acre study area (not including 523 acres of non-jurisdictional estuary) covers the Massachusetts towns of Rehoboth (26,259 acres, 80%), Seekonk (2,675 acres, 8%), and Swansea (1,455 acres, 4%) and the Rhode Island towns of Warren (1,093 acres, 3%) and Barrington (327 acres, 1%) in the Palmer River watershed (Figure 1). The study area also covers portions of Dighton, MA (489 acres, 1%) and Attleboro, MA (372 acres, 1%) in the headwaters of the Palmer River watershed. The Towns of Dighton and Attleboro were not included in the land use change analysis or the municipal regulations review so as to focus efforts on the largest portions of the watershed with highly-developed areas that are directly contributing to surface water segments listed as impaired for pathogens.

Development patterns in the Palmer River watershed range from dense urban residential and commercial development to rural agricultural and low density residential development (Figures 2, 3). The Town of Rehoboth covers most of the watershed, and development patterns in Rehoboth change dramatically moving south to north from downstream to upstream along the Palmer River. The southern, downstream portion of the watershed in Rehoboth is characterized by dense patchworks of agricultural land for both crop and livestock production, mixed in with low-density residential development along secondary, rural roads. In the northern, upstream portion of the watershed in Rehoboth, agricultural land is still prominent but spread out among low-density residental development and large tracts of intact forest. Only two major routes cross the town: Route 44 running east-west and Route 118 running north- south.

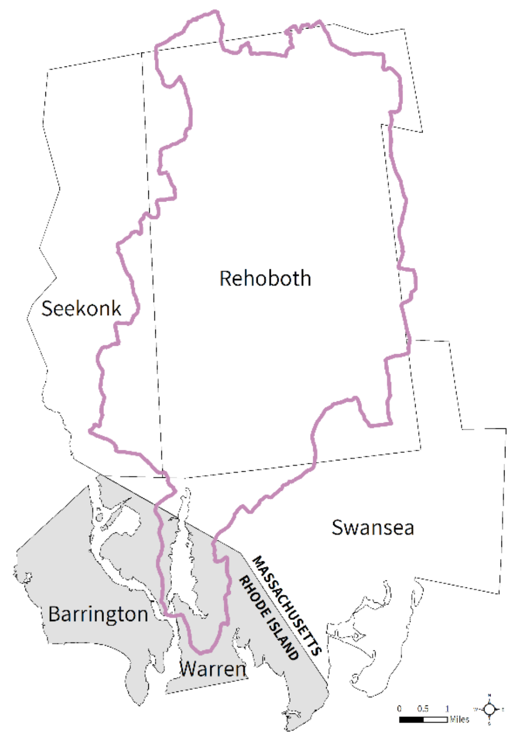

Figure 1. Five Towns in Massachusetts and Rhode Island comprising the vast majority of the Palmer River Watershed.

The Town of Seekonk covers a portion of the western part of the watershed, which is characterized by both high-density urban residential development along Fieldwood Avenue and Olney Street and large patches of agricultural land along Miller and Providence Streets. The Town of Swansea cuts through the southern, downstream portion of the watershed and includes the major routes of Interstate 195 and Route 6, along with the Swansea Country Club golf

[1] The PhyloChip is a rapid, high throughput, DNA microarray based on probing environmental samples for the 16S rRNA gene. The main benefits of using the PhyloChip over traditional culturing techniques are its speed, accuracy, and inclusivity of organisms that cannot survive culturing.

course. Much of the development in Swansea in the watershed consists of commercial development and a few mid-density residential neighborhoods, with some agricultural land.

The lower, eastern portion of the watershed in Warren consists of significant commercial, industrial, and high-density residential development along the major routes of Route 136 and Route 114, with a few agricultural fields off secondary roads. The lower, western portion of the watershed in Barrington consists mainly of high-density residential development along Sowams Road off of which multiple dead-end neighborhoods lead to the estuary shoreline.

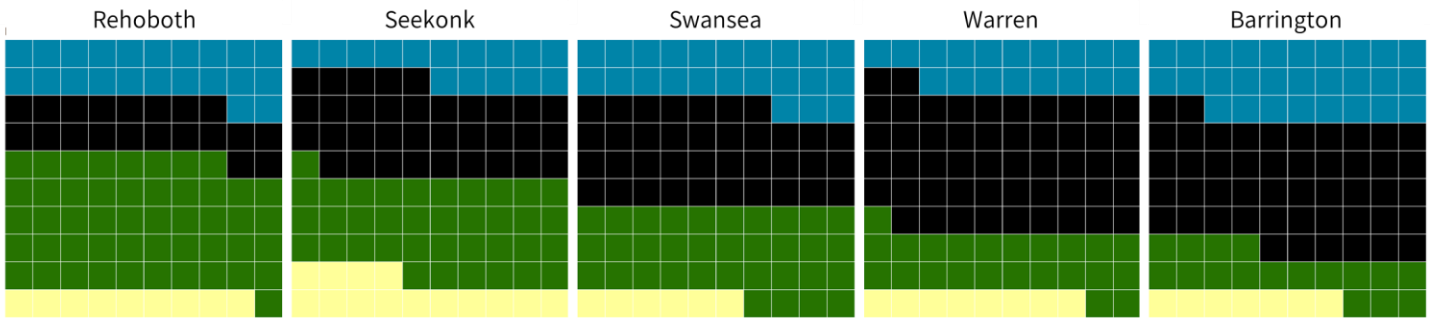

Figure 2. Waffle charts depicting percent land use (based on 2018 land use, refer to Methodology in Land Use Change Analysis section) for each town evaluated in the Palmer River watershed. One square equals one percent. Blue = water/wetland (excluding the estuary which is not in any town jurisdiction). Black = urban. Green = forest. Yellow = agriculture.

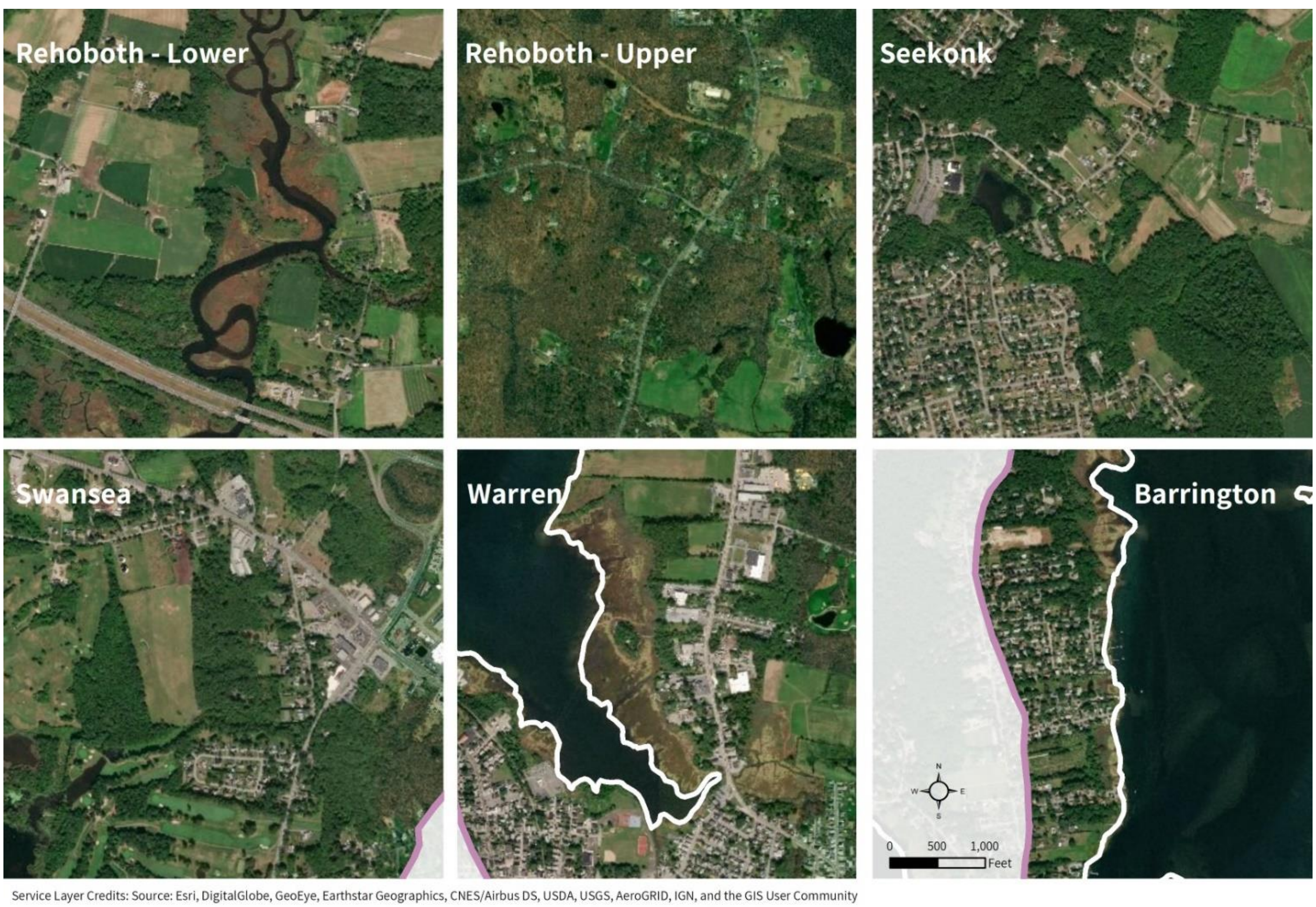

Figure 3. Aerial view of representative development patterns in each town in the Palmer River watershed. Purple lines represent the watershed boundary; white lines represent town boundaries, and semi-transparent white shading represents areas outside the watershed.

LAND USE CHANGE ANALYSIS

METHODOLOGY

We completed a land use change analysis for the Palmer River watershed. The 2005 (MA) and 2003-2004 (RI) land use data files were used as part of the 2012 Barrington-Palmer-Warren River Watershed Management Plan and served as our baseline from which we manually created land use data files for other time periods, namely 1995, 2001, 2011, 2015, and 2018. Refer to Appendix 1 for supplemental methodology discussion.

The 2005 (MA) and 2003-2004 (RI) were reprojected to NAD 1983 State Plane Rhode Island FIPS 3800 Feet and combined into a single file: 2003-2005 (MA/RI). Land use category classifications were matched between the two states and simplified to 18 categories that were useful for input to a pollutant loading model, results of which are described in this report as well as in the Palmer River Water Quality Analysis Report (HWG & FBE, 2019b; Table 1). We used ArcMap 10.6.1 and Google Earth Pro to compare two time periods for changes in land cover and then to update each land cover data file year with the appropriate change in land use category classification. We maintained a resolution scale of 1:5,000 when reviewing aerials and updating land use data files to ensure a similar level of accuracy and comparability among time periods. Time periods viewed in Google Earth Pro included the following: 3/28/1995, 12/30/2001, 8/18/2003 or 10/1/2004, 12/1/2010 or 12/30/2011, 5/2015, and 2/26/2018.

It is important to note that changes in land use were made only based on a change observed when comparing aerial imagery and not changed because the baseline 2003-2005 (MA/RI) was incorrectly labeled. Exceptions were made for mis-labeled land use where agricultural BMPs were installed because accurate land use at a site-specific scale was needed for the pollutant load model (refer to HWG & FBE, 2019b). These changes were also made to all other land use data file years to ensure consistency (unless there was an actual change in land use based on aerial imagery). All changes were tracked and entered into a database.

Land use data from each year were used as input to the EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL) to model expected nutrient and sediment loads for each town, following the latest model and documentation (STEPL 4.4, updated 3/15/18, STEPL 4.4 User's Guide). More specifically, STEPL models the load for total nitrogen (TN), total phosphorus (TP), and total suspended sediment (TSS); load estimates for *E. coli* will be included in the next version update. Refer to Appendix A in the *Secondary Data Quality Assurance Project Plan (QAPP) for the Palmer River Source Tracking, Water Quality Trends Summary, and Watershed Plan*, dated February 4, 2019 (HWG & FBE, 2019a).

The model required at a minimum the town areas draining to the river and the type and areas of land uses within those towns (see Table 1 for land use category classifications), as well as each town's dominant hydrologic soil group obtained from the Natural Resources Conservation Service's online Web Soil Survey. The results presented here reflect changes in pollutant loads from changes in land use only and do not account for any agricultural or stormwater BMPs installed from 2015-2018[2] or changes in the number and type of agricultural animals or septic systems over time from 1995-2018. Mean annual precipitation was kept the same for each time period since STEPL uses normalized (and not individual year) data from the nearest weather station.

For this report, land use and pollutant load values[3] are presented based on the portion of the watershed covered by the five towns. As such, land use and pollutant load values presented in this report may differ from other reports part of the project. For instance, the Palmer River Water Quality Analysis Report presented land use and pollutant load values based on sub-basin areas to the twelve "core" sites (HWG & FBE, 2019b).

We also examined change in conserved land in the portion of each town in the Palmer River watershed. We used readily available spatial data files from MassGIS (spatial file name: Open Space) and RIGIS (spatial file name: Local and State Conservation Areas). We limited MA areas to those with a level of protection marked as "in perpetuity". All areas in the RI files were kept. Both files were clipped to the watershed extent for each town. We used the year the deed was recorded to track growth in conserved land over time but grouped together all conserved areas with deeds recorded in 2000 or prior. Several conserved areas did not have a recorded deed date and were marked as "unaccounted" in Table 4.

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[2] Refer to the Palmer River Water Quality Analysis Report (HWG & FBE, 2019b) for pollutant load analysis related to the success of agricultural BMP installations.

[3] It is important to note that annual pollutant load values are predicted from the STEPL model, which uses pollutant export coefficients sufficient at a regional scale and not necessarily a site-specific scale. Thus, a closer comparison of predicted annual pollutant loads to observed water quality in these towns would be needed to confirm land use change impact to water quality (refer to HWG & FBE, 2019b for further discussion).

Table 1. Land use category classifications derived from the 2003-2005 (MA/RI) land use data file. STEPL = Spreadsheet Tool for Estimating Pollutant Loads model.

Final Simple Land Use Category	Final STEPL Land Use Category	Final Land Use Category	MA Land Use Category	RI Land Use Category
Agriculture	Cropland	Agric 1: Cropland	Cropland, Nursery	Idle Agriculture, Cropland
Agriculture	Cropland	Agric 2: Orchard	Orchard	Orchards, Groves, Nurseries
Agriculture	Pastureland	Agric 3: Pasture	Pasture	Pasture
Agriculture	Cropland	Agric 4: Cranberry Bog	Cranberry Bog	NA
Forest	Forest	Forest 1: Mixed	Forest	Deciduous Forest, Evergreen Forest, Mixed Deciduous Forest, Mixed Forest
Water/Wetland	Forest	Forest 2: Wetland	Forested Wetland	NA
Water/Wetland	Forest	Open 1: Water	Water	Other, Saltwater, Water
Water/Wetland	Forest	Open 2: Wetland	Non-Forested Wetland, Saltwater Wetland	Wetland
Developed	Urban-Open Space	Open 3: Open Space/Mowed	Open Land, Participation Recreation, Golf Course, Cemetery	Vacant Land, Developed Recreation, Cemeteries
Developed	Forest	Open 4: Brushland	Powerline/Utility, Brushland/Successional	Brushland, Powerlines
Developed	Urban-Industrial	Open 5: Exposed Sediment	Mining	Sandy Areas (not beaches), Mixed Barren Areas, Beaches
Developed	Urban-Single Family	Urban 1: Low Den Res	Low, Very Low Density Residential	Low Density Residential
Developed	Urban-Single Family	Urban 2: Med Den Res	Medium Density Residential	Medium, Medium Low Residential Development
Developed	Urban-Multi-Family	Urban 3: High Den Res	Multi-Family Residential, High Density Residential	High, Medium High Density Residential Development
Developed	Urban-Institutional	Urban 4: Institutional	Urban Public/Institutional	Institutional
Developed	Urban-Commercial	Urban 5: Commercial	Spectator Recreation, Commercial, Transportation	Commercial/Industrial Mixed
Developed	Urban-Industrial	Urban 6: Industrial	Industrial, Waste Disposal, Junkyard, Transportation Facilities	Waste Disposal, Other Transportation, Industrial, Water and Sewage Treatment
Developed	Urban-Commercial	Urban 7: Transitional	Transitional	Transitional Areas

LAND USE CHANGE

Overall between 1995-2018, five towns in the Palmer River watershed experienced a decrease in forest (552 acres) and agriculture (141 acres) land use types and an increase in water/wetland (9 acres) and urban (684 acres) land use types (Table 2; Figure 4). More specifically, residential development largely replaced cropland and mixed forest (Appendices 2-4). Increases in water/wetland areas were due to the installation of large stormwater retention ponds or the addition of farm ponds.

From 1995-2018 in the Rehoboth portion of the Palmer River watershed, a significant amount of forest (519 acres) and agriculture (121 acres) were converted to urban development (631 acres) and retention ponds (9 acres) (Table 2, Appendices 2, 4). Nearly half of this development occurred rapidly from 1995 to 2001 (Figure 4), during which 322 acres of forest, 63 acres of cropland, and 3 acres of exposed sediment were converted to urban development (312 acres), pasture and cranberry bog (49 acres), brushland or transitional land (22 acres), and water/wetland (4 acres) (Appendix 3). The pace of development in Rehoboth has declined since 1995 (Figure 4).

From 1995-2018, the Seekonk portion of the Palmer River watershed lost 33 acres of forest and 21 acres of agriculture to urban development (Table 2, Appendices 2, 4). Most of this development occurred rapidly from 1995 to 2001 (Figure 4), during which 5 acres of cropland/pasture and 4 acres of forest were converted to 5 acres of low density residential development and 4 acres of recreation land (Appendix 3). Minimal change in land use occurred from 2001 to 2015. From 2015-2018, 10 acres of recreation land and 4 acres of cropland/pasture were converted to 14 acres of urban development.

From 1995-2018, the Swansea portion of the Palmer River watershed lost 28 acres of forest and 12 acres of agriculture to urban development (Table 2, Appendices 2, 4). The pace of development in Swansea from 1995 to 2015 was relatively consistent with about 3-4 acres of forest or pasture being converted to urban development. From 2015-2018, 11 acres of forest and 8 acres of cropland were converted to 11 acres of low density residential development and 8 acres of pasture.

Portions of both Warren and Barrington in the Palmer River watershed experienced rapid development from 2004-2011 and minimal development in all other years from 1995-2018 (Appendices 2, 4). In total from 1995-2018, Warren lost 8 acres of agriculture and 6 acres of forest to urban development, while Barrington lost 3 acres of forest to urban development (Table 2). From 2001-2004, 32 acres of exposed sediment were converted to industrial land in Warren (Appendix 3; not reflected in Figure 4 because both are considered urban land use so net was zero). From 2004-2011, 45 acres of cropland, 5 acres of forest, and 2 acres of

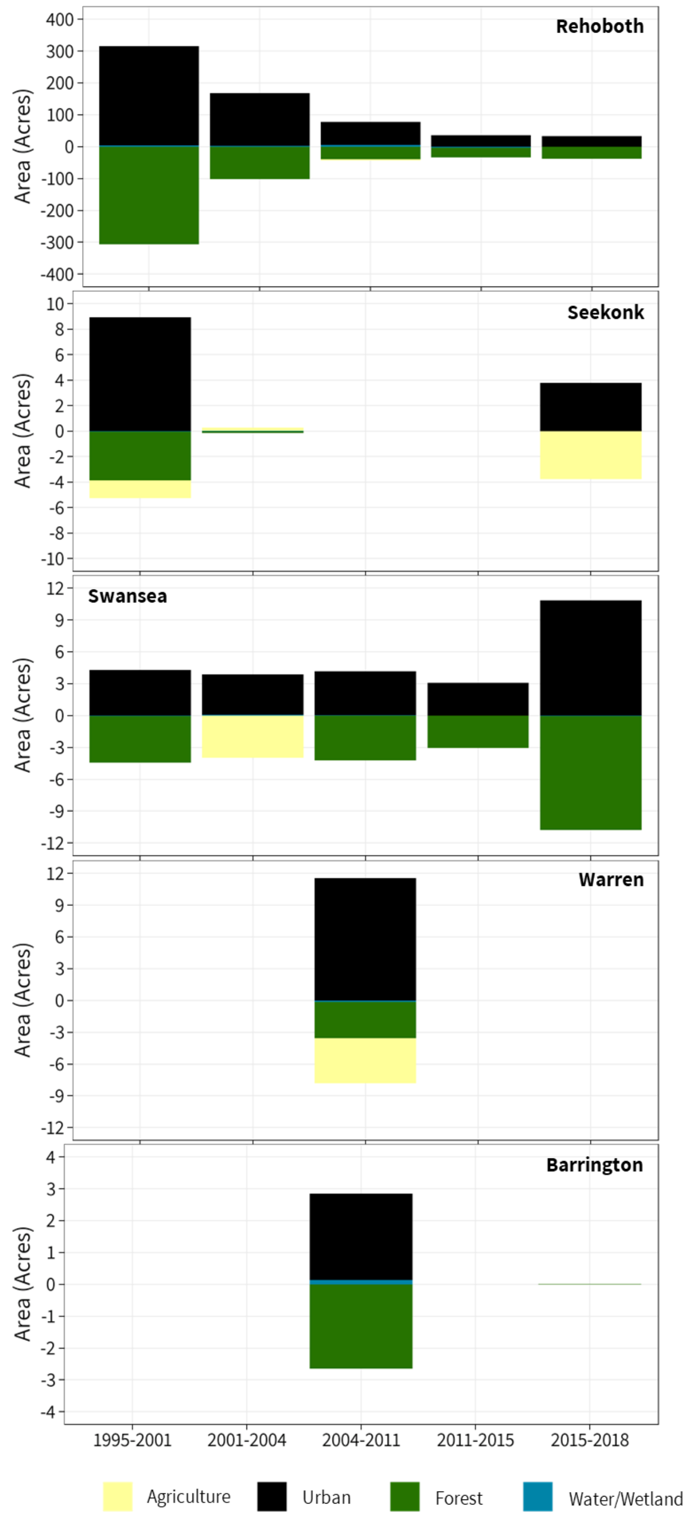

Figure 4. Non-cumulative change in major land use areas (acres) for five towns in the Palmer River watershed. In general, forested and agricultural areas were converted to developed areas at variable rates from 1995-2018. Bars are not stacked (summed) but reflect net value by major land use.

transitional land were converted to 37 acres of pasture, 11 acres of recreation land, 3 acres of medium density residential, commercial, and industrial development, and 2 acres of brushland in Warren. From 2004-2011, 3 acres of forest and 2 acres of recreation land were converted to 5 acres of medium density residential and commercial development in Barrington.

Table 2. Area (acres) by major land use type in 1995, 2001, 2004, 2011, 2015, and 2018 (and net total change for 1995-2018) and changes in area (acres) by major land use type from 1995-2001, 2001-2004, 2004-2011, 2011-2015, and 2015-2018 (and percent net total change for 1995-2018) for five towns in the Palmer River watershed. Grey- and red-highlighted values represent an increase and decrease in land use type from 1995 to 2018, respectively. Town names are abbreviated to the first five letters.

			Total Area by Major Land Use					Change in Total Area by Major Land Use				
Year	**Land use**	**Data Type**	**Rehob**	**Seeko**	**Swans**	**Warre**	**Barri**	**Rehob**	**Seeko**	**Swans**	**Warre**	**Barri**
1995	Agriculture	Land use Area (Acres, %)	2576.3	378.2	90.5	96.7	21.5	*NA*	*NA*	*NA*	*NA*	*NA*
	Forest		13282.2	992.7	521.5	256.9	58.9	*NA*	*NA*	*NA*	*NA*	*NA*
	Urban		4625.6	907.8	514.0	543.5	155.6	*NA*	*NA*	*NA*	*NA*	*NA*
	Water/Wetland		5774.8	396.1	328.7	196.2	90.8	*NA*	*NA*	*NA*	*NA*	*NA*
2001	Agriculture		2562.8	372.9	90.5	96.7	21.5	-13.5	-5.3	0.0	0.0	0.0
	Forest		12976.0	988.8	517.1	256.9	58.9	-306.2	-3.9	-4.4	0.0	0.0
	Urban		4941.2	916.7	518.3	543.5	155.6	315.6	8.9	4.3	0.0	0.0
	Water/Wetland		5779.1	396.0	328.7	196.2	90.8	4.3	0.0	0.0	0.0	0.0
2004	Agriculture		2494.1	373.2	86.5	96.7	21.5	-68.7	0.3	-4.0	0.0	0.0
	Forest		12873.9	988.7	517.3	256.9	58.9	-102.1	-0.2	0.3	0.0	0.0
	Urban		5109.0	916.7	522.1	543.5	155.6	167.8	0.0	3.9	0.0	0.0
	Water/Wetland		5781.8	396.1	328.7	196.2	90.8	2.8	0.0	0.1	0.0	0.0
2011	Agriculture		2450.7	373.2	86.5	88.9	21.3	-43.4	0.0	0.0	-7.8	-0.2
	Forest		12834.2	988.7	513.1	253.4	56.2	-39.7	0.0	-4.2	-3.5	-2.6
	Urban		5186.8	916.7	526.3	555.0	158.5	77.8	0.0	4.2	11.5	2.9
	Water/Wetland		5787.1	396.1	328.7	196.0	90.9	5.3	0.0	0.0	-0.1	0.1
2015	Agriculture		2451.2	373.2	86.5	88.9	21.3	0.5	0.0	0.0	0.0	0.0
	Forest		12800.6	988.7	510.0	253.4	56.2	-33.6	0.0	-3.1	0.0	0.0
	Urban		5222.9	916.7	529.4	555.0	158.5	36.0	0.0	3.1	0.0	0.0
	Water/Wetland		5784.1	396.1	328.7	196.0	90.9	-3.0	0.0	0.0	0.0	0.0
2018	Agriculture		2455.8	369.4	86.5	88.9	21.3	4.5	-3.8	0.0	0.0	0.0
	Forest		12762.9	988.7	499.2	253.4	56.2	-37.7	0.0	-10.8	0.0	0.0
	Urban		5256.3	920.5	540.2	555.0	158.5	33.4	3.8	10.8	0.0	0.0
	Water/Wetland		5783.9	396.1	328.7	196.0	90.9	-0.2	0.0	-0.1	0.0	0.0
1995-2018	**Agriculture**	**Change in Land use Area (Acres, %)**	**-120.5**	**-8.8**	**-4.0**	**-7.8**	**-0.2**	**-0.5%**	**-0.3%**	**-0.3%**	**-0.7%**	**-0.1%**
	Forest		**-519.3**	**-4.0**	**-22.2**	**-3.5**	**-2.6**	**-2.0%**	**-0.2%**	**-1.5%**	**-0.3%**	**-0.8%**
	Urban		**630.7**	**12.7**	**26.2**	**11.5**	**2.9**	**2.4%**	**0.5%**	**1.8%**	**1.1%**	**0.9%**
	Water/Wetland		**9.1**	**0.0**	**0.0**	**-0.1**	**0.1**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

WATER QUALITY IMPACT

Changes in land use over time can have profound impact to water quality. We examined changes in pollutant loads (based on changes in land use only, see Methodology) for TN, TP, and TSS over time for five towns in the Palmer River watershed. For a full review of land use change impact to water quality, refer to HWG & FBE (2019b).

Overall from 1995-2018, conversion of agricultural and forest land to urban development (not accounting for agricultural BMPs installed from 2015-2018) increased pollutant loading to the Palmer River by 1,893 lbs. TN/yr, 208 lbs. TP/yr, and 13 tons TSS/yr (Table 3). Most of the pollutant load increase came from Rehoboth, whose change in land use resulted in a 5.3%, 3.3%, and 2.4% increase in TN, TP, and TSS annual load from 1995-2018, respectively (Table 3; Figure 5). Swansea contributed the second highest load increase at 4.7%, 3.3%, and 1.7% for TN, TP, and TSS annual load from 1995-2018, respectively, followed by Seekonk then Barrington. Pollutant load from Seekonk improved slightly from 1995-2001 because of the type of land use conversion. Seekonk experienced a nearly 1:1 conversion from cropland and forest to lower-impact recreation land and low-density residential development. As discussed in HWG & FBE (2019b), we found that a 1:1 conversion of agricultural land to urban land resulted in improved water quality; however, we also found that for every acre of agricultural land loss, roughly 3 acres of urban land were gained, which increased pollutant loads over time in the Palmer River watershed (HWG & FBE, 2019b).

Change in land use in the portion of Warren in the Palmer River watershed resulted in reduced annual pollutant loads (Table 3, Figure 5). Similar to Seekonk from 1995-2001, Warren experienced a nearly 1:1 conversion of cropland to lower-impact recreation land and brushland from 2004-2011.

Overall from 1995-2018, our analysis of land use change (i.e., increased urban development) and resulting increased pollutant loading to surface waters indicates that pollutant loading to surface waters and resulting degradation of water quality will continue as the watershed becomes further developed, unless development strategies are re-engineered at the local level.

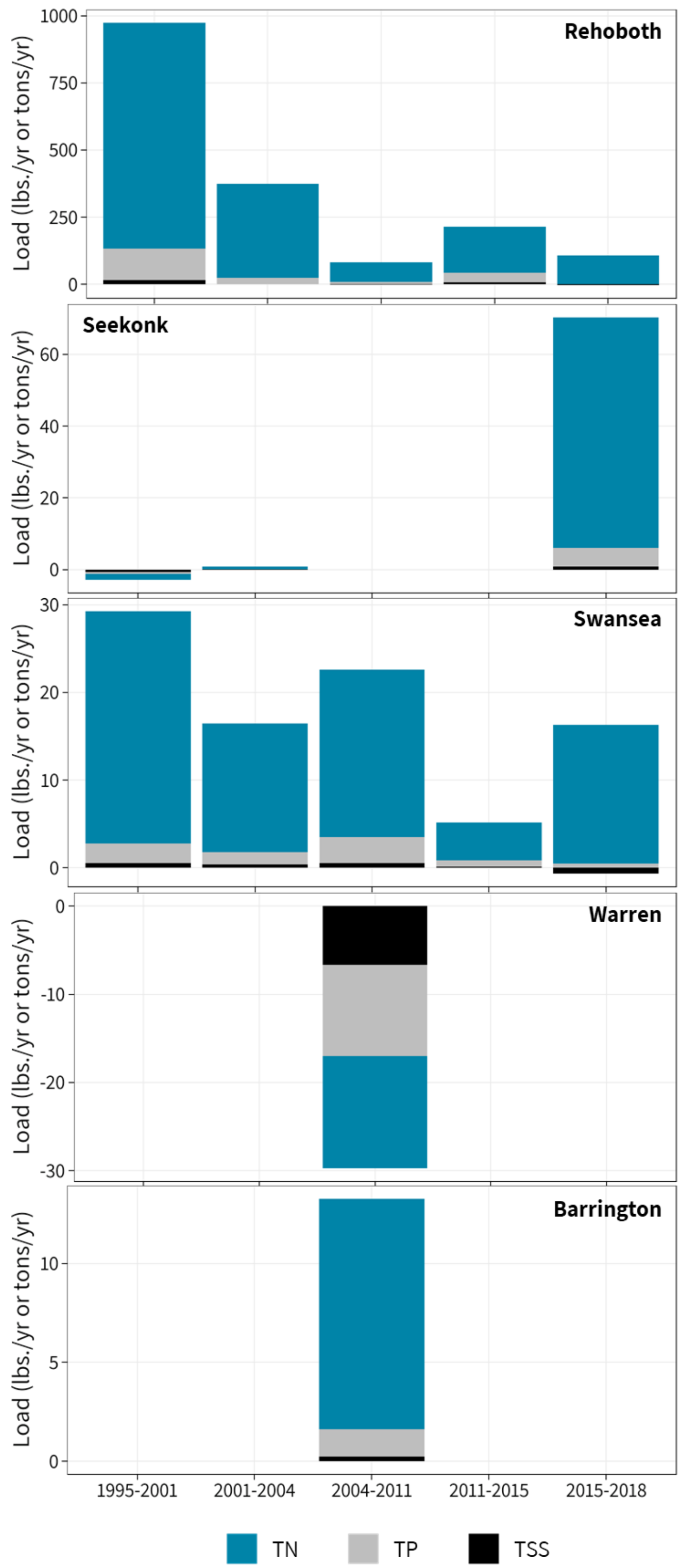

Figure 5. Non-cumulative change in annual load for total nitrogen (TN), total phosphorus (TP), and total suspended sediment (TSS) for five towns in the Palmer River watershed. **Note the different y-axes scales.**

Table 3. STEPL-predicted annual pollutant load for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) in 1995, 2001, 2004, 2011, 2015, and 2018 (and net total change for 1995-2018) and change in predicted annual pollutant load from 1995-2001, 2001-2004, 2004-2011, 2011-2015, and 2015-2018 (and percent net total change for 1995-2018) for five towns in the Palmer River watershed. Town names are abbreviated to the first five letters.

		Pollutant Load					Change in Pollutant Load				
Year	**Pollutant Type (Unit)**	**Rehob**	**Seeko**	**Swans**	**Warre**	**Barri**	**Rehob**	**Seeko**	**Swans**	**Warre**	**Barri**
1995	TN (lbs./yr)	31,419.0	4,046.6	1,830.3	2,584.2	437.6	*NA*	*NA*	*NA*	*NA*	*NA*
	TP (lbs./yr)	6,080.8	682.5	272.9	400.4	83.5	*NA*	*NA*	*NA*	*NA*	*NA*
	TSS (tons/yr)	739.9	123.6	48.5	66.3	12.5	*NA*	*NA*	*NA*	*NA*	*NA*
2001	TN (lbs./yr)	32,392.6	4,043.7	1,859.5	2,584.2	437.6	973.5	-2.9	29.3	0.0	0.0
	TP (lbs./yr)	6,213.6	681.3	275.7	400.4	83.5	132.8	-1.2	2.8	0.0	0.0
	TSS (tons/yr)	756.1	122.9	49.0	66.3	12.5	16.2	-0.6	0.5	0.0	0.0
2004	TN (lbs./yr)	32,766.3	4,044.5	1,876.0	2,584.2	437.6	373.7	0.8	16.5	0.0	0.0
	TP (lbs./yr)	6,237.5	681.4	277.5	400.4	83.5	23.9	0.1	1.8	0.0	0.0
	TSS (tons/yr)	755.7	122.9	49.4	66.3	12.5	-0.4	0.0	0.4	0.0	0.0
2011	TN (lbs./yr)	32,848.4	4,044.5	1,898.5	2,554.4	450.8	82.1	0.0	22.6	-29.7	13.3
	TP (lbs./yr)	6,246.8	681.4	281.0	383.4	85.1	9.3	0.0	3.5	-17.0	1.6
	TSS (tons/yr)	755.0	122.9	49.9	59.6	12.7	-0.7	0.0	0.5	-6.7	0.2
2015	TN (lbs./yr)	33,063.5	4,044.5	1,903.7	2,554.4	450.8	215.2	0.0	5.2	0.0	0.0
	TP (lbs./yr)	6,288.9	681.4	281.8	383.4	85.1	42.1	0.0	0.9	0.0	0.0
	TSS (tons/yr)	761.5	122.9	50.0	59.6	12.7	6.5	0.0	0.1	0.0	0.0
2018	TN (lbs./yr)	33,170.6	4,114.8	1,920.0	2,554.4	450.8	107.0	70.3	16.3	0.0	0.0
	TP (lbs./yr)	6,289.3	687.5	282.3	383.4	85.1	0.4	6.1	0.5	0.0	0.0
	TSS (tons/yr)	757.8	123.7	49.3	59.6	12.7	-3.7	0.8	-0.7	0.0	0.0
1995-2018	**TN (lbs./yr)**	**1,751.5**	**68.2**	**89.8**	**-29.7**	**13.3**	**5.3%**	**1.7%**	**4.7%**	**-1.2%**	**2.9%**
	TP (lbs./yr)	**208.5**	**5.0**	**9.4**	**-17.0**	**1.6**	**3.3%**	**0.7%**	**3.3%**	**-4.4%**	**1.9%**
	TSS (tons/yr)	**17.9**	**0.2**	**0.9**	**-6.7**	**0.2**	**2.4%**	**0.1%**	**1.7%**	**-11.2%**	**1.9%**

CONSERVED LAND CHANGE

Conserved land in the Palmer River watershed increased by 816 acres (63%) from 2000 to 2019, not including conserved lands with unaccounted years for deed records (Table 4) and represented a mix of private and public access properties. Specifically, conserved land grew by 666 acres (80%) in Rehoboth, 34 acres (12%) in Seekonk, 52 acres (215%) in Swansea, 51 acres (44%) in Warren, and 14 acres (28%) in Barrington. As of 2019, conserved land covers a total of 1,540 acres (6%) of Rehoboth, 356 acres (13%) of Seekonk, 81 acres (6%) of Swansea, 166 acres (15%) of Warren, and 75 acres (23%) of Barrington in the Palmer River watershed. Most conserved land is classified as natural cover types such as forest, wetland, or open water: Rehoboth (84%), Seekonk (73%), Swansea (93%), Warren (74%), and Barrington (89%). A significant portion of conserved land is classified as agriculture: Rehoboth (15%), Seekonk (25%), Swansea (5%), Warren (23%), and Barrington (10%). A small percentage of the conserved land in each town (1-3%) is classified as urban development, which could include historical buildings or any dwellings, roads, or other structures on agricultural or forest land.

For Warren and Barrington, conserved land largely covers estuarine shoreline areas, plus a few intact forest lands. Rehoboth, Seekonk and Swansea have significantly less percent coverage of conserved land for portions within the watershed compared to Warren and Barrington. For all five towns, there is likely considerable opportunity for more land to be put into conservation for water quality protection. We recommend that unprotected critical habitat areas be identified and prioritized for conservation in each town, especially areas that could extend existing conserved land and protect larger intact habitat blocks and corridors.

Table 4. Cumulative growth in conserved land area (acres) by year for five towns in the Palmer River watershed. Deeds recorded for conserved land in 2000 or prior were grouped together. Conserved land areas without a recorded deed date were marked as "unaccounted" and included in the total conserved land area for each town. Total percent conserved land area for each town was based on the portion of the town in the watershed. Change in conserved land area for each town was based on the difference between 2000 and 2019 and the percent change from 2000 to 2019.

	Conserved Land Area in the Palmer River Watershed (Acres)				
Year	Rehoboth	Seekonk	Swansea	Warren	Barrington
2000 or prior	827	286	24	115	49
2000				124	52
2001	1034				
2003	1076	287			59
2005				129	
2006					59
2007			71		
2008	1141				
2009	1152		75		
2012	1239	318			63
2013	1269				
2015		320		166	
2016	1378				
2017	1440				
2018	1467				
2019	1493				
Unaccounted	47	36	5	0	12
Unaccounted %	3%	10%	7%	0%	16%
Total	**1540**	**356**	**81**	**166**	**75**
Total %	**6%**	**13%**	**6%**	**15%**	**23%**
Change (2000-2019)	**666**	**34**	**52**	**51**	**14**
% Change (2000-2019)	**80%**	**12%**	**215%**	**44%**	**28%**

MUNICIPAL LAND USE REGULATIONS REVIEW

METHODOLOGY

We gathered and reviewed existing regulatory information, such as municipal ordinances, bylaws, and planning documents, to assess the strength of water quality protections and smart development practices. Older and/or sparse land use regulations for water quality protection were identified using the Center for Watershed Protection's Code and Ordinance Worksheet (COW). The COW served as a standard method of assessment among the towns for noting presence or absence of municipal codes related to nonpoint source pollution prevention and water quality protection. During the review process, questions were noted to clarify certain regulation language or confirm possible gaps identified. We also reviewed municipal master plans to develop questions related to each town's vision of land use development, which helped guide discussions with representatives from the towns (HWG & FBE, 2019c).

After we reviewed the existing regulatory information, we reached out to the town planner of each town to clarify any gaps in the land use regulations review, determine stakeholder land use goals, priorities, and/or concerns, and identify successes and/or challenges to meeting desired land use goals[4]. Refer to the technical memorandums submitted by HWG & FBE (2019c) regarding the stakeholder communication approach (July 23, 2019) and interview notes (September 19, 2019).

[4] We also reached out to Save the Bay to get project background information to help inform discussions with the town planners. It was noted by RIDEM that Save the Bay worked with the Towns of Barrington, RI and Seekonk, MA on the Hundred Acre Cove project, which was supported by the Southeast New England Program (SNEP) Watershed Grant. We also reached out to Mass Audubon. Mass Audubon is completing a similar project in the Taunton River watershed, supported by the SNEP Watershed Grant, to determine if current land use regulations meet water quality and other goals.

KEY FINDINGS

Below provides a summary of information gained through the regulation review and discussions with key town staff. We also provide a summary of strengths identified during review of municipal land use regulations for the five towns (Table 5). Note that the following findings reflect town-wide (and not watershed-specific) information gained from this process.

Rehoboth is a rural farming community (without public sewer) whose values center on maintaining a rural character (i.e., tempered development pace) that includes lack of public water and sewer, as well as large frontage and lot size requirements.

- The Conservation Commission works to purchase and preserve large tracts of land to help maintain the town's rural character especially in environmentally sensitive areas.
- The town's development priorities in the next decade or more include continuing to maintain its rural character through review of subdivision plans, enforcement of environmental protection regulations that minimize tree clearing and wetlands impact, and expansion of the Groundwater Protection District to town-wide.
- The town is currently working to update codes to minimize clearcutting for subdivisions, so that trees (not just significant trees or trees of note) that do not impede the construction of roads, retention ponds, and single-family homes are kept in place. The town has also required developers to provide an escrow account for long-term maintenance of retention ponds for subdivisions, and town-contracted engineers have checked the functioning of retention ponds during the construction period.
- The community has expressed general concerns for natural resource protection and stormwater management of new development projects. Yet, the community rejected proposed code revisions to promote open space or cluster subdivisions (a.k.a., "flexible" development) because numerous, small lot sizes did not reflect a rural aesthetic and space for private wells and septic systems are limited and would require town water and sewer connections. The town will be looking at flexible development again during the current master plan review process.
- The Planning Board was also not in favor of crediting on-street parking toward parking space requirements because of concerns for traffic congestion in the business districts.
- The town noted that it is much easier to work through relevant board meetings to revise code language instead of through town meetings, which the Conservation Commission works through only once per year.
- The town recently adopted a stretch code that requires renewable energy and efficiency standards in building codes.

Seekonk is a mixed suburban and rural farming community (without public sewer) whose long-term development goals are to minimize further sprawl and subdivision development and promote infill and/or redevelopment in areas already developed.

- The town plans to limit sprawl by updating the housing production plan, which currently allows small 0.33-1.37 acre lots on private well and septic systems.
- Around 40-50 multi-family housing units were built in already-developed areas as infill or redevelopment projects; the town plans to continue to develop new housing in this way.
- The town is currently working to incorporate new rules into pre- and post-construction stormwater management.
- The Planning Board is in the process of updating the master plan (last updated in 2012), and there will be a comprehensive review of natural resource protection regulations.
- Current subdivision rules require an environmental impact statement that demonstrates how the project will protect natural resources and existing characteristics such as notable trees, though the list of acceptable trees were not selected based on native species.
- The town is also focused on climate change resiliency and has recently entered the Municipal Vulnerability Preparedness (MVP) program to begin assessment and implementation.
- The town has received no concerted public push for or against these changes.

Swansea is a mixed suburban and rural farming coastal community (without public sewer) with significant coastal and inland water resources. According to the town master plan, the community values its rural character and wishes to limit sprawl by preserving land through town easements and/or land purchases, as well as implementing Smart Growth strategies.

- The town's development priorities in the next decade or more include redeveloping a closed mall, as well as underdeveloped properties along Route 6.

- The town successfully passed an Open Space Residential Design (OSRD) bylaw that reduces the length of roadways (and thus impervious cover) through cluster subdivisions with open space. Most of the community approves of the OSRD bylaw but some of the community is still concerned about unchecked growth and its impact on maintaining municipal services and rural character.
- The community generally welcomes code revisions that serve to protect water quality; however, an ordinance regarding the preservation of trees and native vegetation was rejected by the Planning Board several years ago because they did not have enforcement measures in place.

Warren is a mixed suburban (west and within the Palmer River watershed) and rural farming (east) coastal community with significant coastal and inland water resources. The community values its historic manufacturing character.

- The town's development priorities over the next decade or more are to focus on climate change resiliency to flooding and wetlands protection, incorporate better mixed use in the central area of town, construct better public transportation and workforce housing, and expand the tax base smartly.
- The town has recently entered the MVP program to begin assessment and implementation for climate change resiliency. Of concern with coastal flooding is the area around Belcher's Cove, which floods during king tides or storm surges into commercial areas with potential for pollution discharge (e.g., dry cleaners, furniture stripping, auto shops, etc.). The town is considering property buy-outs for flood-prone areas.
- Open space will be addressed in the comprehensive plan update in 2019 and will cover farm conservation easements, town-owned open space parcels, and Warren Land Trust-owned conservation parcels.
- Cluster subdivisions are only allowed in the eastern part of the town since the western part is highly developed; however, development in the eastern part of the town is limited due to poor water access. In general, Warren has limited new development opportunity, especially in the Palmer River watershed, as most of the town is already developed, which the town noted was poorly planned in terms of parking and stormwater management; thus, the town has focused on redevelopment projects.
- The town identified that one of the challenges with code revisions is the lack of resources and the limited number of staff available to work on revisions.

Barrington is a suburban coastal community with significant coastal and inland water resources. The community values single-family residences with adequate buffer between neighbors.

- The town's development priorities in the next decade or more include updating regulations to be more resilient to flooding or sea level rise and finding opportunities to acquire open space for habitat connectivity and improved trail networks (i.e., "emerald chain" concept).
- The town will be replacing the current Conservation District with the Cluster Subdivision District, which has a formula for open space designation. The Open Space Plan (2011) will be updated soon. The Town is also looking into amending their Subdivision Regulations to ensure open space is dedicated in a manner consistent with the Town's open space acquisition criteria.
- Although the recently adopted complete streets policy does not address stormwater, the town will be considering stormwater as the policy is implemented and as new stormwater system mapping information becomes available. Rhode Island towns generally do not have their own stormwater regulations but rather default to the state's regulations.
- Although Barrington requires zero net increase in runoff (rate not volume) from development projects, there are no impervious coverage regulations for subdivisions.
- The town has partnered with Save the Bay and Ducks Unlimited, among others, with stormwater projects, such as Walker Farm and Allin's Cove.
- The town rezoned an area near George Street by Four Town Farm to discourage water and sewer hook-ups to potential new development and rezoned a former college campus for 300 senior housing units.
- The town identified that one of the challenges with code revisions is the lack of resources and the limited number of staff available to work on revisions.

Table 5. Summary of current strengths and pending or ongoing work identified during municipal land use regulations review for five towns in the Palmer River watershed.

Town	Current Strengths	Pending or Ongoing Work
Rehoboth	• Requires escrow account for long-term maintenance of retention ponds for subdivisions • Requires renewable energy and efficiency standards in building codes • Allows street layouts that minimize the use of cul-de-sacs • Allows for variances to setback and frontage requirements • Allows for reduced sidewalk widths on low traffic roads • Allows for shared driveways • Allows open space to be managed by a qualified conservation organization • Places limits on site clearing and requires limits of disturbance to be shown on construction plans and marked at the site • Restricts development on 100-year floodplain	• Working to minimize clearcutting for subdivisions
Seekonk	• Requires an environmental impact statement for new subdivisions • Entered the Municipal Vulnerability Preparedness (MVP) program • Requires reduced residential street right-of-way widths • Allows street layouts that minimize the use of cul-de-sacs • Requires maximum parking ratio limits based on study of parking demand and use of shared parking • Requires reduced parking stall width • Allows pervious materials to be used for parking areas and driveways • Allows for reduced sidewalk widths on low traffic roads • Allows open space subdivisions where open space is identified first but requires less than 50% of the buildable portion be set as open space • Requires open space to be managed by a qualified conservation organization • Requires planting new trees at sites where none exist • Specifies landscaping requirements for soil amendments, planting methods, species selection, and maintenance • Requires stormwater outfall discharges be directed away from impaired or sensitive waters • Restricts development on 100-year floodplain • Requires specific standards to reduce post-construction runoff volume (not just peak rate) • Requires post-construction inspections and long-term maintenance agreements for erosion and sediment controls • References design guidance or stormwater manual; standards are in one place and consistent	• Promoting infill and redevelopment projects to limit sprawl • Incorporating new rules into pre- and post-construction stormwater management • Will complete a comprehensive review of natural resource protection regulations in master plan update
Swansea	• Passed Open Space Residential Design bylaw that identifies prioritized resources as open space first, requires at least 50% of the buildable portion be set as open space, requires open space to be managed by a qualified conservation organization, defines acceptable uses for open space, and requires open space to be protected in perpetuity • Sets a minimum cul-de-sac radius to limit imperviousness • Alternatives to cul-de-sacs are specifically mentioned • Sets a minimum percentage of parking lots to be landscaped • Allows for reduced sidewalk widths on low traffic roads • Allows for shared driveways • Requires a minimum vegetated buffer along waterways, including ephemeral and intermittent streams and sets larger minimum buffer widths around sensitive resources • Requires a minimum percentage of the buffer be maintained with native vegetation • Requires a natural resource inventory to identify and map natural areas • Restricts development on 100-year floodplain • Requires specific standards to reduce post-construction runoff volume (not just peak rate) • References design guidance or stormwater manual	
Warren	• Entered the Municipal Vulnerability Preparedness (MVP) program • Requires reduced residential street right-of-way widths • Allows utilities to be placed under the paved section of the road right-of-way to limit footprint • Requires adequate (6 ft) spacing between street trees • Sets a minimum cul-de-sac radius to limit imperviousness • Allows street layouts that minimize the use of cul-de-sacs • Parking ratios reduced with shared parking arrangements • Requires reduced parking stall width and length with a fixed portion of spaces with smaller dimensions for compact cars • Sets a minimum percentage of parking lots to be landscaped • Allows irregular lot shapes • Allows for variances to setback and frontage requirements • Allows for reduced sidewalk widths on low traffic roads	• Strengthened wetlands regulations (state-level) will be effective beginning fall 2020*

Town	Current Strengths	Pending or Ongoing Work
	• Allows open space subdivisions but requires less than 50% of the buildable portion be set as open space • Requires open space to be managed by a qualified conservation organization • Defines acceptable uses for open space • Requires preservation of native soils, hydric soils, natural vegetation, or steep slopes • Requires conservation of some portion of native vegetation at development sites • Requires planting new trees at sites where none exist • Has an urban forestry plan that supports landscaping designs • Specifies landscaping requirements for soil amendments, planting methods, species selection, and maintenance • Requires stormwater outfall discharges be directed away from impaired or sensitive waters • Requires specific standards to reduce post-construction runoff volume (not just peak rate) • References design guidance or stormwater manual; standards are in one place and consistent	
Barrington	• Requires narrow roadway widths for low traffic roads • Requires reduced residential street right-of-way widths • Sets a minimum cul-de-sac radius to limit imperviousness • Alternatives to cul-de-sacs are specifically mentioned • Parking ratios reduced with shared parking arrangements • Allows parking credits when nearby on-street parking available • Requires reduced parking stall width and length • Allows irregular lot shapes • Allows for variances to setback and frontage requirements • Allows for reduced sidewalk widths on low traffic roads • Allows open space subdivisions but requires less than 50% of the buildable portion be set as open space • Requires open space to be managed by a qualified conservation organization • Requires zero net increase in runoff (rate not volume) from development projects • References design guidance or stormwater manual	• Strengthened wetlands regulations (state-level) will be effective beginning fall 2020* • Replacing the current Conservation District with the Cluster Subdivision District • Updating the Open Space Plan (2011)

**New RI state wetlands regulations will be finalized soon and will replace any existing municipal wetlands regulations. The state law pertaining to freshwater wetlands (R.I. Gen. Laws §2-1-18 through 2-1-28) was strengthened to better protect freshwater wetland resources. The new rules define a freshwater wetland as vegetated wetlands and surface waters and apply a jurisdictional area to 200 feet outward from the edge of freshwater wetlands, rivers, and floodplains and 100 feet outward from all other wetlands, within which the natural undisturbed buffer condition should be maintained or created. These strengthened rules will help to protect the water quality of the RI portion of the Palmer River watershed.*

RECOMMENDATIONS

We emphasize that the land use regulations review completed for the Palmer River Source Tracking, Water Quality Trends Summary, and Watershed Plan project was limited in its approach and scope and should be considered preliminary. With these limitations in mind, we identified high-level recommendations and opportunities for regulatory amendments and best land use practices to support water quality protection. Since all five towns have room for improvement in requiring best practices for development projects, we summarize generally the key areas for code improvements that address water quality as follows:

- **Minimize imperviousness**: reduce road widths, road right-of-way widths, and road lengths; use permeable paving materials, reduce cul-de-sac radius and add landscaped island for stormwater infiltration or alternative turnarounds; use vegetated open channels, curb extensions, or landscape strips for road runoff; maximize parking ratio limits based on study of parking demand; use shared parking or parking credits; reduce parking stall widths and lengths; maximize percent of parking lot landscaped for stormwater infiltration' relax side and front yard setbacks; minimize sidewalk widths and, where appropriate, use on only one side of the road; use an adequate spacing of street trees; minimize driveway widths and lengths and, where possible, use shared driveways and two-track driveways.

- **Use green infrastructure to treat stormwater runoff**: route runoff to vegetated areas or subsurface chambers for infiltration; use alternative treatment options such as green roofs; enhance protection and management of natural buffers around waterways; require limits on clearcutting; use native vegetation in landscaping; reduce post-construction runoff rate and volume; provide post-construction inspections of erosion and sediment controls; and document a minimum on-site stormwater treatment volume.

- **Promote Open Space Residential Design:** require open space designs with clustered lots to reduce imperviousness and conserve natural areas; require minimum open spaces set to at least 50% of the buildable lot portion; use flexible site design criteria to accommodate clustered development; restrict development on floodplains or other mapped sensitive natural resources; appoint a qualified entity to manage open space; ensure that Master Plan updates promote more strategically, sustainably, and resiliently aligned resource protection goals that are in line with land use trends and policies; design open spaces based on fostering and/or preserving valued land uses, species, habitats, and corridors; provide a clear definition of allowable open space uses; and conserve these open spaces in perpetuity.

An overarching challenge identified by the towns to revising regulations was a lack of resources. From the interviews, lack of staff experience, capacity, community education, and funding were some of the needs that were referenced. Significantly more information could be gained with face-to-face conversations with town staff representing multiple boards or departments, as well as with regional stakeholders to understand potential financial or technical support needs and resources available. We acknowledge that towns resources are limited, so it would be most efficient for them to pool their resources where possible to accomplish some of the goals identified herein. We recommend that the towns participate in a series of in-person meetings with key staff to review current land use regulations, identify specific challenges and solutions to incorporating code revisions, and develop more thorough recommendations for code revisions.

There are also several existing tools for communities to conduct self-evaluations and provide a process for updating regulations. For example, the Mass Audubon Local Land Use Regulations Analysis Tool and online collection of supporting materials which is part of the Massachusetts' Smart Growth/Smart Energy Toolkit are tremendous resources for assisting towns with bylaw review and updates. The Mass Audubon tool promotes smart land use, green infrastructure techniques, and low impact development (i.e., best practices). While the focus of the tool is on residential development, the concepts can be applied to other forms of development as well. Best practices for land use development help to maintain existing forests and vegetated buffers, reduce the amount of impervious cover, minimize alteration of terrain and grading, and better manage stormwater runoff. Use of these best practices in new and redevelopment projects result in considerable cost savings, among many other benefits.

Outside resources can also help improve municipal capacity; some of these include technical assistance from EPA's Southeast New England Program Technical Assistance Network, Save the Bay, and Mass Audubon, as well as financial assistance through grants, such as the Planning Assistance Grants from the Massachusetts Office of Energy and Environmental Affairs.[5] Our communication with Mass Audubon indicated that they are eager to be a resource to towns for improving bylaws. Grants can be used to support each town's efforts to plan, regulate, and act to conserve and develop land. If town staff do not have the technical expertise to review engineering plan applications, towns can hire capable consultants to conduct third-party peer reviews of applications. Lastly, to the extent possible, the MVP Program should be considered for opportunities to leverage environmental co-benefits.

CONCLUSION

This report addressed several objectives of the Palmer River Source Tracking, Water Quality Trends Summary, and Watershed Plan project (outlined in HWG & FBE, 2019a). We assessed land use change and development patterns for five towns in the Palmer River watershed, reviewed municipal regulations related to land development and water quality protection, and provided recommendations for regulatory amendments that support best practices.

- **Land Use Change Analysis.** Using a land use change analysis approach, we were able to model change in nutrient and sediment loads to the Palmer River. Based on this approach and its assumptions, the following conclusions were possible: overall, from 1995 to2018, five towns in the Palmer River watershed experienced a decrease in forest (552 acres) and agriculture lands (141 acres) and an increase in water/wetland (9 acres) and urban lands (684 acres). Over this period, forested and agricultural areas were converted to developed areas at variable rates among the towns. Most of this development occurred rapidly from 1995 to 2001. Overall from 1995 to 2018, conversion of agricultural and forest land to urban development (not accounting for agricultural BMPs installed from 2015-2018) increased pollutant loading to the Palmer River by 1,893 lbs. TN/yr, 208 lbs. TP/yr, and 13 tons TSS/yr.
    - → Given that our assessment indicates land use development in the Palmer River watershed has increased pollutant loading to the river, it is likely that future development will continue this trend under business-as-usual development strategies allowed by local land use regulations. Addressing this threat to the sustainability of the towns' natural resources will require re-engineering of development strategies at the local level.
    - → Most of the modeled pollutant load increase came from Rehoboth. From 1995 to 2018, land use change resulted in an annual load increase of 5.3%, 3.3%, and 2.4% for TN, TP, and TSS, respectively. Given its dominant geographic

[5] https://www.mass.gov/service-details/planning-assistance-grants

representation within the Palmer River watershed, its current rural character, and high potential for development, Rehoboth is the most vulnerable watershed town to future land use change and resulting water quality degradation. Although portions of the other four towns in the watershed do not have as much future development potential as Rehoboth, water quality impacts from these towns could cumulatively be significant.

→ Importantly, between 1995 and 2018 conserved land of primarily forest and agricultural land grew by 666 acres (80%) in Rehoboth, 34 acres (12%) in Seekonk, 52 acres (215%) in Swansea, 51 acres (44%) in Warren, and 14 acres (28%) in Barrington. Conserving large intact forests is critical to maintaining water quality, and given the large tracts of existing undisturbed forest, there appears to be ample opportunity for future land conservation in some of these towns. We recommend that unprotected critical habitat areas be identified and prioritized for conservation in each town, especially areas that could extend existing conserved land and protect larger intact habitat blocks and corridors.

- **Municipal Land Use Regulations Review:** We found that all five towns have long-term development goals that include reducing sprawl and conserving land for natural resource protection and maintaining rural or historic character. These goals are in line with low impact development strategies. While some towns have been able to translate these goals into their codes, other towns have been met with challenges. Our preliminary discussions with these towns showed that code revisions involving best practices have been challenging to implement because of lack of staff experience, capacity, community education, and funding. Some communities are encouraging use of best practices in development projects but without strict language in the bylaws to require it.

    → We acknowledge that the towns would benefit from a series of in-person meetings with key staff to review current land use regulations, identify specific challenges and solutions to incorporating code revisions, and develop more thorough recommendations for code revisions. Further review could also help to prioritize actions needed to address specific changes to land use bylaws and regulations that impact water quality.

    → EPA's Southeast New England Program Technical Assistance Network[6], Save the Bay, and Mass Audubon are three organizations that could further assist the towns in this process and have indicated that they are eager to do so. The Mass Audubon Local Land Use Regulations Analysis Tool and online collection of supporting materials that are part of the Massachusetts' Smart Growth/Smart Energy Toolkit are tremendous resources for assisting towns with bylaw review and updates.

    → Future phases of work for the communities may include a review of the towns' future development preferences and priorities and comparison to desired land uses. Similarly, towns may complete build-out analyses to understand how development may be restricted or grown with current and proposed regulations. The scenarios developed from these analyses may be further evaluated using the STEPL model to determine water quality impacts from the proposed development(s), as well as benefits from proposed regulations promoting the use of green infrastructure and low impact development. Results can be used to help guide the towns to appropriate policies and programs that meet their long-term goals for community growth and natural resource protection.

[6] https://www.epa.gov/snecwrp/funding-opportunities-southeast-new-england-coastal-watershed-restoration-program

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APPENDIX 1

Supplemental methodology for land use change analysis.

Our initial approach was to reconcile land use data files among different time periods and different states. Historical land use for MA was available for 1971, 1985, 1999, and 2005 in 21 or 37 land use categories. Historical land use for RI was available for 1988, 1995, 2003-2004, and 2011. Data files for each state were matched by time period: 1985 (MA) to 1988 (RI), 1999 (MA) to 1995 (RI), and 2005 (MA) to 2003-2004 (RI). Common land use categories among all data files were carefully matched and documented (as many categories were assimilated into a single, more general category) (refer to Table 1).

During this process, we found that advances in technology between land use data file years resulted in files created with varying resolution that reflected both a change in methodology (i.e., accuracy) and a change in land use. For example, the 1985 (MA) and 1999 (MA) land use data files were created under the Resource Mapping Project at the University of Massachusetts at Amherst and were interpreted from 1:25,000 aerial photography hardcopies and ArcINFO software. The 2005 (MA) land use data file was created by The Sanborn Map Company, Inc and was derived from 0.5-meter resolution digital ortho imagery and ESRI's ArcGIS software.

We found that the greatest difference in discrepancy between the 2005 (MA) and 1999 (MA) land use data files was improved wetland identification; however, our review of actual changes in wetland areas in the shown extent showed no significant changes between 1999 and 2005 (Figure A1-1). Using these land use data files would have generated gross errors in land use change and its impact on water quality, attributed to a change in methodology and not solely a change in land use.

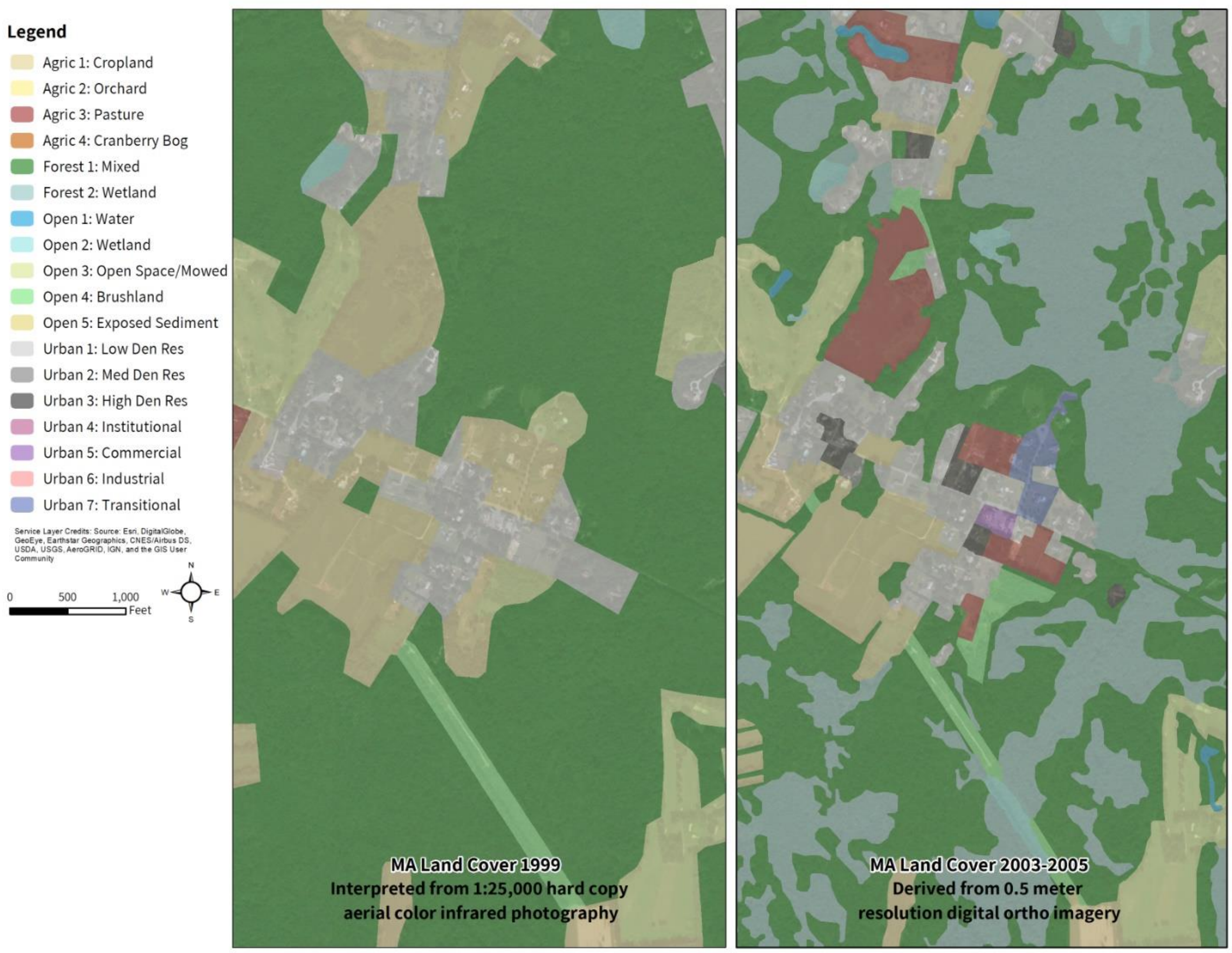

Figure A1-1. Land use data files for 1999 (MA) and 2005 (MA). The change in methodology between these two time periods resulted in higher resolution land use type mapping, making it difficult to determine actual change in land use without also accounting for change in land use as a result of a change in methodology.

APPENDIX 2

Maps depicting change in land use over time for five towns in the Palmer River watershed.

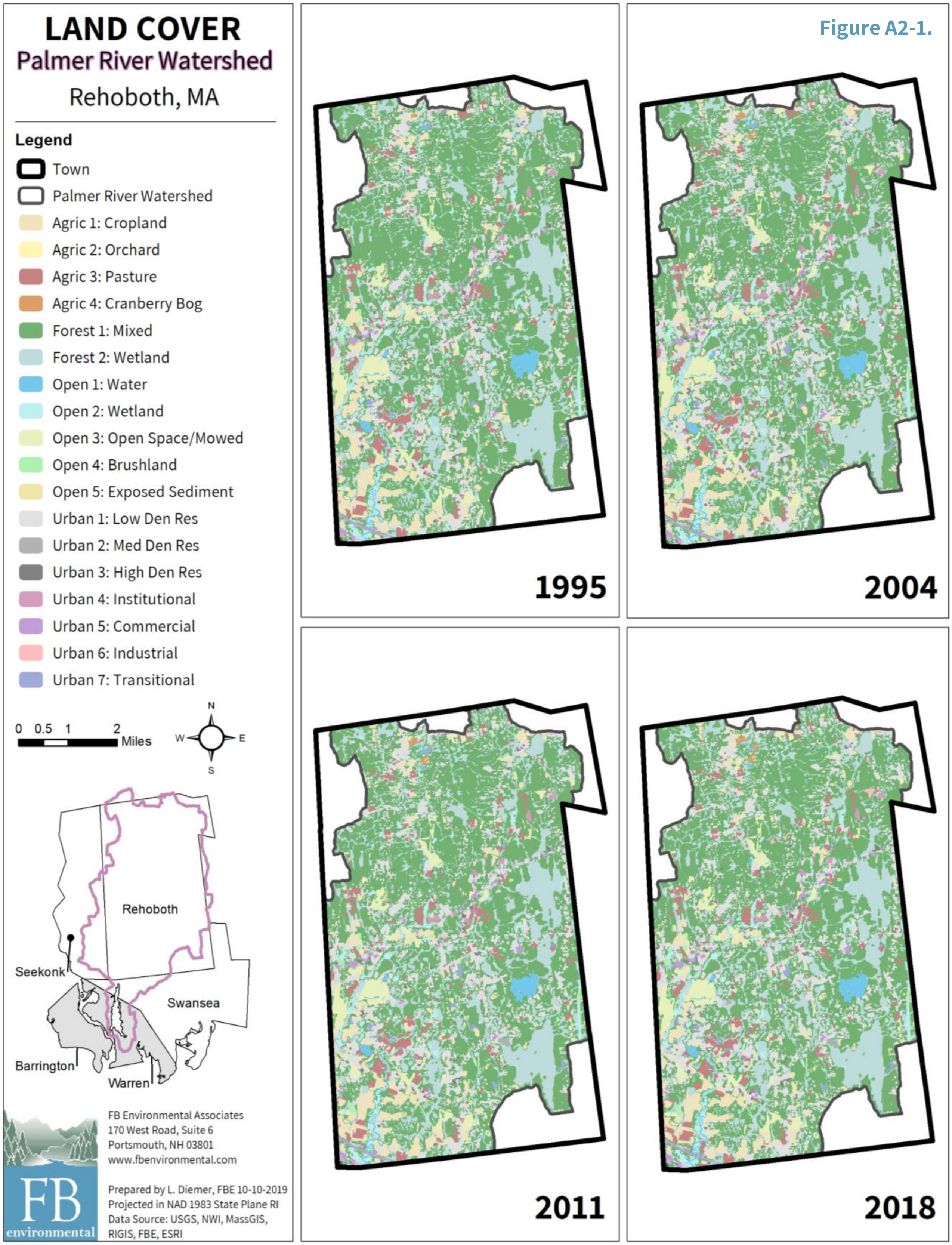

Figure A2-1.

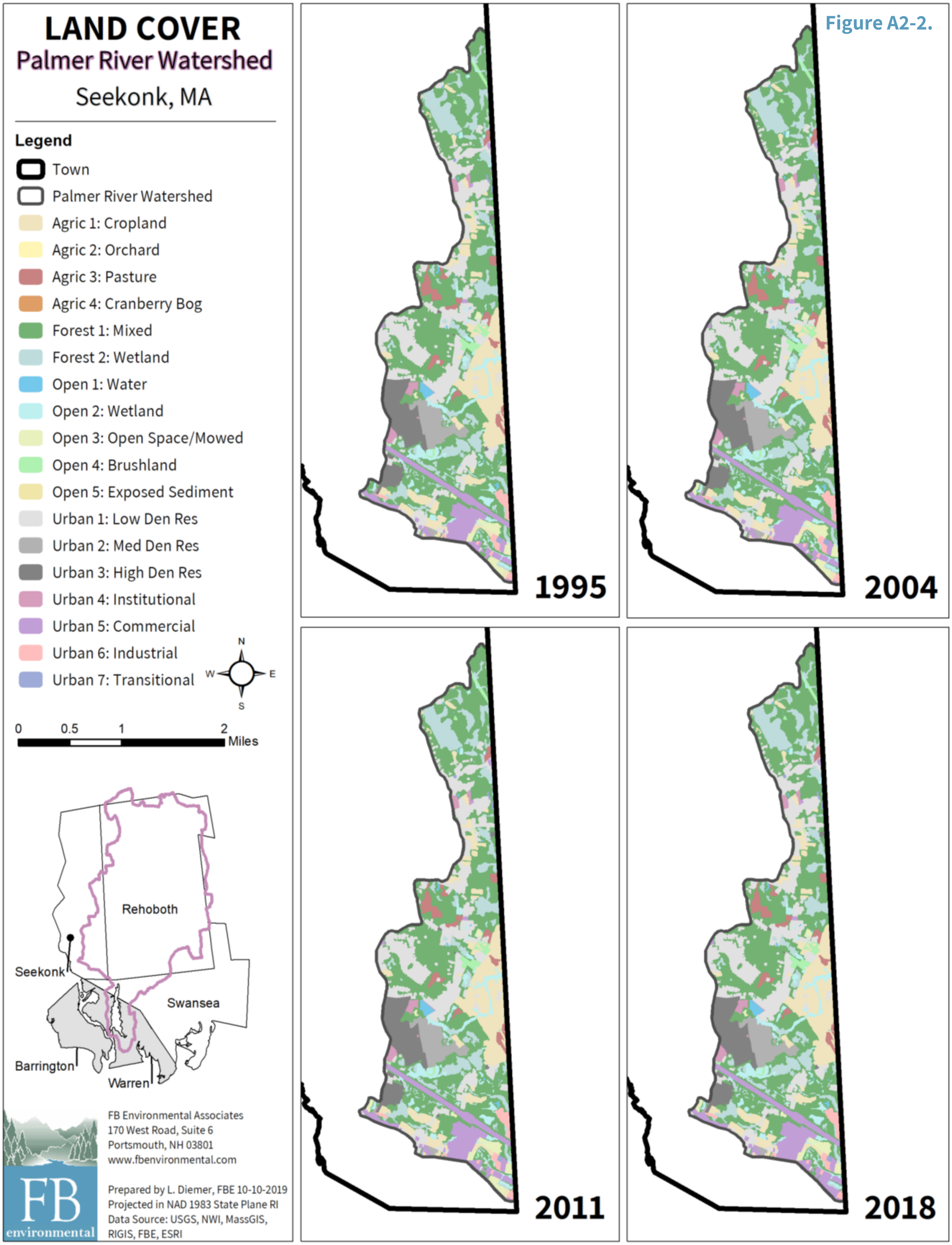
LAND COVER
Palmer River Watershed
Seekonk, MA
Legend
Town
Palmer River Watershed
Agric 1: Cropland
Agric 2: Orchard
Agric 3: Pasture
Agric 4: Cranberry Bog
Forest 1: Mixed
Forest 2: Wetland
Open 1: Water
Open 2: Wetland
Open 3: Open Space/Mowed
Open 4: Brushland
Open 5: Exposed Sediment
Urban 1: Low Den Res
Urban 2: Med Den Res
Urban 3: High Den Res
Urban 4: Institutional
Urban 5: Commercial
Urban 6: Industrial
Urban 7: Transitional
N
W
E
S
0
0.5
1
2
Miles
Rehoboth
Seekonk
Swansea
Barrington
Warren
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
FB
environmental
Prepared by L. Diemer, FBE 10-10-2019
Projected in NAD 1983 State Plane RI
Data Source: USGS, NWI, MassGIS,
RIGIS, FBE, ESRI
1995
2004
2011
2018

Figure A2-2.

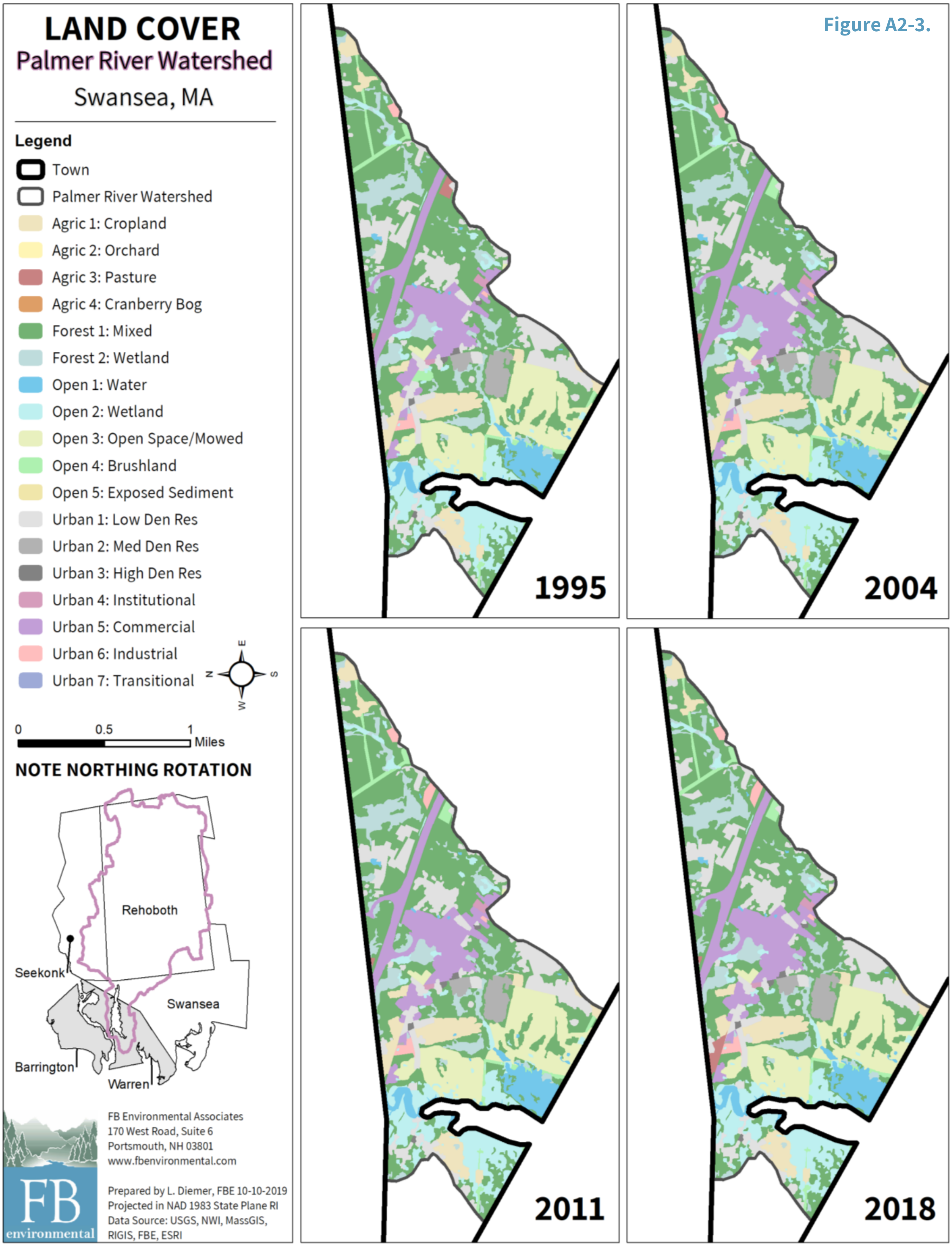
Figure A2-3.
LAND COVER
Palmer River Watershed
Swansea, MA
Legend
Town
Palmer River Watershed
Agric 1: Cropland
Agric 2: Orchard
Agric 3: Pasture
Agric 4: Cranberry Bog
Forest 1: Mixed
Forest 2: Wetland
Open 1: Water
Open 2: Wetland
Open 3: Open Space/Mowed
Open 4: Brushland
Open 5: Exposed Sediment
Urban 1: Low Den Res
Urban 2: Med Den Res
Urban 3: High Den Res
Urban 4: Institutional
Urban 5: Commercial
Urban 6: Industrial
Urban 7: Transitional
N
E
S
W
0
0.5
1
Miles
NOTE NORTHING ROTATION
Rehoboth
Seekonk
Swansea
Barrington
Warren
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
FB
environmental
Prepared by L. Diemer, FBE 10-10-2019
Projected in NAD 1983 State Plane RI
Data Source: USGS, NWI, MassGIS, RIGIS, FBE, ESRI
1995
2004
2011
2018

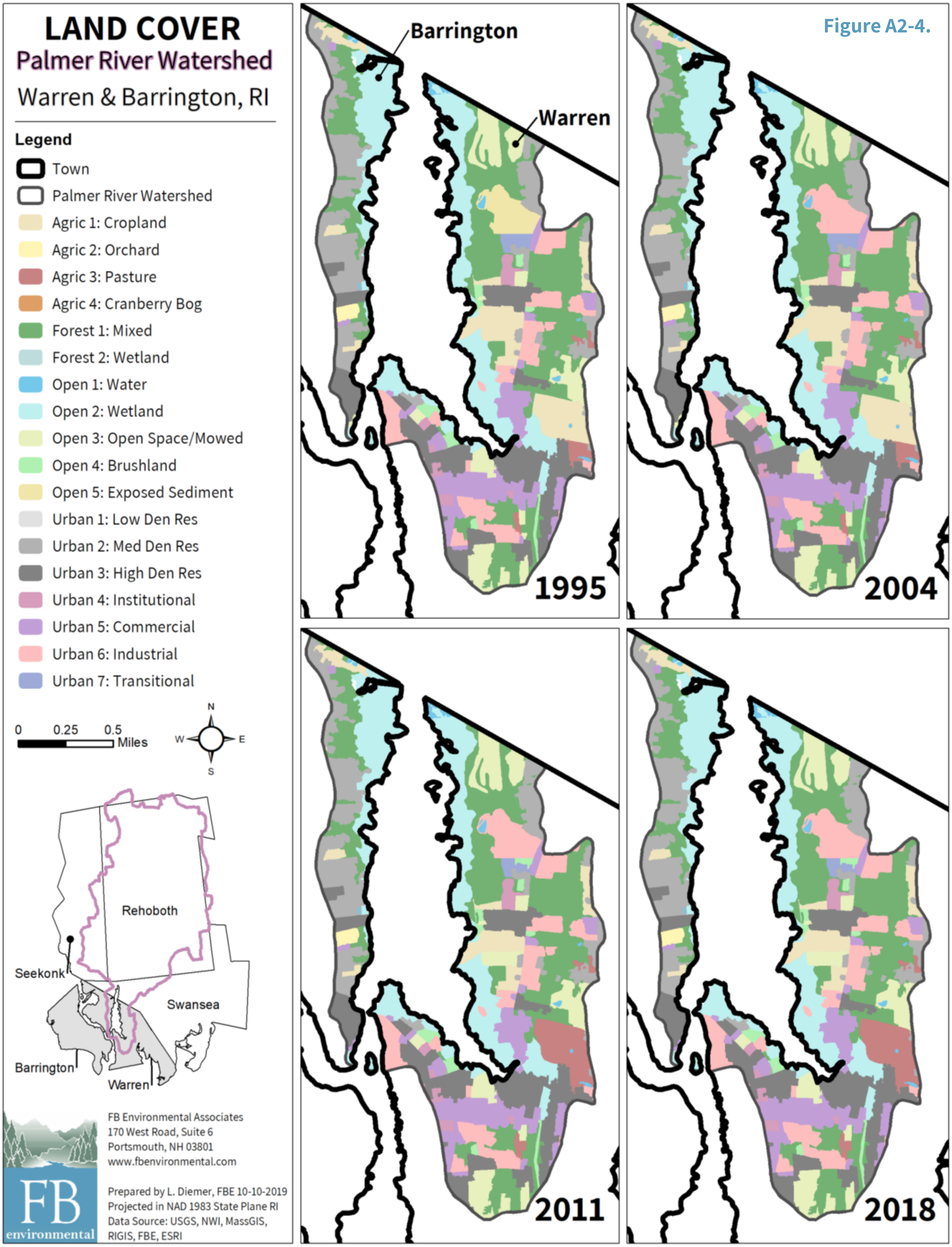
LAND COVER
Palmer River Watershed
Warren & Barrington, RI
Legend
Town
Palmer River Watershed
Agric 1: Cropland
Agric 2: Orchard
Agric 3: Pasture
Agric 4: Cranberry Bog
Forest 1: Mixed
Forest 2: Wetland
Open 1: Water
Open 2: Wetland
Open 3: Open Space/Mowed
Open 4: Brushland
Open 5: Exposed Sediment
Urban 1: Low Den Res
Urban 2: Med Den Res
Urban 3: High Den Res
Urban 4: Institutional
Urban 5: Commercial
Urban 6: Industrial
Urban 7: Transitional
0 0.25 0.5 Miles
N
W
E
S
Rehoboth
Seekonk
Swansea
Barrington
Warren
FB
environmental
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 10-10-2019
Projected in NAD 1983 State Plane RI
Data Source: USGS, NWI, MassGIS, RIGIS, FBE, ESRI
Barrington
Warren
1995
2004
2011
2018

Figure A2-4.

APPENDIX 3

Area (acres) by land use type in 1995, 2001, 2004, 2011, 2015, and 2018 and total area (acres) change in land use type from 1995-2001, 2001-2004, 2004-2011, 2011-2015, and 2015-2018 for five towns in the Palmer River watershed. For change in land use area: positive values (blue) represent land use area gain; negative values (red) represent land use area loss; zero values (black) represent no land use area change.

		Land Use Area (Acres)						Change in Land Use Area (Acres)				
Final Land use Category	**Town**	**1995**	**2001**	**2004**	**2011**	**2015**	**2018**	**1995-2001**	**2001-2004**	**2004-2011**	**2011-2015**	**2015-2018**
Agric 1: Cropland	Rehoboth	1641.0	1578.4	1498.7	1462.9	1458.8	1425.2	-62.5	-79.8	-35.8	-4.2	-33.5
Agric 2: Orchard	Rehoboth	10.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0
Agric 3: Pasture	Rehoboth	919.8	949.1	960.1	952.5	948.5	986.6	29.3	11.0	-7.6	-4.0	38.1
Agric 4: Cranberry Bog	Rehoboth	5.5	25.3	25.3	25.3	34.0	34.0	19.8	0.0	0.0	8.7	0.0
Forest 1: Mixed	Rehoboth	13142.2	12820.0	12720.9	12676.9	12643.3	12605.6	-322.2	-99.1	-44.1	-33.6	-37.7
Forest 2: Wetland	Rehoboth	4767.3	4768.5	4768.4	4768.4	4765.5	4765.2	1.1	0.0	0.0	-3.0	-0.2
Open 1: Water	Rehoboth	331.5	334.6	337.4	342.7	342.7	342.7	3.2	2.8	5.3	0.0	0.0
Open 2: Wetland	Rehoboth	676.0	676.0	676.0	676.0	676.0	676.0	0.0	0.0	0.0	0.0	0.0
Open 3: Open Space/Mowed	Rehoboth	843.1	868.5	899.6	906.3	906.3	894.6	25.4	31.1	6.7	0.0	-11.7
Open 4: Brushland	Rehoboth	140.0	155.9	152.9	157.3	157.3	157.3	16.0	-3.0	4.4	0.0	0.0
Open 5: Exposed Sediment	Rehoboth	2.8	0.0	0.0	0.0	31.3	0.1	-2.8	0.0	0.0	31.3	-31.2
Urban 1: Low Den Res	Rehoboth	3221.0	3491.3	3596.1	3642.5	3655.1	3714.1	270.3	104.8	46.4	12.6	59.0
Urban 2: Med Den Res	Rehoboth	13.5	13.5	13.5	31.9	31.9	31.9	0.0	0.0	18.4	0.0	0.0
Urban 3: High Den Res	Rehoboth	146.6	150.5	151.3	151.3	151.3	151.3	3.9	0.8	0.0	0.0	0.0
Urban 4: Institutional	Rehoboth	83.8	90.1	90.1	88.3	88.3	88.3	6.3	0.0	-1.8	0.0	0.0
Urban 5: Commercial	Rehoboth	191.6	191.7	191.6	202.9	202.9	202.9	0.0	0.0	11.2	0.0	0.0
Urban 6: Industrial	Rehoboth	51.1	57.3	51.1	51.1	56.8	74.2	6.2	-6.2	0.0	5.7	17.4
Urban 7: Transitional	Rehoboth	72.2	78.4	115.8	112.6	99.0	99.0	6.3	37.4	-3.2	-13.6	0.0
Agric 1: Cropland	Seekonk	313.3	308.3	308.3	308.3	308.3	304.6	-5.0	0.0	0.0	0.0	-3.7
Agric 2: Orchard	Seekonk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3: Pasture	Seekonk	64.9	64.6	64.9	64.9	64.9	64.8	-0.3	0.2	0.0	0.0	-0.1
Agric 4: Cranberry Bog	Seekonk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1: Mixed	Seekonk	965.4	961.3	961.4	961.4	961.4	961.4	-4.1	0.1	0.0	0.0	0.0
Forest 2: Wetland	Seekonk	281.3	281.3	281.3	281.3	281.3	281.3	0.0	0.0	0.0	0.0	0.0
Open 1: Water	Seekonk	13.4	13.4	13.4	13.4	13.4	13.4	0.0	0.0	0.0	0.0	0.0
Open 2: Wetland	Seekonk	101.3	101.3	101.3	101.3	101.3	101.3	0.0	0.0	0.0	0.0	0.0
Open 3: Open Space/Mowed	Seekonk	36.5	40.5	40.5	40.5	40.5	30.3	4.0	0.0	0.0	0.0	-10.2
Open 4: Brushland	Seekonk	27.3	27.5	27.3	27.3	27.3	27.3	0.2	-0.2	0.0	0.0	0.0
Open 5: Exposed Sediment	Seekonk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 1: Low Den Res	Seekonk	440.1	445.0	445.0	445.0	445.0	446.3	4.9	0.0	0.0	0.0	1.2

		Land Use Area (Acres)						Change in Land Use Area (Acres)				
Final Land use Category	**Town**	**1995**	**2001**	**2004**	**2011**	**2015**	**2018**	**1995-2001**	**2001-2004**	**2004-2011**	**2011-2015**	**2015-2018**
Urban 2: Med Den Res	Seekonk	78.0	78.0	78.0	78.0	78.0	78.0	0.0	0.0	0.0	0.0	0.0
Urban 3: High Den Res	Seekonk	140.6	140.6	140.6	140.6	140.6	140.6	0.0	0.0	0.0	0.0	0.0
Urban 4: Institutional	Seekonk	23.7	23.7	23.7	23.7	23.7	23.7	0.0	0.0	0.0	0.0	0.0
Urban 5: Commercial	Seekonk	152.2	152.2	152.2	152.2	152.2	165.0	0.0	0.0	0.0	0.0	12.8
Urban 6: Industrial	Seekonk	31.6	31.6	31.6	31.6	31.6	31.6	0.0	0.0	0.0	0.0	0.0
Urban 7: Transitional	Seekonk	5.1	5.1	5.1	5.1	5.1	5.1	0.0	0.0	0.0	0.0	0.0
Agric 1: Cropland	Swansea	83.0	83.0	83.0	83.0	83.0	75.3	0.0	0.0	0.0	0.0	-7.7
Agric 2: Orchard	Swansea	2.4	2.4	2.4	2.4	2.4	2.4	0.0	0.0	0.0	0.0	0.0
Agric 3: Pasture	Swansea	5.0	5.0	1.0	1.0	1.0	8.7	0.0	-4.0	0.0	0.0	7.7
Agric 4: Cranberry Bog	Swansea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1: Mixed	Swansea	495.2	490.7	490.9	486.6	483.6	472.8	-4.4	0.1	-4.2	-3.1	-10.8
Forest 2: Wetland	Swansea	117.7	117.6	117.7	117.7	117.7	117.7	0.0	0.0	0.0	0.0	0.0
Open 1: Water	Swansea	62.8	62.8	62.8	62.8	62.8	62.8	0.0	0.0	0.0	0.0	0.0
Open 2: Wetland	Swansea	148.3	148.3	148.3	148.3	148.3	148.3	0.0	0.0	0.0	0.0	-0.1
Open 3: Open Space/Mowed	Swansea	160.5	160.5	160.5	160.5	160.5	160.5	0.0	0.0	0.0	0.0	0.0
Open 4: Brushland	Swansea	26.3	26.3	26.5	26.5	26.5	26.5	0.0	0.2	0.0	0.0	0.0
Open 5: Exposed Sediment	Swansea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 1: Low Den Res	Swansea	177.5	177.5	177.5	177.5	180.5	191.4	0.0	0.0	0.0	3.1	10.8
Urban 2: Med Den Res	Swansea	28.1	28.1	28.1	28.1	28.1	28.1	0.0	0.0	0.0	0.0	0.0
Urban 3: High Den Res	Swansea	3.9	3.9	3.9	3.9	3.9	3.9	0.0	0.0	0.0	0.0	0.0
Urban 4: Institutional	Swansea	3.7	3.7	3.7	3.7	3.7	3.7	0.0	0.0	0.0	0.0	0.0
Urban 5: Commercial	Swansea	132.4	136.7	140.5	140.5	140.5	140.5	4.3	3.8	0.0	0.0	0.0
Urban 6: Industrial	Swansea	8.0	8.0	8.0	12.2	12.2	12.2	0.0	0.0	4.2	0.0	0.0
Urban 7: Transitional	Swansea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 1: Cropland	Warren	84.6	84.6	84.6	39.5	39.5	39.5	0.0	0.0	-45.1	0.0	0.0
Agric 2: Orchard	Warren	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3: Pasture	Warren	12.1	12.1	12.1	49.4	49.4	49.4	0.0	0.0	37.3	0.0	0.0
Agric 4: Cranberry Bog	Warren	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1: Mixed	Warren	240.0	240.0	240.0	234.9	234.9	234.9	0.0	0.0	-5.0	0.0	0.0
Forest 2: Wetland	Warren	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 1: Water	Warren	6.5	6.5	6.5	6.5	6.5	6.5	0.0	0.0	0.0	0.0	0.0
Open 2: Wetland	Warren	189.7	189.7	189.6	189.5	189.5	189.5	0.0	0.0	-0.1	0.0	0.0
Open 3: Open Space/Mowed	Warren	90.8	90.8	90.8	101.9	101.9	101.9	0.0	0.0	11.1	0.0	0.0
Open 4: Brushland	Warren	17.0	17.0	17.0	18.5	18.5	18.5	0.0	0.0	1.5	0.0	0.0
Open 5: Exposed Sediment	Warren	32.2	32.2	0.0	0.0	0.0	0.0	0.0	-32.2	0.0	0.0	0.0

		Land Use Area (Acres)						Change in Land Use Area (Acres)				
Final Land use Category	**Town**	**1995**	**2001**	**2004**	**2011**	**2015**	**2018**	**1995-2001**	**2001-2004**	**2004-2011**	**2011-2015**	**2015-2018**
Urban 1: Low Den Res	Warren	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 2: Med Den Res	Warren	54.7	54.7	54.7	56.2	56.2	56.2	0.0	0.0	1.5	0.0	0.0
Urban 3: High Den Res	Warren	145.7	145.7	145.7	145.9	145.9	145.9	0.0	0.0	0.2	0.0	0.0
Urban 4: Institutional	Warren	16.6	16.6	16.6	16.6	16.6	16.6	0.0	0.0	0.0	0.0	0.0
Urban 5: Commercial	Warren	101.8	101.8	101.8	102.3	102.3	102.3	0.0	0.0	0.5	0.0	0.0
Urban 6: Industrial	Warren	94.0	94.0	126.1	126.6	126.6	126.6	0.0	32.2	0.5	0.0	0.0
Urban 7: Transitional	Warren	7.8	7.8	7.8	5.5	5.5	5.5	0.0	0.0	-2.2	0.0	0.0
Agric 1: Cropland	Barrington	15.5	15.4	15.5	15.4	15.4	15.4	0.0	0.0	-0.1	0.0	0.0
Agric 2: Orchard	Barrington	6.0	6.0	6.0	5.9	5.9	5.9	0.0	0.0	-0.1	0.0	0.0
Agric 3: Pasture	Barrington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4: Cranberry Bog	Barrington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest 1: Mixed	Barrington	58.9	58.9	58.9	56.2	56.2	56.2	0.0	0.0	-2.6	0.0	0.0
Forest 2: Wetland	Barrington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 1: Water	Barrington	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Open 2: Wetland	Barrington	89.8	89.8	89.8	89.9	89.9	89.9	0.0	0.0	0.1	0.0	0.0
Open 3: Open Space/Mowed	Barrington	1.6	1.6	1.6	0.2	0.2	0.2	0.0	0.0	-1.4	0.0	0.0
Open 4: Brushland	Barrington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 5: Exposed Sediment	Barrington	1.2	1.2	1.2	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0
Urban 1: Low Den Res	Barrington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 2: Med Den Res	Barrington	118.4	118.4	118.4	121.1	121.1	121.1	0.0	0.0	2.7	0.0	0.0
Urban 3: High Den Res	Barrington	32.0	32.0	32.0	32.1	32.1	32.1	0.0	0.0	0.1	0.0	0.0
Urban 4: Institutional	Barrington	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Urban 5: Commercial	Barrington	2.3	2.3	2.3	3.8	3.8	3.8	0.0	0.0	1.5	0.0	0.0
Urban 6: Industrial	Barrington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 7: Transitional	Barrington	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX 4

Representative aerial depictions of change in land use from 1995-2018 for five towns in the Palmer River watershed.

Figure A4-1. Example of land use change over time in the Palmer River watershed (**Rehoboth, MA**). From 1995-2001, forest and cropland were converted to residential development, which further developed and expanded to agricultural land to the south by 2006 and 2018.

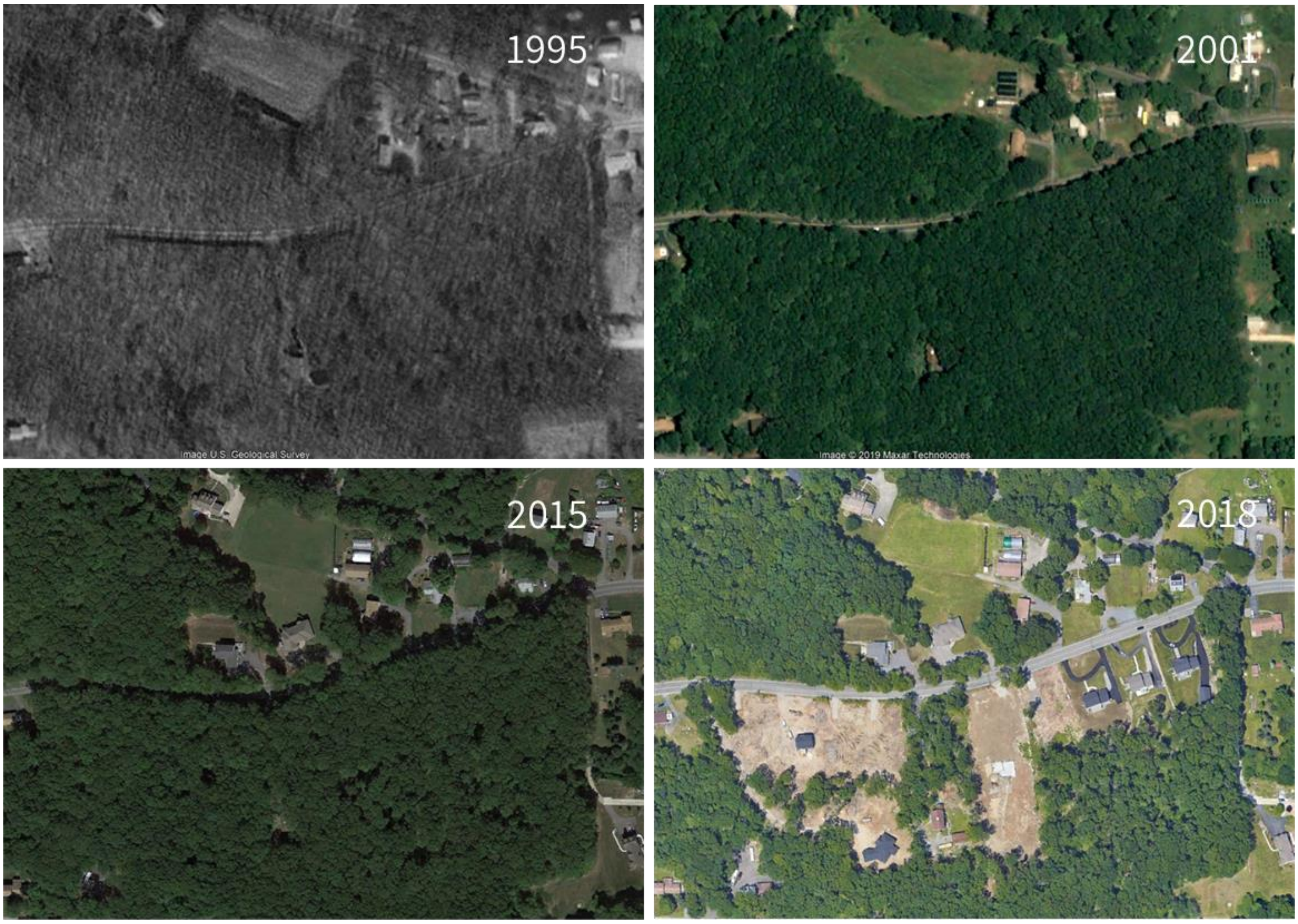

Figure A4-2. Example of land use change over time in the Palmer River watershed (**Seekonk, MA**). Most development occurred between 1995-2001 and 2015-2018, during which forest and cropland were converted to residential development.

Figure A4-3. Example of land use change over time in the Palmer River watershed (**Swansea, MA**). Cropland, pasture, and forest were converted to largely commercial development at a steady pace from 1995-2018, with an increase in the rate of development from 2015-2018.

Figure A4-4. Example of land use change over time in the Palmer River watershed (**Warren, RI**). From 2004-2011, cropland and forest were converted largely to medium density residential, commercial, and industrial development.

Figure A4-5. Example of land use change over time in the Palmer River watershed (**Barrington, RI**). From 2004-2011, forest and recreation land were converted to medium density residential and commercial development.