Minnesota's Lake Superior Coastal Program

North Shore Community Futures: Aquatic resources and growth scenarios

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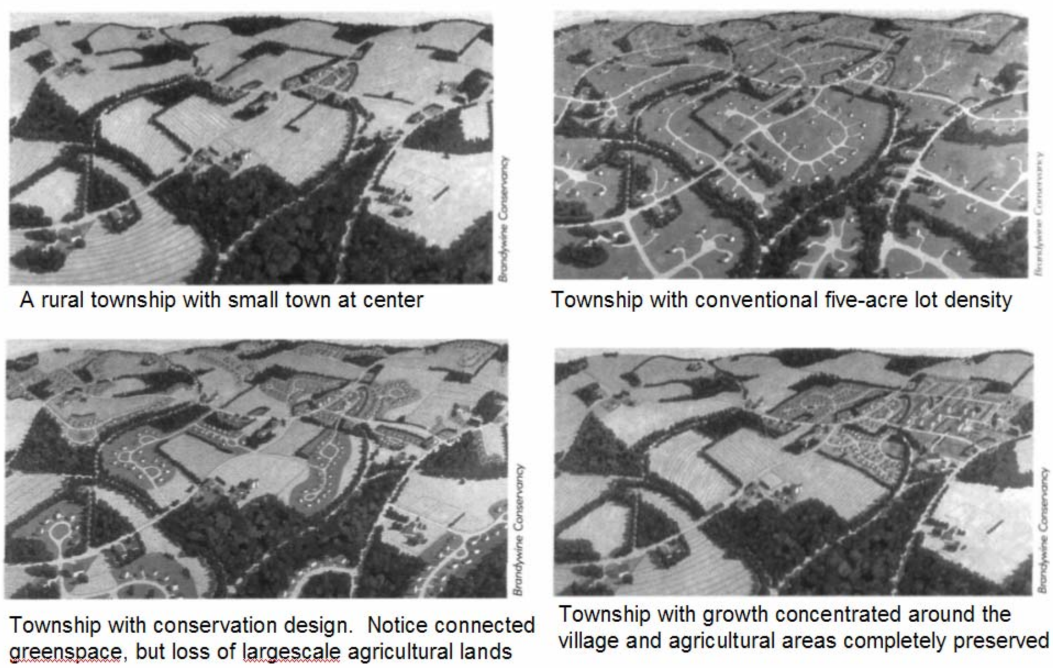
Introduction

North shore communities have recently been growing rapidly, and coastal streams are showing signs of stress. One third of north shore streams are on the MPCA list of impaired waters, including the Lester-Amity system (www.pca.state.mn.us/water/tmdl/tmdl-303dlist.html) . Similar rapid development has been happening all around the coasts of the U.S. (Bartlett et al. 2000). However, few communities have the tools to forecast the potential effects of future growth on their natural and aquatic resources, or to evaluate various growth or zoning scenarios. Nor is it always obvious how the effects of various zoning regulations will be manifested on any given landscape. Insidious cumulative effects of small incremental land use changes can be quite difficult to detect or predict until much of the damage has already occurred. These effects and interactions can be made much more specific and obvious by creating GIS-based maps of the landscapes in question, showing potential development of particular areas of land based on a community's current zoning and also on alternative zoning options. These location-specific maps can highlight areas where current zoning scenarios have the potential to allow degradation of important aquatic resources and natural features. This knowledge can allow a community to act and create alternative, more protective, zoning scenarios that will reduce future restoration costs by reducing or preventing the harm from occuring in the first place.

A build-out scenario creates a map showing changes in landuse patterns and the development of infrastructure (chiefly roads) that would result from a particular landuse plan or set of zoning regulations. Such scenarios are used to help communities visualize the results and potential impact of their landuse decisions, typically for the maximum level of development allowed under the current zoning (Figure 1A and B).



A rural township with small town at center

Township with conventional five-acre lot density

Township with conservation design. Notice connected greenspace, but loss of largescale agricultural lands

Township with growth concentrated around the village and agricultural areas completely preserved

Figure 1. A. starting landscape. B. Conventional 5-acre minimum lot size zoning. C. Conservation design example. D. Smart Growth example.

Instead of full “build-out,” other time periods can also be predicted (e.g., 25 or 50 years hence) using both current zoning regulations and alternative scenarios.

One alternative to conventional zoning is the concept of conservation design (Arendt 1992). Conservation design seeks to maximize protection of natural resources and features such as streams, wetlands, lakes and shoreline, vistas, mature forests, etc (Figure 1C). This design also seeks to help residents access the natural environment by creating hiking and biking paths, maintaining vistas (“viewsheds”), and siting houses to take advantage of these features (Minnesota Land Trust 2000). In this type of zoning, undeveloped land within the community is protected by conservation easements, deed restrictions, and other legal restrictions on development (Arendt 1999). Often the undeveloped land is owned and managed by a residents’ association and use/maintenance decisions are made communally Arendt 1999).

A second alternative to conventional zoning that is being used to rehabilitate older urban and suburban areas is the idea of smart growth. Smart growth design features development concentrated around existing infrastructure, creating “hubs” that provide many of the needs of the community within walking distance, such as groceries, schools, shops, and restaurants (Ewing 1999). Smart growth also focuses on creating a sense of community and making the area safe and attractive for walking and biking, with good links to mass transportation. While smart growth cannot typically be implemented in rural areas, parts of this concept of clustering housing at higher densities to preserve open land, decrease sprawl, decrease driving distances, and create more of a sense of community can be incorporated into conservation design (Figure 1D).

The scenarios we created represent possible “futures” for communities that should enable residents and local government officials to make better, more informed decisions based on their priorities for what they would like their area to look and feel like in the future. Our goal in creating these scenarios was to help communities estimate the potential impacts of various zoning regulations on significant environmental and community resources.

Work Completed

We selected one rural-municipal watershed (Lester-Amity), one municipality (Two Harbors) and one township (Lakewood) as demonstration "communities" to show how this landuse planning approach can be used by various types of communities with various types of zoning and with lots of various sizes. These examples should aid in decision-making and highlight future potential environmental concerns. We chose to include a watershed encompassing multiple governmental jurisdictions because it makes more sense ecologically to manage at the watershed scale, and because the federal government is encouraging use of a watershed management framework (U.S. EPA 1996). In each community we selected a “study area” that is currently undeveloped (Figure 2) and created example growth scenarios including images and 3-D visual flyovers.

These growth scenarios represent possibilities for what each community could resemble 50 years from now assuming that recent rates of growth continue at similar levels. One scenario for each community represents existing zoning; other scenarios represent conservation design, sometimes combined with smart growth concepts, depending on the characteristics of the community. Each scenario used the same growth rate and resulted in the same number of residential units being

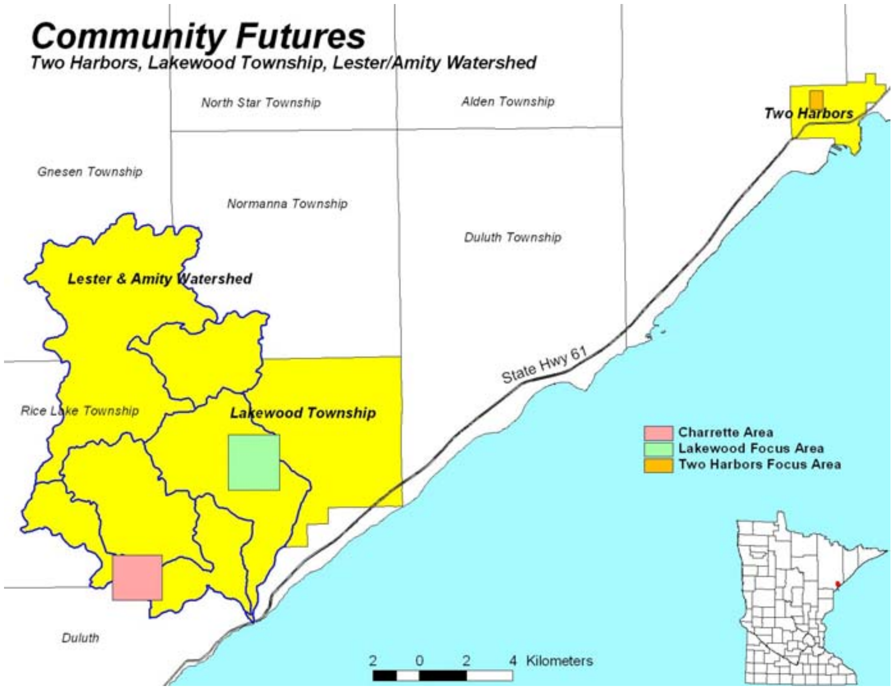


Figure 2. Communities and focus areas featured in the Community Futures project. Communities represent a small town, a township, and a watershed.

added, but the development was allocated differently across the landscape depending on the specific scenario. We chose to use a timeframe of 50 years rather than full build-out because we have found that most residents find true build-out unbelievable, and thus discount it as a likely outcome in their lifetimes. By choosing 50 years instead, we believe we were able to show enough growth to demonstrate the differences among the scenarios while still keeping the number of additional residential units and the timeframe more believable.

Methods

50-year population projection estimates

We were unable to locate pre-existing 50-year population projections for any of our project areas, so we used five different methods to estimate this value (Table 1), and took the average of these. Most data were from the U.S. Census Bureau. We projected the number of homes to be added to the various communities using each community's census data for the number of homes built since 1980 and 1990 and averaged these; we also used the number of homes added between 1990 and either 2000 or 2005; and we used population estimates based on the 30-year population projection and the population change between 1970 and 2000 (Table 1). Population numbers were converted to home numbers by using the local average number of people per dwelling unit of 2.77 people (also from the census data). Finally, we were able to easily obtain building permits for the last decade for two communities. Different areas had different data available, so not all estimates are based on the same methods, but we had at least three estimates for each area. The intent was not to develop a definitive population projection, but to use a value that was reasonable and in keeping with current projections and past trends.

For a number of communities in the Lester-Amity watershed, we were looking at only that portion of the community that fell within the watershed boundary. In these instances, we calculated the percent of the community that was in the watershed, and multiplied this by the population projection for each community from Table 1, assuming an equal distribution of the future population across the community (Table 2). This is likely an incorrect assumption, but again, the intent was to use a reasonable figure for future growth rather than to accurately predict specific population changes for portions of communities.

Table 1. Estimates of the number of homes added to each community based on at least three different sources of information. Final mean estimates of the number of additional homes in each community and the standard deviation around those projections are given in the final two columns.

	Projection based on								
Community	Census: homes built since 1990[a]	Census: homes built since 1980[a]	Avg of 1990 and 1980 homes data	Building permits past decade[b]	Census: # homes 1990 to 2000 or 2005	Census: 30 yr pop projection[c]	Census: 1970-2000 population change[c]	Mean additional homes by 2050	Std dev
Lakewood Twp	892.5	818.1	855.3	714.3		392.5	373.0	583.8	239.3
Gnesen Twp	970.0	861.3	915.6			627.8		771.7	203.5
Normanna Twp	415.0	375.0	395.0			262.2		328.6	93.9
Rice Lake Twp	1236.7	1168.8	1202.7		500.0		469.3	724.0	414.9
Two Harbors	212.5	275.6	244.1	281.8	-80.0	50.7		124.2	169.6
Duluth	10854.2	10018.1	10436.1		5610.0	2483.5		6176.6	4006.5

[a]Source: http://factfinder.census.gov/servlet/SAFFHousing

[b]Source: community planning and zoning departments

[c]Population estimates converted to number of homes using the local average number of people per dwelling unit of 2.77.

Table 2. Projection of number of homes added by 2050 to the portions of communities that fall within the Lester-Amity watershed.

Community	Watershed area (ha)	Community area (ha)	Percent community in watershed	50-yr home projection (table 1)	**Home projection for watershed area**
Gnesen Twp	2964.0	18537.6	16.0	771.7	**123**
Normanna Twp	1034.1	9444.6	10.9	328.6	**36**
Lakewood Twp	3503.5	7184.0	48.8	583.8	**285**
Rice Lake Twp	4440.6	8669.3	51.2	724.0	**371**
City of Duluth	1536.8	22600.2	6.8	6176.6	**420**
Watershed Total	**13478.9**	**66435.7**			**1235**

The same population projection data were used and held constant in each community across all scenarios to demonstrate that alternatives that are better for the environment do not have to come at the expense of limiting community growth.

GIS coverages
Georeferenced digital aerial photographs were compiled for all study communities and are being provided on the enclosed DVD. These photographs allowed accurate location of current buildings in all study areas, a requirement for locating undeveloped property and as input for the computer program, CommunityViz (Placeways LLC, Boulder, CO).

Current zoning regulations were obtained for each community, including all townships in the Lester-Amity watershed. Those not available in GIS format were converted or digitized to that format. These communities include Two Harbors, Lakewood Township, the east end of Duluth, and parts of the townships of Rice Lake, Normanna, and Gnesen. For each scenario, we started with the current zoning map overlayed on GIS coverages of landcover/landuse, National Wetland Inventory aquatic features, and aerial photographs. We then clipped out areas considered unbuildable, including the setbacks required under each scenario (Tables 3 and 4), leaving behind the buildable area coded by each community's zoning. A list of the GIS base layers used for this project can be found in Appendix B.

Current zoning scenario
The current zoning scenarios for each community place no regard on landscape or environmental features other than what is specifically coded into the zoning of each community. Scenarios specifically follow each community's current zoning codes (see tables in Appendix A). Most communities follow the minimum setbacks for natural features specified in the state and county zoning codes (see Appendix A).

Table 3. Setbacks and unbuildable areas used to guide the "current zoning" scenario for each community. More details on current zoning regulations are shown in Appendix A.

Community	Current zoning setbacks and unbuildable areas
Two Harbors residential areas	Avoid lakes and streams using National Wetland Inventory GIS coverage; Lake and stream setbacks of 100 ft; Road setbacks as in current zoning (Tables A4, A5); Avoid existing impervious surface (already built areas).
Lakewood Township	Avoid lakes and streams using National Wetland Inventory GIS coverage; Avoid wetlands > 5 acres, limit development on wetlands 1-5 acres; Stream setback of 150 ft, intermittent stream setback of 100 ft; Road setbacks as in current zoning (Table A1); Avoid existing impervious surface (already built areas); See Table A6 for steep slope restrictions
Lester/Amity watershed	Avoid lakes and streams using National Wetland Inventory GIS coverage; Avoid wetlands > 5 acres, limit development on wetlands 1-5 acres; Stream setback of 150 ft, (Lakewood only: intermittent stream setback of 100 ft); Road setbacks as in current zoning (Table A1); Avoid existing impervious surface(already built areas); See Table A6 for steep slope restrictions

Alternative futures scenarios

Alternative community futures scenarios were generated for each community using either conservation design or a combination of conservation design and some smart growth principles, depending on the community and its setting. Conservation design looks primarily at the natural and cultural features in an area, designates priority conservation areas, and locates development on smaller lots in areas best suited for development (Gilroy 2002). Our emphasis was on protecting aquatic resources, so we worked to eliminate development of wetlands, reduce stream crossings by roads, increase setbacks from aquatic resources, preserve wildlife habitat corridors, and conserve older stands of timber and forests in general in order to help reduce stormwater runoff (Table 4).We used smaller lot sizes, shorter driveways, and, occasionally, more multiple-family dwellings to help reduce the amount of impervious surface and to reduce the amount of land used for developments to leave more shared-ownership open space.

Smart growth emphasizes concentrating new human dwellings and commercial buildings in areas that are already community nodes, co-locating dwellings (including more multiple-family dwellings), commercial and community buildings, and supporting infrastructure such as roads, schools, shops and gas stations, medical and fire facilities, sewer and water supply systems, and power lines (New Urbanism Organization). This type of design strives to create hubs in which housing, schools, and shops are located near each other to allow residents to walk or bike to the store or school, and to create a stronger sense of community (NOAA CSC). We also emphasized maintaining shared community open spaces and natural areas such as parks, trails and recreational areas, view-sheds, and important aquatic resources such as larger wetlands, trout streams and their tributaries, and the Lake Superior coast.

Table 4. Setbacks and unbuildable areas used to guide the “conservation design” scenario for each community. More details on current zoning regulations are shown in Appendix A.

Community	Conservation design scenario setbacks and unbuildable areas
Two Harbors Residential Areas	Avoid lakes, streams, and wetlands using National Wetland Inventory GIS coverage, with a setback of 300 ft for wetlands, lakes, and perennial streams; Avoid intermittent streams; setback 100 feet; Avoid mature forest of white pine, white cedar, and maple; Avoid slopes greater than 12%, bluff setback 125 ft; Avoid existing impervious surface (already built areas); Road setbacks as in current zoning (Tables A4, A5).
Lakewood Township	Avoid lakes, streams, and wetlands using National Wetland Inventory GIS coverage, with a setback of 300 ft for wetlands, lakes, and perennial streams; Avoid intermittent streams; setback 100 feet; Avoid mature forest of white pine, white cedar, and maple; Avoid slopes greater than 12%, bluff setback 125 ft; Avoid existing impervious surface (already built areas); Road setbacks as in current zoning (Table A1).
Lester/Amity Watershed	Avoid lakes, streams, and wetlands using National Wetland Inventory GIS coverage, with a setback of 300 ft for wetlands, lakes, and perennial streams; Avoid intermittent streams; setback 100 feet; Avoid mature forest of white pine, white cedar, and maple; Avoid slopes greater than 12%, bluff setback 125 ft; Avoid existing impervious surface (already built areas); Road setbacks as in current zoning (Table A1).

Neither of these alternative growth scenarios reduced the number of family dwelling units projected to be built in a community. All scenarios added the same number of dwellings without redevelopment of existing structures.

Whole-community projections

The estimated 50-year home projection (Table 1) was used as the base number of new homes to be added in Lakewood Township and Two Harbors. The total amount of impervious surface, roads, clearing, open space, and runoff were calculated by multiplying the per-home numbers from the scenarios by the number of projected new homes. For instance, in Lakewood Township, with 584 projected new homes, the Zoning scenario indicated that there were 0.42 acres of total impervious surface per home. For 584 homes under this scenario, there would be 243 acres of new impervious surface (584 x 0.42 = 243). In both communities, the scenarios developed within that community were used.

For the Lester-Amity watershed, a more complex 50-year projection was used. The watershed includes parts of five communities, with calculated home projections for just the area of each community that is within the watershed. For each community's portion, the most realistic scenarios, based on existing zoning, were applied. For the city of Duluth portion, with some urban and suburban lands, the Two Harbors scenarios (with urban lot sizes) were applied to half of the total home projection, and the other half was attributed to the smart growth scenario (with suburban lot sizes). For Rice Lake Township, the Lakewood scenarios (based on rural zoning) were applied to half of the home projection, and half were again attributed to the smart growth scenario (suburban zoning). For Normanna, Gnesen, and Lakewood Townships, the Lakewood scenarios (rural zoning) were applied to the entire home projection number. Both the existing zoning and conservation design or smart growth scenarios were applied, and summed, for the entire watershed. The result is two separate watershed values for each indicator: a value using the existing zoning scenario data, and a value from the conservation design/smart growth scenarios summed together.

The result is not a perfect projection since it is not based strictly on existing buildable areas and different zoning districts, but it provides a comparison of various development patterns and their effect on open space, forest loss, and water quality, using actual estimates of building potential over the next 50 years.

Indicators

For each focus area, we generated natural resource and social indicators to allow comparisons among the scenarios and to allow extrapolation from the examples to the larger communities. We had intended to calculate indicators using the Community Viz software, but for a variety of reasons we found that doing the calculations in ArcGIS was better (see Appendix C: Assessment of Community Viz software). Community Viz (www.communityviz.com) is an ArcView extension that we found most useful for creating small example scenarios, complete with fly-over imagry (provided on DVD), to help residents and LGU officials visualize the different look and feel of the scenarios. Indicators and descriptions of how they were generated are shown in Table 5.

Table 5. Description of indicators calculated for scenarios and community-wide projections.

Indicator	Use	Description
Lot area	Both	Total area of land that is a part of the lots. This includes driveways and homes, but not roads or road setbacks
Open space	Both	Area of land not a part of roadways, setbacks, or lots
Mean lot size	Scenarios	Average size of the lots in the scenario
Acres of roads	Scenarios	Acres of new roads in each scenario. Road pavement width assumed to be 22'. One-way road widths (in Amity Cr scenario) calculated at 18'
Acres of driveways	Scenarios	Acres of driveways, taking into account minimum setbacks. Driveway widths assumed to be 10'
Miles of roads	Both	Miles of new roads in each scenario
Impervious surfaces	Both	Hard surfaces that do not allow for infiltration. Included in this analysis were: rooftops, driveways, and roadways. No estimates were made for garages, outbuildings, patios, or other structures.
Impervious per lot	Scenarios	Total impervious surface per lot (including roads)
Overall % impervious	Scenarios	% Impervious of the entire development site
% impervious per lot	Scenarios	Average % impervious for the individual lots only (open space excluded)
Total clearing (acres)	Both	Amount of forest land cleared for roads, houses, driveways, and yards. For all lots less than 1 acre, we assumed 100% clearing. For lots larger than 1 acre, we assumed that only 1 acre total would be cleared. For runoff models, we also modeled 100% clearing for all lot sizes.
Clearing per lot (acres)	Scenarios	Average amount of clearing per lot (Total clearing divided by the number of lots)
Total runoff (acre-feet, gals)	Scenarios	Total amount of estimated annual runoff from entire development, using L-THIA model. For lots greater than 1 acre, two runoff simulations were done: one assuming a maximum of 1 acre of forest cleared, and one assuming the entire lot was cleared
% runoff increase	Scenarios	% Increase in runoff due to addition of roads, homes, driveways, and forest clearing
Runoff increase per lot	Scenarios	Increase in runoff per lot due to clearing and impervious surfaces
Total runoff increase	Projections	Total volume of increased runoff from undeveloped condition. Reported in acre-feet 1 acre-foot is volume of water needed to cover an acre of land under a foot of water) and gallons
Average distance (miles)	Scenarios	Average distance from each lot to nearest school, grocery store, fire station, and gas station
Total driving per home (miles)	Scenarios	Total driving distance to take a separate trip to the nearest school, grocery store, and gas station.
Total driving per year (miles)	Scenarios	Total driving distance to take a separate trip to the nearest school, grocery store, and gas station one time per week for an entire year

We used rather moderate house sizes, all the same, for all scenarios. Because we are only calculating impervious surface area, our primary concern was house footprint size. We used a footprint size of 1565 to 1695 sq ft for single family dwellings, and footprints of 1500 – 1700 sq. ft. for multi-family dwellings, which we built up (i.e., added stories) instead of increasing footprint size to make room for more families.

Runoff Modeling

The L-THIA (Long-Term Hydrologic Impact Assessment) model was used to estimate effects of various development scenarios on stormwater runoff. L-THIA was developed as a tool to provide estimates of total annual runoff from potential land use changes for communities. L-THIA uses local long-term climate records for the specific area being modeled. For our purposes, we used the "detailed" version online (http://www.ecn.purdue.edu/runoff/). Required inputs were: total area of land, area of lots, and area of roads and driveways (Appendix D). For forested areas and roads and driveways, we used standard curve numbers for "D" type soils: 77 for forests and 98 for roads and driveways. Curve numbers of the lot areas were calculated specifically for each scenario, based on the percent of impervious surface on the lot, using formulas in the L-THIA documentation for "D"-type soils. Results from L-THIA are reported in both acre-feet (total volume) and inches (depth of runoff, which is standardized by area).

For lots larger than one acre, we calculated two runoff amounts: total runoff assuming 100% of the lot was cleared and converted into lawn, and total runoff if only 1 acre of land was cleared for lawns (Appendix D). These two estimates should bracket the amount a typical home owner is likely to clear, and provides a range of potential runoff for each scenario. This applied only to scenarios in which lot sizes were larger than 1 acre. For this estimate, the 1 acre of cleared land included the house but not the driveway; driveways were incorporated into the road category.

Results and Discussion

Lakewood Township

Lakewood Township is a rural township just outside of the city of Duluth. It has large amounts of remaining forest (Figure 3) and a number of aquatic resources (Figure 4). The township's current zoning shows a desire on the part of residents for the township to retain a rural feel and character. For Lakewood Township, we developed three scenarios to show options for land zoned as FAM2 (Figure 5). Areas under this zoning tend to be large contiguous areas of primarily forested land for which the township has expressed a desire to conserve as much of the forest in large plots as possible. Currently, this desire is expressed as a rather complicated zoning requirement (Planned Residential Development or PRD) that limits development in the example area we chose to a minimum of 35 acres (2 times lot size of 17 acres with 50% open space) unless a variance for a public road is allowed, in which case lot sizes become a minimum of 17 acres. Thus, we developed one scenario showing possible development with the 35 acre minimum lot size, a second scenario under the 17 acre minimum lot size assuming that public roads are built, and finally a conservation design scenario that clusters the development on smaller lots, gives larger buffers to aquatic features, and protects mature forest stands and steep slopes (Figure 6).

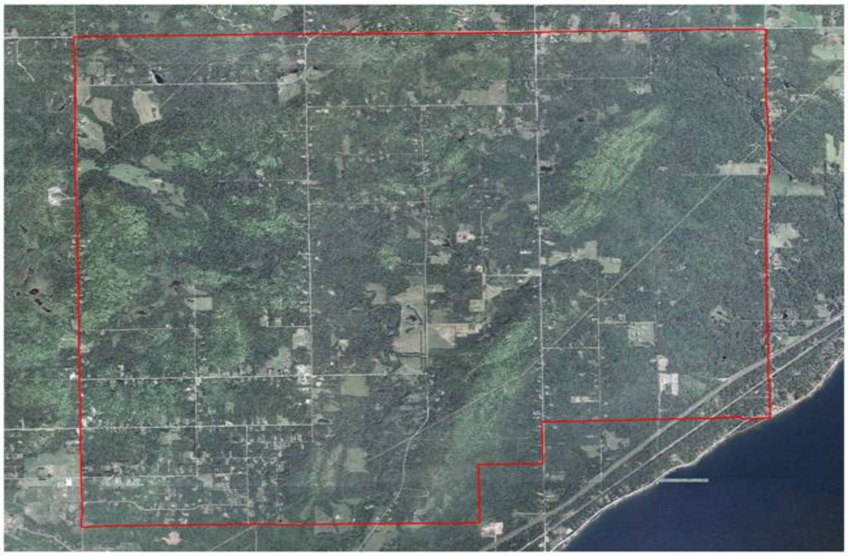


Figure 3. Aerial photograph (year) of Lakewood Township showing open space, roads, dwellings, and cleared areas.

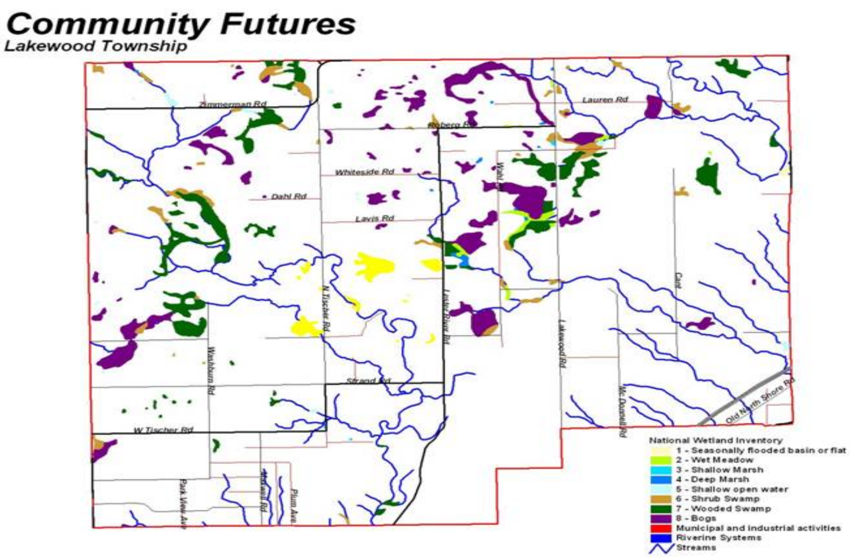


Figure 4. Aquatic resources of Lakewood Township, based on the National Wetland Inventory maps (REF).

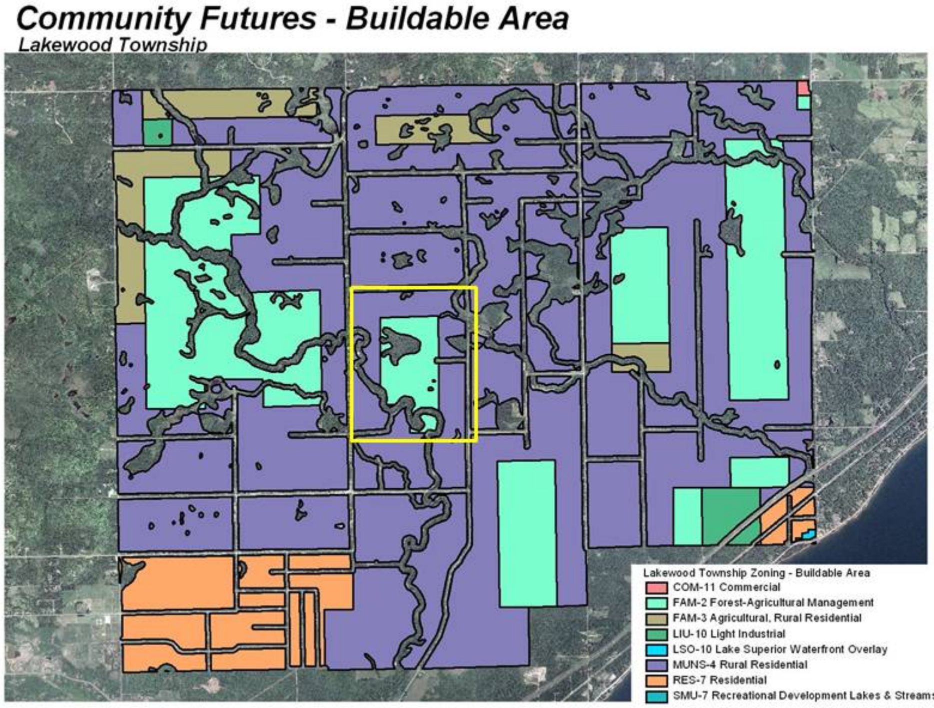


Figure 5. Map of Lakewood Township current zoning, with areas considered unbuildable shown as cut-outs. Most unbuildable areas are aquatic features or buffers around aquatic features, and roads and their buffers. Yellow square outlines study area. See Appendix tables A1-3, A6 for further zoning detail.

Our study area was 316 acres in size; this amount of land was included in all scenarios (Figure 6). The study area included the Lester River, a large wetland complex, several high-value mature forest lands, and a number of areas with steep slopes (> 12 %). This resulted in rather different amounts of area considered "buildable" under current zoning versus the conservation design scenario (Figure 7). The PRD zoning allowed just 3 lots of an average of 34.7 acres

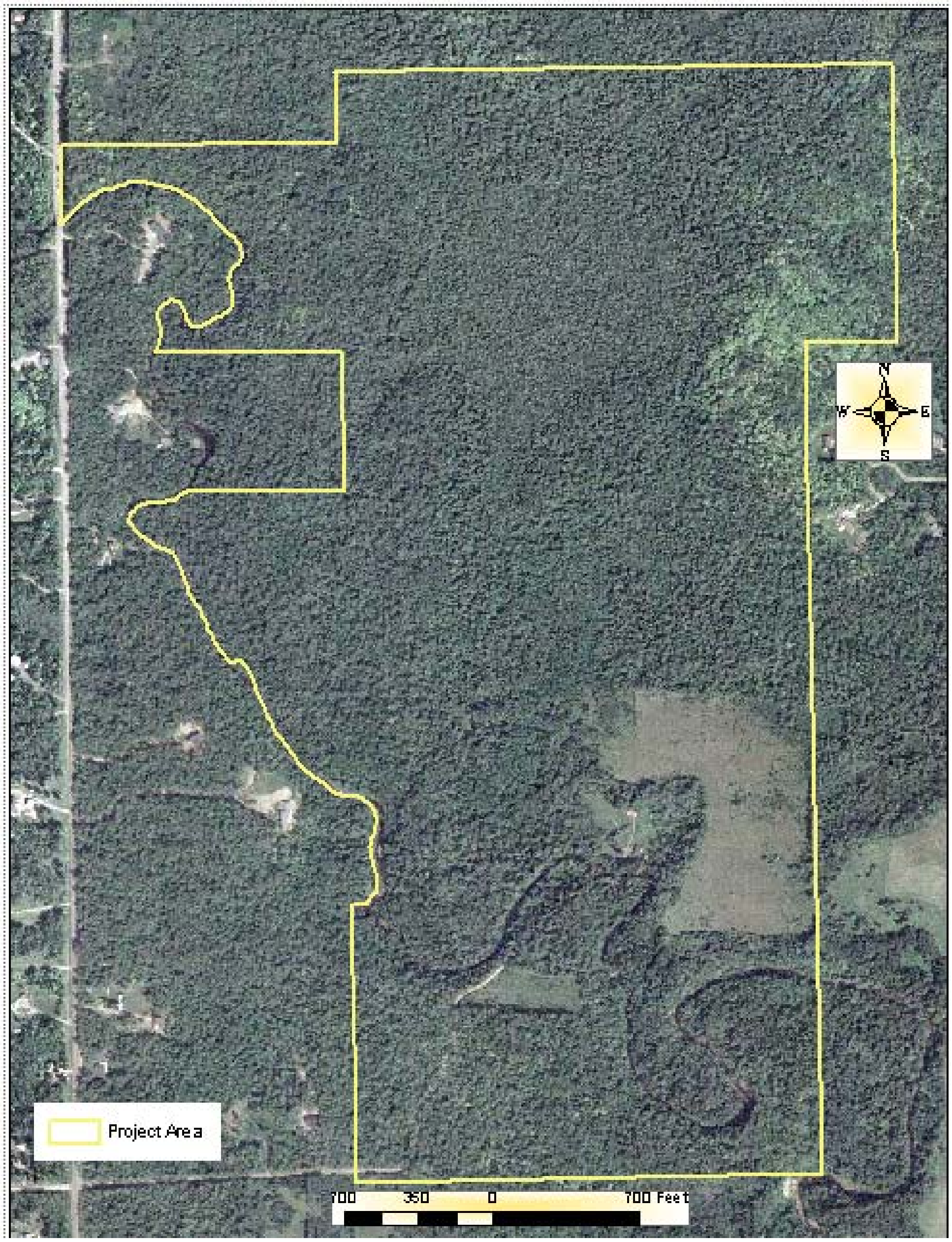


Figure 6. Study area of Lakewood Township.

(Figure 8), while under the standard zoning and conservation design, 15 lots were allowed with average sizes of 18.8 acres and 5.8 acres, respectively (Figures 9 and 10, Table 6). PRD zoning and conservation design preserved roughly the same amounts of public open space in the study area (about 2/3 of it), while almost all the land becomes private ownership under standard zoning. PRD zoning specifies that no new roads can be built, so impervious surface increases under this zoning are from houses and driveways. If public roads were allowed into the area, conventional zoning under our scenario resulted in about twice as much road being added as under our conservation design scenario. Driveways were also shorter under conservation design, adding about the same amount of impervious surface as for the PRD design even though 3 times more houses were added (Table 6).

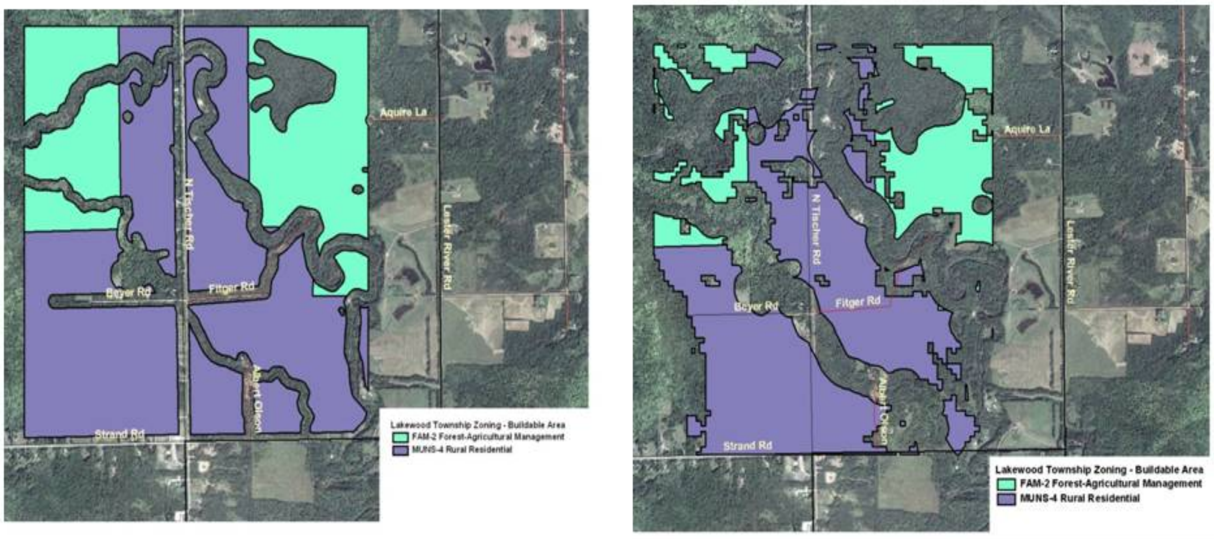
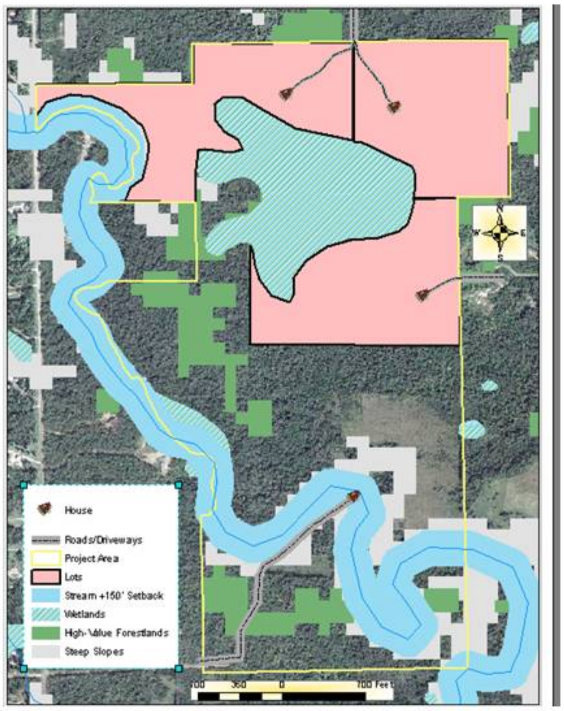


Figure 7. Lakewood Township study area showing areas considered buildable under current zoning (A) and under conservation design (B). Areas considered unbuildable are shown as cut-outs. Most unbuildable areas are aquatic features or buffers around aquatic features, and roads and their buffers.

Total acres of impervious surface added to the area was of course lowest for the PRD design (Table 6). But on a per-lot basis, the amount in acres is lowest under conservation design, although all 3 designs convert less than 0.5 acres to impervious surface. Transforming acres to percent area highlights the smaller lot sizes used in conservation design; with smaller lot sizes, a greater percentage of the lot is converted to impervious surface area.

The amount of land cleared for a particular lot varies, particularly in rural areas with larger lots. Some homes have limited clearing, while other homes may have several acres of forest cleared; largely dependent on the values of the owner, which may include a variety of factors: fire safety, space for gardens, animals, sunlight, shading, wind protection, solar panels, privacy, etc. We assumed an average forest clearing for yards/lawn and homes to be 1 acre. Under this assumption, the amount of land clearing is based on the number of homes added and therefore is much lower for PRD than for the other two scenarios, and is similar on a per-lot basis. When calculating stormwater runoff estimates for each scenario, we used this 1 acre of clearing as the low end of the potential stormwater runoff increase, and we used total lot clearing to generate a high end figure (Table 6). Note that most people on larger lots (especially larger than 5 acres) probably will not clear the entire lot, or if they do so, they will probably put it in orchard or



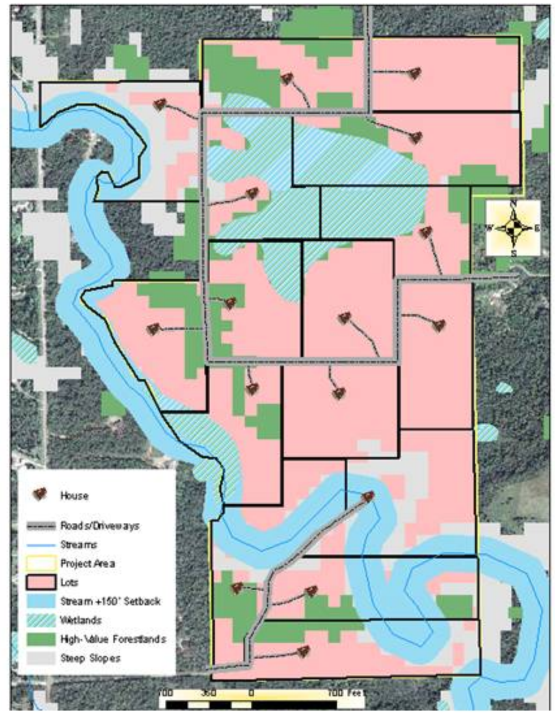


Figure 8. Focus area of Lakewood Township showing Planned Residential Development (PRD) zoning and design. Natural features are shown in colors. Lots are shown in pink with houses as small icons. No new roads were added under this design.

Figure 9. Lakewood Township showing conventional zoning if a variance is allowed for one public road, making minimum lot size 17 acres. Lots are in pink, with house icons. The house within the stream buffer (lower center) already exists, as does the road leading to it.

agriculture, which generate less runoff than does mown grass. So these two figures should bracket the amount of runoff increase that we would expect to see with each scenario. Percent runoff increases would be lowest for PRD and then conservation design, with standard zoning having the highest. Converting to gallons of runoff for the entire study area provides some impressive numbers, even if all property owners only clear roughly an acre plus their house and driveway, with potentially 100,000 or more gallons of increased runoff coming off this land area annually. This water would eventually run into the Lester River, which cuts across the lower portion of the study area.

Finally, we calculated the average distance that each family would have to drive from their house to reach the nearest school, grocery, or gas station, and the distance to the nearest fire station (important for preserving lives and property in these rural areas; Table 6). Because we are working from the same study area in each case, the differences are small, but can add up over a year. If we assume that each family makes one trip to the school, grocery, and gas station per week, over the course of a year, the average family living in the conservation design community would drive over 100 miles less than the average family in the standard zoning scenario. Because homes are closer together in the conservation design scenario, families might also be more willing to do some car-pooling, resulting in even greater savings and less impact on the environment.

Table 6. Comparison of metrics calculated for the three Lakewood Township scenarios. These comparisons are for the study area only.

Metric	PRD	Standard zoning	Conservation Design
Number of lots	3	15	15
Mean lot size (acres)	34.7	18.8	5.8
Open space (acres)	212	30	227
New roads (acres)	0	4.3	2.3
New roads (miles)	0	1.6	0.77
Driveways (acres)	0.77	1.33	0.8
Impervious surface (tot acres)	0.92	6.23	3.6
Impervious surface per lot (acres)	0.3	0.42	0.24
Percent impervious (total area)	0.3	2	1.1
Percent impervious (per lot)	0.9	2.2	4
Land clearing (total acres)	3.8	20.7	18
Land clearing (per lot acres)	1.3	1.4	1.2
Percent runoff increase range	2-29	18-79	12-21
Runoff increase range per lot (thou gal)	87-1,352	159-841	104-282
Mean distance to school (miles)	2.76	2.82	2.71
Mean distance to grocery (miles)	6.1	6.51	5.63
Mean distance to gas stn (miles)	5.9	6.0	5.9
Mean distance to fire stn (miles)	2.63	2.73	2.58
Mean family weekly driving (mi)	29.52	30.66	28.40
Total family driving per yr (mi)	1,535	1,594	1,478

Next we extrapolated some of these metrics up to the scale of the township to show the differences among the scenarios at this larger scale. Based on our population projections from a variety of sources (Table 1), we estimate that 584 homes will be added to Lakewood Township by 2060. Because of the restrictions built into the Planned Residential Development zoning, large amounts of land are used, although 50% is required to remain in open space as long as the zoning holds, but all of the land is in private ownership. Thus, adding 584 lots under the PRD scenario requires 61,500 acres while the other two scenarios require only about one fifth that amount of land (Table 7). Standard zoning would also put most of the land in private ownership, and would provide only 1,156 acres of open space. Conservation design, conversely, uses the same amount of total acreage as standard zoning, but leaves 7 times more acres in open space (8,842), and much of this land is collectively owned or shared by residents of an area, and could be available for recreational uses by community members, depending on specific policies.

PRD zoning does not allow new public roads to be built, but conservation design would result in approximately half the acres and miles of new roads (Table 7) as standard zoning, resulting in a substantial savings in road maintenance for the county and township. Similarly, the amount of impervious surface is likely to be greatest under standard zoning, and least under conservation design, with a difference of over 100 acres. Stormwater runoff increase estimate ranges were calculated using a minimum of an acre of land clearing per lot and a maximum of the entire developable lot being cleared. The actual runoff that might be expected is somewhere between the two, hopefully on the lower end of the range. Thus, the standard zoning scenario would likely result in the greatest increase in stormwater runoff, and the least could come either from conservation design or PRD. Note, however, that because PRD landowners control a large amount of acreage, they have the potential to greatly increase stormwater runoff by their activities on their property.

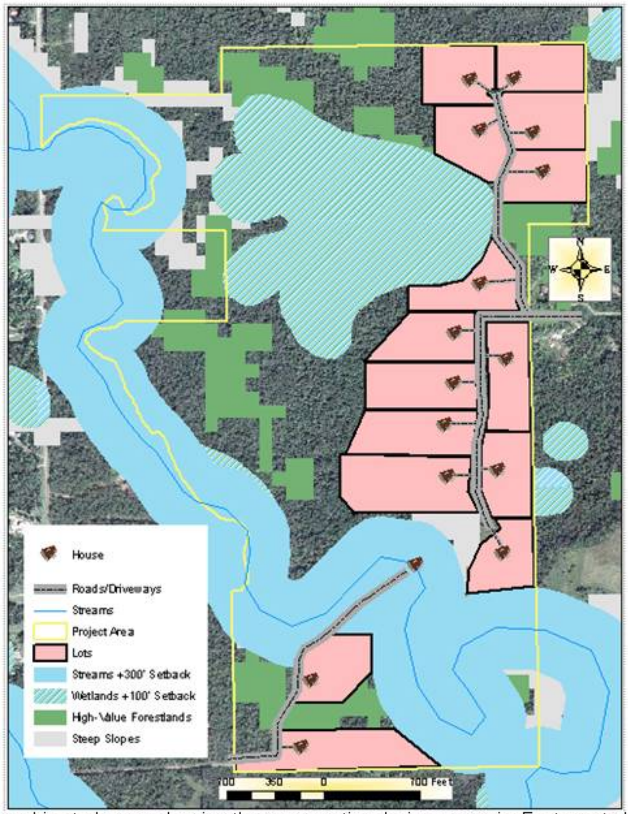


Figure 10. Map of Lakewood Township study area showing the conservation design scenario. Features to be avoided and their setbacks are shaded. Lots created under this scenario are shown in pink. Two roads have been built to access the lots on the north side of the creek; both of these would be cul-de-sacs. The road on the lower left (southwest corner) already exists, as does the house within the stream setback area.

Table 7. Comparison of metrics calculated for the three Lakewood Township scenarios after extrapolation from the study areas to the whole township based on an estimated addition of 584 dwellings to the township by 2060.

Metric	PRD	Standard zoning	Conservation design
Total area of lots (acres)	20,280	10,975	3,370
Number of lots	584	584	584
Open space (acres)	41,220	1,156	8,842
Total space required (acres)	61,500	12,131	12,212
New roads (acres)	0	169	88
New roads (miles)	0	63	30
Impervious surface (tot acres)	178	243	140
Land clearing (total acres)	740	805	702
Total runoff increase range (mil gal)	51-791	93-491	61-165

Two Harbors
There are only a few areas in Two Harbors that contain undeveloped tracts of land of any size (Figure 11).

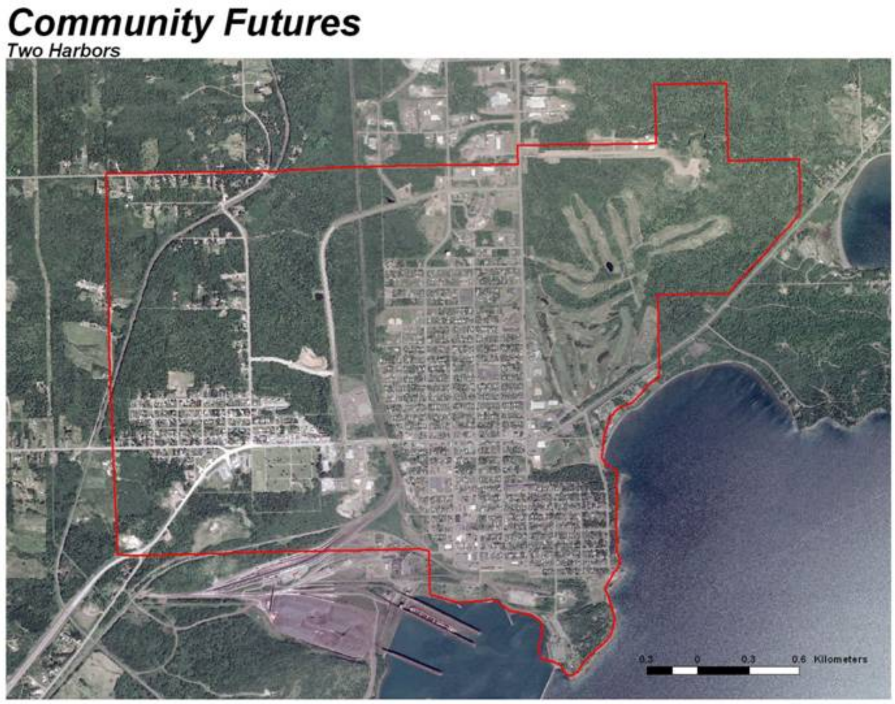


Figure 11. Aerial photograph (year) Two Harbors showing open space, roads, dwellings, golf courses and ski trails, and other cleared areas.

We chose an area near Super One, a grocery store near new roads and homes, indicating that this area may be one of the next to be developed (Figure 12). We used only two scenarios here, standard zoning and conservation design. The available amount of space for the study area is small, only 18.6 acres, but we were able to fit 51 lots (a mix of single and multiple family dwellings) into both scenarios (Table 8). For minimum lot sizes in the zoning scenario, we took the average lot size of an adjacent recent development that's in the same zoning category, which ended up being somewhat higher than the actual minimum lot size listed for that zone. Standard zoning for Two Harbors has smaller setbacks around aquatic features and does not require avoidance of steep slopes. For the conservation design, we used larger setbacks around the aquatic features and avoided some steep slopes and mature forest areas (Figure 13).

Standard zoning typically has no provisions for leaving open space within a development. Thus, the lots under the standard zoning scenario nearly fill the development area (13.6 acres, Figure 14). In contrast, we provided public areas in the conservation design scenario, one of which preserves an overlook above the creek along the road, and the other we have designated as a

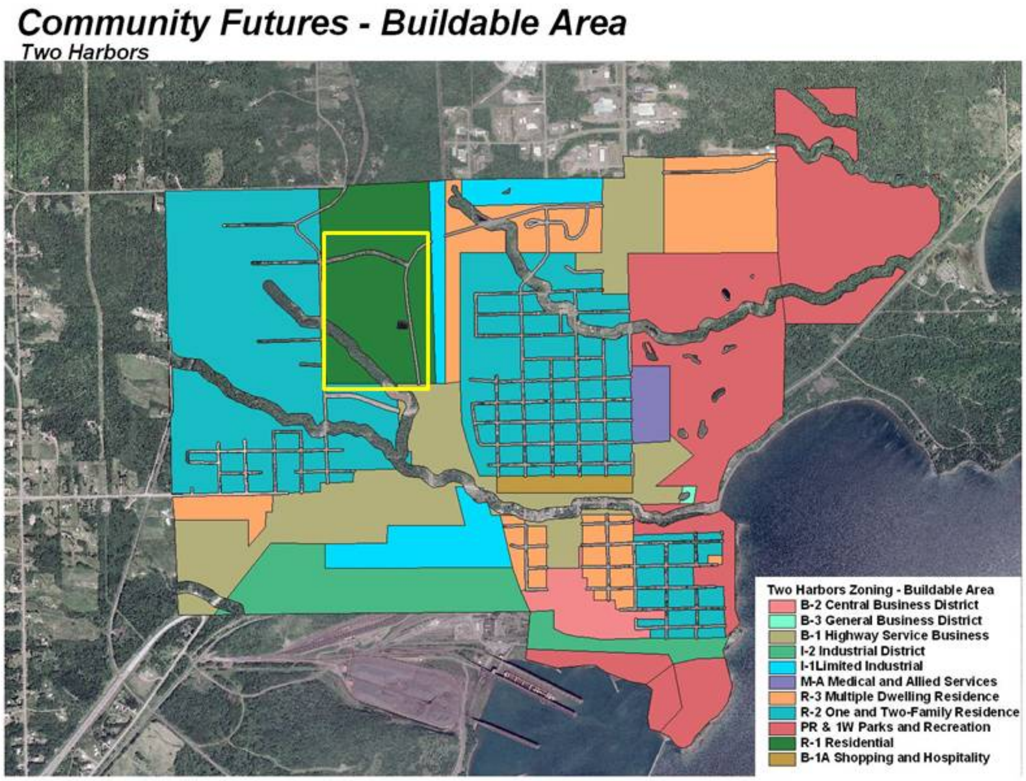


Figure 12. Map of Two Harbors current zoning, with areas considered unbuildable shown as cut-outs. Most unbuildable areas are aquatic features (and their buffers) and roads.

Figure 13. Two Harbors study area, showing the area considered buildable under the current zoning regulations (A) and the area considered buildable under our alternative futures scenario (B).

park/playground for the community. This creates four times more shared open space for the development than is created with standard zoning. To make room for these open areas, we used smaller lot sizes (7,000 sq ft average vs. 11,600 for standard zoning) and added one more multi-family dwelling; total development size is 8.2 acres (Table 8). A final major difference in design is that we allowed the main road of the development to connect all the way through to both adjacent roads under the standard zoning scenario, but turned it into a dead-end with school bus turn around in the conservation design scenario to reduce traffic and slow traffic speeds.

Table 8. Comparison of metrics calculated for the two Two Harbors scenarios. These comparisons are for the study area only.

Metric	Standard zoning	Conservation design
Number of lots	51	51
Development size (acres)	13.6	8.2
Mean lot size (sq. feet)	11,624	7,017
Open space (acres)	2.98	8.74
New roads (acres)	1.57	1.2
New roads (miles)	1.0	0.74
Driveways (acres)	0.59	0.45
Impervious surface (tot acres)	4.5	3.4
Impervious surface per lot (acres)	0.09	0.07
Percent impervious (total area)	25	18.5
Percent impervious (per lot)	32.9	41
Land clearing (total acres)	13.6	8.2
Land clearing (per lot acres)	0.27	0.16
Percent runoff increase	198	138
Runoff increase per lot (gal)	28,688	19,998
Mean distance to school (miles)	1.1	1.1
Mean distance to grocery (miles)	0.44	0.44
Mean distance to gas stn (miles)	0.79	0.79
Mean distance to fire stn (miles)	1.19	1.19
Mean family weekly driving (mi)	4.66	4.66
Total family driving per yr (mi)	242	242

Savings on road building, driveways, and impervious surfaces are small with conservation design in this particular scenario. But they begin to add up as the shorter driveways and smaller lots result in 20% less impervious area for the development. Because all lots are smaller than an acre, we assume that homeowners will clear essentially the entire lot for their house, driveway, and yard. Runoff increases are projected to be 138% for conservation design and 198% for standard zoning, translating roughly to 20,000 (conservation design) to nearly 30,000 (standard zoning) gallons of extra runoff per lot per year (Table 8). We were not able to show any driving savings for this particular conservation design study area. Instead, the most appealing features of the conservation design scenario are that it takes the landscape more into account, creating a roadway that can be a shared overlook over the stream, reducing lot sizes and keeping part of the forest intact to help reduce stormwater runoff and staying back from the steep slopes to protect that stream, trying to manage traffic flow to keep the neighborhood safer for children, and providing a shared park/playground area for the residents.

Extrapolating the results of these scenarios out to the year 2060 for Two Harbors involves adding an estimated 124 dwellings to the town (Table 1). The study area already accounts for 51 of these dwellings, so there does seem to be space yet within Two Harbors to add this number of

Figure 14. Two Harbors study area showing the current zoning scenario. Features to be avoided and their setbacks are hatched. Lots created under this scenario are shown in pink (note that there are several multiple family dwellings). All roads are new since none currently exist to access this land.

additional dwellings. We have done the extrapolation using the same ratio of single-family to multiple-family dwellings as we had in the study area. The primary difference between standard zoning and conservation design is in lot sizes versus open/shared space, driveway lengths, and road miles. So while both scenarios use about the same amount of total space, most of it is in private lots under standards zoning, while over half of it remains shared public open space under conservation design (Table 9).

Table 9. Comparison of metrics calculated for Two Harbors scenarios after extrapolation from the study area to the town based on an estimated addition of 124 dwellings to the township by 2060.

Metric	Standard zoning	Conservation design
Total area of lots (acres)	33.1	20.0
Number of lots	124	124
Open space (acres)	7.3	21.3
Total space required (acres)	40.3	41.2
New roads (acres)	3.8	2.9
New roads (miles)	1.4	1.1
Impervious surface (tot acres)	10.9	8.2
Land clearing (total acres)	33.1	20.0
Total runoff increase (mil gal)	3.6	2.5

There are only small savings in acres and miles of new roads between conservation design and standard zoning because the zoning for most of Two Harbors is quite compact already. For Two

Harbors, the issue may be more about protecting open spaces for the community to ensure that some land remains undeveloped and shared for public use. Simply making lot sizes smaller does not in and of itself preserve land, but under conservation design principles (Arendt), open space is protected legally from development and becomes shared open space that residents can trust will remain undeveloped, rather than fearing what might be put in next to them. Setting land aside as public open space typically results in less land clearing, so the conservation design scenario reduces land clearing by over 30%. This, in turn, leads to a lower predicted increase in stormwater runoff of just over one million gallons (Table 9).

Lester/Amity watershed

The Lester/Amity watershed (Figure 15) presents the greatest challenge to deal with because it involves five different governmental units: the city of Duluth and the townships of Lakewood, Gnesen, Rice Lake, and Normanna. In addition, the watershed has quite a few aquatic and natural features (Figure 16). Figure 17 shows the current zoning for all the different governmental units of the watershed with the areas considered unbuildable clipped out.

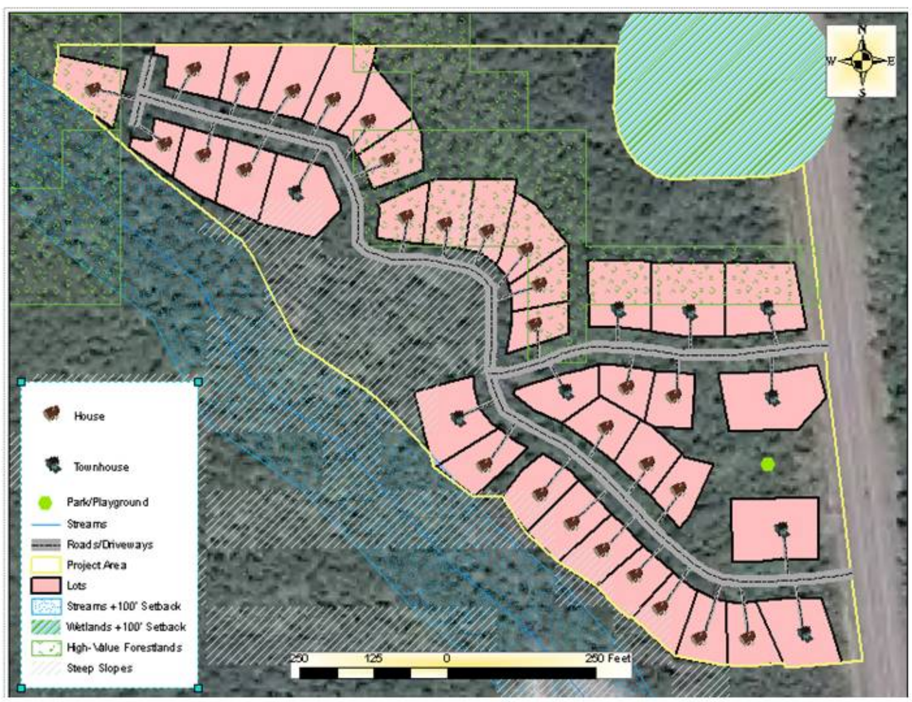


Figure 15. Two Harbors study area showing the conservation design scenario. Features to be avoided and their setbacks are hatched. Lots created under this scenario are shown in pink (note that there are several multiple family dwellings). All roads are new since none currently exist to access this land. Note that the main road now is a dead-end rather than connecting through. Land has been set aside for a community park.

We developed separate population projections for each governmental unit (Table 1), but the study area we chose is within the Duluth city limits and the Amity portion of the watershed. This area was involved in a community charrette process to help the city come up with a development plan that was agreeable to the community, planners, land owners, and those concerned with protecting Amity Creek and the ravines in this area. The scenario that came out of these meetings most closely resembles smart growth and provides a good example of how this type of development can be used in more urbanized areas to help preserve open space, reduce stormwater issues, create a sense of community, and ensure that residents have convenient access to local amenities.

Figure 16. Aerial photograph (year) of the Lester/Amity watershed showing open space, roads, dwellings, golf courses and ski trails, and other cleared areas.

Although we typically kept the number of dwellings the same for all scenarios, the smart growth charrette resulted in more residential units (42) than standard zoning would allow (36) (Table 10, Figure 18), while requiring much less area and leaving large amounts of public open space. The acres required for the development was nearly 50% less under the smart growth scenario than under the current zoning, and mean lot sizes were much smaller, at one third of an acre versus 2 ½ acres.

Table 10. Comparison of metrics calculated for the two Lester/Amity watershed scenarios. These comparisons are for the study area only.

Metric	Standard zoning	Smart growth
Number of lots	36	42
Development size (acres)	94.3	51
Mean lot size (sq. feet)	2.6	0.3
Open space (acres)	0	44.7
New roads (acres)	3.6	2.11
New roads (miles)	0.92	0.89
Driveways (acres)	5.7	0.7
Impervious surface (tot acres)	10.63	3.95
Impervious surface per lot (acres)	0.295	0.094
Percent impervious (total area)	10.9	4.0
Percent impervious (per lot)	11.3	36.2
Land clearing (total acres)	26.51	10.95
Land clearing (per lot acres)	0.74	0.26
Percent runoff increase range	92-140	34
Runoff increase per lot (gal)	102,553-155,593	32,663
Mean distance to school (miles)	0.7	0.46
Mean distance to grocery (miles)	0.76	0.52
Mean distance to gas stn (miles)	0.8	0.55
Mean distance to fire stn (miles)	1.19	0.94
Mean family weekly driving (mi)	4.5	3.1
Total family driving per yr (mi)	235	160

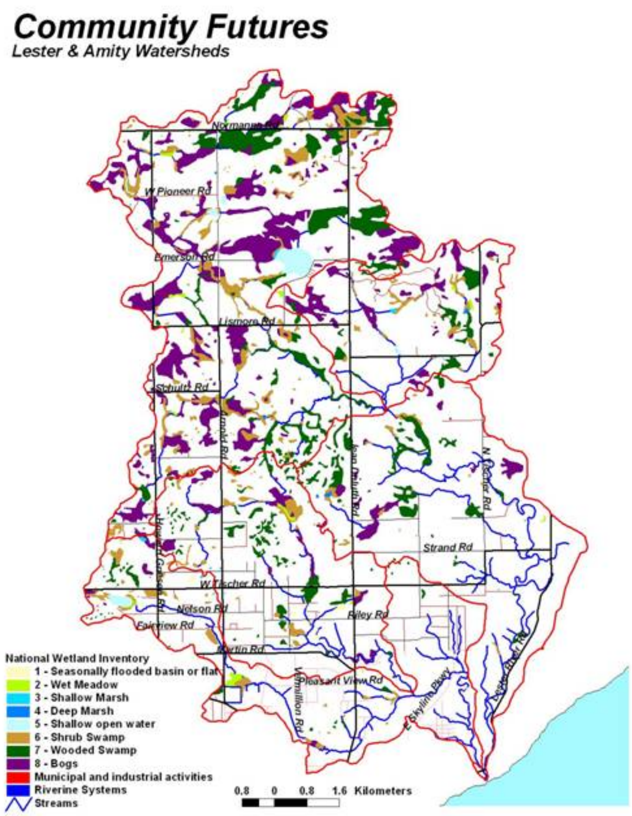


Figure 17. Aquatic resources of the Lester/Amity watershed, based on the National Wetland Inventory maps (REF).

Although the smart growth design resulted in approximately the same amount of new roads as would standard zoning, driveways would be much shorter (Figure 18) because of the smart growth development's compactness. This results in many fewer acres devoted to driveways (0.7 vs. 5.7 acres; Table 10). The smart growth design also clusters all of the new dwellings on the side of Amity Creek near Woodland, reducing driving distances to all amenities available in that area and resulting in families living in the smart growth development to have to drive an estimated 1/3 fewer miles per year to run errands to the grocery store, gas station, or school.

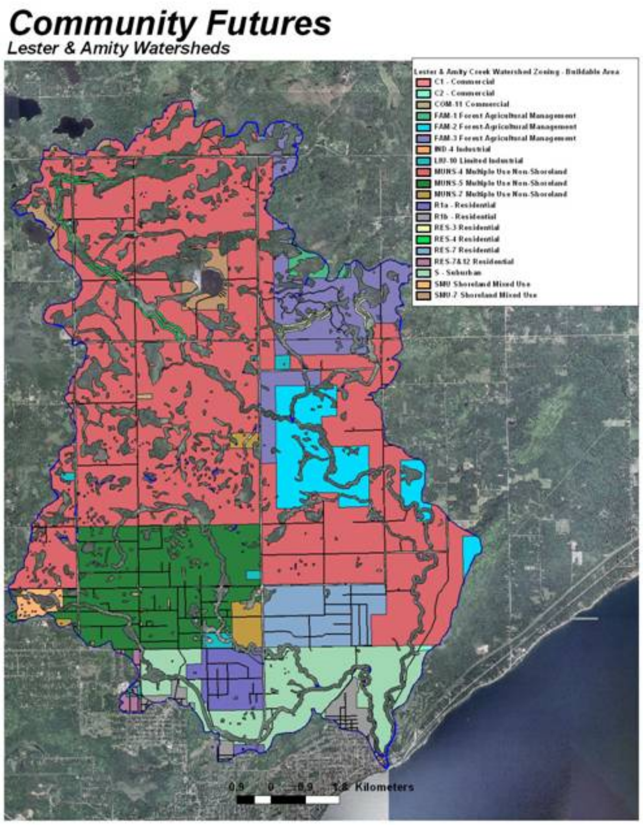


Figure 18. Map of Lester/Amity watershed current zoning, with areas considered unbuildable shown as cut-outs. Most unbuildable areas are aquatic features, and their buffers, and roads. Zoning was compiled and standardized across all LGUs in the watershed (City of Duluth, Rice Lake Township, Gnesen Township, Normanna Township, and Lakewood Township).

The compactness of the smart growth design (Figure 18) results in much less impervious surface being added to the area (4 acres vs. 10.6 acres), although much more of the small lots in the smart growth design will be converted to impervious surface (36% vs. 11%; Table 10). Conversely, land clearing is almost 2/3 less in the smart growth design, with only 11 acres of land cleared versus 26.5 acres under standard zoning. Reductions in driveways, impervious surface, and land clearing lead to large reductions in predicted increased stormwater runoff from the area. Under standard zoning we could expect to see 100, 000 to 150,000 more gallons of runoff per lot, while the smart growth scenario decreases this expected runoff to 32,700 more gallons per lot (Table 10). So stormwater runoff could potentially be reduced by 2/3 or more by these changes, which do not take into consideration any stormwater containment devices like rain gardens or retention ponds, which the smart growth scenario also includes space for.

As with the other areas, we also extrapolated out to 50-year future possibilities. This was a bit more complicated for the watershed because of its five governmental jurisdictions; a full description of how this was done is contained in the methods section. By the year 2060, we project that 1,235 households will be added to the Lester/Amity watershed (Table 1). Under the standard zoning now in place for the five governmental units, this number of dwellings requires lots covering an area of 12,951 acres, while alternative scenarios could provide the same amount of dwellings with lots covering only 3,770 acres, one fourth the amount (Table 11). Instead, these alternative scenarios would protect over 10,000 acres as undeveloped open space, available for recreation, timber management, sugar bush, or other non-development uses.

Table 11. Comparison of metrics calculated for the Lester/Amity watershed scenarios after extrapolation from the study area to the watershed based on an estimated addition of 1235 dwellings by 2060.

Metric	**Standard zoning**	**Conservation design**
Total area of lots (acres)	12,951	3,769
Number of lots	1,235	1,235
Open space (acres)	1,258	10,366
Total space required (acres)	14,438	14,254
New roads (miles)	81.2	42.5
Impervious surface (tot acres)	400	263
Land clearing (total acres)	1223	894
Total runoff increase range (mil gal)	142-599	46-215

Alternative scenarios are also predicted to reduce the number of new road miles needed by nearly half (Table 11), which would result in substantial savings for local governments and hopefully would also improve car-pooling options and reduce travel miles for residents. By compacting lot sizes, shortening driveways, and reducing roads built, the amount of impervious surface added to the landscape could be cut nearly in half under alternative scenarios, and reduce total land clearing by about 25% relative to standard zoning. Together, these conservation measures would likely reduce the predicted increase in total stormwater runoff by 50-75% (Table 11) even before stormwater retention measures are considered.

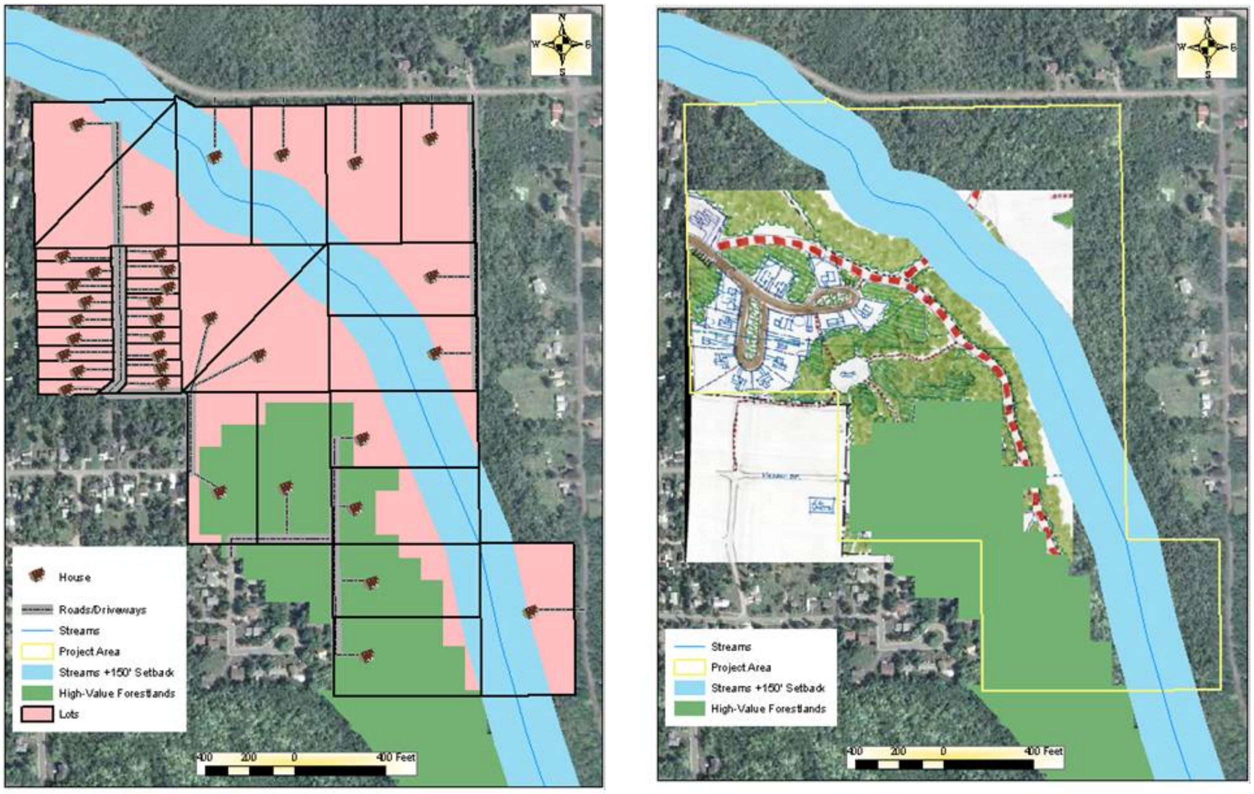


Figure 19. Lester/Amity study area showing development based on current zoning (A) and a design created during a charrette that features elements of conservation design and smart growth (B). Features to be avoided and their setbacks are shaded. Lots created shown in pink in A, but the charrette image has simply been added in B. Note the cul-de-sacs, shared parkland, and trail space (red and white feature) in the charrette.

Conclusions and Next Steps

Since it is likely that development will continue in the townships and communities along the north shore, our goal was to give these communities more options to ensure that this development happens in ways that do not change the fundamental characteristics of the communities themselves. New development techniques like conservation design and smart growth can provide such flexibility and options. For all of our communities, we were able to relatively easily come up with alternative designs other than the standard zoning that would allow the same number of dwellings to be added, but would also protect valuable natural resources, reduce stormwater runoff, and in some cases create a greater sense of community and reduce community resources that have to be spent on roads and similar infrastructure.

Communities across the country have adopted policies to allow, and in some cases, require the use of these techniques in all future development, and specific model ordinances exist for communities interested in applying these concepts. These techniques differ greatly from most current zoning ordinance requirements along the north shore, and in most cases would not be allowed without variances, which is a disincentive for developers interested in applying these techniques. We don't expect wide immediate adoption of new ordinances, but by helping to show what these development styles would look like "on the ground" along the shore and their relative effect on open space, runoff, and infrastructure needs, we believe this research will help communities make more informed choices about development.

A second, more detailed phase extending this research could look at specific zoning and buildable areas and compare the necessary land for the various scenarios, to evaluate “readiness” for future development pressures. As we work with individual communities, we will take these next steps as needed.

We are in the process of scheduling presentations of our findings before planning boards, supervisors, and others of each community used in the study, the North Shore Management Board, and Minnesota's Lake Superior Coastal Program. We hope that our results will show that there are other ways besides traditional zoning to protect natural resources, and that thinking outside the “minimum lot size” box may be much more useful in allowing communities to protect the natural resources and community type that they value. After our presentations, we will solicit feedback on the usefulness of the visualization techniques and ways that we could make the information more useful and more available. We will also provide DVDs of our GIS data layers. We have provided descriptions of our project and preliminary results at a number of local venues (see Appendix E).

Results of the analyses are being incorporated into Sea Grant’s NEMO (Nonpoint Education for Municipal Officals) educational material to help local governments understand the effects of these different development scenarios on their community, and the potential effects on the community’s natural resources. Using our results as examples in the NEMO program will help ensure presentation of our results to a broader audience. We will also provide the results on NRRI’s websites Coastal GIS (http://www.nrri.umn.edu/coastalGIS/) and Lake Superior Streams (www.lakesuperiorstreams.org). The Coastal GIS website represents part of an effort to assemble spatial data and develop decision support tools for the aquatic and terrestrial resources within Minnesota's Lake Superior coastal zone. The Lake Superior streams website provides the public with general stream information and real-time water quality and stream flow information. It includes teaching sections on all aspects of stream ecology and emphasizes how human actions and use of the landscape affect stream quality. Both websites will exist for years into the future.

Acknowledgements

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Appendices

Table A1. Zoning standards and setbacks for Lakewood Township and St. Louis County. See Table A3 for descriptions of column headings.

Community	Zone	Min lot	Min width	Max cover	Prin frt rd	Maj frt rd	Min frt rd	Prin side	Acc side	Prin rear	Acc rear	Max ht
Lakewood	FAM-2	17	600	2	125	125	125	100	100	100	100	
Lakewood	FAM-3	9	300	2	125	125	125	50	25	100	50	
Lakewood	MUNS-4	4.8	300	10	125	125	125	50	25	50	50	
Lakewood	RES-7	1.8	150	25	125	100	88	20	10	45	10	
Lakewood	COM-11	2	100	25	110	85	68	20	20	40	20	
Lakewood	LIU-10	5	200	25	110	85	68	50	50	50	50	
Lakewood	SMU-7*	-	-	-	-	-	-	-	-	-	-	
Lakewood	LSO-10	2	200	25	110	85	68	40	40	45	45	
St. Louis**	1	35	600	2				100	100	100	100	35
St. Louis	1a	35	1200	2				100	100	100	100	35
St. Louis	2	17	600	2				100	100	100	100	35
St. Louis	3	9	300	2				50	25	100	50	35
St. Louis	3a	9	600	2				50	25	100	50	35
St. Louis	4	4.5	300	10				50	25	50	50	35
St. Louis	4a	4.5	400	10				50	25	50	50	35
St. Louis	5	2.5	200	10				20	10	45	10	35
St. Louis	6	2	200	30				20	10	45	10	35
St. Louis	7	1	150	25				20	10	45	10	35
St. Louis	8	1	200	30				20	10	45	10	35
St. Louis	9	1	150	25				15	10	40	10	35
St. Louis	10	2	200	25				15	10	40	10	35
St. Louis	11	0.5	100	25				15	10	40	10	35
St. Louis	12 (sewer)	0.33	100	35				10	5	40	5	35
St. Louis	12 (wtr & swr)	0.25	75	35				10	5	40	5	35
St. Louis	13	2	200	30				25	25	50	50	35

* SMU-7 in Lakewood Township is not buildable property

** Normanna, Rice Lake, and Gnesen townships follow St. Louis County zoning standards

Table A2. Minnesota Department of Natural Resources setbacks and impact zones for state waters.

State waters setbacks	**Setback (ft)**
Natural lake setback	150
Natural lake impact zone	75
Recreational lake setback	100
Recreational lake impact zone	50
General development lake setback	75
General development lake impact zone	50
Trout stream setback	150
Trout stream impact zone	75
Remote river setback	200
Remote river impact zone	100
Forest river setback	150
Forest river impact zone	75
Other river setback	100
Other river impact zone	75
Primitive river setback	300
Primitive river impact zone	150
Urban river setback	100
Urban river impact zone	75
Rural agricultural river setback	200
Rural agricultural river impact zone	150
Recreational river setback	150
Recreational river impact zone	75

Table A3. Metadata descriptions of fields for zoning standards for Lakewood Township, St. Louis County, and Two Harbors, Minnesota.

Abbreviation	Units	Description
Community		Community that zoning regulation is for
Zone		Abbreviation of zone
Min lot	Acre	Minimum lot size in acres
Min width	Feet	Minimum width frontage in feet
Max cover	Percent	Maximum percent lot coverage by impervious surfaces
Prin frt rd	Feet	Principal and major arterial road front setback in feet
Maj frt rd	Feet	Major collector road front setback in feet
Min frt rd	Feet	Minor collector and local road front setback in feet
Prin side	Feet	Principal and major arterial road sideyard setback in feet
Acc side	Feet	Access road sideyard setback in feet
Prin rear	Feet	Principal and major arterial road rear setback in feet
Acc rear	Feet	Access road rear setback in feet
Max ht	Feet	Maximum building height in feet
Front setbk	Feet	Front yard setback in feet (Two Harbors)
Rear width	Feet	Rear yard minimum width in feet (Two Harbors)
Side width	Feet	Side yard minimum width in feet (Two Harbors)

Table A4. Two Harbors zoning standards used for the current zoning scenario. See Table A5 for minimum yard sizes. See Table A3 for metadata descriptions of fields and units of measurement. See Table A6 for exceptions.

Zone	Min lot	Min width	Max cover	Prin frt rd	Maj frt rd	Min frt rd	Prin side	Acc side	Prin rear	Acc rear	Max ht	Nat lake
ParkRec	-	-	-	-	-	-	-	-	-	-	30	
R-1	0.161	50	-	25	25	12.5	8	8	30	30	30	
R-2	0.157	50	-	25	25	12.5	7	7	30	30	30	
R-3	0.155	50	-	25	25	12.5	7	7	30	30	45	
B -1*	-	0	-	0	0	0	0	0	10	10	35	
B-1a*	-	0	-	0	0	0	7	7	10	10	35	
B-2*	-	0	-	0	0	0	0	0	0	0	35	
B-3**	0.229	-	-	10	10	10	0	0	20	20	35	
I-1	-	0	-	Tab. A5	Tab. A5	Tab. A5	Tab. A5	Tab. A5	Tab. A5	Tab. A5	70	
I-2	-	0	-	Tab. A5	Tab. A5	Tab. A5	Tab. A5	Tab. A5	Tab. A5	Tab. A5		
I-W	-	0	-	0	0	0	0	0	0	0	70	
S-O$	0.229	75	30	-	-	-	-	-	-	-	$	40$
M-A#	0.155	50	-	25	25	12.5	7	7	30	30	#	

* Dwellings located in the business district are subject to R-3 setbacks and height requirements.

** If lot adjoins residential district, side lot setback of 5 ft is required.

$ Two Harbors S-O = sensitive overlay. Setback from Lake Superior is from the vegetation line (not OHWL), at 40 ft. Building height is 70 ft for industrial zones, otherwise 35 ft.

Two Harbors M-A = Medical. Residential care facilities may be 45 ft, all others 30 ft.

Table A5. Two Harbors minimum yard sizes are based on the building height. See Table A3 for metadata descriptions of fields. All sizes and heights are in feet. See Table A6 for exceptions.

Max ht	Front stbk	Rear width	Side width
35	25	10	12
35	25	10	25 or 40
50	30	15	17 and/or 30
60	35	20	22 and/or 35
70	40	25	27 and/or 40

Table A6. Exceptions to standard zoning ordinances presented in Tables A1, A4, and A5.

Community	Feature	Exceptions to standards and extra requirements
St. Louis Co., Lakewood Twp	Bluffs on public waters	Bluff definition: slopes toward public water; min of 25 ft higher than ordinary high water mark; slope of 30% or greater; top = clear break in slope. Structures must be set back 30 ft from top of bluffs overlooking public waters. Setback increased by 150% if soil depth over rock ledges is 24 inches or less.
St. Louis Co., Lakewood Twp	Red clay erosion areas	Bluff impact zone increased inland to a point where slope levels off to 6% over 100 feet. Toe of the 6% slope is where OHWL top of bluff measurement is made. Height is multiplied by 4. This distance = bluff impact and shore impact zone for veg removal restrictions. Bluff setback for building = 30 ft.
St. Louis Co., Lakewood Twp	Cemeteries	Setback 50 feet
St. Louis Co., Lakewood Twp	Statutory shoreland	Lot sizes and widths of non-riparian property within the statutory shoreland area must have twice the lot size and width of the zoning designation.
St. Louis Co., Lakewood Twp, Two Harbors	Eroding areas	Setbacks of 125 ft from top of eroding bluffs (measured from uppermost shear zone, where slumping begins on bluff)

Appendix B. List of GIS base layers used in this project.

Database	Scale	Source Data
DNR 24K Lakes	24000	DNR Data Deli
DNR 24K Streams	24000	DNR Data Deli
National Wetlands Inventory Polygons	24000	DNR Data Deli
Farm Services Administration (FSA) Color Orthophotos 2003-2004	NA	DNR Data Deli
DOT Basemap Roads - All Types	24000	DNR Data Deli
GAP Land Cover	NA	DNR Data Deli
St. Louis County Zoning		St. Louis County
Duluth Zoning		City of Duluth, MN
Lakewood Township Zoning		NRRI Digitized
Rice Lake Zoning		NRRI Digitized

Appendix C. Assessment of Community Viz program.

Community Viz is billed as a powerful, yet easy-to-use GIS software program designed to "help people visualize, analyze, and communicate about important land-use decisions." We found community viz to be powerful, with vast customization abilities, but it requires a number of detailed datasets to work smoothly, many of which are not generally available for the communities that we worked in, or didn't make sense for the type of analysis that we were doing. This required a number of work-arounds and oftentimes we just used normal GIS software, finding it more efficient. The program is only as good as your input datasets. If you had parcels (lots), or proposed parcels (lots) for a given future development you could generate numerous metrics for the area, show the benefits and costs for avoiding certain land types, and make design suggestions to either avoid sensitive resources, reduce overall impacts, or achieve other goals. But if you don't have these proposed developments, other GIS techniques could be used to develop the same information. The flyby features were a bright spot. They were easy to use, had many options, and allowed for a wide variety of output options, providing a unique and engaging way to visualize proposed developments. With accurate elevation data, there may be a useful role for Community Viz in doing visual impact assessments for specific proposed developments along the shore.

Technical issues with the program were numerous. The program was affected by basic operating system updates. When there were ArcGIS program updates, the Community Viz program also needed to be updated. It would have been nice to know ahead of time that was going to happen so you could decide if you wanted to do the updates. Eventually, we needed to place the program on a machine that did not get updated, and allowed for only one user, to prevent additional system crashes. Numerous times, work and data was lost because of crashes due to simple updates to either the operating system or ArcGIS.

Community Viz would be a useful tool in cases where there was a dedicated staff person who had the time to become fully versed in the software, the work was focused on smaller developments, and specific information, such as building footprints or road length was needed from each development. This software does not seem designed for community-wide assessments, determining appropriate building sites, assessing overall impacts on natural resources, or evaluating building potential within an entire community.

Table D. L-THIA model input data used to calculate stormwater runoff for the various scenarios. "NA" means not applicable.

Community	Scenario	# homes	Total area (acres)	Total lot area (acres)	Lot size (acres)	Impervious acres	Impervious % per lot	Roads (acres)	Driveway (acres)	% impervious (roads excluded)	Curve number (full clearing)*	Cleared area (max 1 acre yard) (acres)	Curve number (max 1 acre yard)*
Two Harbors	Current Zoning	51	18.2	13.6	0.267	4.475	32.9%	1.569	0.999	21.4%	86.99	na	na
Two Harbors	Cons Dsn	51	18.2	8.2	0.161	3.359	40.9%	1.202	0.738	26.3%	87.68	na	na
Lester/Amity	Smart Growth	42	97.9	10.9	0.260	3.949	36.2%	2.110	0.668	16.9%	86.36	na	na
Lester/Amity	Current Zoning	36	97.9	94.3	2.619	10.628	11.3%	3.600	5.681	7.5%	85.04	41.68	86.36
Lakewood	Cons Dsn	15	315.9	86.5	5.770	3.594	4.2%	2.258	0.773	1.5%	84.22	15.77	85.19
Lakewood	Current Zoning	15	315.9	281.9	18.793	6.230	2.2%	4.337	1.329	2.2%	84.31	16.33	85.62
Lakewood	PRD	3	315.9	104.2	34.727	0.916	0.9%	0.000	0.803	0.9%	84.12	3.80	87.37

*Assumptions: "D" soils and grass in fair condition. Curve number formula from L-THIA documentation.

Appendix E. Presentations and other outreach

Date	Group	Outreach type
March 2007	Northeast Landscape Association	Overview of project
March 2007	NRRI Advisory Board	Overview of project
June 2007	Watershed Festival	Overview of project
August 2007	Twin Ports Freshwater Folk	Overview of project
November 2007	Weber Stream Restoration Initiative group	Overview of project
May 2008	State of the Coast Conference	Project results to date
February 2009	Building Green Conference	Project results to date
March 2009	Energy Design Conference	Project results to date
July 2009	Coastal Zone ’09 (abstract accepted)	Final Project results

Enclosures

1. DVD of GIS coverages and aerial photographs
2. DVD of "flyovers" of community futures scenarios
3. Powerpoint presentation of project and results