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The Impacts of Land Use and Development Patterns on Water Quality of the Belgrade Lakes

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EXECUTIVE SUMMARY

The purpose of this study was to assess the impacts of patterns of land use and development on water quality in the Belgrade Lakes on a regional scale. Regional research and cooperation could identify key areas in the watershed where development or changing land use could have the greatest negative influences on lake water quality. Past work has centered on water chemistry, nutrient dynamics, development and economic factors, but there has been no comprehensive analysis of land use and development history for the entire Belgrade Lakes Region. The Belgrade Lakes are a chain of 7 lakes in central Maine connected by a complex system of streams and wetlands. Existing research on the Belgrade Lakes has focused on individual lakes and watersheds, but due to the interconnectivity of the system, limiting nutrients such as phosphorus (P) have the ability to be transported from one lake to another throughout the chain. The total phosphorus concentration in lakes is a particularly important water quality parameter because it can be a direct cause of algal blooms. Algal blooms threaten lake ecosystems and can result in dissolved oxygen depletion, fish kills, reduced water clarity, foul odors and declines in aquatic plants.

A Geographic Information System (GIS) was used to classify and quantify land use, identify spatial patterns of development and predict areas in the watershed most likely to be developed in the future. Analyses of current watershed development and projections for residential development in 2020, 2035 and 2050 were made using town records and demographic statistics. These projections were used to model the current phosphorus budget and the additional phosphorus load from future development. Cropland, residential land and roads currently contribute a disproportionate 55% of the total external phosphorus load despite covering approximately 11% of the watershed land area.

Residential development is expected to increase by 1,327 units by 2050, which would increase the overall external phosphorus load into the lake system. Currently, approximately 1,811 kg P/yr are inputted to the Belgrade Lakes system from shoreline and non-shoreline residential development combined. By 2050, this could increase to 2,285 kg P/yr if mitigation procedures are not put into place. Moderate increases in total phosphorus concentrations of approximately 1 ppb are expected in Great Pond and Long Pond and

relatively small increases are expected in East Pond and North Pond due to stagnating local populations in the Towns of Smithfield and Mercer. The largest projected increases are in Salmon Lake/McGrath Pond and Messalonskee Lake at approximately 2.3 ppb by 2050. These high expected changes can be attributed to the central location of the Town of Belgrade among several of the lakes and its relative proximity to job centers such as Augusta and Waterville. The Town of Sidney is the fastest growing town in the region and is located directly between Augusta and Waterville, so future development in the Messalonskee Lake watershed will likely be the highest in the Belgrade Lakes watershed. Although some increases are more dramatic than others, all projected phosphorus concentrations are near or within the range necessary for algal blooms in Maine (12 - 15 ppb or higher), except Long Pond.

This study has implications for responsible land use management and development planning that could be combined with existing knowledge of nutrient dynamics to minimize phosphorus loading from future development and reduce loading from existing forms of development. Recommendations were included to assist local municipalities in improving lake water quality in the face of increasing development. Private dirt roads and residences are two areas where local property owners have the greatest ability to reduce phosphorus loading. Routine road maintenance and shoreline buffers consisting of native vegetation are two relatively simple methods of reducing areas of exposed soil and erosion that lead to phosphorus loading. Towns should develop plans to update grandfathered septic systems, especially along the shoreline, to reduce phosphorus loading from existing sources. Additional research is also necessary to examine the regional effects of development in one part of the Belgrade Lakes watershed on another.

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Bureau of Land and Water Quality. The mission of the Lakes Assessment Program is "to promote the protection of Maine's lakes through research, collection and management of sound scientific data, identification of threats to lake ecosystems and dissemination of information to those concerned with lake water quality" (MDEP 2005). Lake monitoring primarily includes research by MDEP personnel, but data gathered by the University of Maine at Orono (UMO), the Colby Environmental Assessment Team (CEAT) and the Volunteer Lake Monitoring Program (VLMP) have also made important contributions.

The VLMP is one of the oldest and largest citizen-based lake monitoring programs in the country. Its mission is to train citizen scientists and local volunteers to protect Maine's lakes by raising awareness and collecting relevant water quality data (Maine Volunteer Lake Monitoring Program 2009). Water quality data for Maine lakes are catalogued and made publicly available through Maine PEARL, an online database associated with the Senator George J. Mitchell Center for Environmental and Watershed Research at the University of Maine. For over 30 years, MDEP has assessed various water quality parameters in over 1000 lakes in Maine. In addition, MDEP conducts assessments on invasive plants, algal growth and blooms and the viability of biomanipulation strategies. UMO and CEAT have also collaborated with MDEP for specific projects (MDEP 2005). UMO has also conducted significant lake research on a variety of related topics including water chemistry, land use, fish species, nutrient cycling and economics.

Maine DEP classifies lakes in five major categories under Section 305(b) of the Clean Water Act that requires states to submit an Integrated Report on water quality data to the EPA every two years (MDEP 2005). The Integrated Report assesses lakes for their ability to perform five designated use categories: (1) drinking water, (2) aquatic life support, (3) fishing, (4) recreation and (5) navigation, hydropower, agriculture and industry-use (MDEP 2008a). Category 1 lakes meet standards for all uses. Category 2 lakes meet some use standards and have insufficient data for other uses. Category 3 lakes have not been sufficiently studied to determine whether all use standards are attained. Category 4 lakes are classified as waters with impaired use and have completed Total Maximum Daily Load (TMDL) assessments (Category 4-A), unless impairment is not caused by pollution (Category 4-C). Category 4 classification is required under Section 303(d) of the Clean

Water Act. Category 5 lakes are impaired lakes needing completion of TMDLs (MDEP 2008a).

The focus of this study is the Belgrade Lakes of central Maine. The Belgrade Lakes are a system of seven lakes connected by a complex network of streams and wetlands. These lakes include East Pond, Great Pond, Long Pond, McGrath Pond, Messalonskee Lake (Snow Pond), North Pond and Salmon Lake. In this study, Salmon Lake and McGrath Pond were considered together because they are physically connected. The entire Belgrade Lakes watershed spans all or parts of 13 townships including Augusta, Belgrade, Manchester, Mercer, Mt. Vernon, New Sharon, Norridgewock, Oakland, Readfield, Rome, Sidney, Smithfield and Vienna, ME. Because the Belgrade Lakes are interconnected and the watershed spans a high number of municipalities, regional watershed management is both particularly important and challenging.

Relatively little research has been conducted on the Belgrade Lakes specifically. Currently, East Pond and Long Pond are classified under Category 4-A and have EPA-approved TMDLs (MDEP 2001, 2008b). Great Pond, Messalonskee Lake and Salmon Lake are classified under Category 3 (MDEP 2008a), meaning more research is needed to determine their status. At Colby College, the Chemistry department conducted a study on the increasing abundance of *Gloeotrichia echinulata*, a species of algae, in Great Pond and Long Pond (King and Laliberte 2005). Algal growth is a sign of eutrophication (see Background: Trophic Status of Lakes), which is the gradual aging process of lakes by which lakes become more productive over time and move toward eutrophic status as a result of nutrient enrichment (Harper 1992). This study reported the ability of *G. echinulata* to recruit phosphorus from lake bottom sediments that increase phosphorus concentrations in the water column (King and Laliberte 2005). Internal loading of phosphorus in Maine lakes has been a widely studied topic. A study of nutrient dynamics in six Maine lakes analyzed and tested classical and newly proposed models of internal phosphorus loading. One of the six lakes was Salmon Lake, which was found to release phosphorus from bottom sediments in anoxic conditions (Lake et al. 2007). A similar, previous study on the iron-phosphorus relationship in eleven selected Maine lakes found that lakes with high phosphorus concentrations, such as

Salmon Lake, exhibit strong correlations between phosphorus concentrations in the water column and iron concentrations in bottom sediments (Amirbahman et al. 2003).

CEAT has conducted the only specific, in-depth investigations on the relationships between water quality and land use of the Belgrade Lakes (CEAT 1997, 1998, 1999, 2000, 2007, 2008, 2010). Each of these projects, however, focuses on a single lake and its watershed at a time and does not thoroughly address the issue of interconnectivity among the lakes. CEAT is currently in the midst of the first comprehensive regional study of the Belgrade Lakes by measuring phosphorus concentrations at lake inlets and outlets to assess the transfer of phosphorus throughout the chain. Phosphorus is the most potent limiting factor for algal growth in Maine lake ecosystems (Lake et al. 2007). Algae often limit water transparency, produce unpleasant odors and deplete dissolved oxygen when they die and decompose, which sets into motion a number of negative trophic implications including fish kills and declines in aquatic plant populations (Maitland 1990).

Phosphorus models are useful tools in lake management, especially in quantifying phosphorus exports from non-point sources (Reckhow and Chapra 1983). Generally, lake phosphorus models quantify phosphorus inputs based on knowledge of land use in the watershed. Measuring phosphorus loading from specific sites is time-consuming and impractical, so phosphorus models often rely on export coefficients from other studies based on calculated areas of watershed land use types. Determining suitable export coefficients can be difficult, so high, low and best estimates are also commonly used to account for model uncertainty. Coefficients are generally expressed in terms of kg P/area unit of land/yr (Reckhow and Chapra 1983). Model results can be validated through laboratory analyses of phosphorus concentrations in field water samples. For this study, the most relevant export coefficients came from previous CEAT studies on the Belgrade Lakes.

On August 1, 2008, Salmon Lake was discovered by a seasonal resident to contain Eurasian water-milfoil (*Myriophyllum spicatum*), one of Maine's 11 most unwanted invasive plant species (MDEP 2008b). Invasive plants spread rapidly, can crowd out native vegetation, reduce native wildlife populations and hurt recreation and property values. The plant was found in the shallow outlet cove to Great Pond near the public boat access, but since discovery has been confined to the area. Maine DEP put into motion a Rapid Response

Plan involving hand removal, benthic barriers and finally herbicide application on September 10, 2009. Full results of the herbicide application will not be known until spring 2010 (Crosby 2009). Containment of Eurasian water-milfoil is especially critical due to the potential for the plant to spread into Great Pond and possibly into the other lakes. Of the other Belgrade Lakes, variable-leaf milfoil (*Myriophyllum heterophyllum*) is currently found in part of the eastern section of Messalonskee Lake. Of the 5,785 lakes and ponds in Maine, 29 are known to contain invasive plant species (MDEP 2008a). Invasive species are currently one of the most critical issues facing the Belgrade Lakes.

In September 2009, the environmental consulting firm FB Environmental Associates, Inc. conducted a build-out analysis for the Great Pond and Long Pond watersheds that predicted future watershed development and the added phosphorus load in 2025, 2050 and 2075 (FB Environmental Associates 2009). This project is the only build-out model constructed for any part of the Belgrade Lakes region. Few build-out models have been created for rural areas such as the Belgrade Lakes. The findings and methodology have been useful for this study. This study also produced phosphorus budget models for Great Pond and Long Pond based on data provided by CEAT at current conditions and different scenarios of future development.

The purpose of this investigation was to assess the impacts of patterns of land use and development on water quality in the Belgrade Lakes on a regional scale. Past research on the Belgrade Lakes has focused on individual lakes and watersheds, but due to the interconnectivity of the lake system, regional research and cooperation could enhance our knowledge of the system and lake water quality. Nutrients such as phosphorus have the ability to be transported from one lake to another throughout the Belgrade Lakes chain, so it is logical that research and monitoring be conducted on a regional level. Other relevant research has centered on water chemistry, nutrient dynamics and economic factors, but there has been no comprehensive analysis of land use and development history in the Belgrade Lakes Region. The results of this study could be applied toward responsible land use management and development planning and combined with existing knowledge of nutrient dynamics to minimize phosphorus loading from future development and reduce loading from existing forms of development.

DESCRIPTION OF STUDY AREA

The Belgrade Lakes watershed covers an area of 46,676 ha and spans all or parts of 13 townships in three counties in central Maine (Figure 1). A watershed is the area of land, including the lake itself, from which precipitation and runoff drain into the lake (Davis et al. 1978). The watershed includes land in the towns of Augusta, Belgrade, Manchester, Mercer, Mount Vernon, New Sharon, Norridgewock, Oakland, Readfield, Rome, Sidney, Smithfield and Vienna, ME.

The Belgrade Lakes are a chain of seven lakes connected by a complex system of streams and wetlands. The flow begins in two places. Salmon Lake and McGrath Pond flow via Hatchery Brook into one of the inlets to Great Pond, known as Hatch Cove. Great Pond then flows into Long Pond, which subsequently flows into and Messalonskee Lake via the Belgrade Stream. Water then exits the watershed via the Messalonskee Stream before emptying into the Kennebec River. Alternatively, flow also originates in East Pond in the northeast corner of the watershed. East Pond drains into North Pond via the Serpentine, a stream surrounded by a large wetland. North Pond then drains via Great Meadows Stream into the second inlet to Great Pond, from which water then follows a single path through Long Pond to Messalonskee Lake. For the purposes of this study, Salmon Lake and McGrath Pond were considered one lake because they are connected by a free-flowing channel of water.

Though connected as part of a greater watershed, there exist substantial distinctions among the individual Belgrade Lakes in terms of watershed area, mean depth, lake surface area, volume and flushing rate (Table 1). The flushing rate refers to the number of times per year the entire volume of a lake is replaced, through precipitation, groundwater, runoff and inlet flow (Chapman 1992). North Pond and East Pond are the shallowest lakes in the system and feature rounded basins. Flushing rate is related to basin shape. Rounded basins often result in lower flushing rates, such as with East Pond (0.29 flushes/yr). North Pond exhibits a much higher flushing rate (1.36 flushes/yr) than East Pond, but is considerably shallower and contains a lower volume of water. Elongated basins, such as those of Long Pond and Messalonskee Lake, typically exhibit faster flushing rates than rounded basins (Chapman 1992).

Table 1. General Characteristics of the Belgrade Lakes

Lake	Watershed Area (ha)	Lake Surface Area (ha)	Mean Depth (m)	Volume (m^3)	Flushing rate (flushes/yr)
East Pond	1,060	677	5.48	33,848,120	0.29
Great Pond	21,471	3,313	6.40	209,160,000	0.52
Long Pond	6,232	1,043	10.67	81,113,391	3.70
Messalonskee	12,508	1,419	10.06	150,249,096	1.59
North Pond	3,092	912	3.96	37,148,856	1.36
Salmon/ McGrath	2,313	466	6.10	28,410,750	0.58

Source: CEAT 1997, 1998, 1999, 2000 2007, 2008, 2010

The Belgrade Lakes are a valuable resource for local residents and tourists. The Belgrade Lakes Region plays host to a variety of recreational activities including boating, fishing, hiking and golf. A number of commercial camps also conducts business along the lakeshores. Recreation and increasing development, however, could potentially threaten the water quality of the Belgrade Lakes. Management of water quality and land use is especially challenging in such a large watershed spanning 13 towns. Cooperation is difficult and many residents do not understand the interconnectedness of the lake system, though this very interconnectedness is what makes regional research and cooperation important.

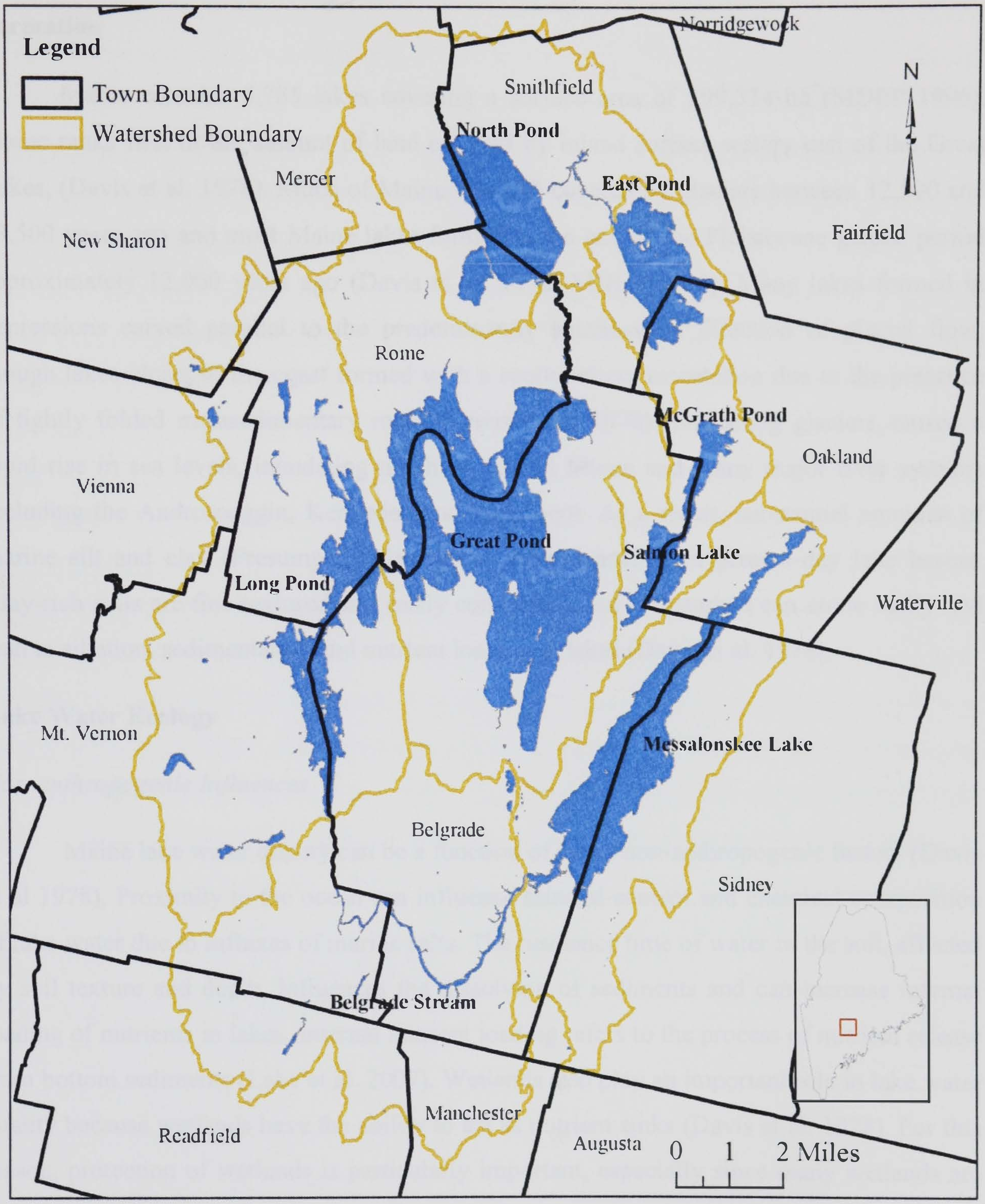

Figure 1. The Belgrade Lakes watershed

BACKGROUND

Formation

Maine contains 5,785 lakes covering a surface area of 399,334 ha (MDEP 1996). Maine ranks first in the amount of land covered by inland surface waters east of the Great Lakes, (Davis et al. 1978). Much of Maine was still covered by glaciers between 12,500 and 13,500 years ago and most Maine lakes formed at the end of the Pleistocene glacial period approximately 12,000 years ago (Davis et al. 1978, MDEP 1996). Many lakes formed in depressions carved parallel to the predominantly southeastern direction of glacial flow, though lakes closer to the coast formed with a southwestern orientation due to the presence of tightly folded metasedimentary rocks (Davis et al. 1978). Retreating glaciers caused a rapid rise in sea levels, inundating much of coastal Maine and many major river systems including the Androscoggin, Kennebec and Penobscot. As a result, substantial amounts of marine silt and clay (Presumpscot formation) were deposited in present-day lake basins. Clay-rich soils are fine-textured and easily compacted, but if disturbed can erode easily and lead to siltation, sedimentation and nutrient loading in lakes (Davis et al. 1978).

Lake Water Ecology

Non-anthropogenic Influences

Maine lake water quality can be a function of many non-anthropogenic factors (Davis et al 1978). Proximity to the ocean can influence mineral content and chemical composition of lake water due to influxes of marine salts. The residence time of water in the soil, affected by soil texture and depth, influences the dissolving of sediments and can increase internal loading of nutrients in lakes. Internal nutrient loading refers to the process of nutrient release from bottom sediments (Lake et al. 2007). Wetlands also play an important role in lake water quality because wetlands have the ability to act as nutrient sinks (Davis et al. 1978). For this reason, protection of wetlands is particularly important, especially since many wetlands are located near lake inlets and generally comprise a small portion of land cover in lake watersheds. Bedrock chemistry, however, is the most important non-anthropogenic factor in the determination of lake water quality due to its strong influence on internal nutrient loading, pH and alkalinity. The composition of dissolved solids generally reflects the

characteristics of its bedrock, which in Maine, consist of metasedimentary granite (Davis et al. 1978).

Thermal Stratification

An important characteristic of lakes in Maine is stratification and turnover according to season and lake bathymetry (Davis et al. 1978). In summer, deeper lakes stratify into layers based on water temperature and density. Water is most dense at 4° C and during seasons of stratification, water at this density is found at the lowest depths of lakes. The uppermost layer is called the epilimnion and extends to the depth at which light can no longer reach. Photosynthesis and most of the productivity of the lake occurs in the epilimnion (Maitland 1990). Below the epilimnion is the metalimnion. At this depth, temperature drops substantially and continues to fall with decreasing depth. Metalimnion depth is highly variable in Maine and can range from 3 -11 m. This point in the water column where temperature abruptly declines is called the thermocline. The thermocline separates the metalimnion and the hypolimnion, located at the bottom of only the deepest lakes. A hypolimnion generally does not exist in lakes shallower than 10 m, though the hypolimnion can begin at shallower depths based on the geology of the lake basin. Photosynthesis does not occur in the hypolimnion, but instead the hypolimnion serves as the location for organic decomposition by aerobic and anaerobic bacteria (Davis et al. 1978). Some shallow lakes can also stratify for a few days or a week in summer until weather causes mixing to occur (Firmage, pers. comm.).

In fall when air temperatures decrease, wind and declining water temperatures mix and de-stratify the water column (Davis et al. 1978). The result is uniform water temperature and density throughout the water column, a phenomenon called seasonal turnover that in Maine typically occurs in October or November. During fall overturn, nutrients are cycled throughout the water column and can lead to algal blooms high in the water column. Fall overturn generally lasts 1 - 2 months and ends when surface water freezes in winter. In winter, cold temperatures compact and increase the density of lake water which facilitates another seasonal phase of lake stratification. High density 4° C water sinks to the bottom of lakes and separates the ice layer with a narrow thermocline (Maitland 1990).

Winter stratification may last 4 - 6 months and generally ends in late April, May or early June with the melting of the ice layer and spring turnover (Davis et al. 1978). Spring turnover is similar to fall turnover and results in a mixing of the water column and thermal uniformity, though algal blooms are less frequent (Harper 1992). Solar radiation warms the upper portion of the water column and eventually reforms the thermal stratification characteristic of lakes in the summer (Davis et al. 1978).

Phosphorus Cycling

Of the nutrients present in Maine lakes, phosphorus is the most potent limiting factor for primary productivity (Lake et al. 2007) and has been shown to enter lakes via non-point sources, particularly agricultural, commercial or residential development (Meals et al. 2008). Phosphorus significantly affects the growth of algae in lake ecosystems. Algal blooms reduce water transparency, restricting light penetration through the water column and the growth of native aquatic plants. In Maine, an algal bloom by definition occurs when water transparency is less than 2 m. Additionally, algae produce unpleasant odors when they die and undergo decomposition by bacteria, a process that depletes dissolved oxygen (DO) (MDEP 2005). Phosphorus concentrations in the water column have been associated with seasonal anoxic conditions (DO < 1 ppm) that generally occur in the deepest portions of lakes where mixing of the water column does not occur (Lake et al. 2007). Anoxia can also occur in shallow lakes during brief periods of stratification in summer (Firmage, pers. comm.). Anoxia can result in fish kills, reducing the value of lakes for sport fishermen as well as the presence of important top predators in lake ecosystems. Larger, cold-water fish, such as salmonids, are often replaced by smaller species, such as cyprinids, tolerant of both higher temperatures and lower dissolved oxygen (Harper 1992). Anoxia also has a substantial impact on internal nutrient loading. The lack of dissolved oxygen results in the reduction of iron (III) hydroxide to iron (II) hydroxide (ferric hydroxide). Iron (III) hydroxide naturally binds to inorganic phosphates, but the reduction to iron (II) hydroxide releases and makes available phosphorus in the water column. Bottom sediments contain 50 - 500 times more phosphorus than the concentration in the water column (Henderson-Sellers and Markland 1987), so anoxia is an important predictor of elevated phosphorus levels and eventually algal growth. As a result of mixing of the water column in the fall, phosphorus released by bottom sediments can be

transported throughout the water column and contribute to algal growth in the epilimnion (Harper 1992) where there is sufficient light present to permit plant production. In Maine lakes, a phosphorus concentration of 12 - 15 ppb is sufficiently high for algal blooms to occur (Bouchard, pers. comm.).

Trophic Status of Lakes

Phosphorus concentrations are directly related to the trophic status of Maine lakes (Davis et al. 1978). The trophic status of a lake refers to the level of productivity of a lake ecosystem. The trophic status of a lake is classified as oligotrophic, mesotrophic, eutrophic or dystrophic (Table 2). Eutrophication is the gradual aging process of lakes by which lakes become more productive over time as a result of nutrient enrichment. Newly formed lakes are classified as oligotrophic and are oxygen-rich, nutrient-poor and feature high water transparency. Oligotrophic lakes are usually deeper, steep-sided and have a low surface area to volume ratio. All of these factors create conditions under which the level of primary productivity cannot support particularly complex ecosystems. Over time, lakes become more eutrophic, experiencing more abundant nutrients and oxygen depletion at the bottom (Harper 1992). The extent of oxygen depletion in the hypolimnion is directly related to the release of nutrients and productivity of a lake ecosystem (Maitland 1990). Mesotrophic lakes are in an intermediate stage between oligotrophic and eutrophic status. Eutrophic lakes are high in nutrients and suspended solids and tend to be shallow and bowl-shaped, facilitating increased growth of aquatic plants and phytoplankton. Eutrophic lakes can experience algal blooms, turning water green or yellow. Dystrophic lakes are small and shallow with lower water quality than eutrophic lakes. They experience lower productivity, species diversity and water transparency (Maitland 1990).

Though eutrophication is a natural process, eutrophication can be accelerated by human activities. This process is called cultural eutrophication and is the result of increased nutrient enrichment from anthropogenic sources such as agricultural, industrial, commercial or residential development that increase surface runoff, erosion and nutrient loading (Harper 1992). Eutrophication can have a number of negative impacts on lake ecosystems. An increase in plant productivity as a result of eutrophication inevitability results in an increase in decomposition. Decomposition is performed at the bottom of the water column by bacteria

that deplete oxygen during respiration that can result in the release of nutrients such as phosphorus from bottom sediments that may cause algal blooms during fall turnover (Harper 1992). Reduced oxygen and increased algal growth can diminish fish populations and the aesthetic value of lakes by creating foul odors and unsightly green, turbid water. As a result, algal blooms can have negative ecological and economic impacts.

Table 2. Description of Trophic States of Maine Lakes

Characteristic	Oligotrophic	Mesotrophic	Eutrophic
Basin shape	Narrow and deep	Moderately round and deep	Broad and shallow
Shoreline	Stony	Variable	Weedy
Water clarity	High	Moderate	Low
Water color	Green or blue	Green or blue	Green or yellow
Dissolved solids	Low, especially in N	Moderate in N, P	High, especially in N, Ca, P
Suspended solids	Low	Moderate	High
Dissolved oxygen	High	High, except at bottom	High at surface only
Phytoplankton	High diversity, low populations	Moderate diversity and population size	Low diversity, high populations
Macrophytes	Low diversity in deep water	Moderate diversity in shallow water	High diversity in shallow water
Zooplankton	High diversity, low populations	Moderate diversity and population size	Low diversity, high populations
Zoobenthos	High diversity, low populations	Moderate diversity and population size	Low diversity, high populations
Fish	Low diversity: salmon, trout	Moderate diversity, few large species	High diversity, especially minnows

Source: Maitland 1990, CEAT 2008, 2009

Human Dimensions

Population

An important consideration in water quality monitoring is the number of people living in a watershed. Humans use lake water for a variety of purposes including agriculture, commerce, and residential use (Maitland 1990). Conversion of forests to agricultural, commercial or residential development increases the area of impervious surface in a watershed. This increases surface runoff and erosion and reduces the natural ability of the environment to capture or filter out runoff and erosion (Smith et al. 1999). Humans also generate a great deal of wastewater that if not treated properly can negatively impact lake water quality in the form of nutrient loading. Higher watershed populations generate more wastewater and develop a higher proportion of a watershed than lower populations (Harper 1992).

Determination of an exact resident population in the watershed is difficult. First, census data is available by town only and many town boundaries only partially overlap with the Belgrade Lakes watershed. Second, a key characteristic of the region is the influx of seasonal residents during the summer months. Seasonal residency varies by area, but it has been estimated that the watershed population can double or triple in size between Memorial Day and Labor Day (Kallin, pers. comm.). Basic population data for the region through the year 2000 (Table 3) was obtained online from the University of Maine census database (Maine Census Data 2009). It should be noted that town population information is information for the entire town and that only Belgrade is completely within the Belgrade Lakes watershed (Rome is not completely in the watershed, but the entire developed portion is). More specific information such as median age (Table 4), mean persons per household (Table 5) and estimates of seasonal residency (Table 6) were obtained online from the Kennebec Valley Council of Governments (KVCOG) (KVVOG 2009). These data are important in understanding some of the demographic factors in future development projections.

Table 3. Historical Populations for Major Towns in the Belgrade Lakes Watershed

Town	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2008 (est)
Belgrade	1058	1037	957	978	1046	1099	1102	1302	2043	2375	2978	3377
Manchester	518	601	485	492	626	664	1068	1331	1949	2099	1465	2544
Mercer	493	441	453	408	381	348	272	313	448	593	647	680
Mt. Vernon	906	898	745	755	653	653	596	1021	1021	1362	1524	1672
Oakland	1913	2257	2473	2664	2730	2679	3075	3535	5162	5595	5959	6389
Readfield	994	996	911	881	986	1022	1029	1258	1943	2033	2360	2550
Rome	420	440	436	398	418	420	367	362	627	758	980	1214
Sidney	1068	927	958	980	989	918	988	1319	2052	2593	3514	4561
Smithfield	449	427	390	374	353	354	382	527	748	865	930	1051

Source: Maine State Planning Office and KVCOG

Table 4. Median Age for Residents of Major Towns in the Belgrade Lakes Watershed

Town	1980	1990	2000
Belgrade	31	35	40
Manchester	33	38	42
Mercer	31	35	42
Mt. Vernon	31	35	40
Oakland	29	33	37
Readfield	30	36	38
Rome	29	37	39
Sidney	38	33	36
Smithfield	28	33	40

Source: KVCOG

Table 5. Mean Persons per Household for Major Towns in the Belgrade Lakes Watershed

Town	1980	1990	2000
Belgrade	2.87	2.67	2.52
Manchester	2.8	2.61	2.52
Mercer	2.99	2.84	2.53
Mt. Vernon	2.63	2.72	2.52
Oakland	2.9	2.7	2.53
Readfield	3.01	2.82	2.72
Rome	2.82	2.7	2.54
Sidney	3.18	2.93	2.66
Smithfield	3.08	2.85	2.5

Source: KVCOG

Table 6. Seasonal Residency Statistics for Major Towns in the Belgrade Lakes Watershed

	Year-round			Seasonal			%Seasonal		
Town	1980	1990	2000	1980	1990	2000	1980	1990	2000
Belgrade	704	891	1178	635	685	774	47.42	41.14	39.65
Manchester	688	804	977	98	163	168	12.47	16.77	14.67
Mercer	150	209	256	93	97	91	38.27	32.33	26.22
Mt. Vernon	388	501	603	281	309	320	42.00	37.64	34.67
Oakland	1783	2089	2352	339	313	317	15.98	13.01	11.88
Readfield	646	722	867	198	238	248	23.46	24.54	22.24
Rome	222	284	386	374	469	538	62.75	57.06	58.23
Sidney	634	888	1314	144	177	166	18.51	16.79	11.22
Smithfield	243	304	372	227	230	218	48.30	44.06	36.95

Source: KVCOG

Regional Economic History

Economic activity in the Belgrade Lakes Region peaked around 1840 (Kallin, pers. comm.). Much of the watershed was used for agriculture, especially small, family-owned farms. These farms produced food during the summer and wool products during the winter, but industrialization eventually crippled local farms in favor of higher-output industry. Large textile mills, particularly in southern New England, could produce much greater yields and eventually pushed smaller producers out of business. Decades later, these textile mills were put out of business by outsourcing overseas. As a result of the decline in agriculture, many lands in the watershed have reverted back to forests. A number of farms still exists in the watershed, but have still been declining in recent years. The population of the Belgrade Lakes Region did not return to 1840 levels until almost the year 2000, though this development had little to do with economic growth in the region. Many of these new residents were retirees, especially people from Massachusetts, New York or New Jersey (Kallin, pers. comm.).

METHODS

Land Use Patterns

Watershed land use was manually digitized into polygons in ArcGIS 9.3 and 9.3.1 from two sets of aerial photographs. Digital orthoquadrangles (DOQ) (ORTHO 1F, ORTHO 2F) were downloaded from the Maine Office of GIS Data Catalog (Data Catalog 2007). These photographs came in 1 x 1 ft and 2 x 2 ft resolution and were taken in early spring 2003. The second set of photographs came from the National Agricultural Imagery Program (NAIP). The NAIP photographs were taken in summer 2007 with a 1 x 1 m resolution. The two sets of photographs were used to cross-reference forest types because coniferous and deciduous canopy cover is difficult to distinguish in summer photographs. When possible, NAIP photographs were used as the primary data source for watershed land use because they are the more recent photographs.

Land use was digitized in 24 categories and assembled into a composite shapefile for the entire Belgrade Lakes watershed. The layer was projected in NAD 1983 UTM Zone 19N. Land use definitions were derived from recent CEAT studies (CEAT 2007, 2008, 2010)

Forest: land that is at least one acre in area and covered by at least 50% trees.

- Coniferous forest: one acre or more of land consisting of at least 50% coverage of evergreen trees.
- Mixed forest: one acre or more of land characterized by at least 50% heterogeneous coniferous and deciduous tree cover. Canopy is spotty and of mixed coloration on the DOQ.
- Deciduous forest: one acre or more of land consisting of at least 50% coverage of trees less dense than coniferous forest, often with spotty wooded areas on DOQ.

Successional land: land characterized by patchy vegetation of similar or variable height, often located near developed areas and exhibiting signs of previous human impacts.

- Transitional forest: one acre or more of land consisting of at least 50% tree coverage of young and mature stands, often resulting in a patchy, uneven canopy.

- Regenerating land: land with a visible perimeter of previous clear-cutting. Trees are relatively shorter, less dense and less green than forests and are all growing back at the same height.
- Reverting land: land with a visible perimeter of previous human, often agricultural impact. Unlike regenerating land, reverting land encompasses various stages of re-growth, including vegetation of variable height.

Bare ground: area of dirt or gravel and without vegetation, often cleared for development purposes.

Cemetery: open, grassy area with narrow paths and tombstones

Cleared land: open area mostly clear of trees or shrubbery and lacking significant buffering capability. Often trees have been cut for residential development, not commercial logging.

Commercial camp: a seasonally functioning area with many different facilities and recreational uses. Camps have multiple buildings with different uses, such as temporary or seasonal residences. There is usually a network of roads connecting different cottage clusters, buildings and recreational sights. The defined area does not include large sections of forests on camp property.

Commercial/Municipal: all businesses and public facilities, such as shops and schools, designated as the smallest area containing buildings, parking lots and other impervious surfaces. Large cleared or wooded areas within the property were classified under different land use types.

Golf course: area of short-cut, green grass, narrow paths, sand traps and small ponds.

Logging area: area with evidence of clear or selective cutting, often characterized by tree regrowth as a result of cutting, skidmarks and/or trails.

Park: land associated with open grass and potential irregularities in shape. May display access by road and trails throughout, as well as distinguishing features such as sports fields, tracks and parking areas at entrances.

Residential: privately owned land with one residential unit and associated buildings such as a garage or shed. The land use area was designated as the smallest area containing the house, associated buildings, lawns and gardens. Large cleared or wooded areas within the private property were classified under different land use types.

- Non-shoreline residential: residential land not adjacent to the shoreline (more than 250 ft away) and with the same associated structures, except boats and docks.
- Shoreline residential: residential land adjacent to the shoreline and within 250 ft of the shoreline, associated with driveways and related structures (pools, sheds, fences, lawns, docks and boats).

Roads: the polyline layer (e911rds_01022007) downloaded from the Maine Office of GIS was used (Data Catalog 2007).

- Dirt roads: usually made of sand or gravel, more likely to erode and used less (include ditch if applicable). Also known as camp roads.
- Paved roads: concrete, public roads with frequent use, maintained by the municipality (shoulder to shoulder).
- State roads: numbered paved roads with frequent use, maintained by state (shoulder to shoulder).

Roads were reclassified as dirt, paved or state roads based on the aerial photographs. The polyline road layer was then converted to polygon for incorporation in the composite land use layer. Road lengths were known, but to calculate road areas it was necessary to determine the widths of roads in the watershed. Road widths of all three road types were manually measured throughout the watershed. Mean width of dirt roads was measured to be 12.5 ± 5.4 ft (n=10). Mean width of paved roads was measured to be 31.1 ± 10.7 ft (n=15). State roads were measured in multiple places along each road and demonstrated a mean width of 41.1 ± 6.8 ft (n=10). The mean width of each road type was then applied as a buffer using 3D

Analyst (ESRI 2009) to the polylines to create polygons. These polygons were then overlaid onto the composite land use layer and used to clip out land uses with which they overlapped.

Agriculture: land consisting of crop lines or large rectangular fields with farm structures, equipment and livestock on or nearby.

- Cropland/farm: includes land recognizable by exposed dirt with crop lines evident and defined by a rectangular or polygon-shaped perimeter.
- Open field: a clear, uniformly, low-vegetation field with a defined perimeter or possibly a fence enclosing livestock. Adjacent structures may include barns, haystacks, animal shelters and trucks. Also known as pastures.
- Orchard: relatively open field with regularly spaced or grouped, mostly deciduous trees. Trees may be immature or mature.
- Tree farm: relatively open field with regularly spaced or grouped trees. Trees may be immature or mature and are seen as darker areas due to coniferous domination.

Wetland: transitional zones between terrestrial and aquatic ecosystems, low elevation land containing darkened, water-saturated soils.

Development Constraints

The development constraints maps were created to display areas in the Belgrade Lakes watershed available and unavailable for future development. The following were used as development constraints and added to each map: conservation land, inland wading bird and waterfowl habitat (IWWH), a 100 ft buffer around each lake (consistent with Maine resource protection regulations for great ponds), a 75 ft buffer around wetlands and perennial streams (consistent with Maine resource protection regulations), lands with slopes higher than 20% (consistent with Maine resource protection regulations), unbuildable parcels that do not meet minimum lot size standards set by watershed towns or parcels without enough land to be further subdivided (FB Environmental 2009). Layers for conservation land (mecnslnd), IWWH (iwwh), lakes (wqponds), streams (wqstreams), slope (DEM) and roads (e911rds_01022007) were obtained from the Maine Office of GIS (Data Catalog 2007).

Slope data were downloaded in DEM (Digital Elevation Model) format and converted to percentages using Spatial Analyst (ArcGIS Resource Centers 2009). Lakes, streams and roads were buffered using 3D Analyst (ArcGIS Resource Centers 2009). A map of additional conservation lands not included in the mecnslnd layer was obtained from the Belgrade Regional Conservation Alliance (BRCA) and added to the maps (Kallin, pers. comm.). Unbuildable parcels were not included on any of the maps because they were too small to be seen.

Population Trends

Historical population data (Table 3) for the Belgrade Lakes Region were downloaded from the Raymond H. Fogler Library of the University of Maine census database (Maine Census Data 2009). Population figures were obtained for the Towns of Belgrade, Manchester, Mercer, Mt. Vernon, Oakland, Readfield, Sidney and Smithfield, ME for each decade from 1900 to 2000. No data were obtained for the Towns of Augusta, New Sharon, Norridgewock or New Sharon because none of these towns contains significant watershed populations. Current population estimates for each town were obtained online from the Kennebec Valley Council of Governments (KVCOG 2009). KVCOG helps coordinate planning, business and community and economic development for town governments in Kennebec, Somerset and Waldo counties. Profiles were available for each town in the Belgrade Lakes watershed that include statistics on total house counts, seasonal residency, median age and mean persons per household (KVCOG 2009). Future population projections (Table 7) were acquired online from the Maine State Planning Office (SPO) (SPO 2009). The SPO "provides planning assistance, policy development, program management, and technical assistance to build a sustainable future for Maine's communities, businesses, and residents" (SPO 2006). Data were available through 2030 and populations past this date to 2050 were calculated based on a linear rate of change function.

Residential Development Patterns

Information on regional development was obtained from municipal offices in the Belgrade Lakes watershed from summer 2008 to spring 2009. The towns of Augusta and Vienna, ME were not visited because neither town contains developed land in the watershed. Paper tax maps were scanned, projected in NAD 1983 UTM Zone 19N and georeferenced in

ArcGIS 9.3 using the NAIP photographs. Lots were then manually digitized into polygon shapefiles. Development history data were obtained from municipal tax assessment records, which were entered manually into Microsoft Excel and then joined or manually entered to the digitized lot layers. Attributes were added for type of wastewater disposal system, presence of buildings and year of construction. Development patterns were displayed by individual lake watershed using a color gradient to indicate development over time. Lighter-colored lots represent relatively early development and darker-colored lots represent relatively recent development. Vacant lots were displayed in light green. Lots with non-residential structures such as barns and sheds were displayed in gray. Houses of unknown age were displayed in brown. Lots of unknown status were displayed in purple.

Table 7. Projected Populations for Major Towns in the Belgrade Lakes Watershed

Town	2010	2015	2020	2025	2030	2035	2040	2045	2050
Belgrade	3391	3591	3775	3923	4062	4251	4418	4585	4753
Manchester	2631	2703	2759	2786	2807	2868	2911	2955	2998
Mercer	651	650	645	633	620	616	608	600	592
Mt. Vernon	1769	1893	2008	2105	2197	2315	2422	2528	2635
Oakland	6467	6625	6744	6792	6825	6956	7044	7132	7220
Readfield	2721	2898	3063	3199	3328	3496	3648	3799	3951
Rome	1138	1214	1284	1342	1398	1470	1534	1599	1664
Sidney	4368	4793	5204	5568	5923	6337	6725	7114	7502
Smithfield	926	921	909	886	864	854	838	822	806

Source: Maine State Planning Office

Future Development Patterns

Before the location of future development could be identified, it needed to be determined what areas were legally and physically buildable. Buildable lots were defined as lots that met municipal minimum lot standards as well as shore or road frontage standards (variable by town and zone). Development constraints such as wetlands, IWWH, steep grades, streams, great pond setback regulations and conservation lands prohibit development of a lot if minimum lot standards cannot be attained due to the presence of one or more constraints. Lots that do not meet minimum lot size standards for future development due to

one or more constraints were considered unbuildable, while all others were considered buildable. Unbuildable lots, however, can theoretically still be developed if combined with adjacent lots to meet minimum lot size regulations. The number of buildable and unbuildable shoreline and non-shoreline lots was counted for each town in each of the seven watersheds to help determine the extent of future development and the potential build-out date. In addition, the number of shoreline and non-shoreline lots with existing road access was also counted because these lots are more likely to be developed sooner (Bouchard, pers. comm.). Vacant lots on and off the shoreline and the potential number of subdivisions along the shoreline were counted for each lake.

Projected population figures (Table 7) and the linear rate of change of mean persons per household (Table 5) were used to determine the number of housing units expected to be built in each town within each watershed in 2020, 2035 and 2050 to accommodate expected population changes. Population is the key driver of future residential development and is the best indicator of housing demand (Bouchard, pers. comm.). Projections for the number of additional residential units in each town and the growth rate for residential development in each lake watershed were used to predict the extent and location of future residential development. GIS was then used to identify areas in the watershed where future development is most likely to occur (see Methods: Development Likelihood Maps). Projections were calculated for 2020, 2035 and 2050. The growth rates for shoreline and combined shoreline and non-shoreline residential development in each town in each watershed were calculated to determine what proportion of projected residential growth would occur on the shoreline. It was assumed that future shoreline development would occur at the same historical proportion of total development. Growth rates were calculated based on the number of houses built in each decade since 1990 because prior development patterns were thought to have little effect on the current housing market. If projected shoreline development exceeded the number of available lots and potential subdivisions on the shoreline, the remainder of the projected development was allocated to non-shoreline lots. It was acknowledged that future town population projections do not accurately reflect watershed populations since only parts of some towns overlap with watershed boundaries. To compensate for this, it was assumed that the proportion of the total number of houses in a town within a watershed would remain consistent in each future scenario. Future housing projections were rounded to the nearest

whole number. These estimates are based, however, on year-round residents and do not account for seasonal residents. Town populations may increase as much as 100-200% between May and September as people come to live in their summer cottages (Kallin, pers. comm.).

Development Likelihood Maps

To determine the location of future development in the watershed, it was assumed that development was most likely to occur near existing roads and lake shorelines (Bouchard and Dennis, pers. comm.). New roads are expensive to build and the lack of road access can deter residential development by raising costs (Kallin, pers. comm.). Using Spatial Analyst, a Euclidean distance for each lake watershed was calculated from existing roads and the lakeshores (Gimond, pers. comm.). The resulting datasets were then combined in an equally weighted sum and extracted to show areas of future development potential using the vacant lots layer as a mask. The resulting raster was extracted to each lake watershed boundary and displayed as individual maps. All kinds of development constraints were displayed as gray and were added to the maps to demonstrate where future development could most likely take place. Roads and lot boundaries were added for reference.

Phosphorus Model

The phosphorus model was used to estimate the amount of phosphorus entering the Belgrade Lakes from different land uses. The manually digitized land use layer was used as the basis for the model (see Methods: Land Use Analysis). Land use types were assigned low, high and best estimates of phosphorus export coefficients in kg P/ha/yr. Export coefficients represent estimates of the amount of phosphorus one hectare of a land use will contribute in kg/yr. Phosphorus export coefficients were based on CEAT studies of the Belgrade Lakes conducted in the past 4 years (CEAT 2007, 2008, 2010). Because these studies encompassed a large portion of the total Belgrade Lakes watershed, low, high and best export coefficients were averaged for each land use type for use in this study. A range of estimates was used to account for uncertainty associated with the extensiveness of the watershed. The area of each land use type was multiplied by its export coefficient to determine its phosphorus contribution relative to other land uses in the watershed. The sum

of these inputs was used to calculate expected total phosphorus concentrations for each individual lake under present and future conditions.

The phosphorus model was adapted from previous area studies (CEAT 2007, 2008, 2009, 2010) and Reckhow and Chapra (1983). The following equation was used to calculate the annual influx of phosphorus from various sources in the watershed. W represents the total amount of phosphorus (kg) entering the Belgrade Lakes each year. Export coefficients are represented by Ec. The phosphorus model included coefficients for the following land use categories: Mixed forest (Ecmf), coniferous forest (Eccf), deciduous forest (Ecdf), regenerating land (Ecrl), reverting land (Ecrv), transitional forest (Ectf), open field (Ecof), cropland/farm (Eccr), logging areas (Eclg), wetlands (Ecw), cleared land (Ecc), commercial/municipal land (Eccm), dirt roads (Ecdr), municipal roads (Ecmr) state roads (Ecsr), parks (Ecpk), shoreline residential (Ecs), non-shoreline residential (Ecn), golf courses (Ecgc) and tree farms (Ectr). Coefficients for atmospheric (Eca) and sediment (Sdcs) inputs were also included (Appendix 4).

W = (Ecmf* Areamf) + (Eccf* Areacf) + (Ecdf* Areadf) + (Ecrl* Arearl) + (Ecrv* Arearv) + (Ecof*Areaof) + (Eccr*Areacr) + (Eclg*Arealg) +(Ecw* Areaw) + (Ecc*Areac) + (Eccm*Areacm) + (Ecdr*Areadr) + (Ecmr*Areamr) + (Ecsr*Areasr) + (Ecpk*areapk) + (Ecs*Areas) + (Ecn*Arean) + (Ecgc*Areagc) + (Ectr*Areatr) + (Eca*Lake area) + (Sdcs*Lake area)

In addition to low, high and best estimate scenarios, a phosphorus budget was calculated for projected watershed conditions in 2020, 2035 and 2050. The same export coefficients were used, but increases in the amount of land devoted to residential development increased in each successive scenario. Each additional shoreline house was assigned 0.5 ac (0.202 ha) of land and each additional non-shoreline house was assigned 1 ac (0.404 ha) of land (Firmage, pers. comm.). These lands were subtracted from the total mixed forest area. Although the amount of land devoted to agriculture has declined in recent decades, the farms that have survived to the present are likely to persist in the future (Kallin, pers. comm.), so no changes were assumed in agricultural lands. Successional lands, however, are expected to undergo changes over time. In 2035, it was assumed that 25% of the current areas of reverting and regenerating lands would become transitional forest and

that 25% of the current land area of transitional forest would become mature forest (classified as mixed forest) (Cole and Firmage, pers. comm.). In 2050, it was assumed that 50% of the current areas of reverting and regenerating lands would become transitional forest and that 50% of the current area of transitional forest would become mature forest (Cole, pers. comm.). All other areas of land use types remained constant in each time scenario.

To calculate the estimated total phosphorus concentration in the lakes, other factors were considered in addition to the external loading from land use. Shoreline and non-shoreline houses were broken into two categories: seasonal and year round. Based on values used in previous CEAT studies, it was assumed that seasonal residents spend 95 days at home per year and that year-round residents spend 355 days (CEAT 1997, 1999, 2000, 2007, 2008, 2010). These values were used to calculate figures for capita years, which is an estimate of the amount of time spent in the watershed by people living on and off the shoreline, seasonally and year-round. Capita years were calculated by multiplying the mean number of persons per household by the estimated proportion of the year people living on and off the shoreline reside in the watershed. A watershed average value of 2.56 persons per household was used in each time scenario. Although family sizes have been declining consistently in recent decades, projections are by town and not watershed, so it was not attempted to vary mean family size within watersheds that contain several towns. Capita year values were multiplied by high, low and best export coefficients (Appendix 4) and added to the land use-based external load. The resulting value (W) was next divided by the total bottom surface area of the lakes (As) to calculate the amount of phosphorus (kg/ha/yr) contributed from both land and internal sediment loading. This resulting value (L) was then entered into the following equation to determine the estimated phosphorus concentration in the lakes. The term qs represents the atmospheric input of phosphorus expected each year.

$$P = L(11.6 + 1.2qs)$$

This procedure was repeated and applied to each of the individual lake watersheds to produce high, low and best estimates of total phosphorus concentrations for each lake. The same export coefficients, residency times and mean number of persons per household were used in each calculation.

RESULTS/DISCUSSION

Land Use Patterns

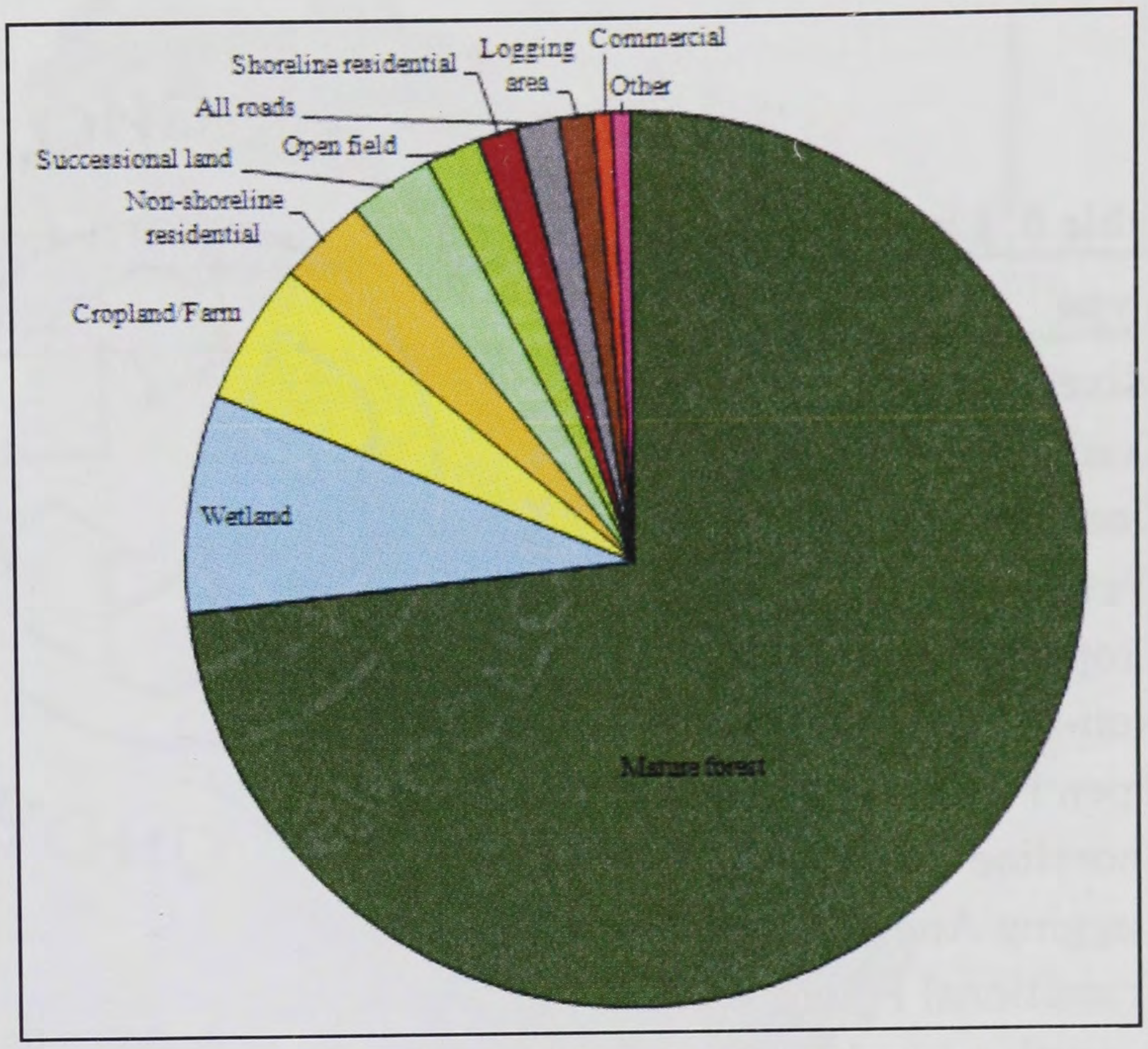

Figure 2. Proportions of land use types in the Belgrade Lakes watershed

The Belgrade Lakes watershed comprises a land area of 38,522 ha, exclusive of lake surface area (Table 8), and is characterized by a wide variety of land use types (Figures 2 - 3). Most of the land in the watershed is still undeveloped and over 70% of the watershed is covered by mature forests (coniferous, deciduous and mixed). Wetlands are the next most common land use type and take up 7.86% of the total watershed area. Wetlands are scattered throughout the watershed, but the largest wetlands are most often located near the inlets and outlets of the lakes. Croplands comprise 5.08% of the watershed and are concentrated primarily in the southern portion of the watershed, though several large farms are located along ME-8 in Smithfield. Residential areas cover 4.70% of the watershed and tend to be clustered along lakeshores and major roads. Residential development occurs throughout the watershed, but housing density is lower in the more rural northern and western portions of the watershed. Successional lands cover 2.76% of the watershed and are commonly found near agricultural areas. Many of these lands were previously used for agriculture but are slowly reverting to forests. Roads cover just 1.45% of the total watershed area, but this small land quantity can have a disproportionately large impact on lake water quality by acting as pathways for stormwater runoff and nutrients (MDEP 2007). Roads are found throughout the watershed and can facilitate future development because development is more likely to occur in accessible areas. Commercial and municipal lands, cleared areas, commercial camps and recreational lands each comprise less than 1% of the total watershed area, but these land use types can also have disproportionately high impacts on lake water

quality by contributing relatively large amounts of phosphorus relative to land use area because they contain impervious surfaces.

Table 8. Land Use Types by Total Area in the Belgrade Lakes Watershed

Type	Total Hectares	% of Total
Mixed Forest	15750.91	40.89
Coniferous Forest	6554.77	17.02
Deciduous Forest	5955.45	15.46
Wetland	3027.50	7.86
Cropland/Farm	1957.76	5.08
Non-shoreline Residential	1256.99	3.26
Open Field	749.63	1.95
Shoreline Residential	554.12	1.44
Logging Area	466.92	1.21
Transitional Forest	434.28	1.13
Reverting Land	401.00	1.04
Regenerating Land	227.71	0.59
Dirt Road	216.87	0.56
Paved Road	198.12	0.51
Commercial/Municipal	182.73	0.47
State Road	148.30	0.38
Cleared Land	100.83	0.26
Tree Farm	91.80	0.24
Camp	81.97	0.21
Gravel Pit	69.04	0.18
Golf Course	62.99	0.16
Park	19.58	0.05
Bare Ground	5.99	0.02
Cemetery	3.39	0.01
Orchard	3.11	0.01
Total	38521.74	

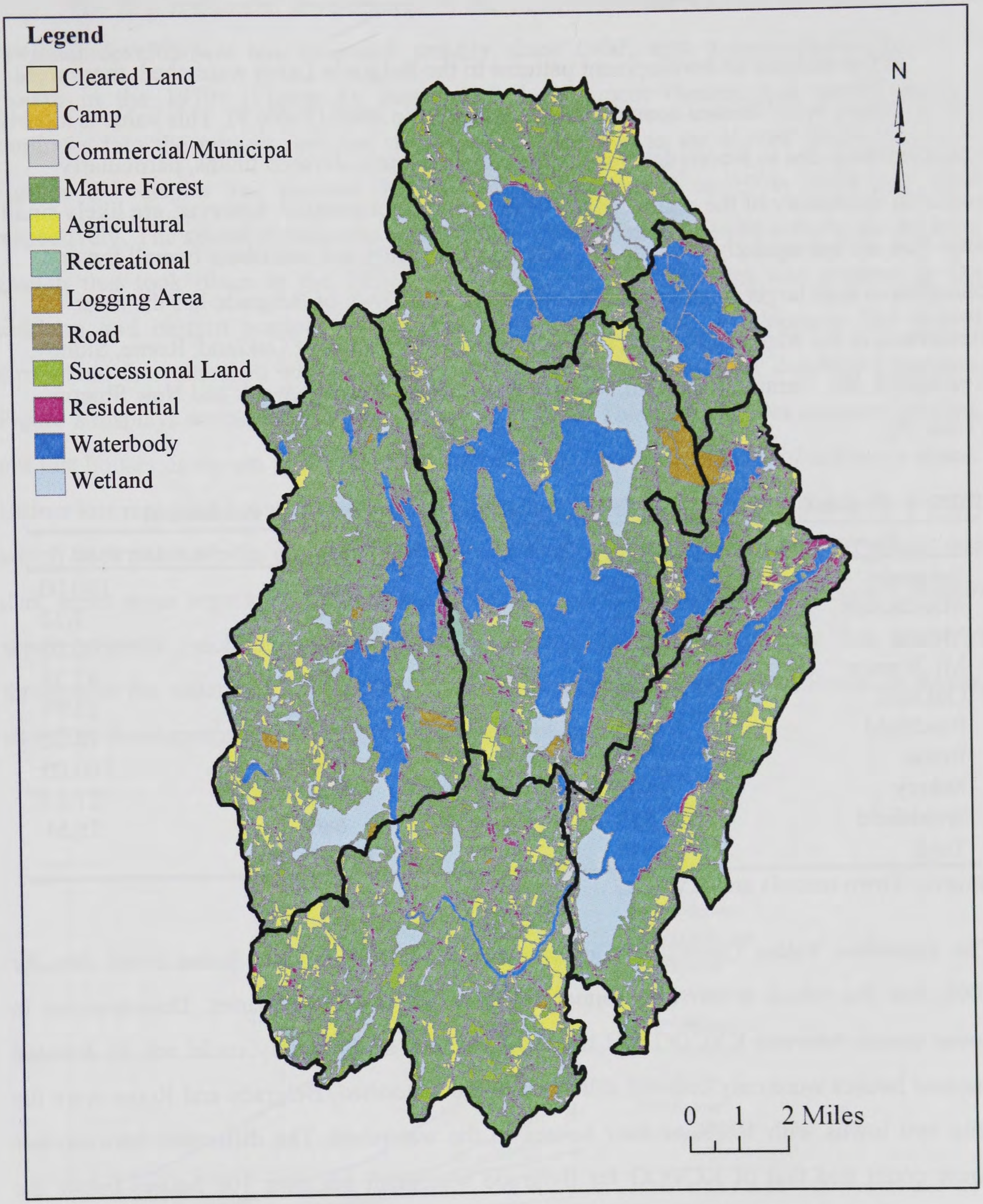

Figure 3. Land use in the Belgrade Lakes watershed. Land uses were manually digitized in ArcGIS 9.3 using 2003 digital orthoquadrangles (DOQ) and 2007 NAIP aerial photographs.

Residential Development Patterns

In the analysis of development patterns in the Belgrade Lakes watershed, there were approximately 6,037 houses counted in the watershed in 2008 (Table 9). This value is a fairly rough estimate due to incomplete record-keeping in some watershed towns, particularly earlier in the history of the region. Many of the houses not counted, however, are likely small units that are infrequently used, do not have septic systems and contribute overall lower phosphorus than larger, regularly used residences. The Town of Belgrade has the most residences in the watershed with 2,185, followed by the Towns of Oakland, Rome, Sidney, Smithfield, Mt. Vernon, Readfield, Mercer, Manchester, Norridgewock and New Sharon (Table 9).

Table 9. Present House Counts for Towns in the Belgrade Lakes Watershed

Town	Houses	KVCOG Count (2008)	% in watershed
Belgrade	2185	2200	100.00
Manchester	92	1257	7.32
Mercer	118	393	30.03
Mt. Vernon	442	1043	42.38
Oakland	1048	3085	33.97
Readfield	168	1261	13.32
Rome	923	1058	100.00
Sidney	543	1994	27.23
Smithfield	518	686	75.51
Total	6037	12977	-------

Source: Town records and KVCOG

The Kennebec Valley Council of Governments (KVCOG) provides house count data for 2008, but the values it provides cannot consider watershed boundaries. Discrepancies in house counts between KVCOG and the results of this study largely could not be detected because houses were only counted if located in the watershed. Belgrade and Rome were the only two towns with 100% of their houses in the watershed. The difference between our house count and that of KCVOG for Belgrade was small but over 100 houses below the KVCOG count for Rome. This inconsistency can be attributed to inadequate record-keeping by the Town of Rome or failure on behalf of Colby to locate all available data. No residences in Augusta or Vienna are located in the watershed.

The first residential development in the watershed occurred in 1732 in Mt. Vernon. Regional development has increased steadily since 1900, with a considerable period of growth in the 1970s (Figure 4). Residential development (houses and mobile homes) continues into the present, but has slowed since 2007 due to the United States economy. Figures 5-7 display the increase in residential development in 1900, 1950 and 1980 respectively. The spatial distribution of residential development in 1980 reflects the regional growth that took place in the 1970s. Prior residential development was greatest in the southern and eastern portions of the watershed, but by 1980 development had spread throughout the watershed while also increasing in density in previously developed sections. Figure 8 displays development in the watershed in 2008. This map includes commercial sites, not just houses as shown in the previous maps. Purple lots represent lots of unknown status. Brown lots represent houses of unknown age. Many of these houses are located in the Mercer which does not have tax assessment records prior to 1993. Light green lots are vacant and dark green areas represent protected lands. Gray lots are developed lots but do not contain septic systems (such as garages, sheds or barns). Recent development has occurred throughout the watershed but has been heaviest in Belgrade, Oakland and Rome. In Rome, shoreline development has been particularly rapid in recent years.

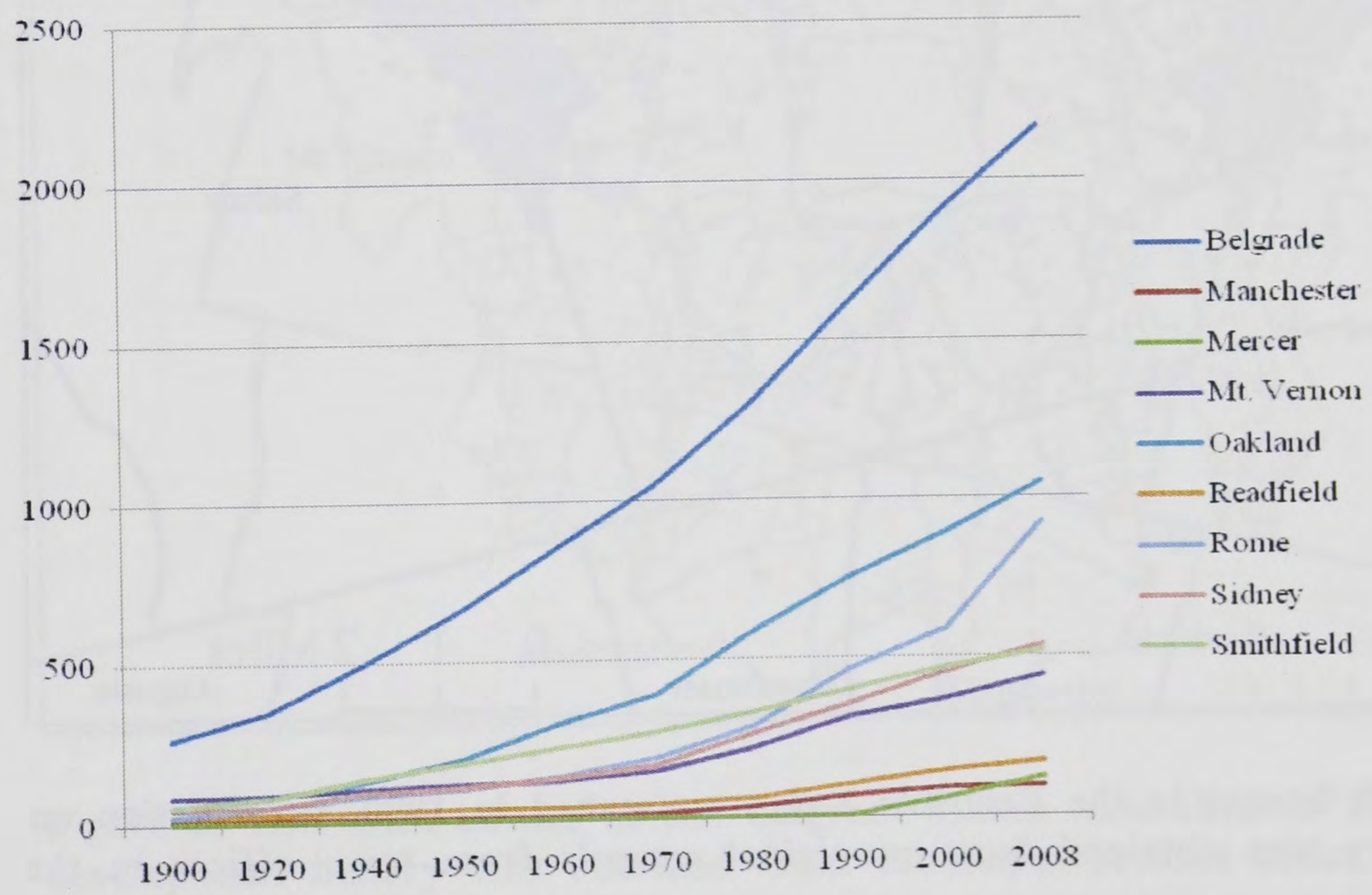

Figure 4. Residential development (houses and mobile homes) by town in the Belgrade Lakes watershed. Decade is on the horizontal axis and development is on the vertical axis.

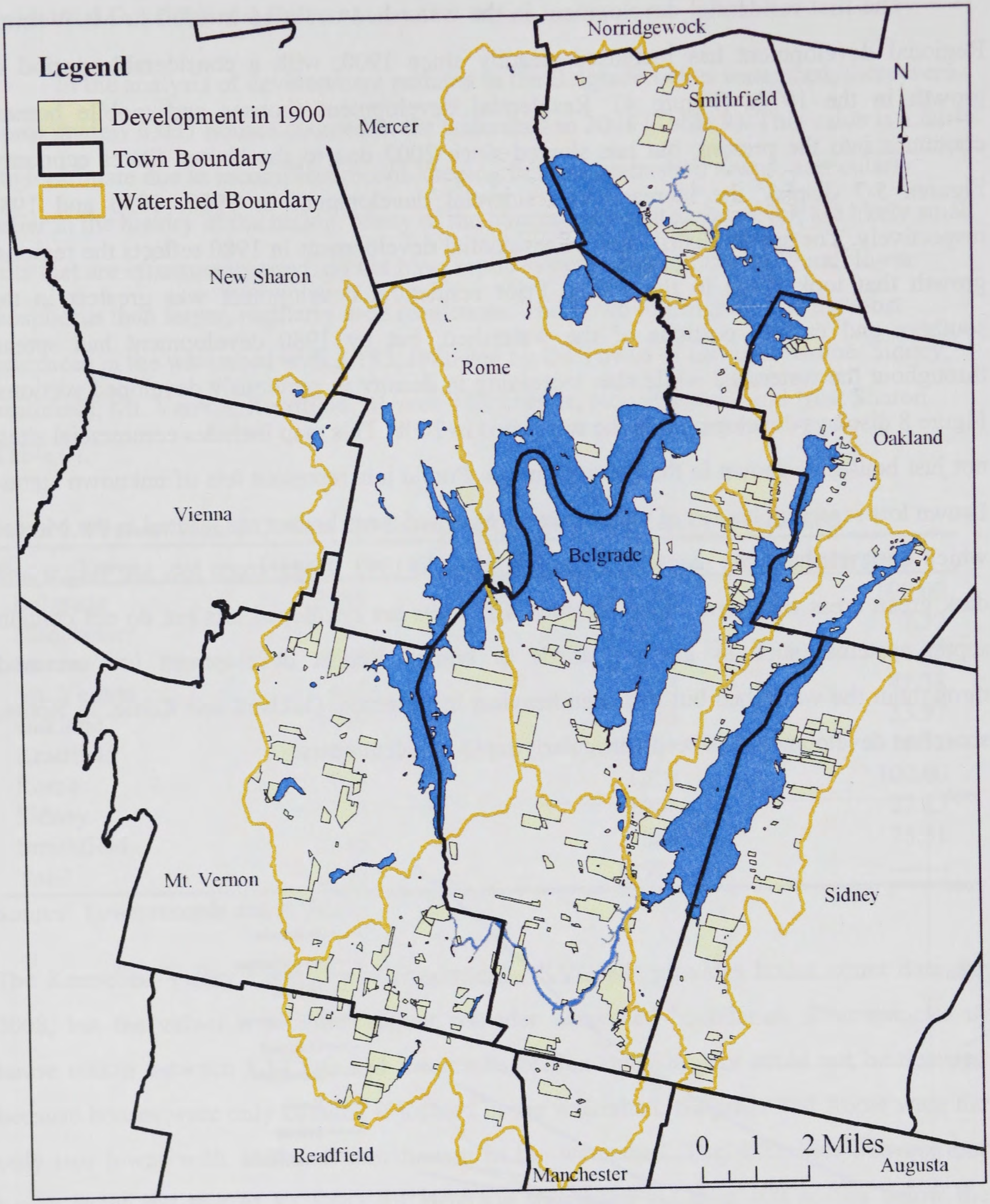

Figure 5. Lots with houses in the Belgrade Lakes watershed in 1900. Information on development history was obtained from municipal records from town offices in the watershed.

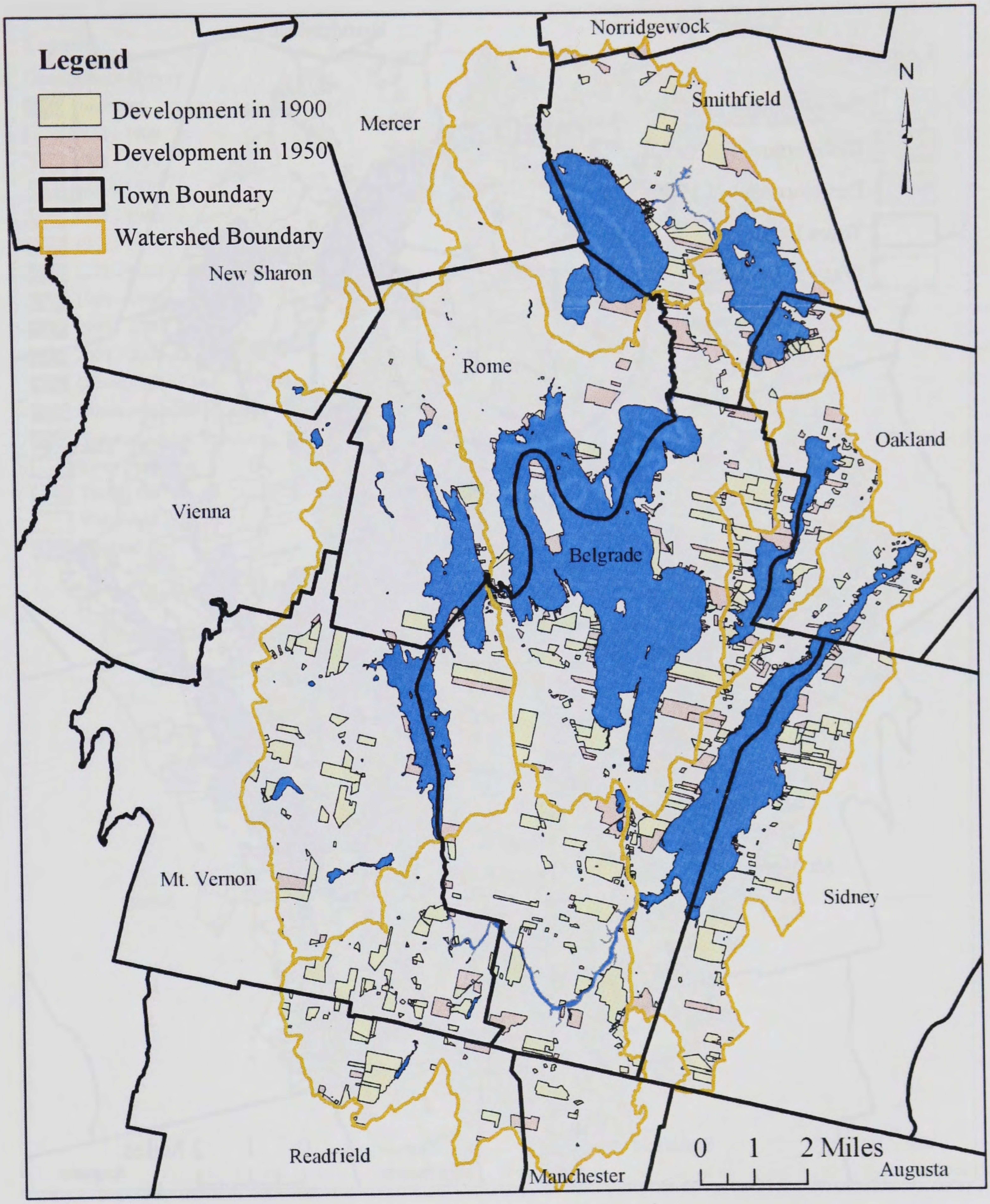

Figure 6. Lots with houses in the Belgrade Lakes watershed in 1950. Information on development history was obtained from municipal records from town offices in the watershed.

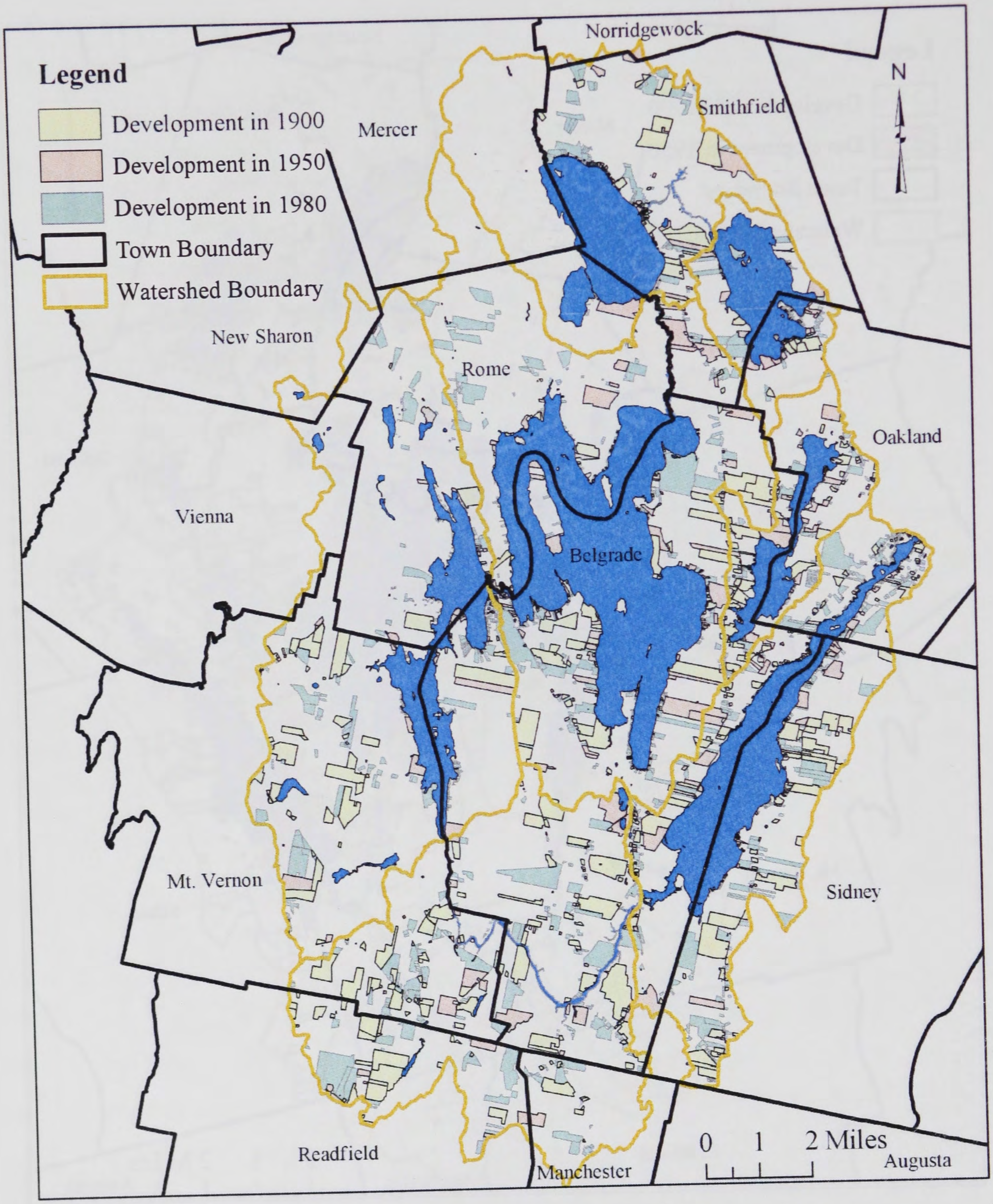

Figure 7. Lots with houses in the Belgrade Lakes watershed in 1980. Information on development history was obtained from municipal records from town offices in the watershed.

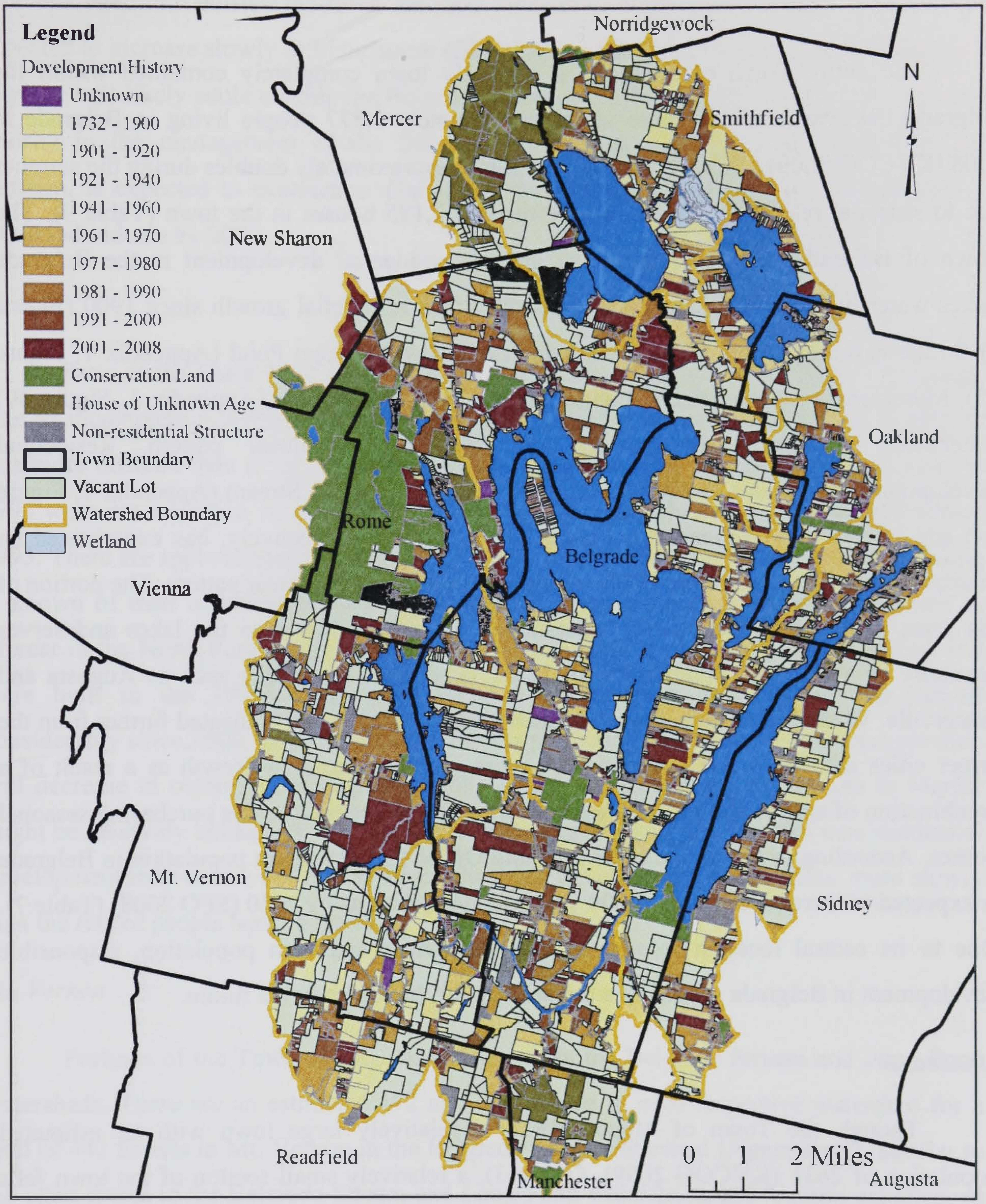

Figure 8. Development in the Belgrade Lakes watershed in 2008. Information on development history was obtained from municipal records from town offices in the watershed. Development includes houses, mobile homes and commercial properties.

Belgrade

The entire Town of Belgrade is the only town completely contained within the Belgrade Lakes watershed. There were approximately 3,377 people living in Belgrade in 2008 (KVCOG 2009) (Table 3), though this figure approximately doubles during the summer due to seasonal residents. There are an estimated 2,185 houses in the town (Table 9). The Town of Belgrade has experienced the greatest residential development in the Belgrade Lakes watershed and has demonstrated overall linear residential growth since 1900 (Figure 4). In the eastern portion of the town, which includes the Great Pond (Appendix 1, Figure 25), Messalonskee (Appendix 1, Figure 28) and Salmon/McGrath (Appendix 1, Figure 30) watersheds, residential development has followed this linear pattern. Residential development in southern and western Belgrade, in the Belgrade Stream (Appendix 1, Figure 24) and Long Pond (Appendix 1, Figure 27) watersheds respectively, has experienced an increased growth rate since the 1970s with respect to the overall linear pattern. The portion of the town in the Belgrade Stream watershed is located further from the lakes and serves primarily as a bedroom community for larger cities with more jobs such as Augusta and Waterville. Western Belgrade, though located close to Long Pond, is located further from the larger cities and likely has experienced a more recent increase in growth as a result of a combination of sprawl and retirees less concerned about access to cities purchasing seasonal homes. According to the Maine State Planning Office (SPO), human population in Belgrade is expected to increase to nearly 5,000 year-round inhabitants by 2050 (SPO 2008) (Table 7). Due to its central location in several lake watersheds and high population, responsible development in Belgrade should be a top priority for the region in the future.

Manchester

Though the Town of Manchester is a relatively large town with an estimated population of 2631 (KVCOG 2009), (Table 3), a relatively small section of the town falls only within the Belgrade Stream watershed. Of an estimated 1,257 houses in Manchester (KVCOG 2009), only 92 are located in the Belgrade Stream watershed (Table 9). Similar to the portion of Belgrade located in the Belgrade Stream watershed, Manchester experienced an increase in residential development in the 1970s (Appendix 1, Figure 24). The livelihoods of Manchester residents are not derived significantly from the Belgrade Lakes, so many

residents commute outside the town for jobs. According to the SPO, human population is expected to increase slowly in Manchester (SPO 2008), (Table 7), but most of this population increase will likely settle outside the Belgrade Lakes watershed, making Manchester a lower priority in the management of the Belgrade Lakes. The population of Manchester, in addition, is expected to experience relatively little growth in population and remain under 3,000 individuals by 2050.

Mercer

Parts of the Great Pond and North Pond watersheds fall within the Town of Mercer. Due to incomplete municipal records, assessing residential development history in Mercer was more difficult than in any other town in the watershed. Tax assessment records prior to 1993 were not available, so it was not possible to determine when houses were built before 1993. There are approximately 14 houses in Mercer in the Great Pond watershed, but nothing is known of their construction date (Appendix 1). There are approximately 104 houses in Mercer in the North Pond watershed. Many of these houses are located on the shoreline and were built in the 1990s. This rapid increase in shoreline development has slowed considerably since 2000, however, and the SPO is predicting that human population pressure will decrease in coming decades (SPO 2008), (Table 7), so future development in Mercer might be relatively unlikely. Under these circumstances it is still possible that new residential development may occur, but it is assumed that such development would occur more slowly than the rate of people leaving the town.

Mt. Vernon

Portions of the Town of Mt. Vernon lie within the Belgrade Stream and Long Pond watersheds. There are an estimated 172 and 270 houses in each respective watershed for a total of 442 houses in Mt. Vernon in the Belgrade Lakes watershed (Appendix 1). Similar to the other towns in the Belgrade Stream and Long Pond watersheds, Mt. Vernon experienced a large increase in residential development in the 1970s. Prior to this period, watershed development in Mt. Vernon was relatively low. Currently, Mt. Vernon houses 1,672 residents (Table 3) and the town population could increase by nearly 1,000 individuals by 2050 (SPO 2008), (Table 7). This increase could possibly be explained by the presence of high amounts

of available land that could attract both commuters and retirees. Due to the longer distance of the town from local cities, however, Mt. Vernon could see more retirees moving in than job-seekers (Kallin, pers. comm.).

New Sharon

There are only two houses in the Town of New Sharon located in the Long Pond watershed (Appendix 1) in the Belgrade Lakes watershed. There are 7 buildable lots in New Sharon within the watershed, but even if New Sharon were completely built-out in the watershed, such development would likely have an insignificant impact on lake water quality. All these lots are non-shoreline and are separated from the lakes by heavily forested, protected areas, so New Sharon should not be a major priority in the management of development and water quality of the Belgrade Lakes Region.

Norridgewock

There are only four houses in the Town of Norridgewock located in the North Pond watershed (Appendix 1). There are only 2 buildable lots in Norridgewock in the watershed, so similar to New Sharon, even if these lots were developed, the impact on lake water quality would be relatively small because Norridgewock is located on the edge of the watershed and contains very little land within the watershed.

Oakland

The Town of Oakland is the largest town in the Belgrade Lakes Region with an estimated 2008 population of 6,388 individuals (KVCOG 2009), (Table 3). The population is expected to increase to 7,220 people by 2050 (SPO 2008), (Table 7). Though Oakland has the largest town population, the entire town is not included in the Belgrade Lakes watershed and it is estimated that Belgrade contains more residents within the watershed. Parts of Oakland fall within the East Pond, Great Pond, Messalonskee Lake and Salmon/McGrath watersheds. Residential development in Oakland has increased steadily since 1900 (Figure 4), but development patterns have varied within individual watersheds. East Pond has experienced steady growth since 1900 (Appendix 1, Figure 25) and this trend could continue considering there are 43 buildable vacant lots in Oakland in the watershed. Oakland only

overlaps with a small portion of the Great Pond watershed. There are only three houses in Oakland in the Great Pond watershed and only 3 buildable, vacant lots, so Oakland has a relatively minor impact on Great Pond compared to Belgrade, Mercer, Rome and Smithfield. In the Messalonskee Lake watershed, Oakland experienced an increase in residential growth in the 1950s that has continued into the present (Appendix 1, Figure 28). There are a total of 112 buildable vacant lots in the watershed, so there is potential for this rate of increase to continue. In the Salmon/McGrath watershed, residential development in Oakland increased considerably in the 1970s and has also continued steadily into the present (Appendix 1, Figure 30). There are 84 buildable vacant lots in Oakland in the watershed, so there is also room for this pattern of increasing development to continue.

Much of Oakland is located in a unique position in the Belgrade Lakes watershed. Both McGrath Pond and East Pond are considered headwaters in the system and eventually flush water into the other lakes. As a consequence of these natural conditions, responsible developers in the town of Oakland should take into consideration the potentially disproportionate impact of local development on water quality of the Belgrade Lakes.

Readfield

The Town of Readfield only contains land within the Belgrade Stream watershed. There are approximately 168 houses in the watershed out of a total of 1,261 houses in the entire town (KVCOG 2009), (Table 9). Residential development in Readfield grew slowly at the beginning of the 20^{th} century and consistent with other towns in the region picked up in the 1970s (Appendix 1, Figure 25). Since then, the growth rate of residential development has further increased and this trend could continue based on SPO projected population increases (SPO 2008). Among watershed towns, Readfield is expected to experience some of the highest population growth in the region and could reach nearly 4,000 individuals by 2050 (Table 7). Although many of people can be assumed to settle outside the watershed, there are 63 buildable, vacant lots in the watershed in Readfield that could accommodate new development. Water flows through the Belgrade Stream into Messalonskee Lake, which is nearing the critical phosphorus concentration range for algal blooms. Phosphorus concentrations are thought to change little along the Belgrade Stream (CEAT unpublished

data), so extra phosphorus inputs from Readfield could be felt directly by Messalonskee Lake.

Rome

Though the entire Town of Rome does not quite lie completely within the Belgrade Lakes watershed, all developed areas fall within the watershed. Rome includes land in the Great Pond, Long Pond and North Pond watersheds and contains the second highest number of houses (1,070) in the watershed (behind 2,285 in Belgrade). Despite the high number of buildable vacant lots both on and off the shoreline in Rome (Appendix 1), the SPO projects a relatively small population increase of under 500 from its current population estimate of 1,214 (KVCOG 2009) individuals by 2050 (SPO 2008), (Table 7). Other towns such as Belgrade, Oakland and Sidney have considerably larger expected population increases, likely due to their closer proximity to local centers such as Augusta and Waterville. Rome is still a relatively rural area where access to jobs is low, but its central location among Great Pond, Long Pond and North Pond would be desirable to retirees or people looking for seasonal homes. Nonetheless, due to the extensive amount of available land in Rome, the potential for negative effects on water quality of the Belgrade Lakes is high if these lands were developed and proper precautions were not taken.

Rome is the location of the Wildwood Estates near the western shore of the north basin of Long Pond and the Blackhorse Estates on Ingham Pond. These lots are currently too small for housing development due to minimum lot size regulations and the impracticalities of establishing septic systems on lots as small as 0.25 ac. The parcels were created before minimum lot size regulations were in place, but grandfathered exemptions only apply to lots developed before standards were enacted. To be developed, two or more lots depending on size would have to be purchased and combined by potential owners. Due to these conditions, development is less likely in these areas (Bouchard, pers. comm.).

Sidney

Sidney overlaps only with the southeastern portion of the Messalonskee Lake watershed. Residential development in Sidney has increased fairly steadily since 1900, but experienced a dramatic period of growth in the 1970s (Figure 4), consistent with regional

development patterns. Sidney is a relatively large town with an estimated 2008 population of 4,561 individuals (KVCOG 2008), (Table 3), though the majority of these people lives outside the watershed. There are approximately 543 houses in Sidney in the Messalonskee Lake watershed (Table 9) with 123 buildable vacant lots (Appendix 1). The SPO projects large population increases for the town of over 3,000 new individuals by 2050 (SPO 2008), (Table 7). Sidney is the fastest growing town in the Belgrade Lakes Region (Kallin. pers. comm.), so there is a potential for many vacant areas in the watershed to be developed in the next few decades. On the shoreline, there are currently only 16 buildable vacant lots which are expected to be fully developed by 2035 (Appendix 1), so most of the development in Sidney will likely occur off the shoreline. Sidney is located just south of Waterville and directly north of Augusta, so the location of the town is particularly attractive to people seeking work in either city. As a result, special attention should be paid to development in the Town of Sidney and the health of Messalonskee Lake should continue to be monitored. One potentially positive implication of heavy development in Sidney, however, is the fact that Messalonskee Lake is the last lake in the Belgrade chain, so water that flows into the lake does not significantly affect other lakes in the system, though potential effects could be felt outside the watershed.

Smithfield

Smithfield is a rural town with land in the East Pond, Great Pond and North Pond watersheds. Residential development in Smithfield has been slow and steady since 1900 (Figure 4). Development in each individual watershed has also been steadily increasing slowly compared to other towns in the Belgrade Lakes watershed. There are 104, 46 and 368 houses in Smithfield in the East Pond, Great Pond and North Pond watersheds respectively (Appendix 1). There is also a considerable amount of developable land in each watershed, so there is the space for additional development to occur, but the SPO is projecting a slowly decreasing population that could curtail future development. This could possibly be explained by Smithfield's rural location and aging population (median age = 40), which has been steadily increasing since 1980 and makes Smithfield one of the oldest towns in the region (Table 4). As with Mercer, residential development could still occur in the future, but more slowly than the rate at which current residents leave the town.

Regional Development Projections

Based on population projections, residential development patterns and the linear rate of change in mean persons per household, there is an expected increase of 1,327 residential units in the Belgrade Lakes watershed from 6,037 units in 2008 to 7,364 units by 2050 (Table 10). The Town of Belgrade is projected to experience the largest increase in residential units (559). The Town of Sidney is expected to experience the highest percent increase in residential development, increasing from 543 to 856 houses from 2008 to 2050, a 36.6% increase. The Towns of Mt. Vernon, Oakland, Readfield and Rome are expected to see fairly substantial residential growth, but are not expected to develop as quickly as Sidney or to the extent of Belgrade. The number of residential units in the Towns of Mercer and Smithfield is projected to decline based on decreasing human populations between the present and 2050. The Town of Manchester is expected to gain 13 new residential units by 2050, a relatively insignificant change in the context of the greater watershed.

Table 10. Projected House Counts by Town in the Belgrade Lakes Watershed

Town	2008	2010	2020	2030	2035	2040	2050
Belgrade	2185	2191	2345	2461	2538	2607	2744
Manchester	92	95	98	100	101	103	105
Mercer	118	115	114	111	111	110	108
Mt. Vernon	442	458	499	531	551	569	605
Oakland	1048	1059	1096	1107	1125	1138	1162
Readfield	168	176	193	207	215	223	238
Rome	923	893	951	997	1025	1052	1104
Sidney	543	523	610	686	730	772	856
Smithfield	518	480	475	460	457	452	442
Total	6037	5989	6382	6660	6854	7024	7364

Source: ME State Planning Office and development history from town records

Development Likelihood Maps

Projected housing pressures will likely be greatest in the eastern and central portions of the Belgrade Lakes watershed, as well as along lakeshores and major roads. Future development will be restricted by development constraints (Figures 9-15) including conservation land, steep grades, existing development, great pond setback regulations (100 ft), wetlands, perennial stream setback regulations (75 ft) and inland waterfowl and wading

bird habitat (IWWH). Residential development likelihood is displayed in the development likelihood maps (Figures 16-22). The map is based on a color gradient with redder areas more likely to be developed and greener areas less likely to be developed. Development constraints are shown in gray.

Looking at the residential development alone, past development irrespective of time has been heaviest along lakeshores and major roads, especially in the eastern part of the watershed where population and road densities are high. The Town of Belgrade is the largest town in the watershed in terms of land area and population, so large increases in residential development would be consistent with historical patterns. The Town of Sidney is a desirable location for commuters to Augusta or Waterville, so it would be logical for development pressure to be high in this section of the watershed, though much of the development in Sidney will likely occur outside the watershed. There are few job prospects within the watershed, so many incoming residents will look outside the watershed for work. These commuters will likely settle primarily in the eastern section of the watershed to reduce commute times, but will buy property in other parts of the watershed as well, particularly along major roads. Commuters are generally year-round residents who prefer not to have to plow their own roads in winter, so living along publically maintained roads is desirable (Kallin, pers. comm.).

It should be noted that future development is expected to occur in areas with potentially high negative impacts on lake water quality. Shoreline septic systems contribute relatively more phosphorus to lakes than non-shoreline septic systems and roads are major transport pathways for nutrient runoff and soil erosion, especially after periods of rain. For these reasons, homeowners should make efforts to put in adequate shoreline buffers, maintain dirt roads (if applicable), make use of up-to-date septic systems and minimize areas of exposed soil (see Recommendations).

Seasonal residents, on the other hand, are usually not interested in economic opportunities or concerned about snow removal in winter. These people tend to be older, often retired people who are seeking to retreat from their busier lives elsewhere in the country. They prefer to settle along or near the lakeshore to maximize accessibility to the lakes. Many of these residences will be found along privately owned and maintained dirt

roads. They are generally not interested in more urban forms of recreation such as movies, shopping and restaurants and do not mind living far from town centers (Kallin, pers. comm.).

In general, the Belgrade Lakes Region is experiencing an emerging trend of conversion from seasonal to year-round residences (Kallin, pers. comm.). This recent trend may be attributed to the national economic situation in which maintaining two residences is increasingly expensive and impractical for some people. Seasonal residences are frequently located on or near the lakeshore where the anthropogenic impact on lake water quality is highest. Shoreline residential development is one of the highest contributors of phosphorus (see Phosphorus Model: Results). Shoreline septic systems contribute overall higher phosphorus than non-shoreline septic systems and are used more frequently when people inhabit the shoreline for longer periods of time. Accordingly, homeowners should make installation of adequate shoreline buffers and up-to-date septic systems a priority when converting seasonal shoreline homes to year-round homes (see Recommendations).

Phosphorus Model

The phosphorus model indicated the current relative phosphorus contributions of different land use types in the watershed (Figure 23, Table 11). Cropland was the highest contributor of phosphorus (19.62%) despite covering only 5.08% of the total watershed area. Other large contributors were non-shoreline residential, mature forests, shoreline residential and open field. Combined non-shoreline and shoreline residential land accounted for less than 5% of the total land area, but contributed nearly 25% (24.13%) of the total phosphorus load. Roads were a disproportionately large contributor. Roads comprised less than 2% of the total land area, but accounted for 11.14% of the total phosphorus load. Dirt roads alone account for 0.55% of the watershed, but contribute 6.56% of the total phosphorus load. Golf courses, despite covering 0.05% of the watershed, contributed a disproportionate 0.31% of the total phosphorus load.

Under current conditions, the mean total phosphorus concentration throughout the Belgrade Lakes is 11.93 ppb when sediment release is taken into consideration, according to best estimate of the model (Table 13). In subsequent decades, the concentration is projected to increase approximately 0.2-0.3 ppb per decade due to increases in residential development

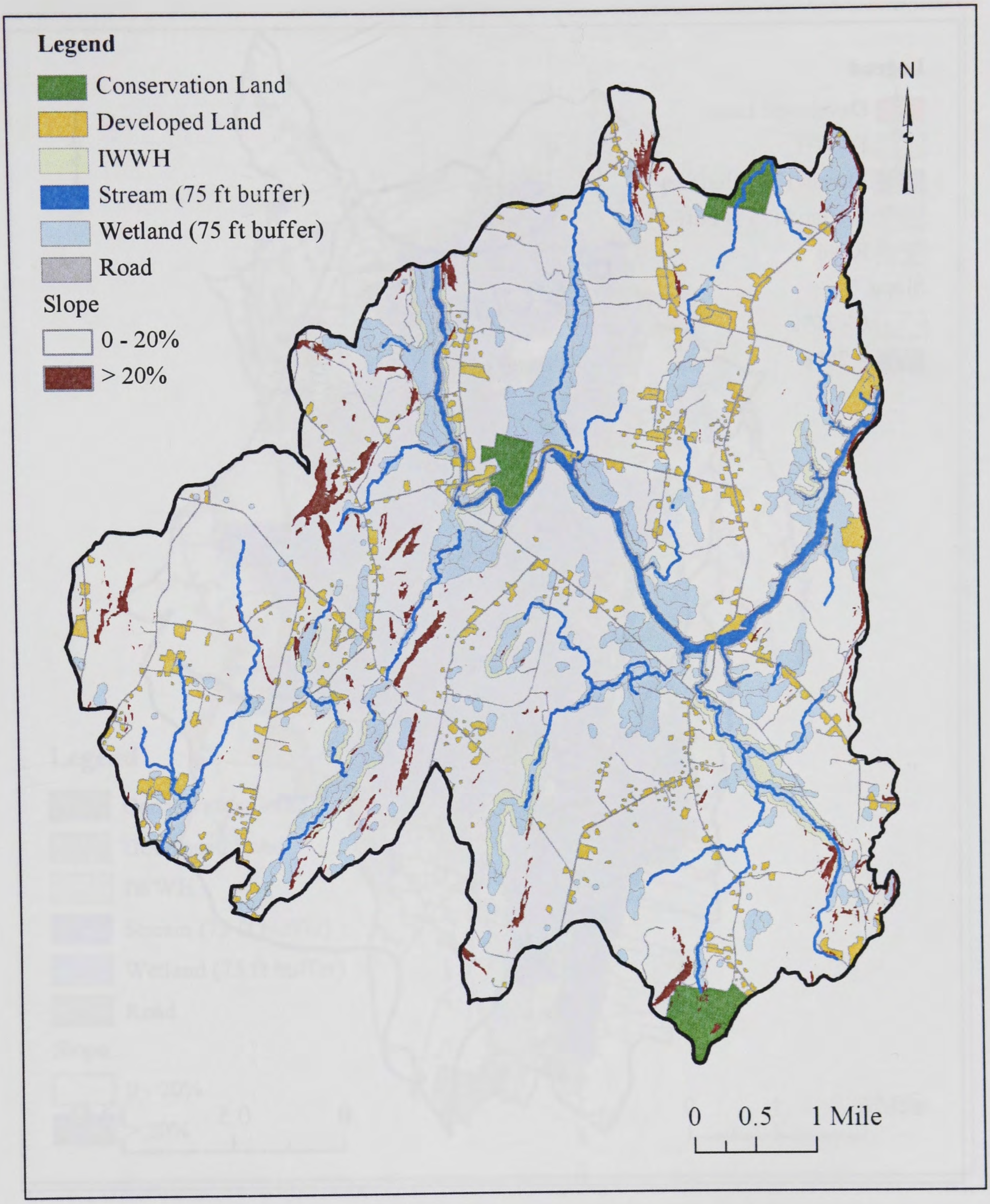

Figure 9. Development constraints in the Belgrade Stream watershed. Development cannot occur on grades steeper than 20%, conservation land, already developed areas, inland waterfowl and wading bird habitat (IWWH) or within 75 ft of perennial streams or wetlands.

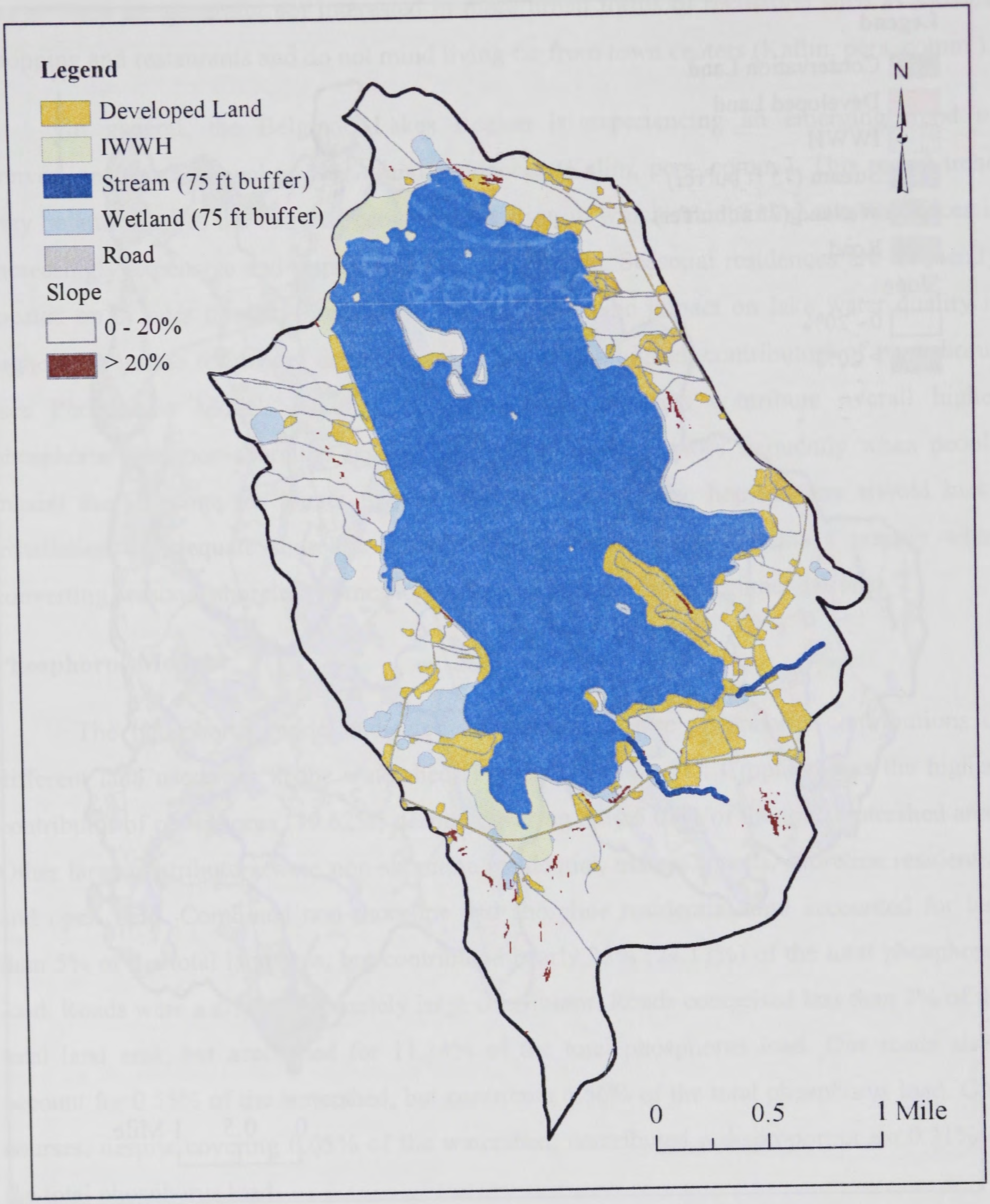

Figure 10. Development constraints in the East Pond watershed. Development cannot occur within 100 ft of great ponds, on grades steeper than 20%, already developed areas, inland waterfowl and wading bird habitat (IWWH) or within 75 ft of perennial streams or wetlands.

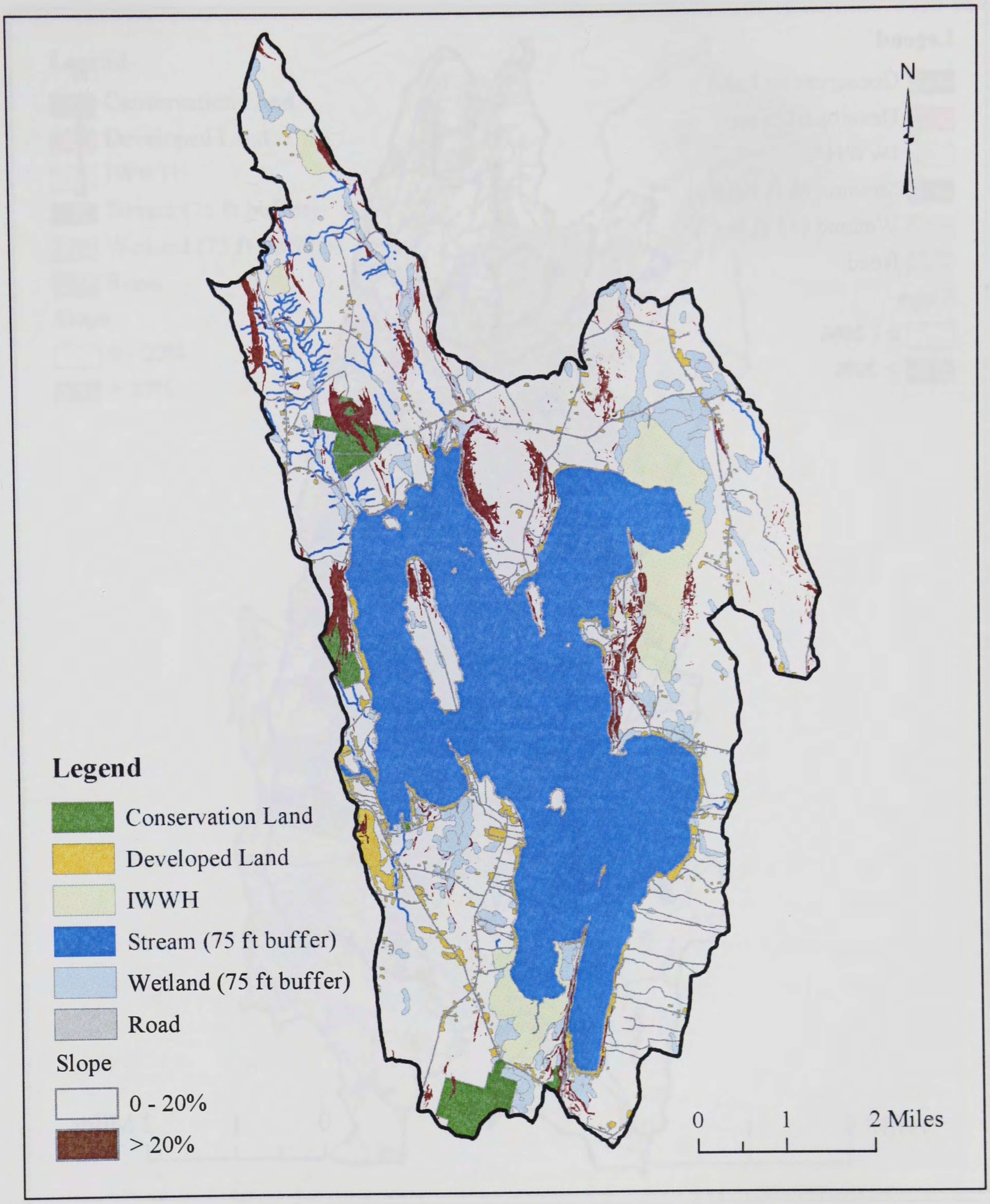

Figure 11. Development constraints in the Great Pond watershed. Development cannot occur within 100 ft of great ponds, on grades steeper than 20%, conservation land, developed areas, inland waterfowl and wading bird habitat (IWWH) or within 75 ft of perennial streams or wetlands.

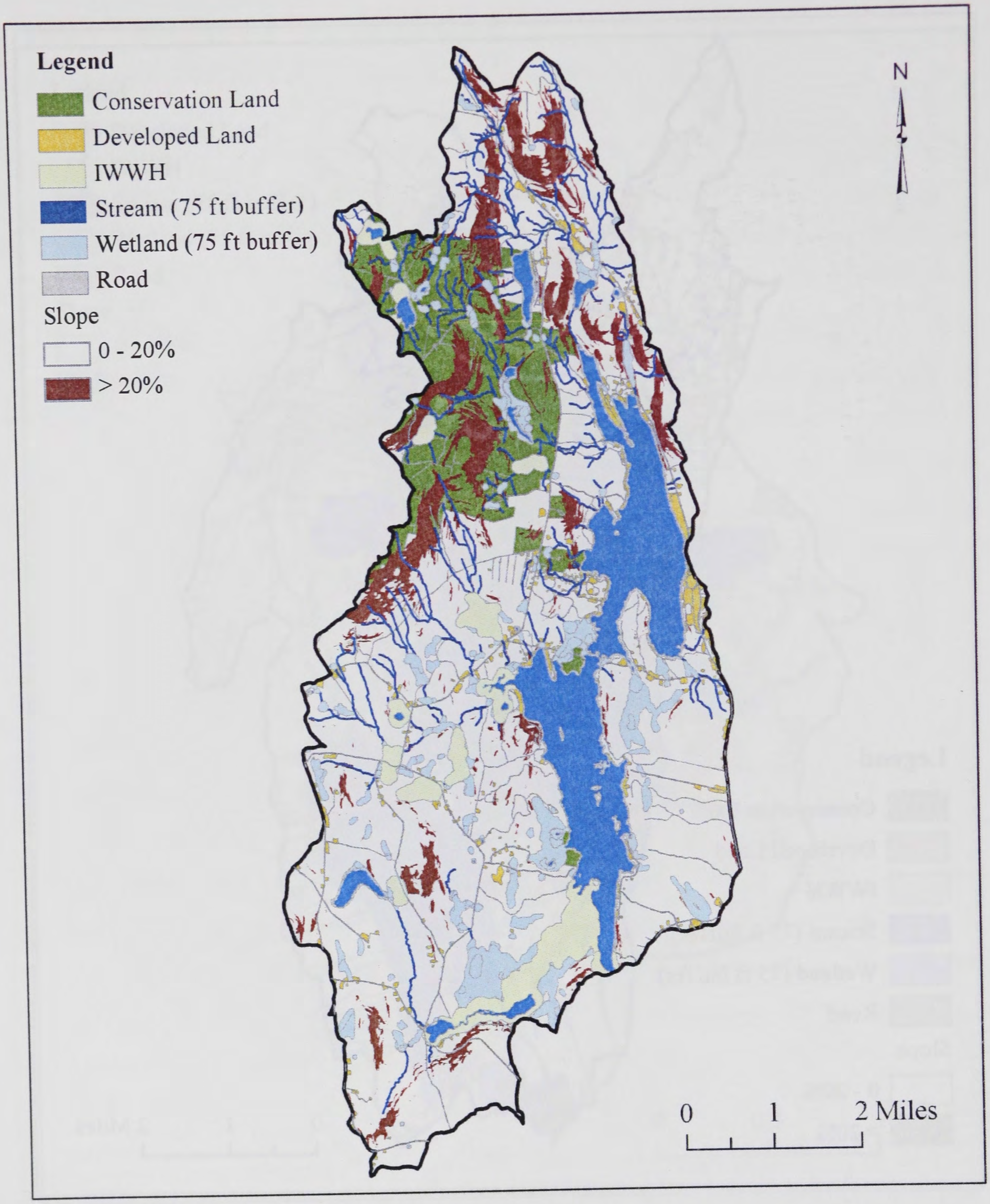

Figure 12. Development constraints in the Long Pond watershed. Development cannot occur within 100 ft of great ponds, on grades steeper than 20%, conservation land, developed areas, inland waterfowl and wading bird habitat (IWWH) or within 75 ft of perennial streams or wetlands.

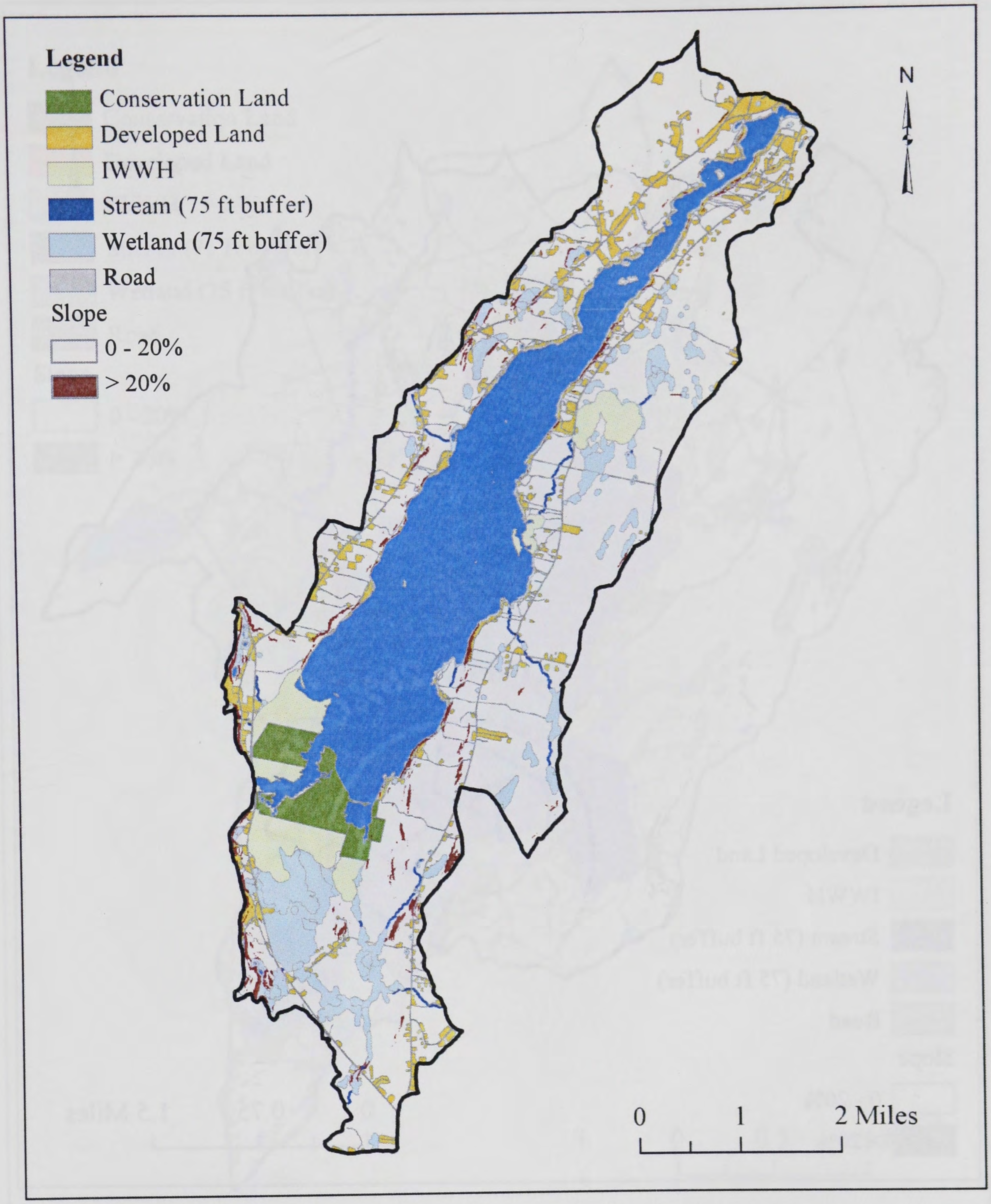

Figure 13. Development constraints in the Messalonskee Lake watershed. Development cannot occur 100 ft from great ponds, on grades steeper than 20%, conservation land, developed areas, inland waterfowl and wading bird habitat (IWWH) or 75 ft from perennial streams or wetlands.

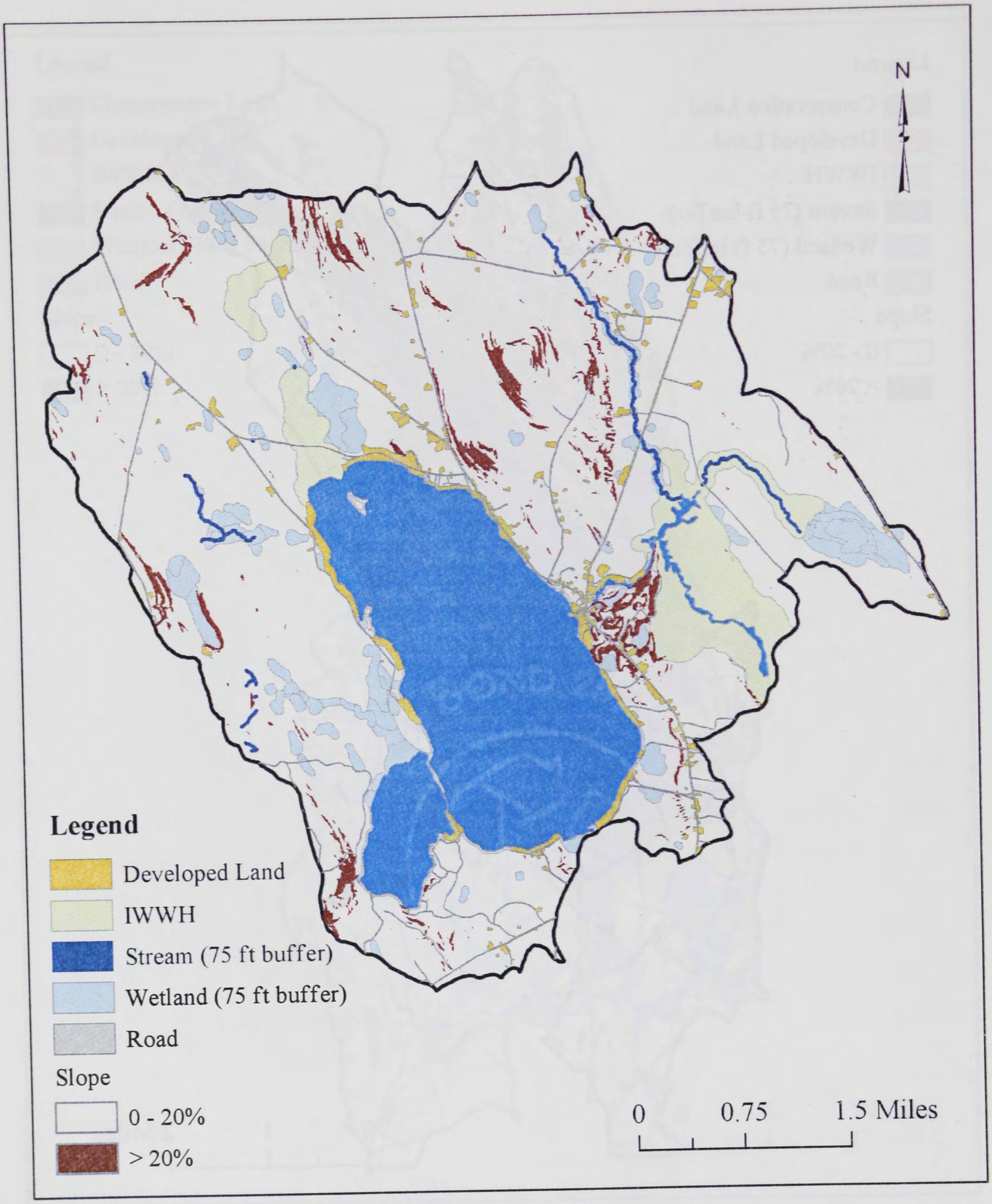

Figure 14. Development constraints in the North Pond watershed. Development cannot occur within 100 ft of great ponds, on grades steeper than 20%, already developed areas, inland waterfowl and wading bird habitat (IWWH) or within 75 ft of perennial streams or wetlands.

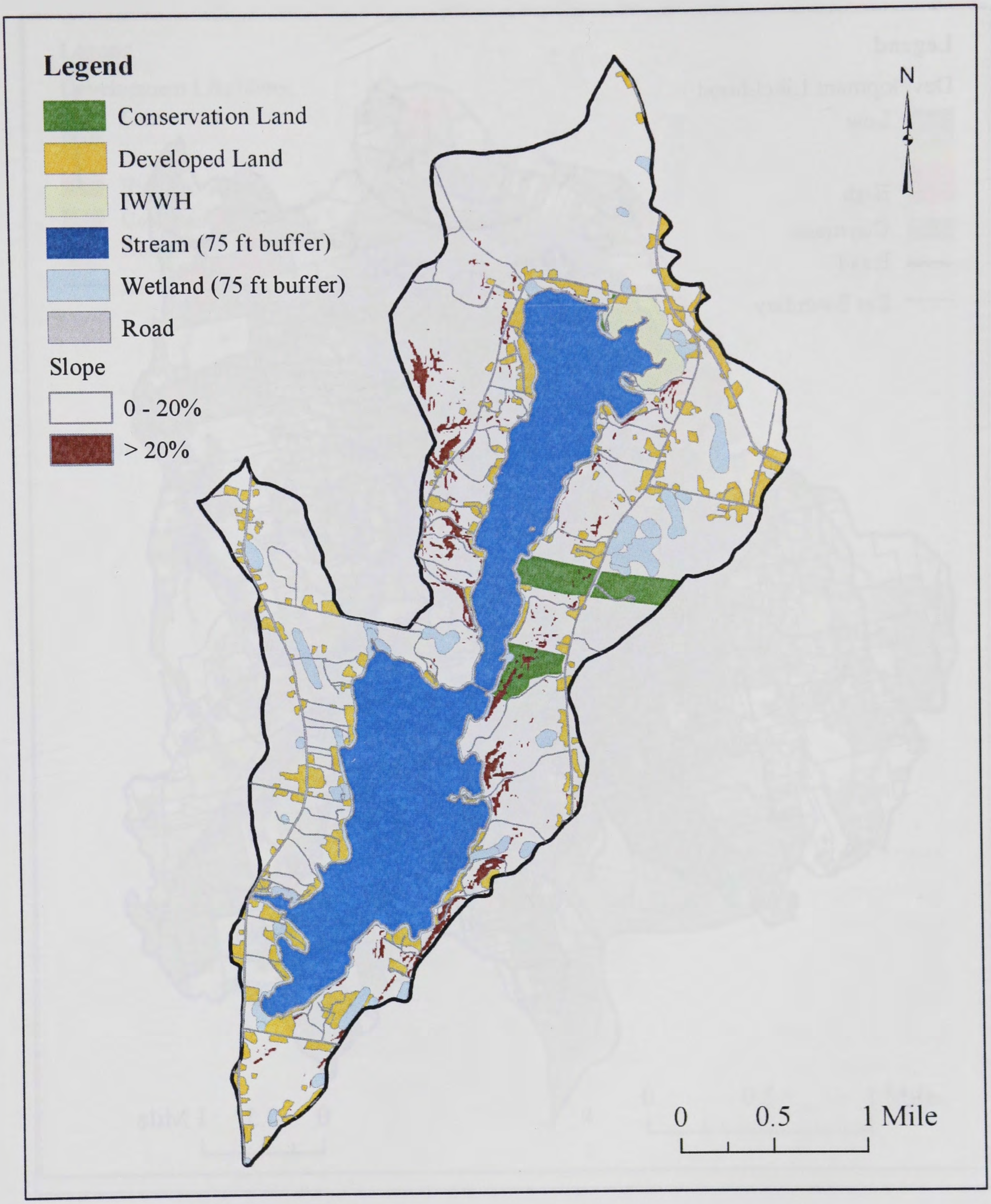

Figure 15. Development constraints in the Salmon/McGrath watershed. Development cannot occur 100 ft from great ponds, on grades steeper than 20%, conservation land, developed areas, inland waterfowl and wading bird habitat (IWWH) or 75 ft from perennial streams or wetlands.

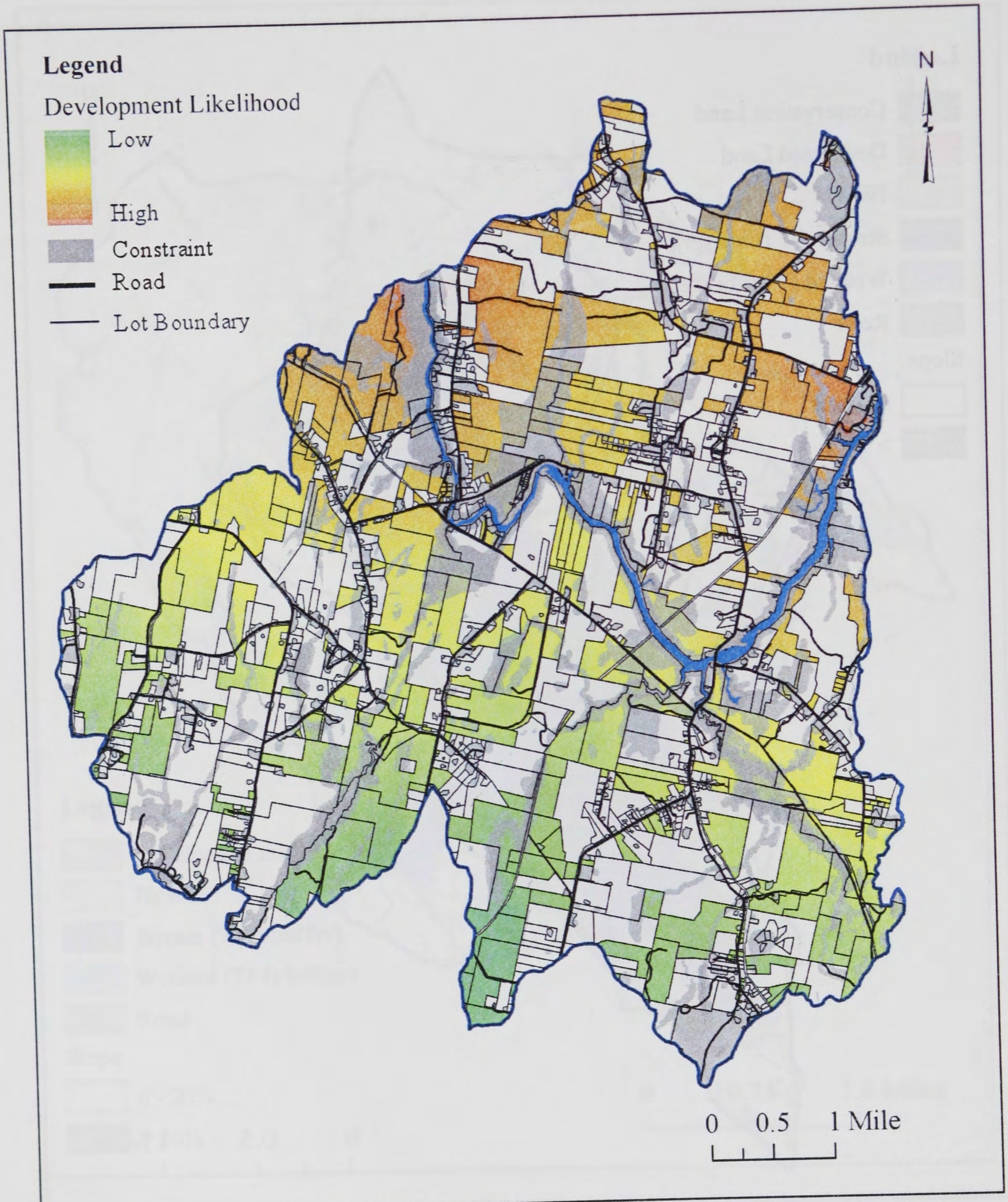

Figure 16. Development likelihood in the Belgrade Stream watershed, based on an equal weighted overlay of Euclidean distances to lakes and roads for vacant lots in the watershed. Gray areas represent physical or legal constraints to development, including existing development.

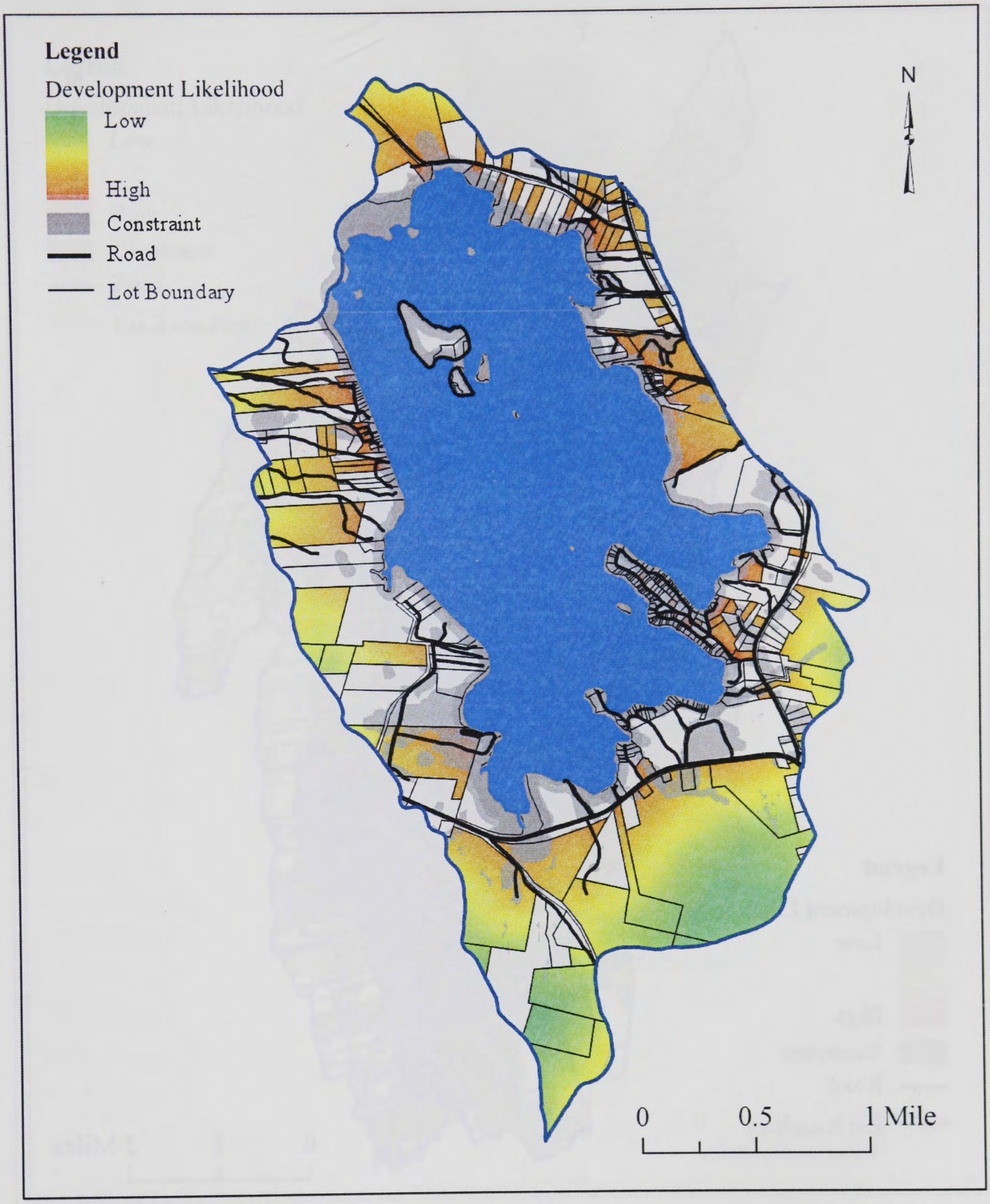

Figure 17. Development likelihood in the East Pond watershed, based on an equal weighted overlay of Euclidean distances to lakes and roads for vacant lots in the watershed. Gray areas represent physical or legal constraints to development, including existing development.

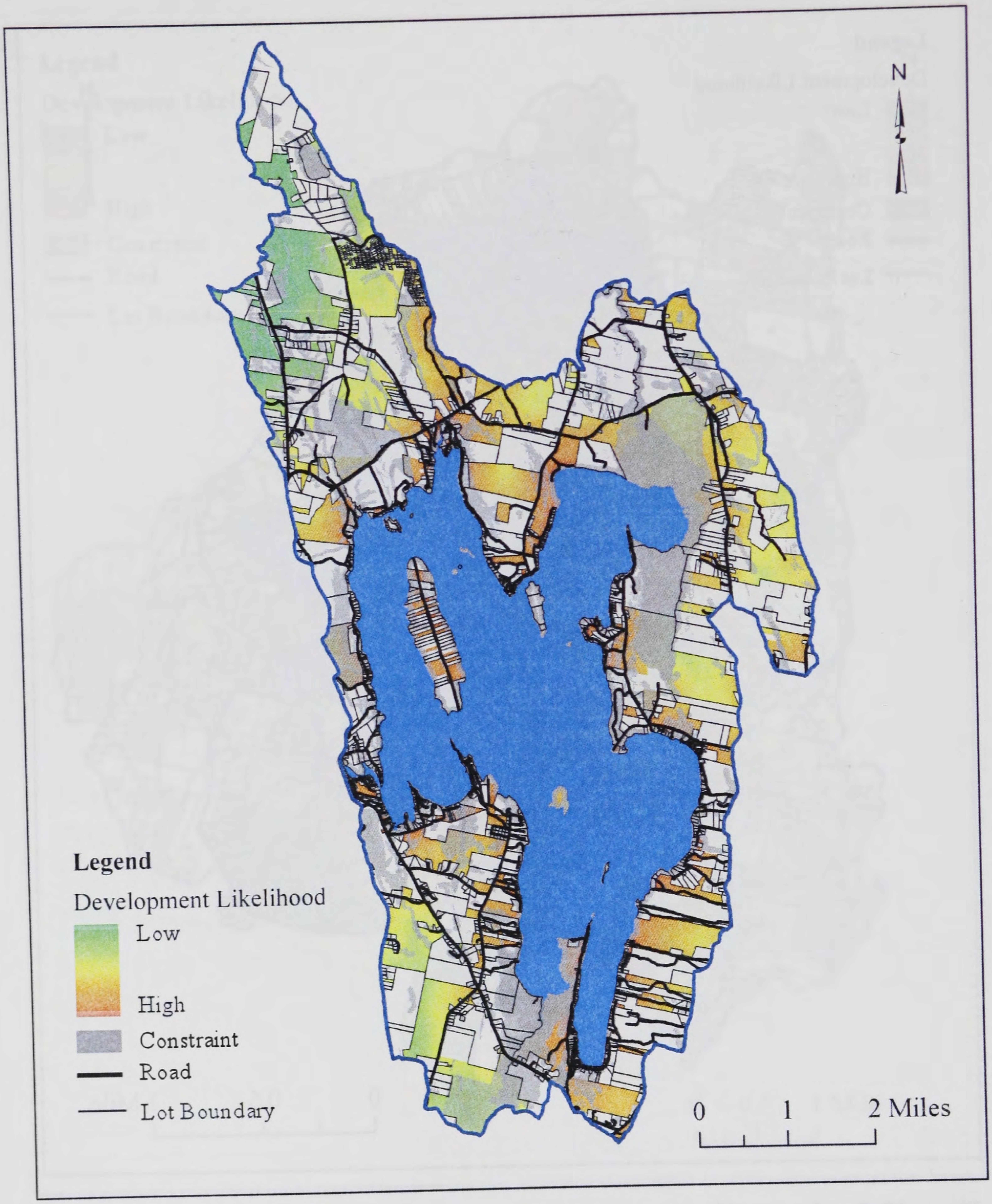

Figure 18. Development likelihood in the Great Pond watershed, based on an equal weighted overlay of Euclidean distances to lakes and roads for vacant lots in the watershed. Gray areas represent physical or legal constraints to development, including existing development.

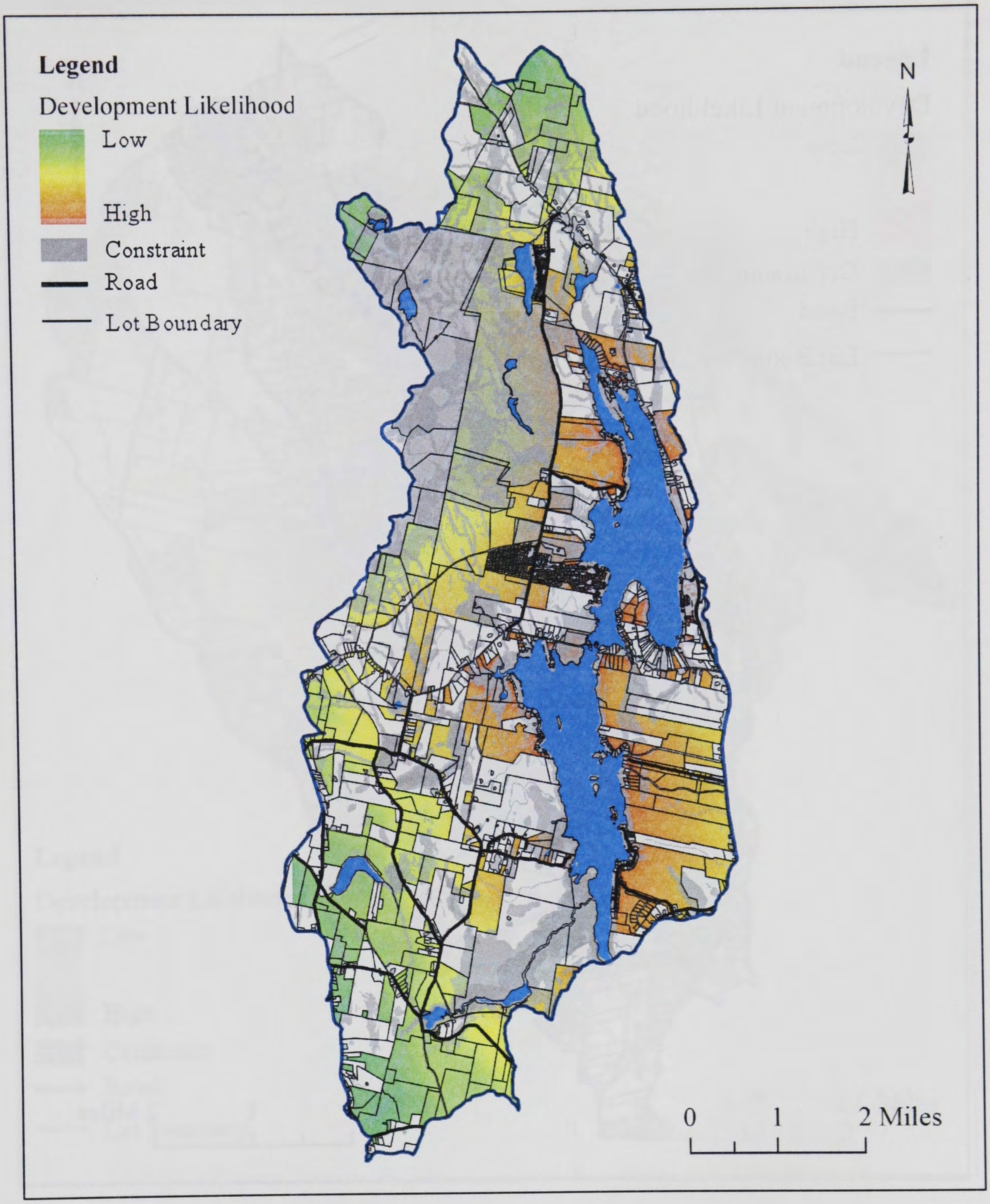

Figure 19. Development likelihood in the Long Pond watershed, based on an equal weighted overlay of Euclidean distances to lakes and roads for vacant lots in the watershed. Gray areas represent physical or legal constraints to development, including existing development.

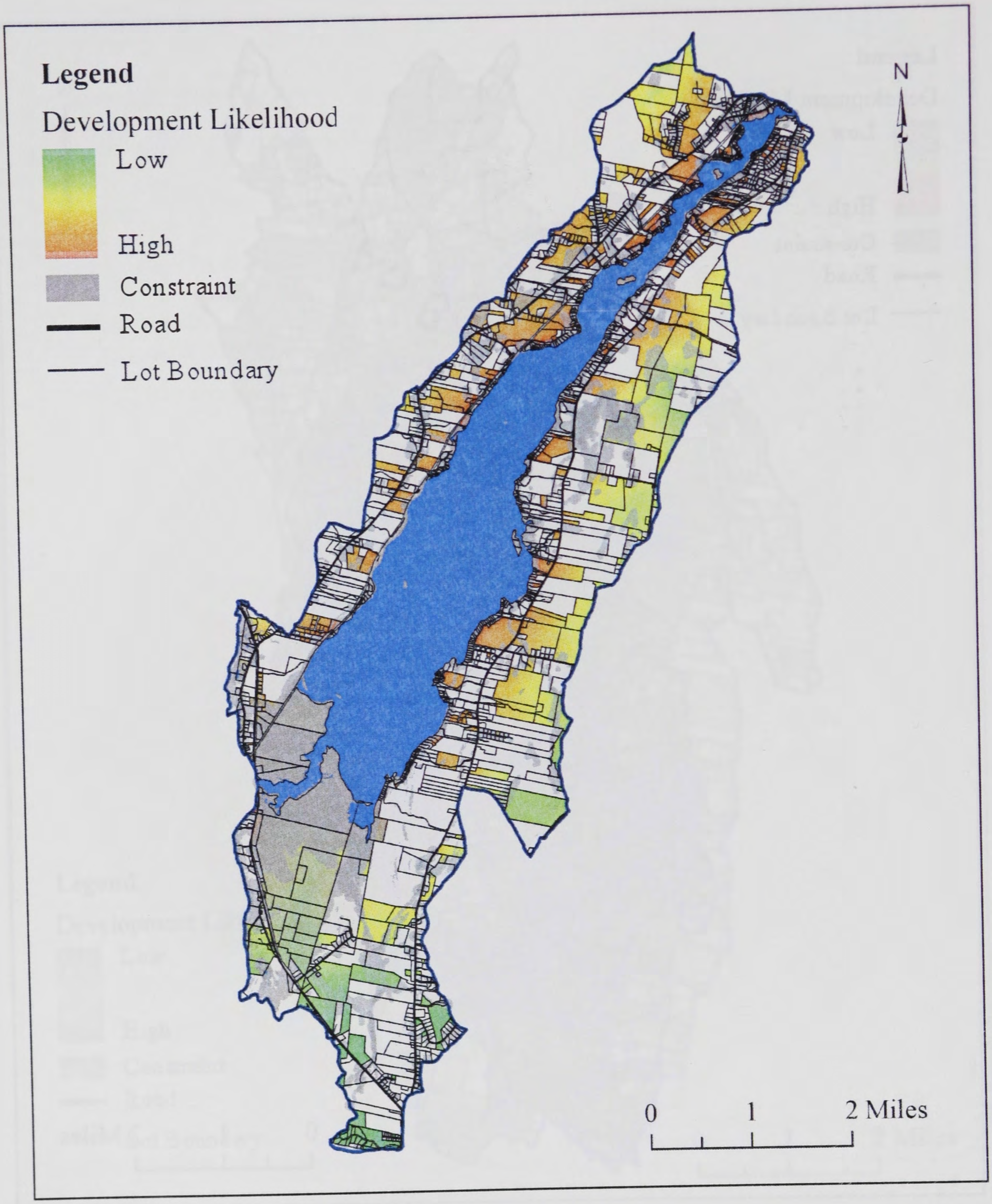

Figure 20. Development likelihood in the Messalonskee Lake watershed, based on an equal weighted overlay of Euclidean distances to lakes and roads for vacant lots in the watershed. Gray areas represent physical or legal constraints to development, including existing development.

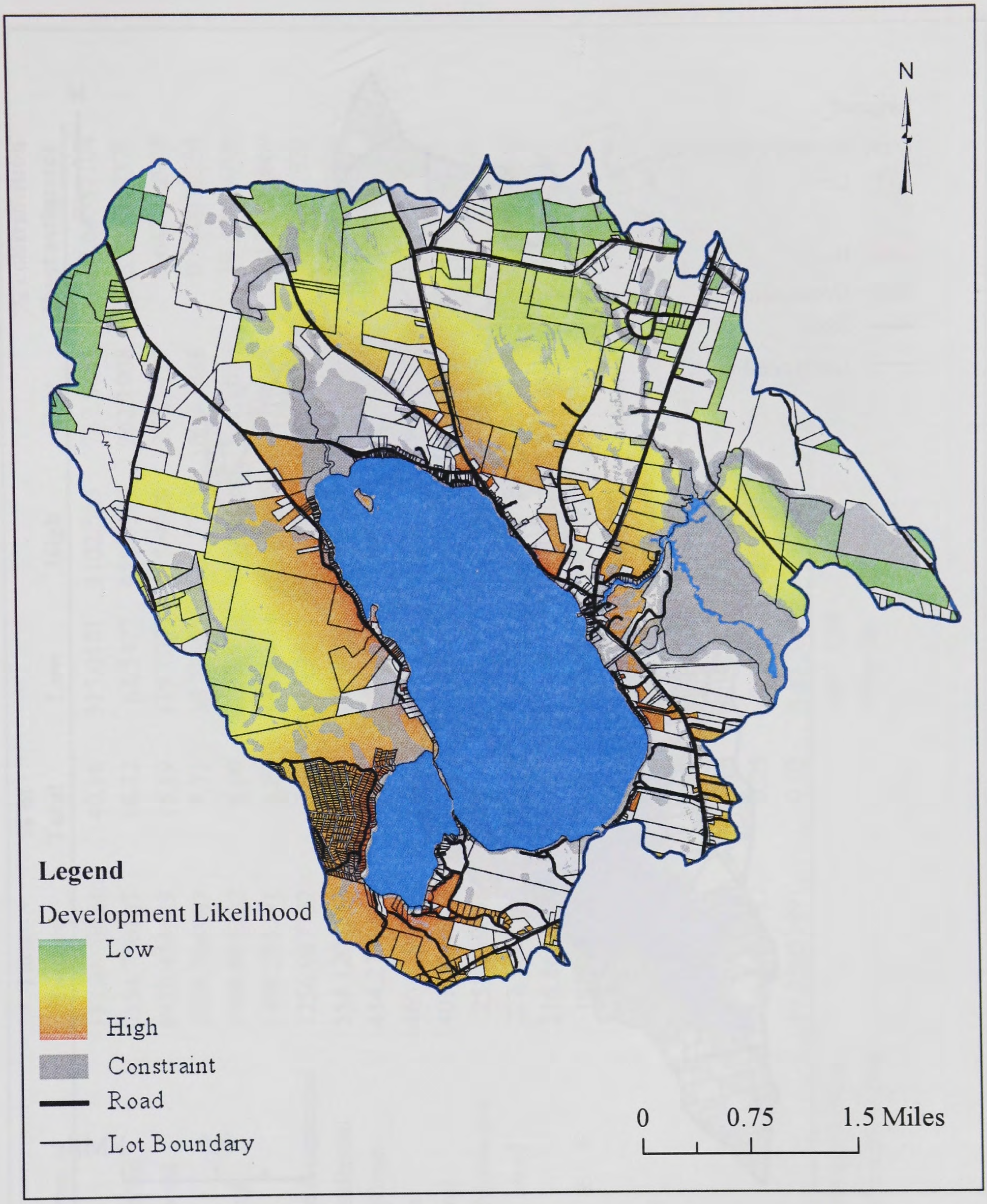

Figure 21. Development likelihood in the North Pond watershed, based on an equal weighted overlay of Euclidean distances to lakes and roads for vacant lots in the watershed. Gray areas represent physical or legal constraints to development, including existing development.

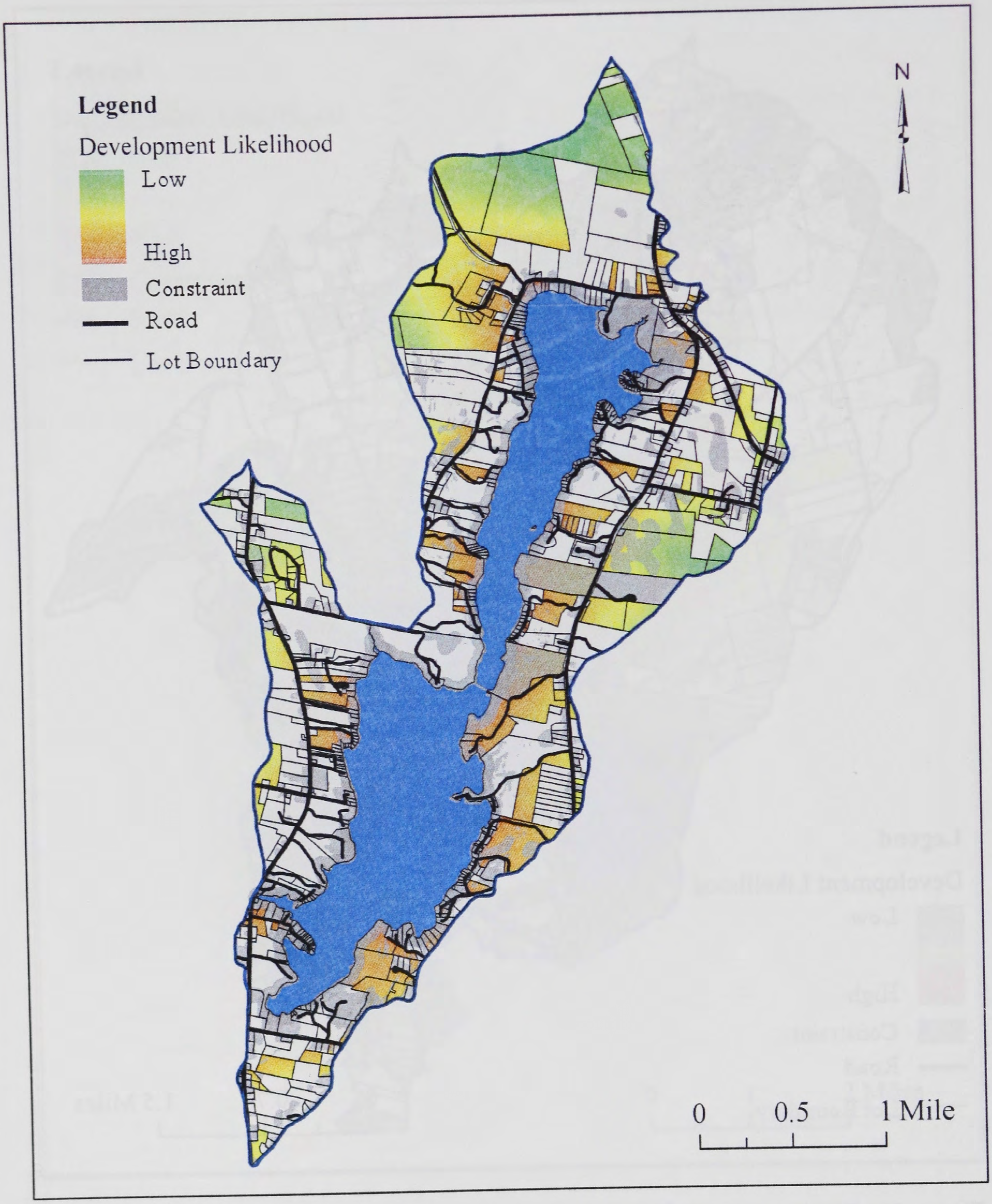

Figure 22. Development likelihood in the Salmon/McGrath watershed, based on an equal weighted overlay of Euclidean distances to lakes and roads for vacant lots in the watershed. Gray areas represent physical or legal constraints to development, including existing development.

Table 11. Current Phosphorus Inputs (kg/yr) (estimates) by Land Use Type in the Belgrade Lakes Watershed

Type	Total Hectares	% of Total	Low	High	Best	% contribution (best estimate)
Mixed Forest	15750.90658	40.18	315.0181	1102.563	787.5453	9.64557104
Coniferous Forest	6554.770107	16.72	65.5477	458.8339	262.1908	3.211218371
Deciduous Forest	5955.454529	15.19	119.1091	535.9909	297.7727	3.647012916
Wetland	3027.504907	7.72	30.27505	151.3752	80.83438	0.990030333
Cropland/Farm	1960.865202	5.00	1078.476	2980.515	1602.027	19.62104708
Open Field	1499.255191	3.82	1199.404	1949.032	1499.255	18.36233664
Non-shoreline Residential	1256.987702	3.21	339.3867	1508.385	1194.138	14.62537525
Shoreline Residential	554.1207361	1.41	267.6403	1063.912	775.769	9.501339186
Transitional Forest	434.2768406	1.11	65.14153	390.8492	130.2831	1.595659816
Logging Area	466.9190559	1.19	93.38381	280.1514	186.7676	2.287462452
Reverting Land	401.0019063	1.02	32.08015	80.20038	72.18034	0.8840388
Commercial/Municipal	251.769698	0.64	88.11939	251.7697	100.7079	1.233433769
Regenerating Land	227.7087745	0.58	34.15632	204.9379	72.18368	0.884079687
Dirt Road	216.8683749	0.55	114.9402	1329.403	535.6649	6.560630253
Paved Road	198.116677	0.51	94.10542	752.8434	213.966	2.620578505
State Road	148.296607	0.38	70.44089	563.5271	160.1603	1.961586003
Cleared Land	106.817673	0.27	26.70442	149.5447	56.93382	0.697304882
Tree Farm	91.79569431	0.23	4.589785	9.179569	7.343656	0.089942443
Camp	62.98784124	0.16	30.42313	120.9367	88.18298	1.080033295
Golf Course	19.5780787	0.05	18.10972	53.83972	25.4515	0.311720817
Park	19.35051091	0.05	4.837628	18.9635	15.48041	0.189598461
Total w/o sediment release			4091.889	13956.75	8164.839	
Total with sediment release			4908.96	21310.39	13067.26	

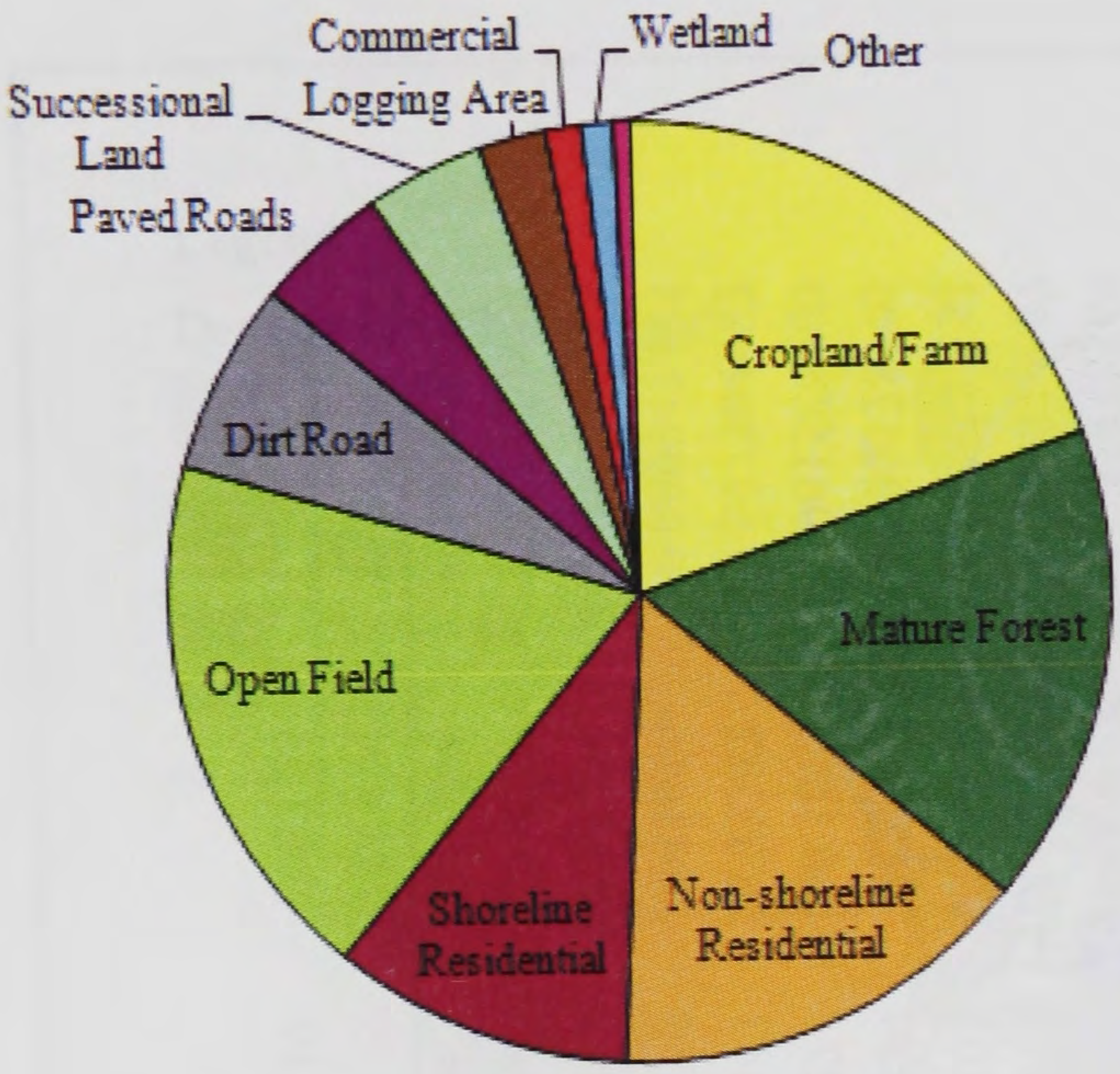

Figure 23. Comparison of phosphorus contributions by land use type in the Belgrade Lakes watershed

The contribution of shoreline and non-shoreline residential development is expected to increase in each successive time scenario. In 2020, both types of residential development are expected to contribute an additional 141.00 kg P/yr from 2008 levels (Table 12). In 2050, residential development is projected to contribute an additional 473.89 kg P/yr from 2008 levels. By 2050, the average total phosphorus concentration in the Belgrade Lakes is expected to be 12.55 ppb. The high estimate predicts increases of approximately 0.5 ppb approximately every 15 years, with the phosphorus concentration increasing from a current high estimate of 20.55 to 21.95 ppb by 2050. It should be noted, however, that phosphorus concentrations vary greatly from lake to lake and that some Lakes are expected to experience greater changes than others.

Table 12. Current and Projected Phosphorus (kg/yr) Inputs from Residential Land in the Belgrade Lakes Watershed

Type	Current	2020	2035	2050
Shoreline Residential	554.12	584.02	619.97	645.02
Non-shoreline Residential	1256.99	1368.09	1486.46	1639.98
Total	1811.11	1952.10	2106.43	2285.00
Change		141.00	154.33	178.57

The model was run for individual lake watersheds to highlight lakes with higher susceptibility to future increases in phosphorus concentrations based on expected increases in residential development. All of the Belgrade Lakes currently fall within or near the 12 – 15 ppb total phosphorus concentration range for algal blooms, except Long Pond. In terms of

total phosphorus, Long Pond is in the best current condition with a best estimate of 6.12 ppb

Table 13. Best Estimates of Total Phosphorus Concentrations in the Belgrade Lakes (with sediment release)

Lake	2008	2020	2035	2050
East Pond	13.07	13.15	13.28	13.48
Great Pond	11.04	11.18	11.48	11.98
Long Pond	6.12	6.26	6.56	7.02
Messalonskee	13.01	13.34	14.14	15.37
North Pond	11.76	11.77	11.80	11.85
Salmon/McGrath	17.40	17.79	18.55	19.64
Average	11.93	12.13	12.35	12.55

from Reckhow and Chapra (1983) and CEAT 2007, 2008, 2009, 2010

(Table 13). Despite moderate projected increases in residential development in Belgrade, Mt. Vernon and Rome, Long Pond is naturally less susceptible to high phosphorus concentrations due to its fast flushing rate (3.70 flushes/yr) (Table 1) and elongated basin. In 2050, the predicted total phosphorus concentration for Long Pond is 7.02 ppb, demonstrating slightly less than a 1 ppb increase over a 40 year period. In contrast, Messalonskee Lake appears to be the most vulnerable to residential development related phosphorus increases. Currently, Messalonskee Lake is at 12.98 ppb, but is expected to increase to 15.37 ppb in 2050. This can be attributed to the high level of projected growth in residential development in Sidney, the fastest growing town in the watershed. Belgrade and Oakland, also located within the Messalonskee Lake watershed, are the two largest towns in the Belgrade Lakes Region and can expect moderate development increases. The Messalonskee Lake watershed is situated within three large towns near the cities of Waterville and Augusta, so its relative high vulnerability to phosphorus increases should make responsible development planning and mitigation of current phosphorus loading sources a priority for the management of the lake. At the same time, however, Messalonskee Lake is located at the end of the Belgrade Lakes chain, so increases in its phosphorus concentration do not affect the other Belgrade Lakes. Salmon Lake and McGrath Pond, like Messalonskee Lake, are expected to experience a large increase in total phosphorus of approximately 2.36 ppb by 2050. Regardless of the level of increase, Salmon Lake and McGrath Pond are vulnerable to algal blooms based on the phosphorus concentration above the critical range. The Salmon/McGrath watershed is also

relatively small compared to the other lake watersheds, so development within the watershed can have a greater affect on lake water quality. It should be mentioned, however, that Salmon Lake is likely considerably more vulnerable to algal blooms that McGrath Pond. Salmon Lake has experienced blooms several times in the past and McGrath Pond never has. Phosphorus concentrations in Salmon Lake are generally higher than in McGrath Pond (CEAT 2010).

The other Belgrade Lakes can expect smaller increases in phosphorus concentrations of 1 ppb or less by 2050. North Pond and East Pond are expected to increase less than 0.5 ppb between now and 2050. This is consistent with development projections in the northern part of the watershed. Smithfield and Mercer are not expected to experience growth in residential development in the foreseeable future, so the current water quality of these lakes at least can be maintained in the future. East Pond has been susceptible to algal blooms in the past, however, so efforts should focus on lowering current inputs. North Pond currently rests near the critical phosphorus concentration range at 11.76 ppb, so North Pond could be susceptible to algal blooms, though its susceptibility is not expected to increase substantially in coming decades. Great Pond, the largest lake in the system, is projected to increase approximately 1 ppb in the next 40 years. This projected phosphorus concentration of Great Pond (11.98 ppb), like North Pond, falls very close to the 12 – 15 ppb critical range, so future residential development could increase the likelihood of algal blooms if measures are not taken to reduce phosphorus loading from existing and future sources.

The results of the phosphorus model suggest that the phosphorus contributions of agricultural lands (croplands and open fields), residential areas and roads should be priorities in reducing phosphorus loading into the Belgrade Lakes. Although mature forests were the overall greatest contributors, forests perform a number of important ecological functions and are generally considered beneficial to watersheds and lake water quality. Agricultural land use has been decreasing in recent decades, so it is feasible that phosphorus loading from agricultural areas could decrease. For lands that remain under cultivation, it is important that farmers make efforts to reduce soil erosion and avoid the use of phosphorus-containing fertilizers. Vegetative buffers should be installed if farms are located near streams and lakes. Residential areas are lands with some of the highest potential for reduction in phosphorus

inputs. Homeowners on and off the shoreline should keep areas of exposed soil to a minimum to decrease erosion. An effective way to reduce shoreline residential inputs is through the use of shoreline buffers (see Recommendations: Shoreline Buffers).

Dirt roads are another land use type that could use improvement. Dirt roads are particularly important because they are often located near the shoreline and serve as transport pathways for nutrients and erosion during or after rainfall. At the same time, dirt roads can be challenging to maintain because maintenance is the responsibility of private landowners (state and municipal roads are publically maintained). Dirt road maintenance can be expensive and many landowners lack the funds or the necessary knowledge to maintain dirt roads properly. The Kennebec County Soil & Water Conservation District (KCSWCD) publishes a useful guide for successful dirt road maintenance (KCSWCD 1987) (see Recommendations: Roads).

It should be noted that the predicted increases in phosphorus loading from residential land use do not take into consideration potential mitigation practices homeowners might undertake to reduce phosphorus loading, such as driveway improvements, shoreline buffer installation or efforts to reduce soil erosion. It is also important to recognize that these expectations are based on population projections only. Accurate projections are increasingly difficult further into the future and a fair amount of uncertainty is involved due to the variety of factors that could impact development or water quality. Economic factors could increase or decrease development pressure in the watershed. New techniques could be developed to reduce erosion from existing non-point sources. At the same time, however, most of the shoreline will likely be developed by 2050, so updating septic systems and installing proper shoreline buffers should be among the highest priorities moving forward. These factors should be taken into consideration in future development projects, but similar efforts should also be undertaken to reduce the phosphorus input of existing development.

It also should be noted that this model did not take into consideration other potential changes in land use beyond changes in residential land, mature forest and successional land. As residential land increases, new roads will likely be constructed, which could increase the overall external phosphorus load. It is possible that our assumptions for succession rates may not accurately reflect the vegetative composition of the overall watershed, especially if

logging areas were to increase unexpectedly. As with population, predicting future changes in land use is difficult later in the future because changes in land use can be attributed to human activities affected by population flux. Although it is fairly certain that land use will change over time and that certain land use types can have greater impacts on phosphorus loading, the amount that land use will change is less clear.

Finally, the projected phosphorus concentrations represent mean concentrations for a lake system that historically has shown variability. Phosphorus concentrations can vary substantially in different parts of the lakes and this study cannot predict what areas of lakes are more susceptible algal growth than others. Some lakes are also likely to be impacted more than others by future development. The northern portion of the watershed is expected to experience less development pressure, which is fortunate because East Pond and North Pond are located at the top of the Belgrade chain. In addition, some of the greatest development pressure is expected to occur in the Long Pond and Messalonskee Lake watersheds, which is also beneficial to the system as a whole. Both of these lakes have deep, elongated basin shapes and high flushing rates, so algal blooms are naturally less likely. Continued research on the regional transfer of phosphorus through the Belgrade Lakes chain is needed to understand better the relative vulnerability of specific areas.

RECOMMENDATIONS

Septic Systems

- Towns should develop plans for updating grandfathered septic systems, particularly those along the shoreline. Septic systems are one of the largest contributors to phosphorus loading in the Belgrade Lakes Region and old septic systems contribute many times more phosphorus than systems that meet current regulations (Bouchard, pers. comm.). Upgrading old septic systems would help mitigate additional phosphorus loading from new development.
- Information should be gathered on the status of septic systems throughout the watershed, especially in towns with less complete records. Data on the number of grandfathered systems would be useful in directing efforts to update these systems.

Roads

- Dirt (camp) roads should be properly maintained. Dirt roads are a large source of soil erosion and serve as transportation for nutrients and eroded sediments during or after heavy rain. Adequate, ditching, crowning and culverts for proper drainage should be inspected annually. Ditches and culverts should be kept clear of debris. Maine DEP publishes an informative manual on dirt roads that homeowners might find useful in making camp road maintenance as efficient as possible. A guide to dirt road maintenance provided by the Kennebec County Soil & Water Conservation District (KCSWCD) is available online from Maine DEP free of charge at (KCSWCD 1987): http://www.maine.gov/dep/blwq/docwatershed/camproad.pdf
- Construction of new roads should be kept to a minimum. New development would contribute less phosphorus if it were built on existing roads.
- Road associations can also be useful in sharing maintenance costs of dirt roads. It is estimated that $1 invested in road maintenance can prevent up to $15 of maintenance spending in the future when problems can worsen (CEAT 2010). A Guide to Forming Road Associations (MDEP 2004) can be obtained free of charge at: http://maine.gov/dep/blwq/docwatershed/roadassociation.htm

Shoreline Buffers

- Adequate shoreline buffers should be installed and maintained to minimize nutrient loading from stormwater runoff. Shoreline buffers prevent nutrients from entering the lakes by absorbing and slowing down runoff, maintaining soil structure and reducing the impact of falling precipitation.

- Buffers should consist of a variety of vegetation types including trees, shrubs, groundcover and a duff layer (leaf litter).
    - Considered a Best Management Practice (BMP), ideal buffers consist of deeply rooted native vegetation, span the entire length of the property and extend 50-250 ft inland in the direction of the house.
    - Paths leading to the shoreline should be winding to reduce direct paths for stormwater runoff.
    - Areas of exposed soil should be minimized or eliminated if possible.
- Aside from mitigating nutrient runoff, shoreline buffers can also have a number of benefits to homeowners (MDEP 1998):
    - Increased privacy and reduction of noise from neighbors and watercraft
    - Diversion of heavy winds and the provision of shade
    - Low-maintenance costs
    - Enhancement of property values
    - Provision of natural habitat for native plants and animals

The Buffer Handbook can be obtained from Maine DEP free of charge at: http://maine.gov/dep/blwq/docwatershed/bufa.htm.

- Homeowners may find useful the Belgrade Regional Conservation Alliance (BRCA) Conservation Corps, which provides free labor for shoreline buffer installation along all the Belgrade Lakes. Homeowners must pay only for materials and potential permit fees. More information is available here: http://www.belgradelakes.org/corps.html.

Community Involvement

- Membership in lake associations is a useful way to raise awareness about lake water quality and what homeowners can do to improve it. Lake associations provide informative newsletters, courtesy boat inspections for invasive plants and periodic meeting forums for discussions of issues surrounding the lakes.
    - The Belgrade Lakes Association (Great Pond and Long Pond): http://www.belgradelakesassociation.com/
    - East Pond Association: http://www.eastpond.org/
    - McGrath Pond Salmon Lake Association: http://www.salmonlake.org/index.html.
    - North Pond Association: http://www.northpond.net/.
    - Snow Pond/Messalonskee Lake Association: http://www.snowpond.org/Resources.html.

- The Belgrade Regional Conservation Alliance should continue to provide education and strategies for watershed protection as well as continue its efforts to hire local high school students for work in the Conservation Corps.

Research

- Monitoring of water quality parameters, especially phosphorus concentrations, should continue. Colby College is currently investigating potential changes in phosphorus concentrations along different points in the Belgrade Lakes chain. This information would be helpful in determining if certain land areas exert disproportionate impacts on the entire Belgrade Lakes watershed and would help enable improvement strategies to be developed. Monitoring of more specific water quality parameters in each lake should also be continued to determine the susceptibility to potential problems such as algal blooms and anoxia.
- Special attention should be paid to Salmon Lake, McGrath Pond and East Pond because these lakes are the first links in the Belgrade chain.

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APPENDIX 1. DEVELOPMENT STATISTICS BY WATERSHED AND TOWN

This appendix contains development information obtained from town tax assessment records for each of the six Belgrade lake watersheds and the Belgrade Stream. Included are the numbers of houses, mobile homes, commercial camps and commercial and municipal establishments in each town for each watershed. Also included are the numbers of vacant lots on and off the shoreline in each town. Vacant lots were considered buildable if they met minimum lot size and in the case of shoreline lots, minimum shore frontage requirements, despite the presence of development constraints (see Methods: Development Constraints).

Belgrade Stream Watershed

Current Development

Town	Houses	Mobile Homes	Commercial Camps	Commercial/ Municipal	Total
Belgrade	409	49	0	7	465
Manchester	92	20	0	0	112
Mt. Vernon	172	40	0	0	212
Readfield	168	35	1	1	205
Watershed	841	144	1	8	994

Source: Town records

Housing Development History

Year	Belgrade	Manchester	Mt. Vernon	Readfield	Total
1750-1900	55	9	33	25	122
1901-1920	4	0	2	1	7
1921-1940	19	0	8	7	34
1941-1950	16	0	4	4	24
1951-1960	8	3	5	1	17
1961-1970	26	3	10	10	49
1971-1980	41	19	26	13	99
1981-1990	75	31	37	39	182
1991-2000	94	22	19	40	175
2001-2008	65	5	28	27	125
Watershed	403	92	172	167	834

Source: Town records

Note: 6 houses of unknown age in Belgrade, 1 in Readfield

Vacant Non-shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	170	144	26	127
Manchester	34	32	2	29
Mt. Vernon	105	77	28	65
Readfield	72	63	9	56
Watershed	381	316	65	277

Source: Tax assessment maps, Maine Office of GIS and development constraints
Buildable lots meet minimum lot size standards despite the presence of development constraints

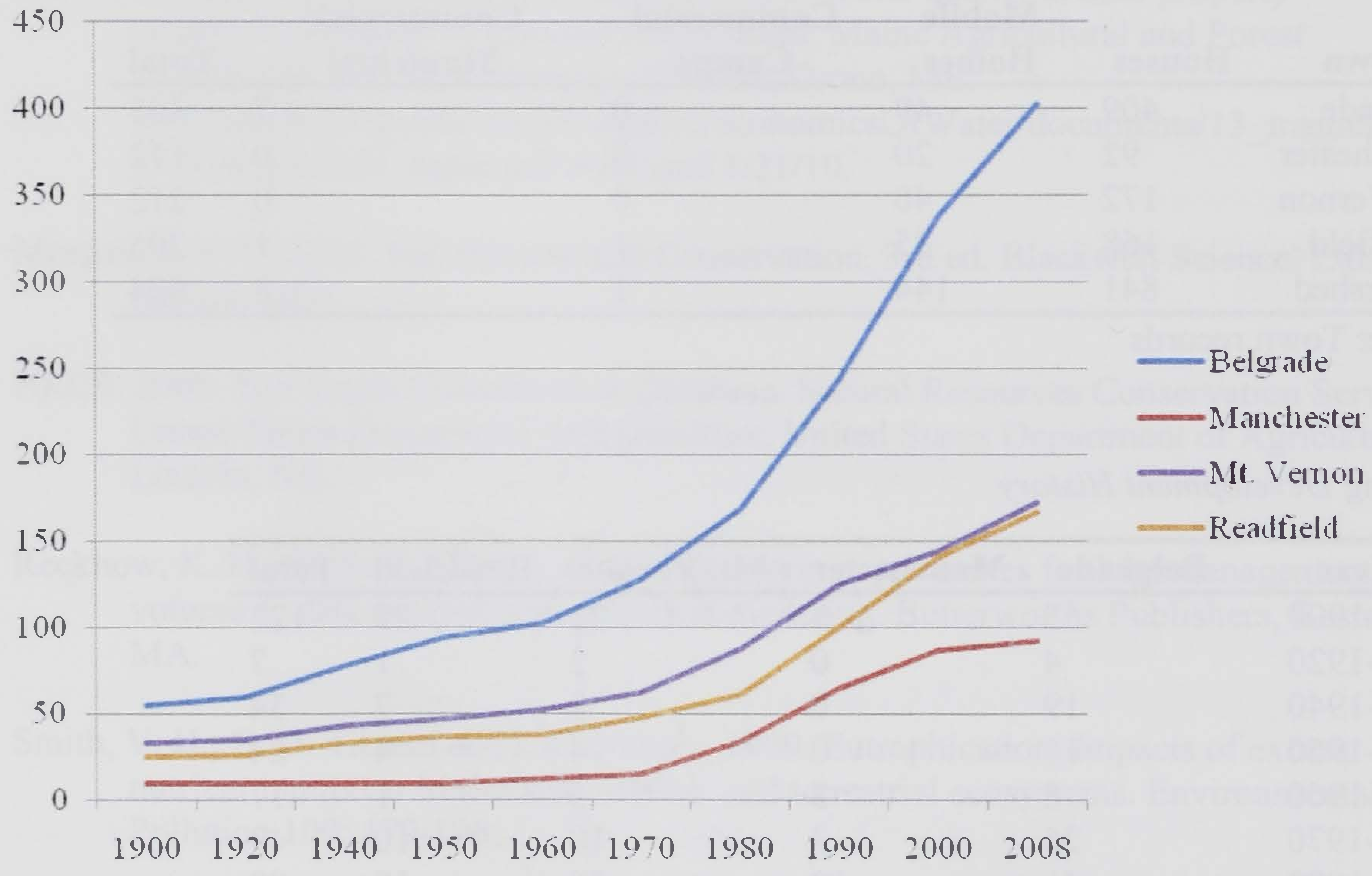

Figure 24. Residential development (houses and mobile homes) by town in the Belgrade Stream watershed. Decade is on the horizontal axis and development is on the vertical axis.

East Pond Watershed

Current Development

Town	Houses	Mobile Homes	Commercial Camps	Commercial/ Municipal	Total
Oakland	194	9	1	1	205
Smithfield	104	3	1	0	108
Watershed	298	12	2	1	313

Source: Town records

Housing Development History

Year	Oakland	Smithfield	Total
1870-1900	2	5	7
1901-1920	16	5	21
1921-1940	17	9	26
1941-1950	16	3	19
1951-1960	24	7	31
1961-1970	15	8	23
1971-1980	30	7	37
1981-1990	23	16	39
1991-2000	21	21	42
2001-2008	30	22	52
Watershed	194	103	297

Source: Town records
Note: 1 house in Smithfield of unknown age

Vacant Shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Oakland	15	3	12	2
Smithfield	25	17	8	16
Watershed	40	20	20	18

Source: Tax assessment maps, Maine Office of GIS and development constraints
Buildable lots meet minimum lot size standards despite the presence of development constraints

Vacant Non-shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Oakland	42	40	2	37
Smithfield	38	33	5	30
Watershed	80	73	7	65

Source: Tax assessment maps, Maine Office of GIS and development constraints

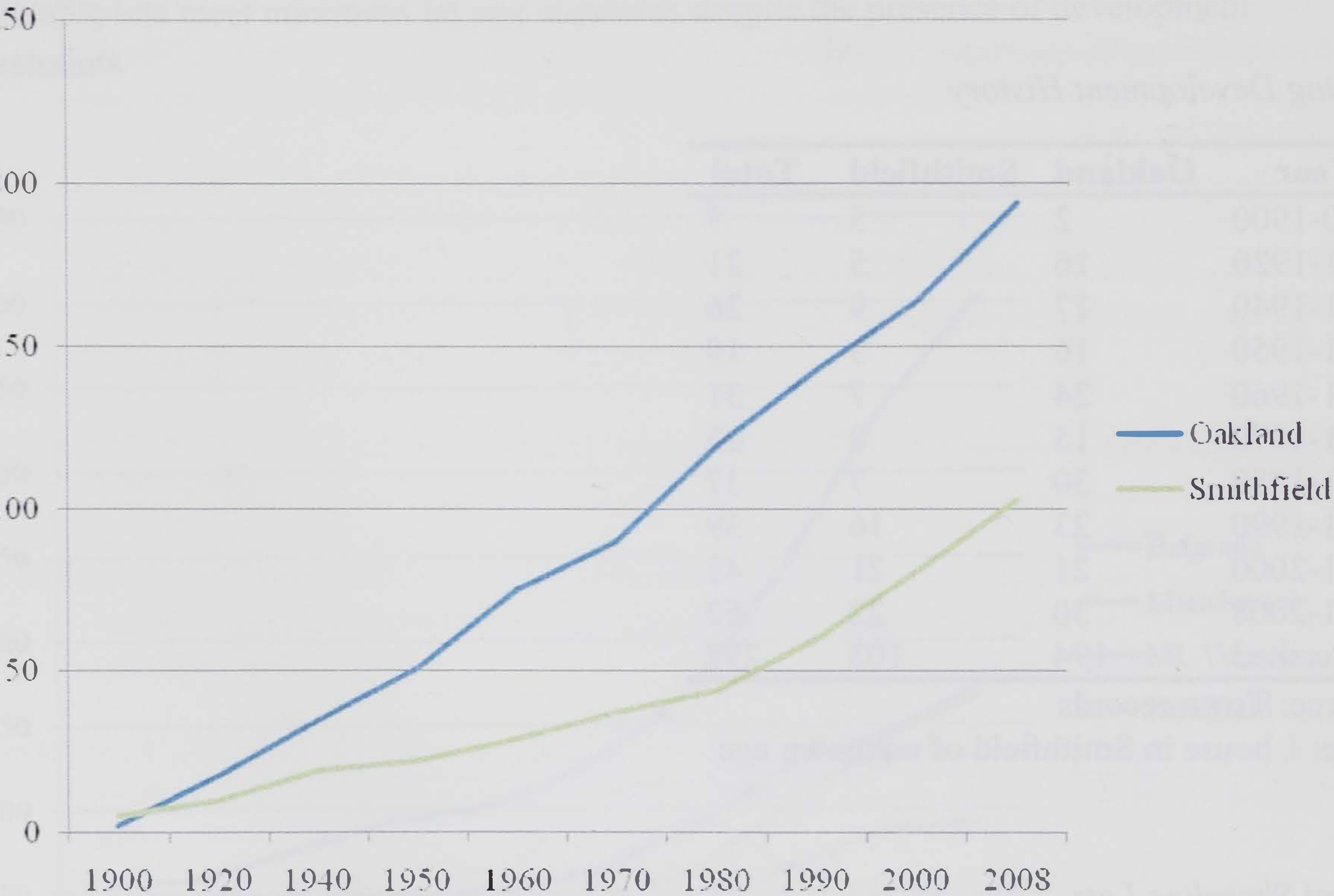

Figure 25. Residential development (houses and mobile homes) by town in the East Pond watershed. Decade is on the horizontal axis and development is on the vertical axis.

Great Pond Watershed

Current Development

Town	Houses	Mobile Homes	Commercial Camps	Commercial/ Municipal	Total
Belgrade	911	26	2	11	950
Mercer	14	0	0	0	14
Oakland	3	1	0	0	4
Rome	443	34	1	2	480
Smithfield	46	5	0	1	52
Watershed	1417	66	3	14	1500

Source: Town records

Housing Development History

Year	Belgrade	Mercer	Oakland	Rome	Smithfield	Total
1785-1900	81		0	17	8	106
1901-1920	47		0	17	0	64
1921-1940	64		0	16	5	85
1941-1950	78		0	17	2	97
1951-1960	129		0	15	7	151
1961-1970	71		0	28	1	100
1971-1980	102		0	37	6	145
1981-1990	125		0	66	4	195
1991-2000	119		1	58	9	187
2001-2008	87		2	170	3	262
Watershed	903	14	3	441	45	1406

Source: Town records
Note: 8 houses of unknown age in Belgrade, 14 in Mercer, 2 in Rome, 1 in Smithfield

Vacant Shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	65	38	27	35
Mercer	0	0	0	0
Oakland	0	0	0	0
Rome	31	20	11	16
Smithfield	0	0	0	0
Watershed	96	58	38	51

Source: Tax assessment maps, Maine Office of GIS and development constraints
Buildable lots meet minimum lot size standards despite the presence of development constraints

Vacant Non-shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	158	123	35	114
Mercer	41	38	3	22
Oakland	4	3	1	0
Rome	469	113	356	89
Smithfield	15	11	4	9
Watershed	687	288	399	234

Source: Tax assessment maps, Maine Office of GIS and development constraints

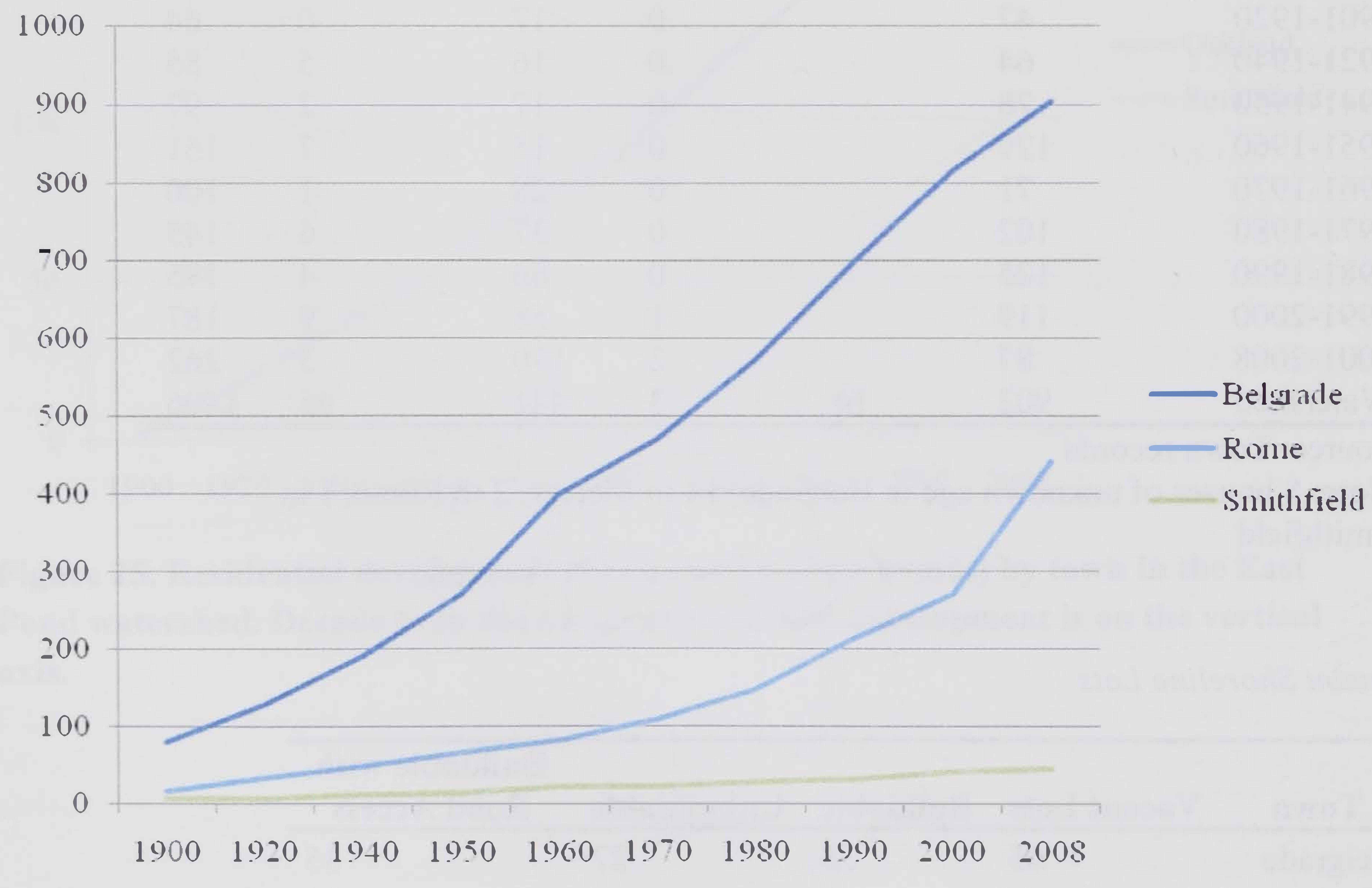

Figure 26. Residential development (houses and mobile homes) by town in the Great Pond watershed. Decade is on the horizontal axis and development is on the vertical axis.

Long Pond Watershed

Current Development

Town	Houses	Mobile Homes	Commercial Camps	Commercial/ Municipal	Total
Belgrade	283	3	1	4	291
Mt. Vernon	270	34	0	1	305
New Sharon	2	0	0	0	2
Rome	426	38	0	3	467
Watershed	981	75	1	8	1065

Source: Town records

Housing Development History

Year	Belgrade	Mt. Vernon	New Sharon	Rome	Total
1732-1900	26	47	0	6	79
1901-1920	4	6	0	9	19
1921-1940	9	8	0	13	30
1941-1950	17	4	0	3	24
1951-1960	17	7	0	18	42
1961-1970	37	14	0	20	71
1971-1980	65	42	0	54	161
1981-1990	29	57	0	101	187
1991-2000	26	35	0	64	125
2001-2008	52	44	2	135	233
Watershed	282	264	2	423	971

Source: Town records

Note: 1 house in Belgrade of unknown age, 6 in Mt. Vernon, 3 in Rome

Vacant Shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	40	21	19	17
Mt. Vernon	26	9	17	8
New Sharon	0	0	0	0
Rome	60	16	44	13
Watershed	126	46	80	38

Source: Tax assessment maps, Maine Office of GIS and development constraints
Buildable lots meet minimum lot size standards despite the presence of development constraints

Vacant Non-shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	120	82	38	79
Mt. Vernon	187	146	41	125
New Sharon	7	7	0	6
Rome	578	65	513	56
Watershed	892	300	592	266

Source: Tax assessment maps, Maine Office of GIS and development constraints

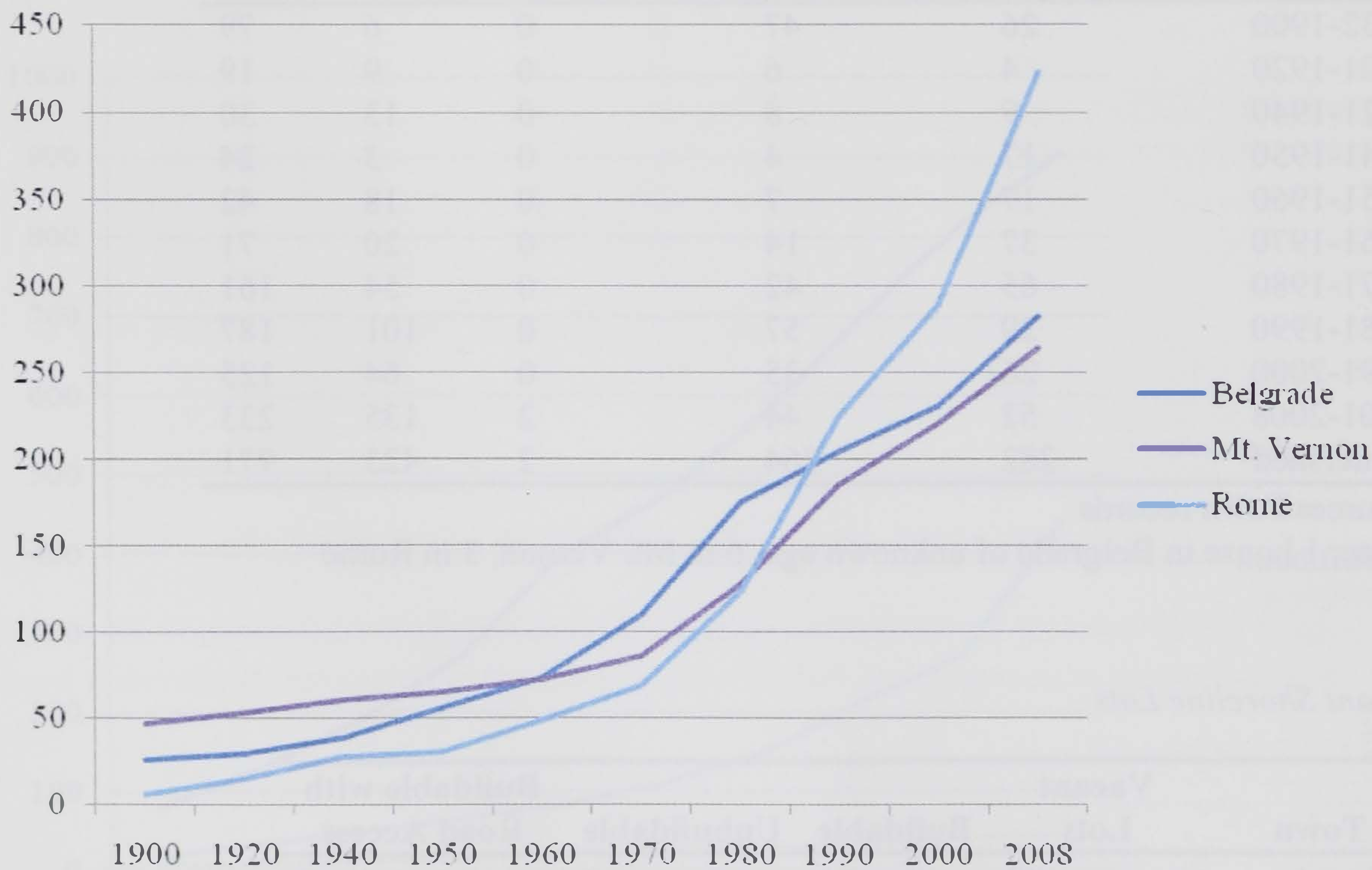

Figure 27. Residential development (houses and mobile homes) by town in the Long Pond watershed. Decade is on the horizontal axis and development is on the vertical axis.

Messalonskee Lake Watershed

Current Development

Town	Houses	Mobile Homes	Commercial Camps	Commercial/ Municipal	Total
Belgrade	336	24	0	13	373
Oakland	547	10	0	1	558
Sidney	543	45	1	6	595
Watershed	1426	79	1	20	1526

Source: Town records

Housing Development History

Year	Belgrade	Oakland	Sidney	Total
1760-1900	64	34	48	146
1901-1920	25	5	2	32
1921-1940	35	17	39	91
1941-1950	29	31	16	76
1951-1960	21	67	26	114
1961-1970	25	54	38	117
1971-1980	33	96	93	222
1981-1990	39	101	89	229
1991-2000	31	72	101	204
2001-2008	32	70	79	181
Watershed	334	547	531	1412

Source: Town records

Note: 2 houses of unknown age in Belgrade, 12 in Sidney

Vacant Shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	16	11	5	10
Oakland	19	9	10	5
Sidney	29	16	13	9
Watershed	64	36	28	24

Source: Tax assessment maps, Maine Office of GIS and development constraints

Buildable lots meet minimum lot size standards despite the presence of development constraints

Vacant Non-shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	125	84	41	77
Oakland	124	103	21	84
Sidney	122	107	15	70
Watershed	371	294	77	231

Source: Tax assessment maps, Maine Office of GIS and development constraints

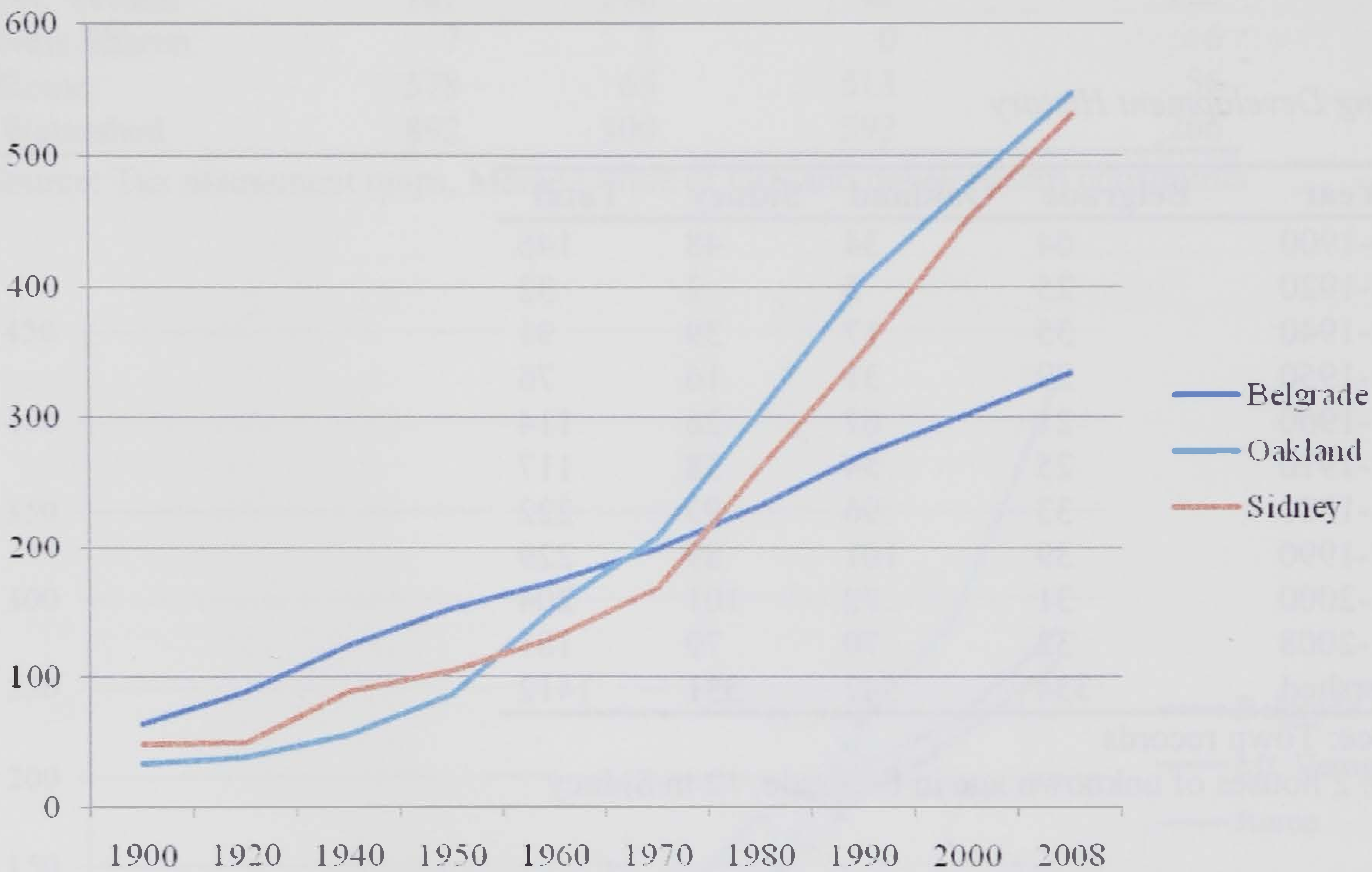

Figure 28. Residential development (houses and mobile homes) by town in the Messalonskee Lake watershed. Decade is on the horizontal axis and development is on the vertical axis.

North Pond Watershed

Current Development

Town	Houses	Mobile Homes	Commercial Camps	Commercial/ Municipal	Total
Mercer	104	7	0	0	111
Norridgewock	4	2	0	0	6
Rome	54	2	1	0	57
Smithfield	368	19	1	6	394
Watershed	530	30	2	6	568

Source: Town records

Housing Development History

Year	Mercer	Norridgewock	Rome	Smithfield	Total
1800-1900	0	0	1	40	41
1901-1920	0	0	0	20	20
1921-1940	0	0	2	44	46
1941-1950	0	1	0	38	39
1951-1960	0	0	3	32	35
1961-1970	0	0	7	37	44
1971-1980	0	0	0	47	47
1981-1990	0	1	10	45	56
1991-2000	54	1	2	39	96
2001-2008	6	1	29	24	60
Watershed	104	4	54	366	528

Source: Town records
Note: 44 houses of unknown age in Mercer, 2 in Smithfield

Vacant Shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Mercer	24	3	21	3
Norridgewock	0	0	0	0
Rome	27	10	17	7
Smithfield	14	1	13	1
Watershed	65	14	51	11

Source: Tax assessment maps, Maine Office of GIS and development constraints
Buildable lots meet minimum lot size standards despite the presence of development constraints

Vacant Non-shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Mercer	58	46	12	33
Norridgewock	5	2	3	2
Rome	397	25	372	22
Smithfield	120	88	32	15
Watershed	580	161	419	72

Source: Tax assessment maps, Maine Office of GIS and development constraints

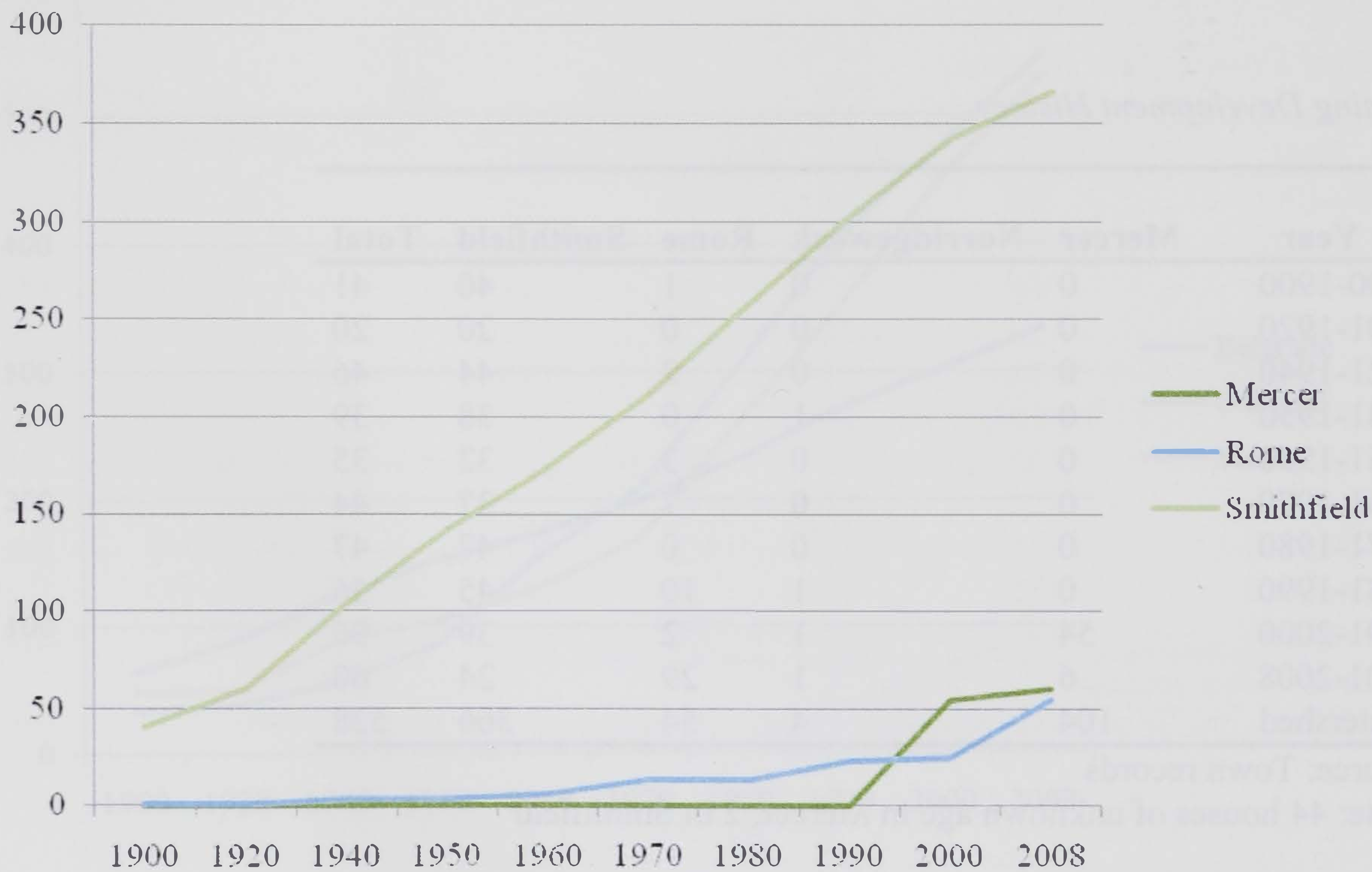

Figure 29. Residential development (houses and mobile homes) by town in the North Pond watershed. Decade is on the horizontal axis and development is on the vertical axis.

Salmon/McGrath Watershed

Current Development

Town	Houses	Mobile Homes	Commercial Camps	Commercial/ Municipal	Total
Belgrade	246	8	3	3	260
Oakland	304	41	0	4	349
Watershed	550	49	3	7	609

Source: Town records

Housing Development History

Year	Belgrade	Oakland	Total
1790-1900	35	16	51
1901-1920	5	7	12
1921-1940	22	14	36
1941-1950	26	20	46
1951-1960	22	18	40
1961-1970	15	17	32
1971-1980	24	66	90
1981-1990	38	42	80
1991-2000	31	45	76
2001-2008	28	58	86
Watershed	246	303	549

Source: Town records

Note: 1 house in Oakland of unknown age

Vacant Shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	13	8	5	8
Oakland	24	7	17	7
Watershed	37	15	22	15

Source: Tax assessment maps, Maine Office of GIS and development constraints

Buildable lots meet minimum lot size standards despite the presence of development constraints

Vacant Non-shoreline Lots

Town	Vacant Lots	Buildable	Unbuildable	Buildable with Road Access
Belgrade	45	38	7	36
Oakland	90	75	15	70
Watershed	135	113	22	106

Source: Tax assessment maps, Maine Office of GIS and development constraints

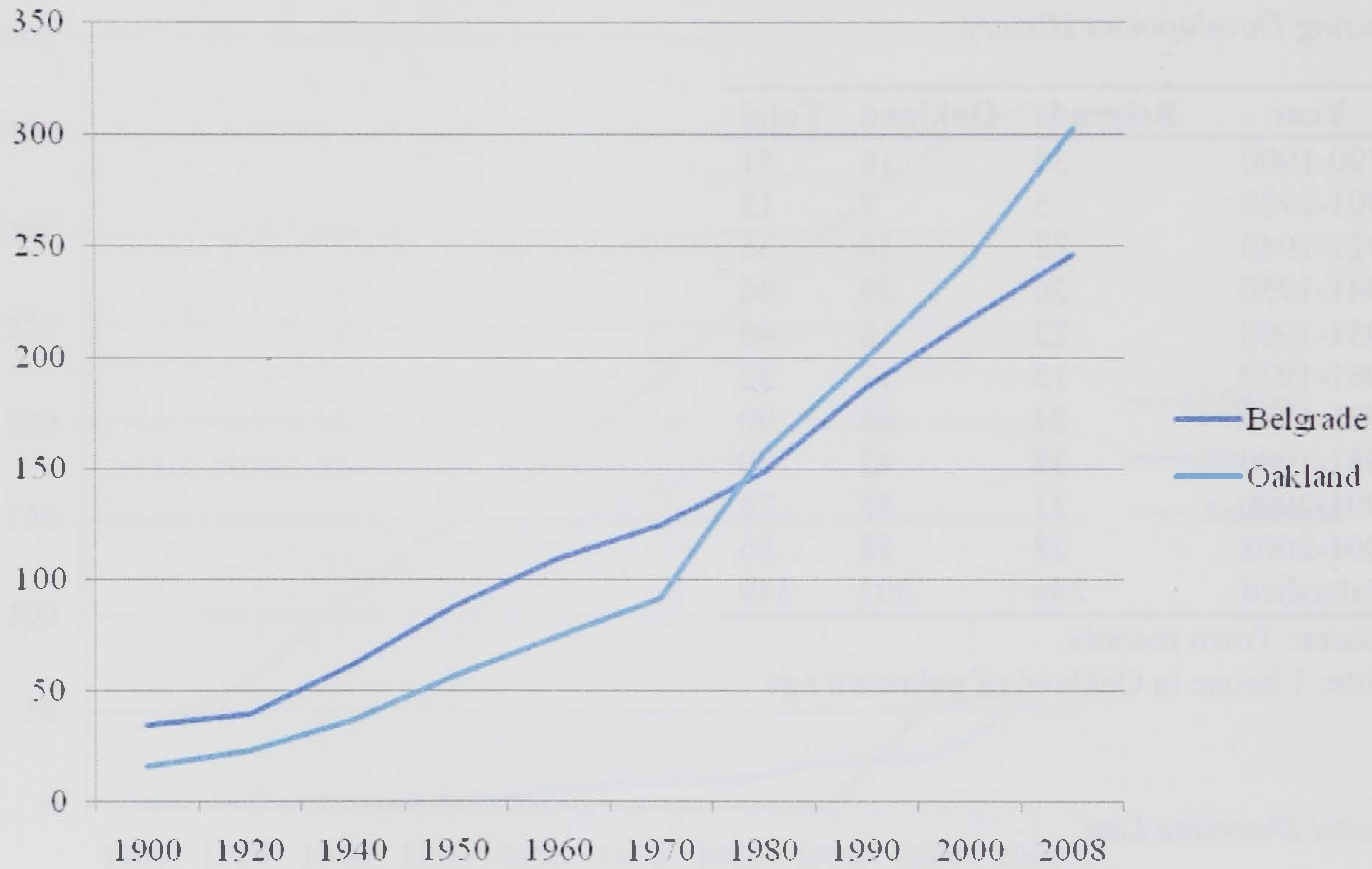

Figure 30. Residential development (houses and mobile homes) by town in the Salmon/McGrath watershed. Decade is on the horizontal axis and development is on the vertical axis.

APPENDIX 2. POSSIBLE SHORELINE SUBDIVISIONS

The number of possible shoreline subdivisions is based on municipal minimum lot size and shore frontage regulations and Maine state resource protection laws (see Methods: Development Constraints). It should be noted that these values represent the number of potential subdivisions that could occur on the shoreline. It is possible for lots subdivided from shoreline lots to be designated as non-shoreline if they are located more than 250 from the shore. Subdivisions of vacant lots are subdivisions of currently vacant lots. Subdivisions of developed lots are lots with existing development that could be further subdivided.

East Pond

Town	Of Vacant Lots	Of Developed Lots	Total
Oakland	0	29	29
Smithfield	9	59	68
Watershed	9	88	97

Great Pond

Town	Of Vacant Lots	Of Developed Lots	Total
Belgrade	22	78	100
Mercer	0	0	0
Oakland	0	0	0
Rome	37	69	106
Smithfield	0	0	0
Watershed	59	147	206

Long Pond

Town	Of Vacant Lots	Of Developed Lots	Total
Belgrade	28	27	55
Mt. Vernon	2	21	23
New Sharon	0	0	0
Rome	1	43	44
Watershed	31	91	122

Messalonskee

Town	Of Vacant Lots	Of Developed Lots	Total
Belgrade	13	29	42
Oakland	14	8	22
Sidney	3	19	22
Watershed	30	56	86

North Pond

Town	Of Vacant Lots	Of Developed Lots	Total
Mercer	2	2	4
Norridgewock	0	0	0
Rome	4	2	6
Smithfield	2	11	13
Watershed	8	15	23

Salmon/McGrath

Town	Of Vacant Lots	Of Developed Lots	Total
Belgrade	9	10	19
Oakland	21	0	21
Watershed	30	10	40

APPENDIX 3. LAND USE AREAS (ha) BY TYPE AND WATERSHED

Type	Belgrade Stream	East Pond	Great Pond	Long Pond	Messalonskee	North Pond	Salmon/ McGrath
Bare Ground	0.00	0.00	2.20	0.01	3.77	0.00	0.00
Camp	0.00	20.71	18.11	0.81	5.61	5.87	30.86
Cemetery	0.00	0.00	0.00	0.00	3.39	0.00	0.00
Cleared Land	13.71	5.86	10.80	20.20	8.84	32.66	8.76
Commercial/Municipal	63.90	3.32	17.20	10.21	72.12	4.32	11.65
Coniferous Forest	1812.88	360.84	1488.67	1976.90	391.49	337.67	186.32
Cropland/Farm	595.09	1.19	282.46	365.52	371.47	279.53	62.49
Deciduous Forest	1150.15	152.49	620.23	2327.45	783.29	844.37	77.47
Dirt Road	37.70	15.35	49.52	48.45	35.54	14.39	15.92
Golf Course	0.00	0.00	54.96	8.03	0.00	0.00	0.00
Gravel Pit	1.86	0.00	39.96	0.00	0.01	27.23	0.00
Logging Area	31.50	0.00	222.43	140.27	0.00	0.00	72.72
Mixed Forest	3325.54	364.88	3864.15	3151.89	1936.48	2280.20	827.77
Non-shoreline Residential	350.28	44.77	179.86	194.39	324.76	68.25	94.68
Open Field	279.92	8.51	117.76	138.81	105.11	76.69	22.82
Orchard	0.00	0.00	0.00	0.00	3.11	0.00	0.00
Park	8.61	0.80	0.35	0.00	7.50	0.00	2.32
Paved Road	52.23	4.93	33.23	47.26	21.85	25.25	13.38
Regenerating Land	76.21	1.43	29.99	11.50	16.87	88.28	3.41
Reverting Land	124.88	19.13	37.26	53.43	56.27	86.37	23.68
Shoreline Residential	0.00	63.45	137.44	95.15	132.02	52.71	73.36
State Road	0.00	4.21	33.97	25.88	52.97	19.16	12.10
Transitional Forest	148.43	3.55	171.00	12.51	44.75	35.42	18.62
Tree Farm	13.42	0.00	36.39	14.13	18.79	9.06	0.00
Wetland	470.06	36.07	706.20	757.75	662.43	368.44	26.56
Total	8556.38	1111.47	8154.13	9400.56	5058.44	4655.86	1584.89

APPENDIX 4. PHOSPHORUS LOADING EXPORT COEFFICIENTS (kg P/ha/yr)

Land Use Type	Low	High	Best
Mixed Forest	0.02	0.07	0.05
Coniferous Forest	0.01	0.07	0.04
Deciduous Forest	0.02	0.09	0.05
Wetland	0.01	0.05	0.0267
Cropland/Farm	0.55	1.52	0.817
Non-shoreline Residential	0.27	1.2	0.95
Open Field	0.8	1.3	1
Shoreline Residential	0.483	1.92	1.4
Logging Area	0.2	0.6	0.4
Transitional Forest	0.15	0.9	0.3
Reverting Land	0.08	0.2	0.18
Regenerating Land	0.15	0.9	0.317
Dirt Road	0.53	6.13	2.47
Paved Road	0.475	3.8	1.08
Commercial/Municipal	0.35	1	0.4
State Road	0.475	3.8	1.08
Cleared Land	0.25	1.4	0.533
Tree Farm	0.05	0.1	0.08
Camp	0.483	1.92	1.4
Golf Course	0.925	2.75	1.3
Park	0.25	0.98	0.8
Sediment Release	0.1	0.9	0.6
Shoreline Septic Systems	0.5	1.3	0.65
Non-shoreline Septic Systems	0.5	1	0.4

Source: CEAT 2007, 2008, 2010

APPENDIX 5. FUTURE ADDITIONAL SHORELINE AND NON-SHORELINE DEVELOPMENT PROJECTIONS BY TOWN AND WATERSHED

Town	Watershed	2020 Shore	2020 Non	2020 Total	2035 Shore	2035 Non	2035 Total	2050 Shore	2050 Non	2050 Total
Belgrade	GP	43	24	67	63	17	80	32*	54	54
Belgrade	LP	11	9	20	14	11	25	23	4	27
Belgrade	MS	6	19	25	8	22	30	8	24	32
Belgrade	BS	0	30	30	0	36	36	0	38	38
Belgrade	SMcG	14	4	18	13*	9	22	0	23	23
Manchester	BS	0	6	6	0	3	3	0	2	2
Mercer	GP	0	0	0	0	0	0	0	0	0
Mercer	NP	0	0	0	0	0	0	0	0	0
Mt. Vernon	LP	8	46	54	11	21	32	13*	20	33
Mt. Vernon	BS	0	35	35	0	20	20	0	21	21
Oakland	EP	4	5	9	2	3	5	3	4	7
Oakland	GP	0	0	0	0	0	0	0	0	0
Oakland	MS	19	6	25	11	4	15	1*	18	19
Oakland	SMcG	6	8	14	3	6	9	4	7	11
Readfield	BS	0	25*	25	0	0	0	0	0	0
Rome	GP	7	6	13	18	18	36	19	19	38
Rome	LP	7	6	13	17	17	34	18	18	36
Rome	NP	1	1	2	2	2	4	3	2	5
Sidney	MS	22	45	67	16*	104	120	0	126	126
Smithfield	EP	0	0	0	0	0	0	0	0	0
Smithfield	GP	0	0	0	0	0	0	0	0	0
Smithfield	NP	0	0	0	0	0	0	0	0	0

Source: Town records, KVCOG and ME State Planning Office population projections. * indicates build-out (maximum capacity in watershed) reached. Watershed abbreviations: BS = Belgrade Stream, EP = East Pond, GP = Great Pond, LP = Long Pond, MS = Messalonskee Lake, NP = North Pond, SMcG = Salmon Lake/McGrath Pond