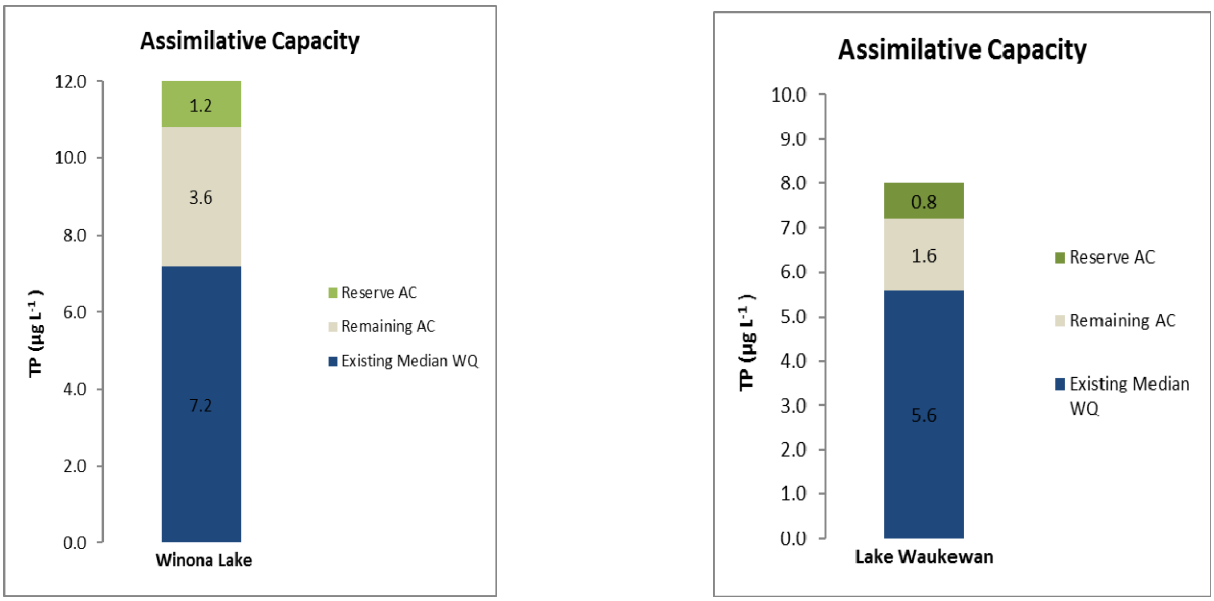


Figure 7. Graph depicting the results of the Assimilative Capacity analysis for total phosphorus for Winona Lake and Lake Waukewan

3.0 Watershed Assessment

3.1 Description of the Study Area

The Lake Waukewan and Winona watershed (Figure 8) encompasses approximately 8,300 acres or 13 square miles of forested and developed land in Belknap and Grafton Counties. The watershed is part of the larger Lake Winnipesaukee watershed and drains to Meredith Bay to its south. It includes portions of five towns: Meredith, New Hampton, Center Harbor, Holderness, and Ashland, New Hampshire. Watershed boundary data was obtained from GRANIT, the New Hampshire GIS clearinghouse maintained by the University of New Hampshire. The Watershed boundaries were edited to accommodate the goals of the Lake Loading Response Model (LLRM) and the watershed restoration plan.

Communities: Thirty-three percent (33%) of the watershed area lies within the town of Meredith, followed closely by Center Harbor and New Hampton at 29% and 24% respectively.

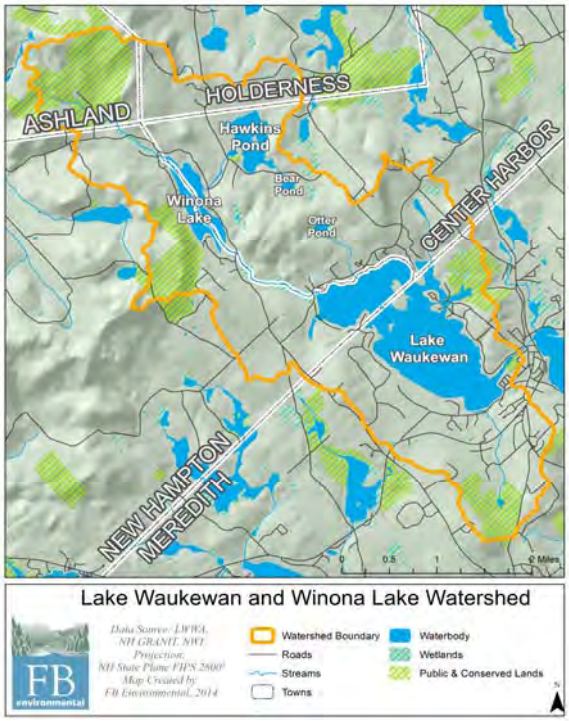


Figure 8. Lake Waukewan and Winona Watershed

The small land area of Ashland and Holderness that lies within the watershed is characterized by forested and agricultural land. Seventy-nine percent (79%) of the land area that lies within Ashland's town boundary is in conservation, which is important as the headwaters to Lake Winona are located here (Table 6).

Municipality	Area (acres)	Percent of Watershed Area (%)
Ashland	699	8.4
Center Harbor	2,370	28.6
Holderness	527	6.4
Meredith	2,732	33
New Hampton	1,951	23.6

Table 6. Municipalities, associated acreage and percent of land cover in the Waukewan Watershed, New Hampshire.

Population and Growth Trends: The Lake Waukewan and Winona watershed is moderately developed with urban and concentrated residential development located mostly in the southern portion of the watershed in the Town of Meredith, NH (Figure 9). Population trends between 2000 and 2010 census data show an increase in population in all five watershed communities (Table 7) (NH Office of Energy & Planning, 2013). An increase in population often leads to increases in developed land which may lead to increased stormwater pollution if not properly planned and managed.

Table 7. Change in Population from 2000-2010 of the five Watershed Municipalities

Town	2000 Census	2010 Census	% Change
Meredith	5,943	6,241	5%
New Hampton	1,950	2,165	11%
Center Harbor	996	1,096	10%
Ashland	1,955	2,076	6%
Holderness	1,930	2,108	9%

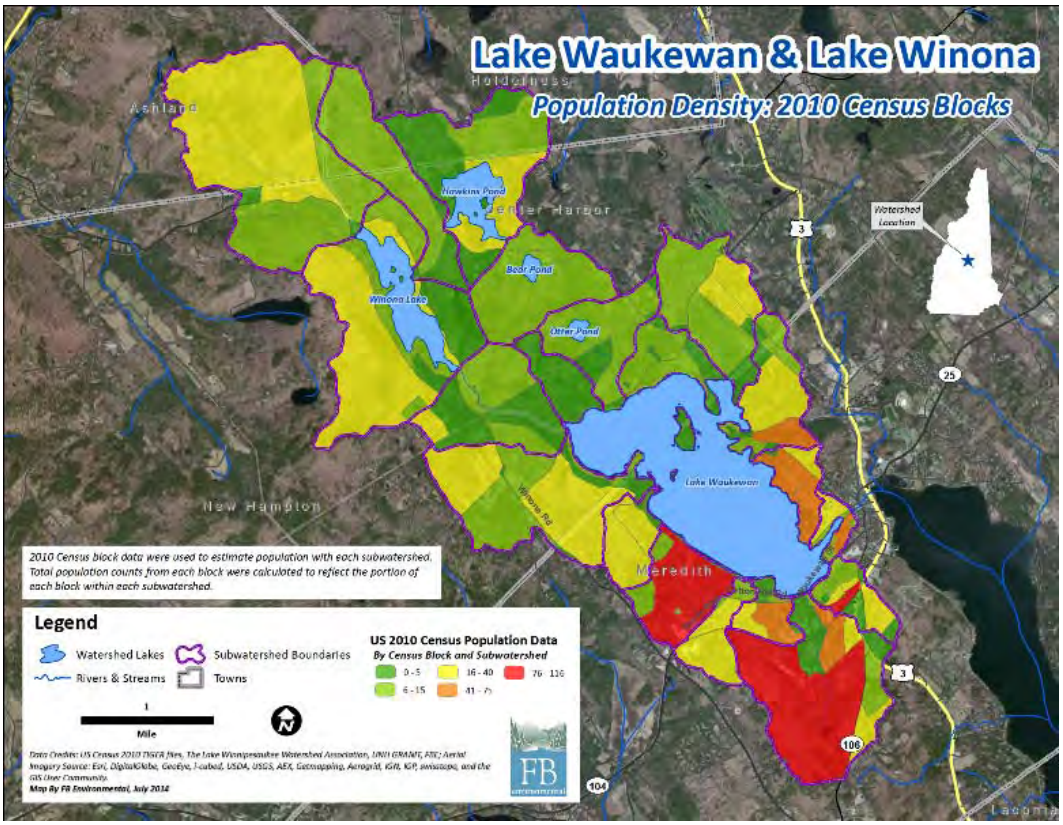


Figure 9. Population density in the study area, by US Census (2010) block, calculated for each sub-watershed.

Climate: Climate in the lakes region of New Hampshire is considered continental due to prevailing westerly winds, and highly variable due to the mid latitude location. Four distinct seasons are experienced with wide ranges in both daily and annual temperatures. Due to this factor the lakes are dimictic, turning over twice each year, once in the spring, and again in the fall, and will stratify during the summer months.

Precipitation for the area is calculated from long-term climate data from several weather stations near the watershed. A weighted yearly precipitation total, based on geographical positioning of the weather stations that compensates for local weather patterns, is calculated at 48.65 inches (1.24 m) for input in the current Lake Load Response Model (LLRM).

Topography: Terrain within the watershed ranges from steep slopes (47%) to rolling terrain. The average slope in the watershed is approximately 12%. Elevations range from 1,500 feet on Beech Hill near Sky Pond in New Hampton, to 540 feet at the Lake Waukewan outflow point in Meredith. *(excerpted from the Management Plan for the Waukewan Watershed)*

Soils: The mixture or composition of soil components (clay, loam, sand, silt) impacts the ability of the soil to infiltrate water, and thus reduce runoff. The USDA Natural Resource Conservation Service (NRCS) groups soils into four main hydrologic soil categories (A, B, C, D) based on estimates of runoff potential (U.S.D.A Natural Resource Conservation Service, 2007).

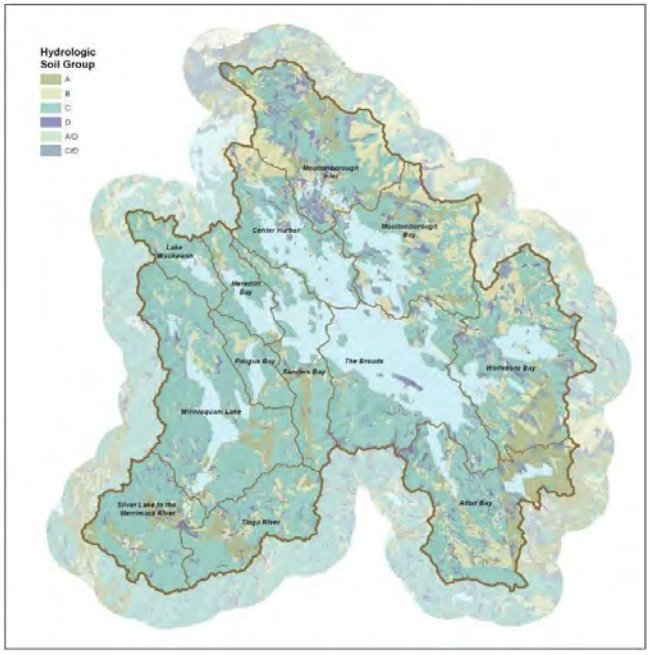
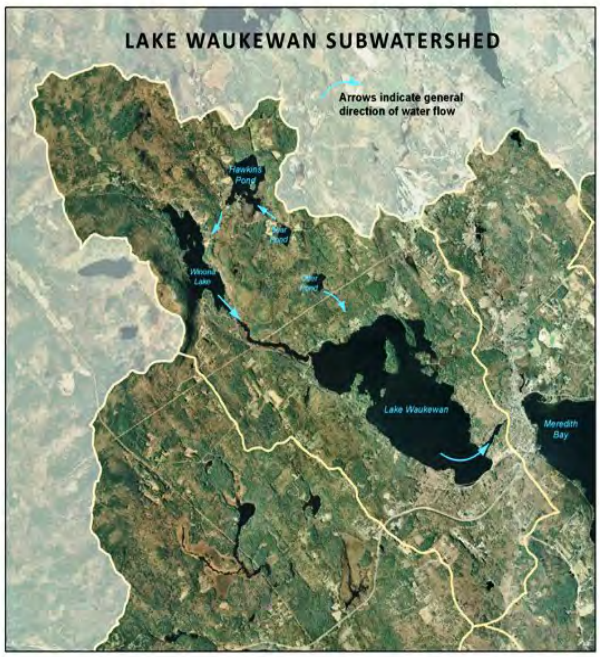


Figure 10. Map depicting Soil Hydrologic Groups for the Winnipesaukee River watershed.

The majority of soils in Belknap County fall within Hydrologic Soil Group C (Figure 10). Group C soils have a slow infiltration rate when thoroughly wet and therefore a moderately high runoff potential. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 to 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures (U.S.D.A Natural Resource Conservation Service, 2007).



Ponds and Streams: In addition to Lakes Waukewan and Winona, the watershed also includes eight tributaries, various wetlands, and three small ponds: Hawkins Pond, Bear Pond, and Otter Pond,. Otter Pond flows to a tributary that empties directly into Lake Waukewan. Bear Pond flows into Hawkins Pond which then flows into Winona Lake (Figure 11).

Figure 11. Direction of water flow of ponds and lakes within the Waukewan Watershed.

Fisheries: Lake Waukewan and Winona provide excellent habitat for a variety of cold and warm water fisheries. Lake Waukewan is classified as both a coldwater and warm water fishery by the NH Fish and Game Department and contains stocked rainbow trout, smallmouth bass, chain pickerel, horned pout and white perch among other species. Lake Winona is classified as a coldwater fishery and provides habitat for both rainbow trout and brook trout. However, Lake Winona also has a warm water fishery component and contains large and small mouth bass (NHF&G Dept., 2012). Both lakes and the various streams located within the watershed are valued for their beauty, recreational opportunities, ecological richness, and contribution to the local economy.

A summary of the fish surveys of the major tributaries to Lake Winona and Lake Waukewan (Figure 12) conducted in June 2010 by the NH Fish and Game Department can be found on the Winnipesaukee Gateway website at http://winnipesaukeegateway.org/lake-management/plan-2/appendices/.

For more information regarding the soils, wetlands, streams and tributaries in the Waukewan Watershed please refer to the 2005 *Management Plan for the Waukewan Watershed*.

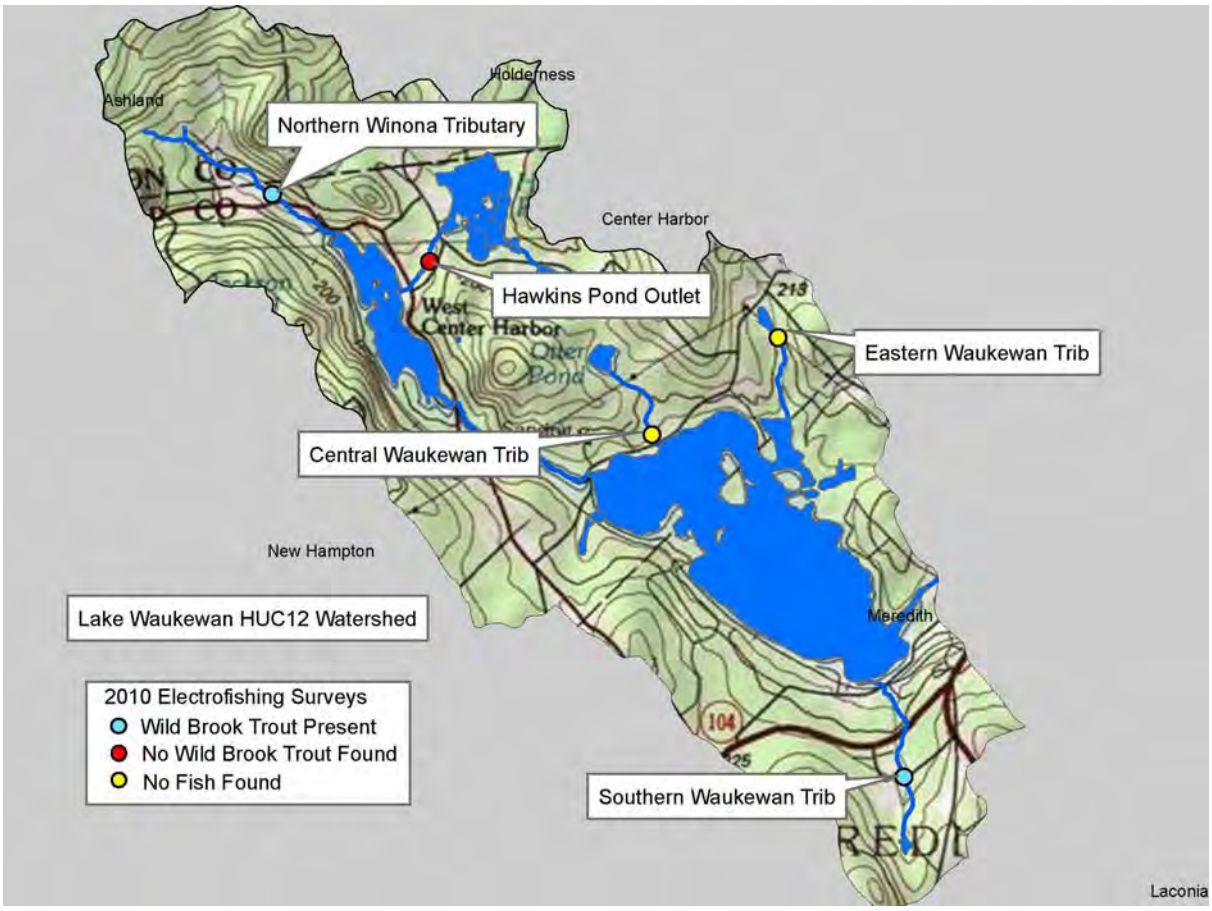


Figure 12. Map of 2010 fish stream survey locations in the Lake Waukewan watershed.

3.2 Subwatershed Delineations

In order to determine drainage flow and assess pollutant load, the Waukewan watershed was delineated into subwatersheds, including separated drainage areas for Lake Winona. Watershed boundary data obtained from the Lake Winnipesaukee Association (LWA) were edited to accommodate the goals of the LLRM and the watershed restoration plan. Further watershed delineations were made using digital topographic maps and the digital elevation model (DEM) obtained from GRANIT, the New Hampshire GIS clearinghouse maintained by the University of New Hampshire (Figure 13).

A total of twenty-one (21) subwatersheds were delineated; five (5) for the Lake Winona watershed and sixteen (16) subwatersheds which drain directly to Lake Waukewan. The Snake River subwatershed receives drainage from the five Lake Winona subwatersheds through the outlet of Lake Winona and therefore is the largest source of water inflow to Lake Waukewan.

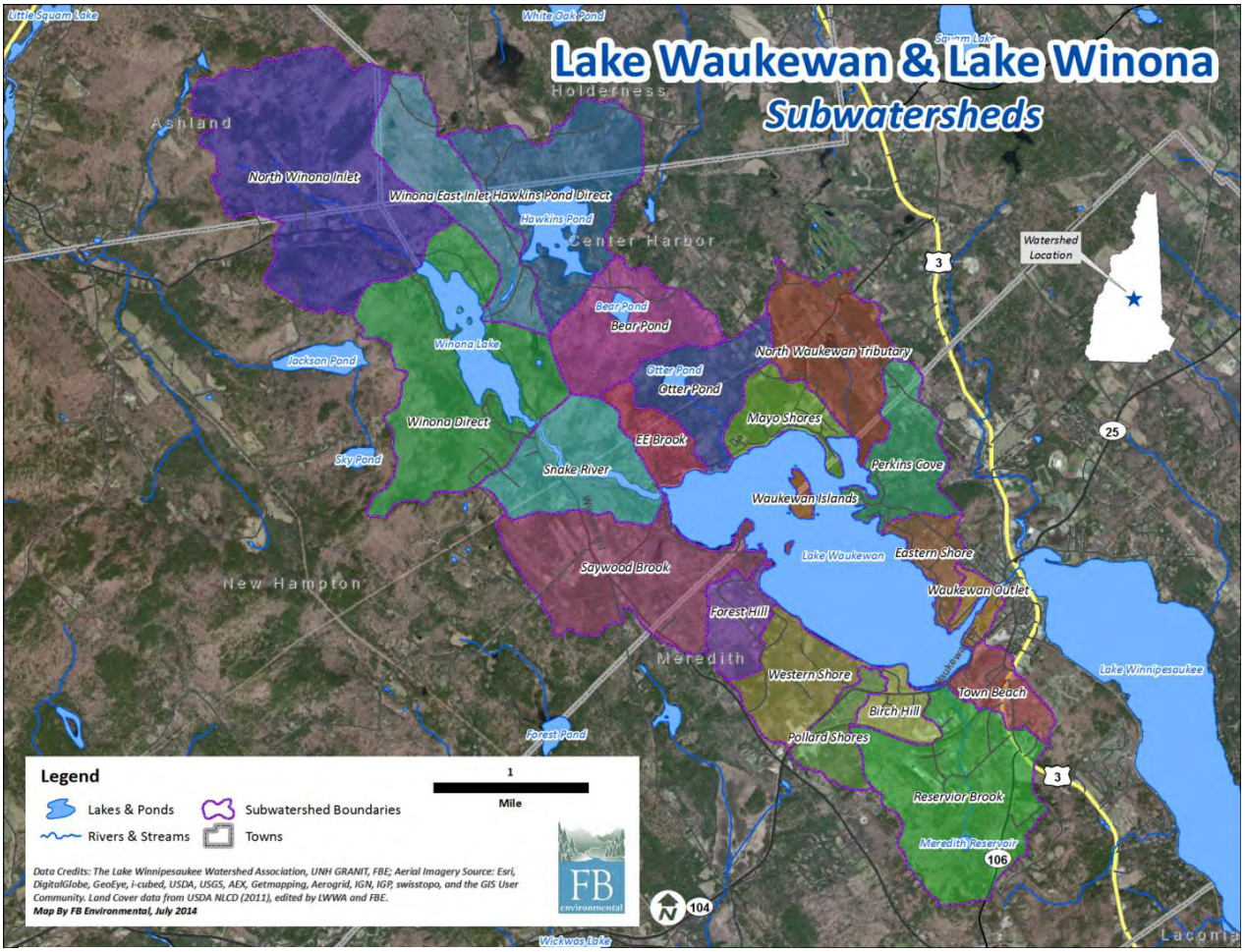


Figure 13. Subwatersheds in the study area.

3.3 Land Use/Land Cover

Land cover data is used to estimate the transport and retention patterns of phosphorus as it moves through a watershed. Land cover data (NLCD 2011) for the study area has been verified and edited as necessary using current aerial imagery (Figure 14). Forested land is the predominant land cover in both the Lake Waukewan and Winona Lake watersheds at 71% and 86% respectively. Lakes, ponds, and wetlands comprise the second largest land cover in both watersheds, with developed land area coming in third (Table 8, Figure 15). Land use data for the individual subwatersheds are listed in Table 9. Note that the land areas for the Waukewan watershed in Table 8 and Figure 15 include Winona's watershed area.

Table 8. Comparison of land area in each subwatershed (data are in hectares).

Land Use/Land Cover	Winona	Waukewan
Developed	62.3	329.9
Agriculture	23.5	56.6
Forest	1168.7	2429.0
Wetlands/Lakes	108.2	515.5
Disturbed Land	0.7	19.0

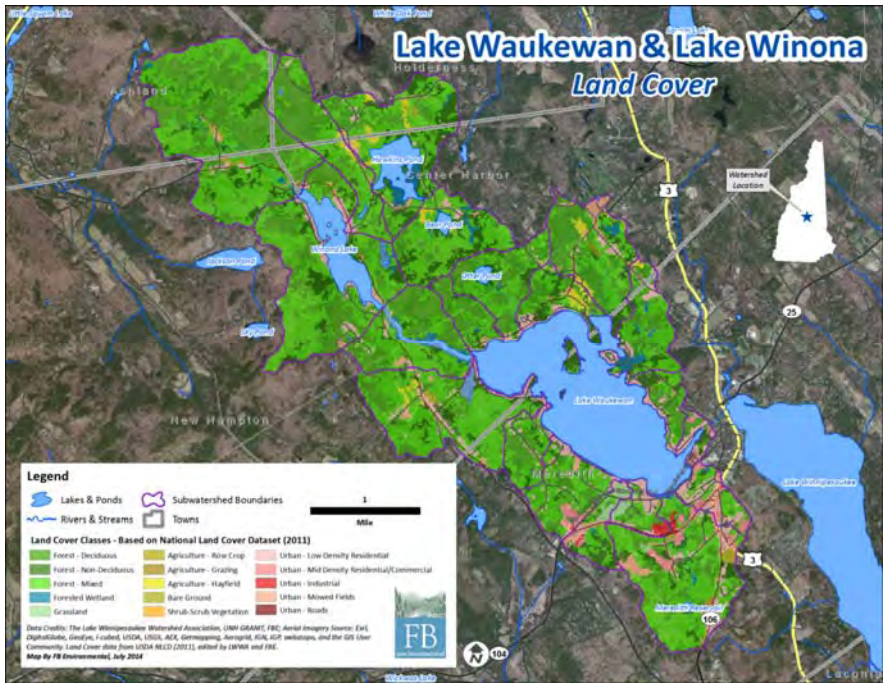


Figure 14. Land Cover in the study area (NLCD 2011, with edits by LWA and FBE).

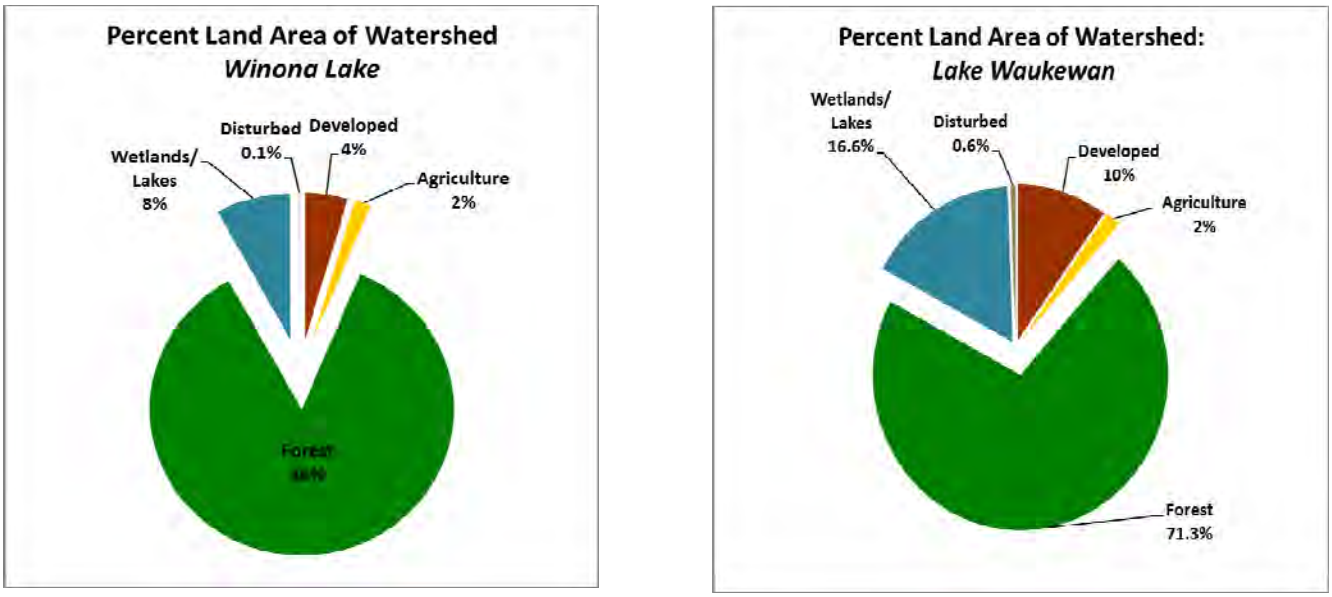


Figure 15. Percent land area for the Lake Winona and Lake Waukewan Watersheds

A breakdown of the 'Developed' portion of the land area indicates low density residential land use makes up the largest land use in each watershed at 56.8 % in Winona and 50.8% in the Waukewan watershed (Figure 16). Mowed fields is the second largest category (20.6%) in the Waukewan watershed followed by the road network; whereas, the road network makes up the second largest urban category in the Lake Winona watershed, followed closely by mowed fields. As mentioned previously, land areas for the Waukewan watershed include Lake Winona's watershed area. There is no industrial or mid-density residential/commercial land use in the Lake Winona watershed.

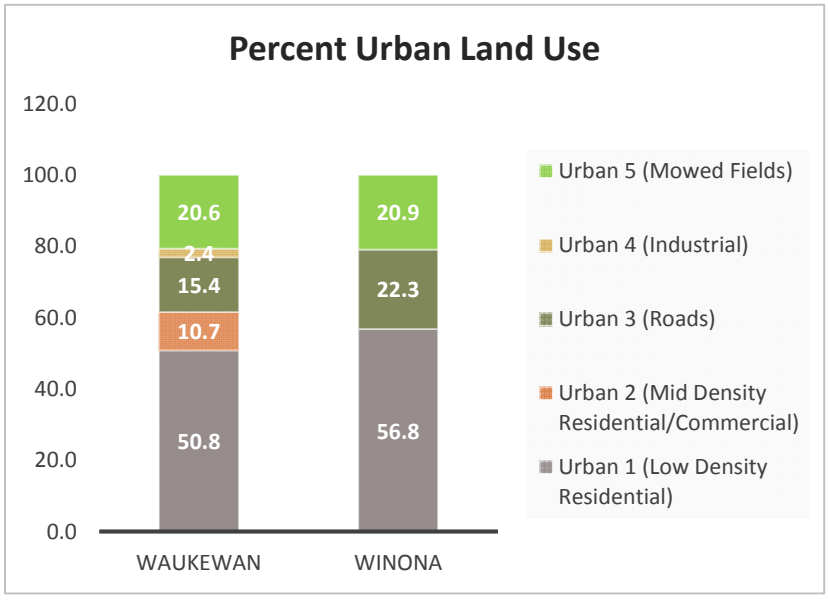


Figure 16. Breakdown of the Urban land use category by watershed.

Land Cover Type	*Lake Waukewan*										
	North Waukewan Tributary	Reservoir Brook	Snake River	Waukewan Direct - Birch Hill	Waukewan Direct - Eastern Shore	Waukewan Direct - EE Brook	Waukewan Direct - Forest Hill	Waukewan Direct - Mayo Shores	Waukewan Direct - Otter Pond	Waukewan Direct - Perkins Cove	Waukewan Direct - Pollard Shores
Urban - Low-Density Residential	5.5	18.5	3.2	10.9	9.3	1.1	5.7	6.2	2.3	10.2	3.9
Urban - Mid-Density Residential/commercial	0.6	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Urban - Roads	3.0	6.3	1.7	2.3	2.0	1.0	1.3	3.0	0.7	1.9	1.2
Urban - Industrial	0.0	2.8	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Urban - Mowed Fields	11.1	17.5	2.3	1.8	1.1	0.9	1.1	2.3	0.5	1.3	5.3
Agriculture - Row Crop	2.8	4.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Agriculture - Grazing	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture - Hayfield	6.3	0.1	0.0	0.0	0.0	0.0	0.0	7.3	0.0	1.1	0.0
Forest - Deciduous	62.6	41.9	67.9	6.2	15.3	25.7	22.1	19.1	47.4	26.1	1.1
Forest - Non-Deciduous	17.2	22.9	3.7	0.1	7.0	3.4	4.0	13.4	11.2	10.5	14.3
Forest - Mixed	49.6	144.8	61.9	11.6	16.2	19.5	27.7	19.4	47.3	47.0	17.7
Forested Wetlands	2.8	1.0	8.1	0.0	0.0	0.5	0.0	0.0	0.5	8.1	0.5
Open Water	0.3	1.0	11.2	0.1	0.6	0.4	0.0	1.3	5.4	1.7	0.0
Disturbed Land	0.0	1.6	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.9	9.4
Grand Total (ha)	**161.7**	**278.4**	**159.9**	**42.3**	**51.5**	**52.5**	**62.0**	**72.1**	**115.2**	**108.8**	**55.9**

Land Cover Type	*Lake Waukewan*					*Lake Winona*				
	Waukewan Direct - Saywood Brook	Waukewan Direct - Town Beach	Waukewan Direct - Western Shore	Waukewan Islands	Waukewan Outlet	Bear Pond	Hawkins Pond Direct	North Winona Tributary	Winona Direct	Winona East Tributary
Urban - Low-Density Residential	19.3	17.1	9.7	0.2	9.2	3.2	2.9	3.1	21.8	4.3
Urban - Mid-Density Residential/commercial	0.0	10.9	6.2	0.0	4.1	0.0	0.0	0.0	0.0	0.0
Urban - Roads	5.0	3.7	2.3	0.0	1.2	1.0	3.2	3.0	4.6	2.2
Urban - Industrial	0.0	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban - Mowed Fields	3.7	0.8	5.3	0.0	0.0	1.0	5.2	2.4	2.8	1.6
Agriculture - Row Crop	3.0	0.0	0.0	0.0	0.0	0.0	1.5	4.6	0.0	0.0
Agriculture - Grazing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture - Hayfield	4.6	0.0	0.0	0.0	0.0	3.0	11.5	0.0	0.0	2.9
Forest - Deciduous	41.5	3.5	23.3	0.0	7.2	13.7	36.2	186.4	97.8	68.8
Forest - Non-Deciduous	15.4	2.2	4.1	8.1	2.8	31.0	42.7	26.9	28.9	5.5
Forest - Mixed	150.6	16.6	55.3	0.8	0.6	82.9	97.2	213.1	151.3	63.5
Forested Wetlands	0.0	0.7	0.0	0.0	0.0	6.1	11.5	3.2	1.8	0.0
Open Water	7.2	0.2	0.1	1.7	0.7	5.3	37.0	0.3	5.0	0.7
Disturbed Land	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Grand Total (ha)	**250.4**	**56.1**	**107.6**	**10.8**	**25.8**	**147.2**	**249.0**	**443.0**	**314.7**	**149.6**

Table 9. Land cover statistics for subwatersheds in the study watershed. See Figure 13 for location of subwatersheds. Data are in hectares (1 hectare = 2.47 acres). Note: Open Water category does not include area for Lake Waukewan or Lake Winona.