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Sustainable Neighborhood Development

A Major Qualifying Project Report

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by

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Abstract

Every year America's population increases while millions of acres of farmland and forests are lost and billions of gallons of non-renewable fossil fuels are burned. American society is consuming resources at a rate far greater than the Earth can provide. The goal of this project is to design a community that makes use of sustainable practices as set forth by the Leadership in Energy and Environmental Design (LEED) Guidelines for Neighborhood Development. The design must be economical, socially equitable, environmentally responsible and feasible with today's technology. The final design complied with the standards set for the prestigious LEED silver rating, achieving the main goals set forth.

Acknowledgements

We would like to thank everybody that has helped us with this project, without them we would not have been able to complete it. We would like to give a special thanks to Professor Leonard Albano for his continued support and dedication. We would also like to thank Michelle Buck from Leicester Town Hall for all her time and help.

Capstone Design

This project made considerations regarding the eight real world constraints. Below are the constraints and the considerations made for each:

Economic: Making use of alternative and renewable energy resources drastically lowers lifecycle costs. By using sustainable construction methods and materials this project would be eligible for numerous federal and state rebates and incentives

Environmental: Heavy emphasis is placed on storm-water management to reduce runoff into surrounding ponds and streams. The development will make use of rain gardens, porous pavement, and a retention irrigation system.

Sustainability: The use of alternative energies and responsible community design are intended to reduce the use of fossil fuels.

Manufacturability: The design includes methods, materials and technologies that exist and have been previously used and tested.

Ethical: This design falls within the first canon of the American Society of Civil Engineers (ASCE) Code of Ethics stating that "Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties."[1]

Health and Safety: Safety is paramount, all state and local building codes and zoning bylaws hold priority in design over Leadership in Energy and Environmental Design (LEED) guidelines. Placement, size and building heights of the buildings were determined by dimensional requirements provided by Leicester, MA zoning by-laws. *Massachusetts State Building Codes* governed the structural design for each building giving spacing and dimensional requirements. LEED guidelines offered alternative processes to conventional design and construction.

Social: Individual dwelling units will have small yards and outdoor community gathering areas are going to be placed in strategic locations to compensate. The design incorporates multiple community areas to promote social interaction.

Political: State and Federal government along with many private organizations have been encouraging sustainable building. State and federal governments have passed some legislation promoting and mandating environmentally friendly and sustainable building methods, materials and technologies. As LEED becomes more nationally accepted, state agencies adopt many of the LEED credits for sustainable building programs. To ensure that the most responsible design, criteria from LEED for Neighborhood Development, LEED for new Homes and LEED for New Construction were followed.

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[1] "Code of Ethics," American Society of Civil Engineers, July 23, 2006, http://www.asce.org/inside/codeofethics.cfm, 03/08/10.

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Key Points and Concepts .... Lee

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Cost Analysis .... DiLeo/Lee

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1.0 Introduction

According to the US Census Bureau the population of the United States increased by over 25 million people between the years of 2000-2009. Each year the population of the United State grows by nearly three million people. The moderately steady annual population growth in the United States indicates the need for sustainable development.

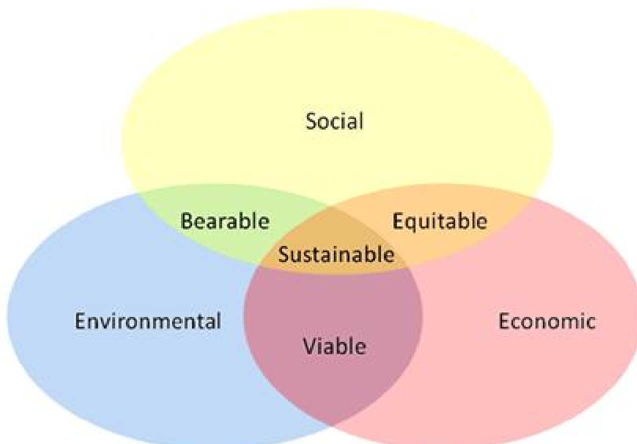

Figure 1-1: Three Areas of Sustainability, recreated from figure from Wikipedia

Sustainable development, as defined by the Brundtland Report in 1987, is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[2] This definition does not specify that sustainable development only refers to environmental sustainability, but implies that there are more than just physical needs that need to be met. In order for a society to make efforts to become truly sustainable considerations must also be made to economic and social sustainability. Figure 1-1 shows the three areas of sustainability and how they related to each other.

[2] "Our Common Future," *Report of the World Commission on Environment and Development*, World Commission on Environment and Development, 1987.

Many people credit Rachel Carson 1962 and his book “Silent Spring” (published in 1962) for beginning the sustainable development movement. Carson criticized the wide use of pesticides in buildings and commented on the earth’s finite ability to absorb toxins. Carson’s book was highly controversial at the time and created a worldwide dialog about the carrying capacity of the Earth.

Carson’s book may have focused on environmental aspects of sustainability, but this project will focus on the three aspects of sustainable development: environmental, social and economic. The environmental considerations are the most obvious to notice, through the use of sustainable and environmentally safe materials (relative to traditional materials) and systems that minimize necessary outside resources. Economic considerations are often the governing deciding factors for a project.

The goal of this project is to spread the awareness that sustainable development is an investment. Building costs may be higher than a traditional development but this project hopes to wean down all the sustainable building options to the most affordable and cost-saving alternatives. This project will also make considerations to the social aspects of sustainability. It is impossible to create the social bonds that form a community, but much effort will be placed into creating an environment in which healthy social bonds can grow.

To achieve this goal a development in Leicester, MA will be designed using the LEED for Neighborhood Development guidelines. Maps in Appendix D show the location of the site. The goal of the guidelines is to create a sustainable, socially equitable community. Efforts will be made to achieve the LEED Platinum rating, the highest rating possible, for the neighborhood and house designs. The LEED rating will help to serve as a measure of the effectiveness of the project in defining a sustainable community development.

2.0 Background

There is a multitude of green building alternatives and a great deal more alternatives that have unsubstantiated claims to being sustainable. There are many organizations that have developed in order to determine the efficacy of individual alternatives and manufacturer or developer claims. One organization that has really taken the initiative is the United States Green Building Council (USGBC) and their development of the LEED.

This chapter will discuss a variety of alternatives for green building. The alternatives discussed are not the sole alternatives available, but instead a small sampling that pertain to this project.

2.1 LEED Guidelines

The USGBC is the mastermind organization behind LEED. The USGBC was formed in 1993 to address green building criteria and today is compromised of 78 local affiliates, over 20,000 companies and organizations. The USGBC describes LEED as a "green building certification system, providing third-party verification" that a building meets given guidelines. [3]

The first LEED program, LEED Version 1.0, was launched in 1998 at the USGBC Membership Summit. Two years later, after extensive modifications, LEED Version 2.0 was released. Subsequent releases include Version 2.1 in 2002, Version 2.2 in 2005 and Version 3 in 2009, which is the most current version. The early LEED programs focused on new commercial construction. Today LEED guidelines have expanded to encompass construction and

[3] "About USGBC," 01/21/10, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=124

modification of schools, commercial buildings, homes and existing building. LEED guidelines have also been developed for operations and maintenance of neighborhood development, health care facilities, retail, homes and commercial interiors.

All of the LEED rating systems evaluate criteria in the following areas or credit categories: sustainable site, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, locations and linkages, awareness and education, innovation in design, and regional priority. The credit categories in a given LEED rating system directly indicate the focus of the rating system, by highlighting the key priorities.

2.1.1 LEED for Neighborhood Development

In 2007 the USGBC, the Congress for New Urbanism, and the National Resources Defense Council (NRDC) released a pilot version for a new set of LEED guidelines, LEED for Neighborhood development. Then in 2009 the LEED for Neighborhood Development Rating System was released after two years of market research. [4]

Unlike previous LEED programs that focus on individual building elements, the LEED for Neighborhood Development has a broader goal, focusing on creating a neighborhood and relating that neighborhood to the surrounding landscape and region. This rating system focuses on key building and construction elements rather than itemizing construction techniques and materials. LEED for Neighborhood Development hopes to reduce land consumption, reduce automobile dependency, increase pedestrian activity, reduce storm-water runoff, improve air quality and provide sustainable communities to people from all income levels.

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[4] *LEED for Neighborhood Development*, 01/21/10, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=148

The LEED for Neighborhood Development includes the following credit categories: smart location and linkage, neighborhood pattern and design, green infrastructure and buildings, innovation and design process, and regional priority.

Smart location and linkages (SLL) awards credit to designs that consider location; this includes land conservation and access to alternative transportation. Neighborhood pattern and design (NPD) awards credit to egalitarian designs that promote an active healthy lifestyle. Green infrastructure and buildings (GIB) promotes repurposing historical structures as well as sustainable construction methods and materials that reduce energy and water usage. Innovation and design process (IDP) awards credit to innovative designs that go beyond the given LEED credits as well as design teams that include LEED-accredited professionals. The final credit category, regional priority (RP) awards credits to projects that take into consideration the specific environmental, social and public health concerns of the region.[5]

In order to gain this specific LEED certification, there are three main stages: optional pre-review, certification of an approved plan and certification of a completed neighborhood development. The initial optional pre-review is an aid to developers; this review would take place at any time during the planning process before the entitlement process. The pre-review can give contractors leverage when trying to obtain entitlement, financing and occupants.

The certification of a plan approved by the USGBC occurs after entitlement and all necessary approvals; the certificate states that the proposed neighborhood plan meets LEED requirements.

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[5] "Foundation of LEED," United States Green Building Council, July 17, 2009.

The final stage, certification of a completed neighborhood design, takes place after substantial or full completion of the project. Any changes to the approved plan could potentially affect, positively or negatively, the credits received. If certification is achieved, LEED will issue the neighborhood a plaque or similar public display of the award.[6]

2.1.2 LEED for New Construction

The LEED for New Construction Rating System is designed to guide and distinguish high-performance commercial and institutional projects, including office buildings, high-rise residential buildings, government buildings, recreational facilities, manufacturing plants and laboratories.[7] The most recent version was released in 2009. LEED certification for New Construction is divided into four categories. The first category is “Certified” which is awarded when the project acquires between 40 to 49 points. When the project accrues between 50 and 59 points “Silver” is awarded. “Gold” is awarded when there is between 60 and 79 points. 80 points and above achieves “Platinum” certification.

The rating system addresses several topics which include: sustainable site, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design, and regional priority. Sustainable Sites (SS) awards credit for projects that minimize disruption of the natural ecosystem surrounding the site. Water Efficiency (WE) awards credit to designs that promote responsible water use, minimizing the burden on municipal water supplies and wastewater systems. Energy and Atmosphere (EA) awards credit

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[6] *LEED for Neighborhood Development Pilot Version*, United States Green Building Council, Introduction (Pages 1-3).

[7] *LEED for New Construction*, 01/18/10, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=220#v2.0.

to designs that minimize negative environmental impacts associated with excessive energy use, promote use of grid tied on-site energy sources, and eliminate the use of harmful refrigerants in heating and cooling systems. Materials and Resources (MR) awards credit for designs that reduce the depletion of raw materials and specify wood that was harvested by responsible foresting practices. Materials and Resources also promotes the use of locally manufactured materials and recycled materials, reducing the amount of waste that will eventually make its way to landfills. Indoor Environmental Quality (IEQ) awards credit for designs that enhance the indoor air quality by reducing any contaminates and designs that give the occupants control of lighting and cooling as well as heating systems that will provide comfort and well being. Credit is also awarded for designs that promote natural light capture. Innovation in Design (ID) awards credit for designs that surpass the LEED requirements. Regional Priority (RP) awards credit for designs that address and achieve geographically specific environmental priorities.

The minimum program requirements for certification under the New Construction and Major Renovations rating system are:

1. Must Comply with Environmental Laws
2. Must be a Complete, Permanent Building or Space
3. Must Use a Reasonable Site Boundary
4. Must Comply with Minimum Floor Area Requirements
5. Must Comply with Minimum Occupancy Rates
6. Must Commit to Sharing Whole-Building Energy and Water Usage Data
7. Must Comply with a Minimum Building Area to Site Ratio

2.1.3 LEED for New Homes

LEED for Homes newest rating system was released in January 2008. The purpose of the rating system is to promote more sustainable home building practices. The rating system encompasses the owner, designers, contractors, material suppliers and accrediting professional. Most states have their own programs that promote sustainable home construction. LEED is trying to provide a national standard that will illustrate the sustainable features and allow any builder to achieve LEED accreditation. “By recognizing sustainable design and construction in homes nationwide, LEED for Homes helps home builders differentiate their homes as some of the best homes in their markets, using a recognized national brand. Furthermore, homebuyers can more readily identify third-party verified green homes”.[8]

LEED certification for New Homes is divided into four categories. The first category is “Certified” which is awarded when the project acquires between 45 to 59 points. When the project accrues between 60 and 74 points “Silver” is awarded. “Gold” is awarded when there is between 75and 89 points. 90 points and above achieves “Platinum” certification. To participate in the LEED for Homes rating systems there are five steps to follow:

1. Contact a LEED for Homes Provider and join the program.
2. Identify a project team.
3. Build the home to the stated goals.
4. Certify the project as a LEED home.
5. Market and sell the LEED home.

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[8] *LEED for New Homes*, Overview of LEED for Homes (Page IV).

LEED for Homes rating system is a measurement of how the home performs throughout the life of the structure. The eight categories that measure the performance are Innovation and Design Process (ID), Location and Linkages (LL), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (EQ) and Awareness and Education (AE). Innovation and Design Process awards credit for designs that surpass the LEED requirements.

Location and Linkages awards credit for socially and environmentally responsible placement of homes with regards to the whole community. Sustainable Sites awards credit for projects that minimize disruption to the natural ecosystem and surrounding the site. Water Efficiency awards credit to designs that promote responsible water use, minimizing the burden on municipal water supplies and wastewater systems. Energy and Atmosphere awards credit to designs that that minimize negative impacts that excessive energy use has on the environment and promotes use of grid tied on-site energy sources and eliminating the use of harmful refrigerants in heating and cooling systems. Materials and Resources awards credit for designs that reduce the depletion of raw materials and wood that was harvested by responsible foresting practices. Indoor Environmental Quality awards credit for designs that enhance the indoor air quality by reducing any contaminates and designs that give the occupants control of lighting and cooling and heating systems that will provide comfort and well being. Awareness and Education awards credit for homeowner, tenant, or building manager being educated on the operation and maintenance of the green features of the home.

2.2 Green Technologies

The 21st century is the age of environmental awareness. “Green” and “sustainable” are the new “it” words in legislation and press conferences. You cannot turn on the television or listen to the radio without hearing about a new environmentally friendly appliance or cleaning product.

Over the past decade environmental awareness has worked its way into society. Companies are scrambling to find the newest, greenest products, and everyday researchers are studying how to mitigate damage to the environment as the market demand grows exponentially. The sustainable technology boom is an economic gold rush. Companies that have adapted are happy because people are rushing to the store to buy the latest, greatest technology, and consumers are happy because sustainable technologies can save them a lot of money. Sustainable products are a win-win-win situation, companies prosper, consumers save and the environment gets a much need break.

This section outlines some of the most economical and feasible technologies that are available today. A major goal of the USGBC with the LEED rating systems is to encourage the use of alternative energies, while reducing the demand for water and energy. Many of the technologies are not new, but due to recent innovation they are being used in new, more practical applications.

2.2.1 Alternative Energies

In 2009 nearly 85% of the energy used in the United States came from coal, natural gas and petroleum. [9] Fossil fuels are formed from decaying organic matter that was buried underground millions of years ago. The implications of this are that it takes millions of years for the fuel stores to resupply themselves. The United States is using fossil fuels at rate far greater than they are being restored. A danger with the Unites States' reliance on fossil fuels is energy security. If an event occurred that rendered the use of fossil fuels highly difficult or impossible (e.g. stores run out, natural disaster inhibits distribution) the United States would be in a severe energy crisis.

Fossil fuels are used for everything from cars to electricity to heating. One major goal of the USGBC and LEED councils is to reduce the amount of fossil fuels consumed. Reducing the amount of fossil fuels burned will reduce harmful greenhouse gases and help to ensure energy security by diversifying sources.

2.2.1.1 Solar

The power generated from the sun is a viable and responsible source of energy. The energy can be captured two different ways. The first way is passive solar power, which directly allows the sunlight to heat, cool and light a structure. And the second way is active solar power. Active solar power uses a solar collector that will store and distribute energy throughout the structure.

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[9] "Early Energy Outlook 2010 Early Release," *Total Energy Supply and Disposition Summary*, US Energy Information Administration, http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.

The energy of the sun has been understood for centuries, as indicated by the myth of Archimedes Heat Ray. In the myth Archimedes is credited with lighting ships on fire with a mirror made of polished bronze. Whether this heat ray ever existed or worked as indicated is lost to history, but the myth signifies that people even in second century BC understood the energy that the sun radiated.[10] The first utilization of solar energy came from cave-dwellers, who preferred south-easterly facing caves. The first recorded wide-scale usage of solar energy design occurred in the late BC and early AD when the Roman Empire made use of passive heating systems and greenhouse technology in their architecture.

The "Climax," in 1891, was the first patented solar water heater. Invented by Clarence M. Kemp, the "Climax" was a black water tank inside an insulated glass box. Solar hot water heaters were common in homes until the 1940s and 1950s when electricity prices fell and copper prices rose. [11]

Today the leading technology in the solar energy field is the use of photovoltaic (PV) cells. PV cells use semiconductor to create direct current (DC) electricity. The DC energy runs through a power inverter and is converted to alternating current (AC) power to be used in the home or to charge batteries for later use. PV cells are comprised of two thin layers of silicon, a phosphorus-doped and a boron-doped layer. Electricity is generated when energy from the sun is transferred between these two different layers of silicon. Figure 2-1 shows how a basic solar energy system operates.

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[10] Elements of Physics or Natural Philosophy, General and Medical, Neil Arnott, Page 126, London, 1829.

[11] Solar Water Heating: A Comprehensive Guide to Solar Water and Space Heating, Bob Lamrow, New Society Publisher, 2006.

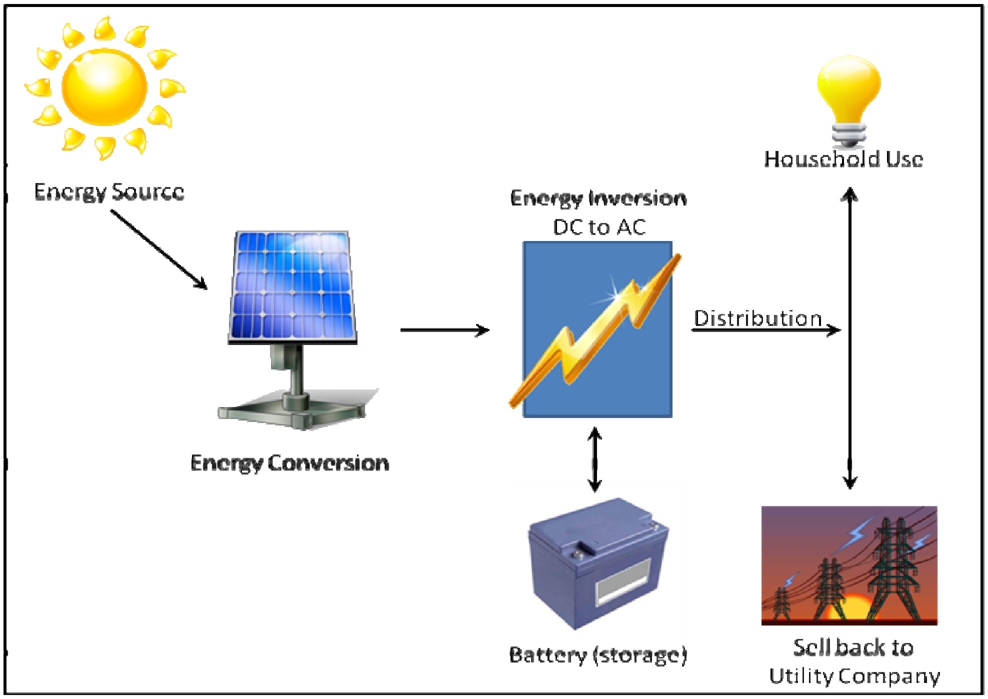

Figure 2-1: How Sunlight becomes Electricity

There are two main types of solar electricity systems, grid-tied and non grid-tied. A non-grid tied system is a good system for houses that do not have access to electricity from a utility company. The elecricty created by the PVs is stored in batteries where it is available for later use. Batteries can be a large expense for this type of system, and they require replacement approximate every ten years. One advantage of a non-grid tied systems is that if service from the utility company in interrupted, electricity is stored in the battery.

A grid-tied system is connected to the electricity grid. The electricity created by the PVs is sent directly to the house. The energy that is not immediately used is then sold back into the electricity grid for fair market value of the electricity. There are also hybrid systems that utilize both the advantages of a grid-tied system with the security of a non grid-tied system.[12]

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[12] "Florida Solar Energy Center," http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/index.htm.

2.2.1.2 Geothermal

Geothermal energy comes from the combination of “geo,” meaning earth and “thermal,” meaning heat. Geothermal can be used very effectively in two ways: to pump superheated water from underground to the surface and use the steam to create electricity, or to utilize the stable temperatures of the earth to heat and cool buildings.

The most efficient form of geothermal energy is hydrothermal energy. Hydrothermal energy is capturing steam from superheated water, usually 300 to 700 degrees Fahrenheit, from underground. The superheated water is formed when magma comes close to water trapped in pores in rocks. The steam captured is then used to run generators in a plant to create electricity. There are over 50 hydrothermal plants in the United States. California and Nevada are leading the way in hydrothermal energy plants with 34 and 15 plants respectively. Hydrothermal energy would be an extremely valuable part of the energy infrastructure of the US if the resources were abundant, but the resources are limited to certain geographic areas such as Hawaii and the western continental United States.

The most accessible geothermal resource is the stable temperature of the earth about ten feet underground. On average this temperature remains between forty-five and seventy-five degrees, depending on geographic location. The stable ground temperatures are used to cool air in the summer and heat air in the winter. The ground temperature is utilized by installing a geothermal heat pump (GHP) to pump water, steam or air through pipes buried underground. The pipes then connect back to the hot water heater, boiler, furnace or air conditioner. Conventional heating and cooling systems utilize the varying outside air temperature while geothermal heat pumps take advantage of the earth’s constant temperature. When used in conjunction with traditional heating systems, on cold winter nights efficiencies can reach as high as 300% to 600% of traditional heating systems alone.

There are two pipe configurations that can be used with GHPs: lateral and vertical. Vertical pipes require drilling a hole, usually around 50 feet deep, into the ground and installing a loop of pipe to run water down and back up. This option makes GHPs possible for people that have small properties or are installing a GHP after their house is constructed. The other option for GHPs is a lateral pipe layout. In lateral pipe layout the pipes are usually placed approximately 15 feet underground, and may be placed under the foundation of the house. This pipe layout does not involve drilling equipment and can be the most cost effective system if constructed before the house; the equipment that is necessary for excavation is already on location to dig the foundation.

2.2.1.3 Wind

Wind energy is an indirect form of solar energy. Wind is created by temperature differentials in the atmosphere, which is a result of the sun heating the atmosphere at variable rates. Since air has mass, it has kinetic energy when it moves. Wind turbines are used to remove some kinetic energy from the moving air masses and produce electricity, hence wind energy.

Wind resources are virtually inexhaustible. Wind provides a domestic source of energy that releases no harmful emissions. The domestic factor is extremely important from an economic standpoint: it eliminates the volatility of energy prices that is a result of both international trade and limited resources and production capacity. Wind is the fastest growing energy source in the United States; contributing 42% of new generating capacity in 2008. Figure 2-2 compares the new generating capacity of wind to the other sources. The United States

Department of Energy (DOE) estimated that it was feasible, with the proper initiative, for wind power to generate 20% of the United States' electricity by the year 2030, like Denmark does today. Approximately one-third of the land area of the United States has wind resources that are sufficient to economically generate electricity.

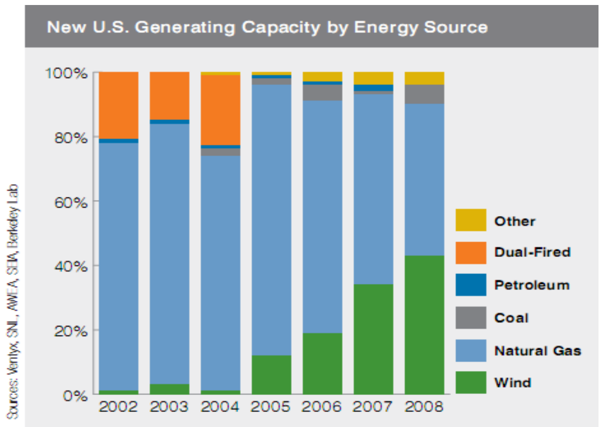

Figure 2-2: Energy Generating Capacity by Source ("Wind power Outlook 2009," American Wind Energy Association)

Wind energy is captured through the use of wind turbines. Figure 2-3 (next page) shows a diagram of the different parts of a wind turbine. Wind turbines capture the kinetic energy of the moving air mass and convert it to mechanical energy. The mechanical energy is then used to power a generator which creates electricity. The main visual parts of a wind turbine are the rotor blades, tower and nacelle. The rotor blades capture the kinetic energy from the moving air mass by rotating. The nacelle is the compartment behind the rotor, containing the gearbox, generator and transformer. The gears transfer the mechanical energy from the rotating blades to the generator. The generator converts the mechanical energy into electrical energy, and the electricity is conveyed to a transformer, where it becomes available for distribution or use.[13]

[13] "Wind Energy Fact Sheet," American Wind Energy Association, 02/12/10, http://www.awea.org/pubs/factsheets/Wind_Energy_How_does_it_Work.pdf.

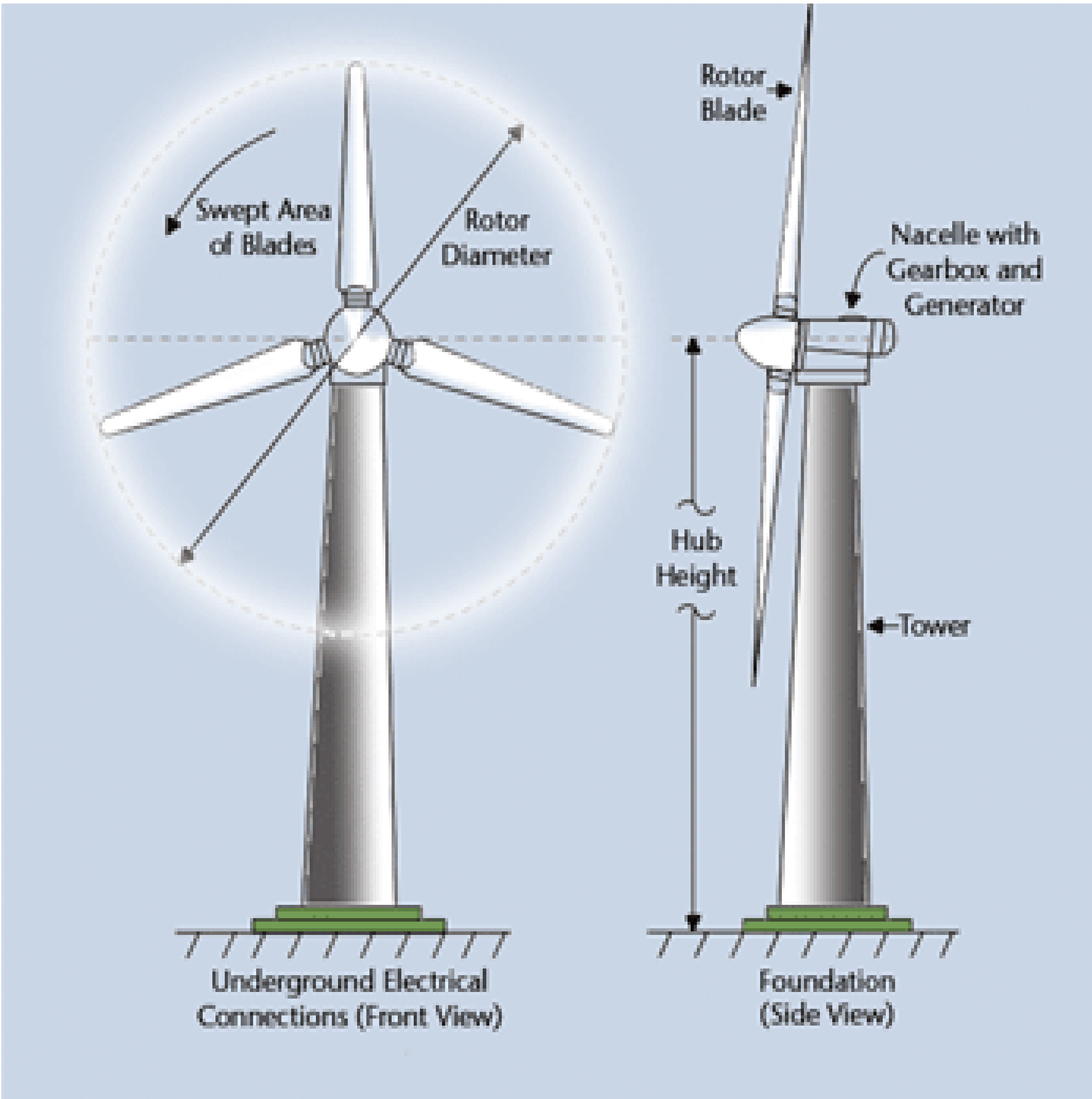

Figure 2-3: Components of a Wind Turbine (Source: http://ec.europa.eu/research/energy/nn/nn_rt_windd/article_1101_en)

2.2.2 Neighborhood Resource Protection Technologies

The energy saved by the use of compact fluorescent bulbs over incandescent bulbs or the installation of a new Energy Star refrigerator can be easily recognized by dollars saved on a household electricity bill. One thing that most people never see is the electricity bill for the streetlights or the heating bill for the town hall; it is just as important to make use of sustainable practices and technology outside of the home as it is in the home.

2.2.2.1 Street Lighting

According to data from the United State Environmental Information Association (EIA), in 2008 Massachusetts has the third highest price for electricity in the United States, over 16 cents per kilowatt hours (kWh).[14] The average sodium streetlamp uses approximately 15 kWh a night. This means that the average streetlight costs $2.25 a night to operate. If there are 1000 streetlights in a town, it costs the town $2,250 a night, $67,500 a month and $821,000 a year to keep the town lit.

There are multiple solutions to reducing the money and electricity spent annually on street lights. The first and most simple solution is to turn them off. Many towns and cities have taken this action and turned off either some or all of their street lights. Another option is to use Light Emitting

Figure 2-4: Solar Street Lights by Sol Inc. (Palm City, FL)

[14] "Average Monthly Bill by Census Division, and State 2008 ," United States Census Bureau, http://www.eia.doe.gov/cneaf/electricity/esr/table5.html

Diode (LED) lights. LED lights use on average 2.5 kWh per night, which is over 115% the efficiency of sodium bulbs. LEDs also have a much longer lifespan reducing need for maintenance and replacement. One final option, and the most progressive, is solar street lamps. Figure 2-4 shows a street light design by Sol Inc., a company in Palm City, FL.

Solar street lights are completely self-contained and require no outside wiring or electricity. The lamp unit consists of an LED bulb, solar collection panel and a battery. The solar collectors gather energy all day and store the electricity in the battery, where it can then be used at night.

There are many advantages to solar street lights. One great advantage of solar streetlights is that is electricity service is interrupted; the street lights will still have power. Since the individual street lamps require no outside power, no trenching is required for installation. Another advantage is that solar streetlamps have no daily operating costs; however, they do require maintenance approximately every ten years. The cost of solar street lights (obtained from Sol Inc. in Palm City, FL) to purchase and install is comparable to traditional street lights, and when considering the free operation, solar street lights are extremely economical.

2.2.2.2 District Heating and Cooling

District heating and cooling (DHC) is a large centralized thermal energy system. DHC allows heat, hot water, steam and/or air-conditioning, like electricity or natural gas, to be sold as a commodity. Heat is produced at a centralized plant and then is distributed through underground pipes. According to the EIA, DHC has been proven effective in reducing greenhouse gases.

Figure 2-5: District Heating and Cooling System (Source: www.sustainable-development.veolia.com)

Figure 2-5, from Veolia Environmental, shows a DHC system that was built in Vénissieux, France. DHC is very convenient for a household because there is no need for a heating system or maintenance. All the heating equipment required is maintained and operated at a plant. Since the plants are large much larger than individual units, using principles of economy of scale, they can more economically make use of waste burners, alternative energies and cogeneration. DHC plants are both sustainable and economical to operate.

Not all DHC systems sell heat. Today in the United States DHC is commonly used in institutions that have multiple buildings, such as colleges and universities, military bases and large commercial institutions. Figure 2-6 shows an aerial view of some dormitories at Assumption College, in Worcester, MA, that make use of district heating and cooling. The United States has the most DHC systems than any other country, but DHC systems are usually limited to large institutions. In Europe DHC systems are commercial operations. Companies own and operate DHC systems and sell heat and hot water to local residents.

Figure 2-6: Aerial View of Assumption College Dormitories (Source: Google Earth)

2.2.2.3 Grey-Water Reuse Systems

The United States withdraws over 300 billion gallons of freshwater daily, with nearly 50 billion gallons of public supply going to residential use. More than fifty percent of the water used in the average household is grey water. Figure 2-7 (next page) shows the breakdown of the average indoor household water usage; note that over fifty percent of the average household water usage is reusable grey water.

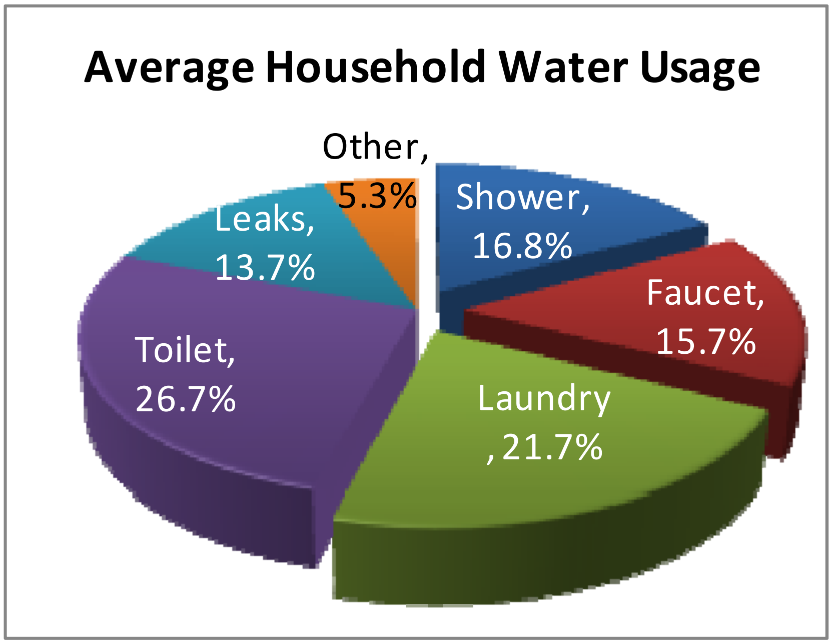

Figure 2-7: Average Household Water Usage by Source

Untreated grey water cannot be reused in the home; however it can be used for underground irrigation. Australia is leading the world in grey water reuse systems. One company has revolutionized residential grey water treatment systems, Nubian Water Systems. Their systems clean grey water well enough to be used for toilet flushing, laundry, above ground irrigation and car washing. Most of their residential units area above ground grey water treatment system. They work by first filtering the water and removing any solid particles. The water then goes though a microbial aerobic degradation, which involves safe bacteria to kill the harmful bacteria and pathogens. The Nubian company has put a lot of design effort towards making this system compatible with current household piping, so installment requires minimal plumbing. Figure 2-8 shows one of the residential Nubian Grey Water Filtration and Storage units.[15]

Figure 2-8: Nubian Greywater Storage Tank

There are other grey water treatment systems available. The most common systems in the United States run grey water through buried perforated pipes. These pipes may be buried in a garden or under a lawn. The grey water from the house is then used to irrigate the landscape.

[15] "Nubian GT600 Greywater Treatment Systems," 11/31/10, http://www.nubian.com.au/Residential-Greywater-Treatment-System.asp

2.2.3 Outdoor Water Management

Managing outdoor water, such as storm water and water used for gardening, is a key aspect of sustainable development. From an environmental standpoint it is very important to protect water quality and to minimize storm water runoff. Urban areas can have as much as 85% impervious areas. When it rains, water washes oils, sediment, nitrogen, phosphorous and heavy metals into surrounding water sources and water bodies. Large paved areas also interrupt the natural groundwater replenishment that happens when it rains.

2.2.3.1 Porous Pavement

Porous pavement is one way to reduce impervious area. Porous pavements allow water to be absorbed back into the ground while still maintaining a solid surface. There are three main types of porous pavement: porous asphalt, unit pavers and granular materials.

All three types of pavements are placed over a bed of pervious crushed stone or sand. Unit pavers are blocks that are placed on the ground and either filled or surrounded by stone dust. Granular materials are areas covered with sand, rocks or gravel.

Porous asphalt contains four layers. Figure 2-10 shows a design that the State of New Hampshire used. The topmost layer is the actually porous asphalt. This asphalt was created by mixing aggregates and binding agents; all aggregate below two millimeters were removed to obtain an ideal 18-20% void space in the asphalt. The second layer is four inches of 3/4 inch stone. This stone allows water to run through to the next layer while offering structural support to the asphalt. The third layer is 24 inches of poorly graded sand. The sand acts as a filter removing any sediment form the water. The final layer is 21 inches of 3/8 in crushed stone. The

21 inches is designed for soils that have low permeability rates, such as clay. This layer also protects in areas where freeze/thaw might damage the asphalt. In areas with native soils with high permeability and freeze/thaw is not an issue, a smaller layer could be used. This layer also includes a six inch perforated drain pipe in case the water is not being percolated back into the native soil quickly enough.

Although the effectiveness of porous asphalt has been proven, there are several considerations that should be made. Porous asphalt can cost two to four times more than traditional asphalt. Porous pavement needs to be vacuumed or swept every three to six months to keep the voids clear of debris and inspected annually to look for visible signs of deterioration. One final downside to porous pavement is that salt and other ice melting chemicals cannot be used because the water runs directly into the groundwater.[16]

Figure 2-9: Demonstration of Porous Asphalt (Source: www.greenblog.com)

[16] "Porous Asphalt," University of New Hampshire Stormwater Center, 01/20/10, http://ciceet.unh.edu/unh_stormwater_report_2007/treatments/porous_asphalt/

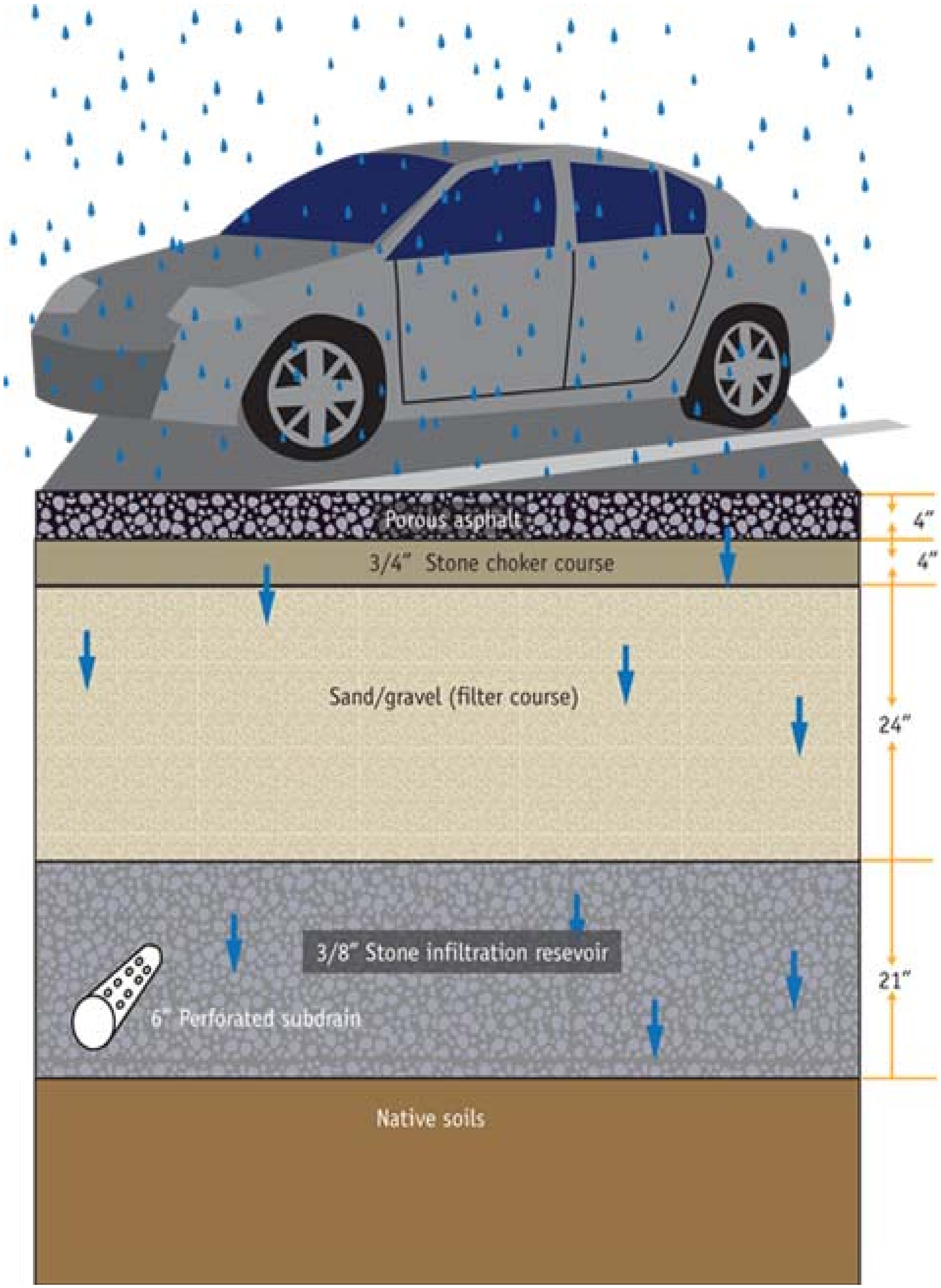

Figure 2-10: **Layers of Porous Asphalt (Source: http://ciceet.unh.edu/unh_stormwater_report_2007/treatments/porous_asphalt/images/process.jpg&imgrefurl=http://ciceet.unh.edu/unh_stormwater_report_2007)**

2.2.3.2 Rain Gardens

Rain gardens are shallow depressions in the ground that are planted with trees, shrubs or native plants. Rain gardens are often used to collect runoff water from roofs and parking lots. Rain gardens have been gaining popularity across the United States, but little research has been done into the actual pollutant reducing capabilities. Rain gardens can also be used to remove or reduce standing water. Figure 2-11 shows a cross-sectional view of a rain garden.

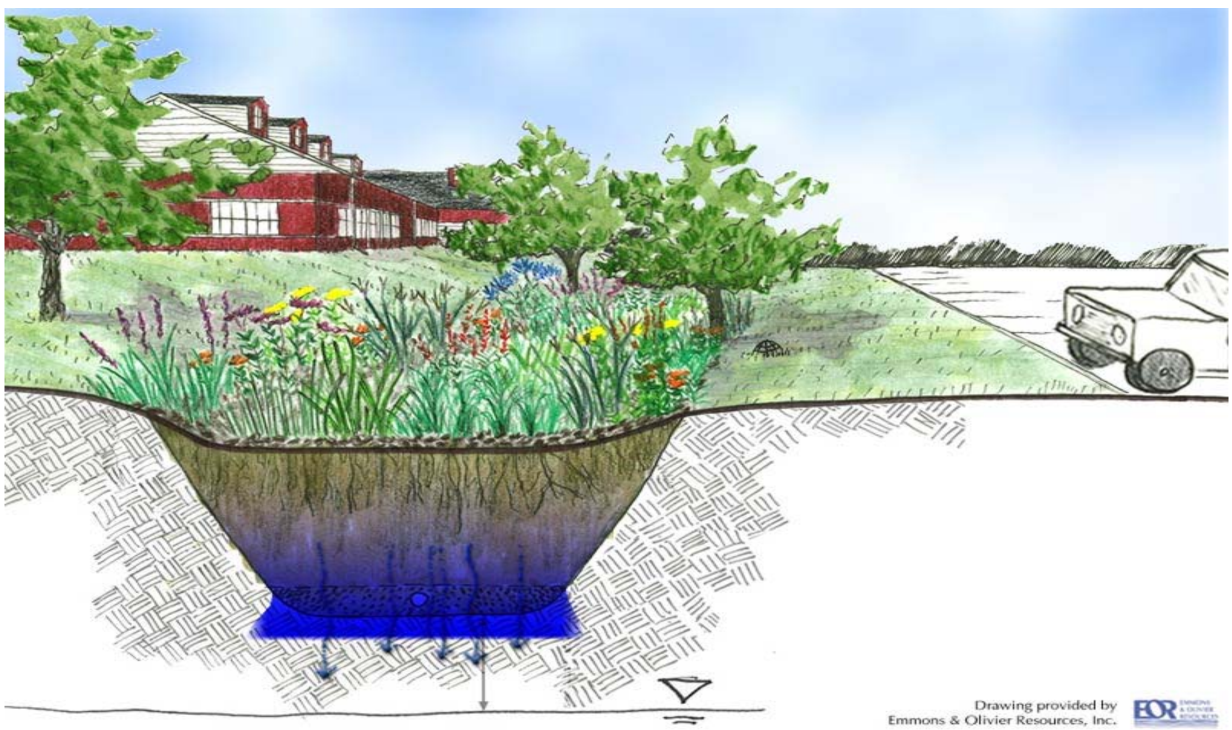

Figure 2-11: Cross Sectional View of Rain Garden (Source: Emmons and Oliver Resources, Inc., Oakdale, MN)

In some areas soils may not be sufficiently porous to percolate the water quickly and an under drain may be installed. Under drains are not as sustainable as pure rain gardens, but they do offer some water filtration and some water goes back into the ground water.

2.2.3.3 Retention-Irrigation

One viable method for reducing storm-water runoff is through retention-irrigation. This process involves capturing storm-water runoff in wet ponds. A wet pond is a permanent retention pond that is always filled with water; the water level may fluctuate during various seasons. The process which the water goes through before use removes the majority of sediments and harmful materials.

The design of a retention-irrigation system involves two retention ponds and a pumping system. Storm-water runoff is captured by a traditional storm-water system and transferred to the first retention pond. The runoff must pass through a large sediment filter before it enters the first retention pond. The water will sit in the first retention pond for a time period that is sufficient to remove local sediments; this varies but is usually varies between 12 and 30 hours. The water is then moved into a larger storage retention pond. The water has to be run through a final sediment filter before it is used. Water can be used to irrigate lawns and gardens.

By capturing, treating and using the water for irrigation, storm-water runoff into nearby streams is greatly reduced or eliminated. This reduces pollution due to contaminants as well as thermal pollution caused by warm water from the retention pond entering streams. Irrigation can also be used as a method to manage storm-water, by dispersing the water over pervious areas, other than gardens and lawns, after a rainfall.[17]

[17] "Retention/Irrigation," *Stormwater BMP Handbook*, California Stormwater Quality Association, January 2003.

2.2.3.4 Landscaping

Landscaping is important to a community for several reasons; landscaping reduces noise, reduces erosion and is esthetically pleasing. However, maintaining landscaping can be an inefficient use of water, time consuming and can contribute to polluting local water and drinking water with pesticides. Another major problem that occurs with landscaping is the use of non-native plants that become invasive.

Figure 2-12: Native Landscape Design in Montana (www.picassa.com/b_bar_ranch)

According to the EPA, 67 million pounds of pesticides are on lawns and approximate 60 to 70 million birds are poisoned each year. Grass has only ten percent the capacity to absorb rainwater than a forest floor would have. The water that is not absorbed by lawns can cause erosion or pool in low lying areas. In the United State as high as sixty percent of water used in a given region goes to watering lawns. The average homeowner spends forty hours a year mowing their lawn and over 580 million gallons of fuel is used in the US each year to run lawnmowers.

The solution to reducing the impact of landscaping is to make use of a variety of native plants. Figure 2-12 shows a landscape design using only native plants at B Bar Ranch in Emigrant, MT. Native plants thrive in their local environment and will not become invasive. Native plants also require minimal care and watering. Another key aspect of sustainable landscaping is to use annual plants, which will come back each year. Not only are perennials more economical but they also reduce the need to transport plants annually.

One way to reduce the use of pesticides is to make plantings in higher densities. This will reduce noticeability of imperfections due to pests in the plants. Denser gardens also absorb more water and increase the cooling capacity of plants.[18]

2.3 Building Materials

When building a LEED accredited building, the building materials used play a significant role in the amount of points awarded in accordance with the rating guidelines. Depending on the final look and required use of the structure there are several choices of materials to build with.

2.3.1.1 Foundation Alternatives

The first step in building construction is to erect the footings and the foundation walls. The common practice is to use formed cast-in-place concrete. Depending on the geographical location and the use of the structure, concrete is batched in a specific way to achieve the required strength for the appropriate application. Concrete consist of water, aggregate, Portland cement which is a mix of lime, silica, iron oxide and alumina and admixtures which are chemicals added to the mix design. Common admixtures are water reducers and air entraining chemicals. By using these chemicals the concrete plant can improve the strength of the concrete and prevent damage caused by freezing and thawing cycles.

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[18] "Sustainable Landscaping," Environmental Protection Agency, 01/12/10, http://www.epa.gov/greenacres/smithsonian.pdf

Strict environmental laws caused a push for more sustainable alternatives in the production of concrete. To reduce the amount of waste sent to landfills and reduce the amount of material mined for aggregate, concrete manufacturers are turning to using recycled materials in the mix design. Demolished concrete, bricks and rocks are ground down and used as aggregates along with fly ash and slag cement which is used as a replacement for Portland cement. Fly ash is a byproduct generated from the burning of coal, and slag cement is a byproduct of steel manufacturing. This geo-polymer concrete or "green concrete" can greatly reduce the amount of greenhouse gases emitted from manufacturing plants. Concrete manufacturers state that this green concrete because of the properties in the ingredients used is a far more superior product than the standard concrete design.

Along with using a more responsible concrete mix there are more sustainable alternatives in foundation construction. The common cast-in-place method produces a large amount of wasted material. Also, the chemicals needed to release the forms from the cured concrete can potentially cause harm to the environment. Several alternatives are on the market that not only reduce waste and building time but also offer added benefits to the performance of the entire structure.

2.3.1.2 Framing Materials

The most common material used in residential construction is wood. The three types of wood that are used are softwood, hardwood and manufactured products that are made from wood products and a binder to keep them together. The most common softwoods for construction are pine, fir and cedar. Common hard woods are oak, maple, and poplar. These woods are harvested, taken to mills and cut to size, and then kiln dried to remove the moisture which makes the material stronger and resistant to rotting. Most state building regulations require that construction grade lumber be Forest Stewardship Council (FSC) certified. FSC certified lumber is harvested by strict guidelines that promote sustainable forestry. All of the parties involved in the logging industry are working together responsibly to ensure that no permanent destruction is done to the environment. The harvesting is done in such a way that minimum destruction is done to the forest therefore allowing the trees to be replanted and available for harvesting sometime in the future.

Steel and concrete are becoming commonplace in home construction as alternatives to wood. Commercial and industrial construction, make use of these materials because of their high strength capabilities. Steel framing material is a reliable building product because of its ability to resist deformation. Steel's characteristics rely on the ingredients and the treatment to solidify the molten liquid. Just like concrete manufacturers turning to recycled products, steel manufacturers are recycling steel to eliminate waste and unnecessary mining for materials. Steel framing is an effective alternative building material to traditional wood construction because in terms of weight to volume ratio, it is often the strongest low cost building material available.[19]

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[19] "Building Construction Illustrated," Francis D.K. Ching, page 12.08, New York, John Wiley and Sons Inc., 2001

2.3.1.3 Window and Door Options

Windows and doors are essential in creating a thermal break in any type of structure. Proper orientation of the structure to the sun maximizes the exposure time that the structure can benefit from the passive solar radiation. Originally windows were single panes of glass with a wood border that minimized thermal leakage either into or out of the structure. The next generation of windows was double pane glass with an insulating gas between the panes. These windows also provided greater noise reduction for the interior of the structure. Window manufacturers went one step further and created a triple pane window with the insulating gas between each pane and Low emissivity (Low-E) glazing on the glass. Depending on the desired use of the window, the Low-E glazing will be placed on a specific pane to achieve the desired result. The selection of which pane the glazing is placed does not affect the insulating value of the window. Placing the gazing on the exterior side of the middle pane allows for passive solar radiation to heat the interior of the structure and will not allow for heat lose. To Control the passive solar radiation, the glazing will be placed on the inside of the outermost pane of glass.

Thermal efficiency is also a desirable factor in door selection. Originally doors were solid wood slabs that provided a minimal thermal break to the climate. Many generations of doors have been manufactured to achieve desired results. The modern door is made from wood, fiberglass, or metal with insulation sandwiched between the panels, all having their own insulating properties. Doors with glass often have Low-E glazing on the panes to provide maximum thermal efficiency.

Using energy efficient doors and windows and proper placement of the structure will reduce heating and cooling needs of a mechanical system, thereby minimizing the dependence on outside energy sources and reducing operational costs.

2.3.1.4 Exterior Finishes

Sustainable exterior home finishes consist of recycled materials, reclaimed materials and FSC certified wood products. Home construction exterior finishes commonly consist of vinyl siding products that ultimately make for easier installation

2.3.1.5 Plumbing and Electrical Alternatives

The United States, along with Canada, is the largest user per capita of fresh water supply. Finding alternatives to minimize the depletion of this limited resource is crucial. As the population grows so does the demand on freshwater. To reduce the demand on freshwater supplies, recycling grey water can greatly reduce the demand. Grey water is any water discharged from a home or building that does not include water flushed from toilets. In America most plumbing codes do not allow for grey water to be used for inside the facility unless the discharge is purified. Besides recycling grey-water responsible water use can include the capturing of storm water and used Not only is it imperative to find responsible solutions to water use the material used in the plumbing system needs to be addressed.

Old plumbing fixtures, washing machines and dishwashers are the leading factors in excessive water use. Replacing old fixtures and fittings more than half the water consumed. An average sized home uses about 16,000 gallons of water annually from showerheads and faucets. Low-flow aerating units deliver a strong flow of water by introducing air into the system while using less water. These new systems can save around 8000 gallons of water annually. An extensive amount of research and engineering has been done to reduce the amount of water used when flushing a toilet. An old style toilet delivers 3.5 gallons of water per flush. New toilets reduce the amount of water per flush by half using about 1.6 gallons per flush. Toilet manufacturers have designed an option of toilets that have dual flushing options the toilet uses .8 gallons of water or 1.6 gallons of water per flush. Manufacturers also designed self composting toilets that contain no water. These systems are odorless and can produce usable compost after some time.

There is a large debate on green piping material. Several options for piping material are available, and which one to use depends on the specific application. Manufacturers of cast iron and copper piping claim that their materials are “Green” because the material is made from recycled metals but it requires a significant amount of energy to melt done these metals and produce new pipes. The energy consumed contributes to the emissions of greenhouse gases. Polyvinyl chloride (PVC) piping and Acryonitrile Butadiene Styrene (ABS) piping are made from oil, a limited natural resource. Less energy is consumed in making the plastic pipes but there is also the concern of toxic fumes being released from these materials.

2.4 Building Methods

Determining the style of home is the most important step in building a new home. Determining the materials to be used and how the structure will be built is just as important. Residential home construction utilizes several building methods depending on the location and style of home chosen. Several styles of construction methods include conventional construction, steel and concrete. Most conventional construction produces a significant amount of construction waste and over-built.

2.4.1 Conventional Construction

Conventional construction utilizes a wooden structure that transfers the load to a concrete foundation. Depending on the size of member chosen for the specific application building codes regulate the maximum spacing allowed to support the load. Typically two by four studs and two by ten joists are used for framing. The concrete foundation supports the floor joists that support walls that will support additional floor joists and girders and walls. Conventional construction spaces the wooden members sixteen inches on center for constructability by subcontractors. This allows for faster construction and decreased labor costs.

2.4.2 Steel Construction

Steel construction provides a beneficial alternative to wood framing. The use of steel framing generally cost less than wood framing and can provide a unique look for the home. Steel can accommodate larger loads than wood allowing for less material to be utilized.

2.4.3 Concrete Construction

Concrete is the most proven building material used to date. Concrete in conjunction with reinforcing steel is a durable, strong and inexpensive solution of building construction. There are several ways concrete can be used in home construction, first concrete masonry units can be used to erect walls. Then steel and wood can be used to build the floors. Second insulated concrete forms utilize two layers of foam insulation that provide a beneficial thermal break and are resistant to fire and wind damage. Another type of concrete construction is the use of precast panel system, these panels are constructed at the factory and shipped to the site where they are tilted into place. This allows for faster erection which reduces labor costs.

2.5 Regulations

Construction and development projects often have to comply with multiple regulatory authorities. In Massachusetts projects must comply with town by-laws, state building codes and Massachusetts DEP regulations.

2.5.1 Town of Leicester, MA Zoning By-Laws

Zoning by-laws are a set of guidelines produced by each individual town or city in a given state. The by-laws control how land is used in the given community and controls the rate of growth of the town. In Massachusetts each town or city is divided into areas of common uses. Dividing the land into common uses will protect homeowners from having a large factory built right next door that may possibly decrease the value of the home or make the home unsellable. Zoning will also help to separate residential from industrial areas, ensuring safey of local residents. Some of the uses may be Industrial, Residential, Business or Agricultural along with several others. The Zoning By-laws are constraints on how the land is used, where buildings can be located, types of buildings that are allowed on the site and how the facility can be used. Also, zoning by-laws control the dimensions of the lot, parking requirements, the maximum building height allowed and the minimum setback distance for the facility to be located from the street. Zoning by-laws are important objectives set forth by the given community that ensure that the objectives and policies are followed by all citizens.

Leicester, Massachusetts first adopted zoning by-laws in 1946, and the most recent zoning by-laws were updated and then released on November 2, 2009. Since Leicester adopted its current Master Plan the town has actively updated their zoning regulations to accommodate the Plan. The town's zoning by-laws were adopted from Massachusetts' General Laws, Chapter 40-A, "The Zoning Act." Leicester actively amends their By-laws to direct growth responsibly, preserving open-space and recreational areas. The By-laws define each district and appropriate use. There are currently 12 zoning districts with two overlay districts. An overlay district is additional zoning restrictions that do not affect original zoning restrictions with the purpose of protecting watershed areas.

In addition to Leicester's zoning by-laws the town has adopted Subdivision Rules and Regulations from Massachusetts General Laws. These rules and regulations affect residential development of newly constructed neighborhoods. The regulations are a sub by-law of the town's zoning by-laws that only regulate standards inside the subdivision. The Subdivision Rules regulate construction standards and lot characteristics for new subdivisions. Current construction standards are under review for future development that will decrease the environmental impact that these large developments have. A zoning map can be found in Appendix E.

2.5.2 Massachusetts Building Codes

The *Massachusetts State Building Code* is now in its seventh edition. The current edition is divided into two volumes. The first volume regulates all buildings except one and two family dwellings and the second volume regulates one and two family dwellings. The first volume was released in September of 2008 and the second volume ran concurrent with the sixth edition during 2007 until January 2008. The first volume is based on the *ICC International Building Code-2003* (*IBC-2203*) that Massachusetts has modified to meet the states needs. The second volume is based on the *ICC International Residential Code* (*IRC-2003*) that has been modified for Massachusetts needs. The *International Code Council* (*ICC*) is a membership association that developed codes and standards to regulate building safety and fire prevention. The ICC codes are used to construct residential and commercial buildings. All fifty states in the United States and some federal agencies have adopted the ICC Codes.

Massachusetts Building Codes regulates structural standards, life, and the fire safety of all new, renovated, and demolished buildings. The building codes do not regulate construction methods. "The purpose of the State Building Code is to protect public safety by ensuring that buildings that are intended for occupancy are structurally sound, are constructed of appropriate materials, have adequate egress for fire safety, promote energy conservation, and have adequate sanitary facilities. The building code is written by the State Board of Regulations and Standards, and is administered locally by board-certified building inspectors."[20]

2.5.3 Massachusetts Department of Environmental Protection

The Massachusetts Department of Environmental Protection (MassDEP) is the state agency that is responsible for the preservation of wetlands. There are two types of wetlands, the first is a wetland coastal wetland and the second is an inland wetland. Coastal wetlands include beaches, salt marshes, dunes, coastal banks, rocky intertidal shores and barrier beaches. Inland wetlands include marshes, wet meadows, bogs and swamps. Inland wetlands are areas of land where the water table is at the surface of the ground or just below the surface

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[20] "19. Massachusetts State Building Code," 02/19/10, http://www.mass.gov/czm/permitguide/regs/buildingcode.htm.

of the ground. These areas support certain types of animals, insects, plants and soils. In warmer seasons inland wetlands can appear dry but contain enough water to support its ecosystem. Massachusetts adopted the first wetlands protection act in the 1960s. Since the 17th century about one third of the states wetlands have been destroyed. “The Wetlands Protection Act [Massachusetts General Laws (MGL) Chapter 131, Section 40] protects wetlands and the public interests they serve, including flood control, prevention of pollution and storm damage, and protection of public and private water supplies, groundwater supply, fisheries, land containing shellfish and wildlife habitat.”[21]

During the planning stages of any new development developers are required to provide information regarding the sites location to any known wetlands. If work is to occur in the proximity of wetlands the party responsible for the work must file a Notice of Intent to MassDEP and the conservation commission. If any work preformed will alter wetlands the owner is responsible to reclamate the same amount of land that is destroyed. The Wetlands Protection Act regulates the distance that any construction can occur in proximity to the wetlands. Depending on the type of wetland, the distance can vary. Most Massachusetts communities have adopted the Wetland Protection Act with variations specific to their community.

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[21] “Protecting Wetlands in Massachusetts,” 02/24/10, http://www.mass.gov/dep/water/resources/protwet.htm.

2.6 Key Points and Concepts

This chapter covered a lot of material that will serve as a knowledge base to this project. All of the material in the next few chapters will further investigate principles in this chapter and apply practical applications in the design of the community, houses and buildings. The LEED Guidelines specify end goals for the development, but this project investigates the methods, tools and materials that will be need to satisfy the LEED Guidelines.

3.0 Methodology

This section describes the methods that were used in design. Information is given about the factors that were involved in decision making. Information is also given about software and key sources that were used.

3.1 Neighborhood Design

For the neighborhood design, the LEED for Neighborhood Design Guidelines were the most utilized decision making source. LEED for Neighborhood Guidelines were held priority in all decisions unless the guidelines conflicted with state or local Building Codes or By-Laws.

Site plans were created through the use of Autodesk AutoCAD Civil 3D 2010 (AutoCAD) and Google Earth. The newest versions of AutoCAD allow for Google Earth satellite images to be imported, along with geographical location, surface topography and elevations.

The LEED for Neighborhood Development Guidelines seek to design a safe, social and active community.

3.1.1 Community Center Design

The community center was designed to meet the needs of the neighborhood and surrounding community. The community center will be a public building that is available to all residents of Leicester, MA. The building will serve the recreational, social and administrative needs of the community.

LEED for Neighborhood Development Guidelines award credit for diverse uses in the immediate area of the development. The community center will house a post office and café, which both serve as diverse uses. Credit is also awarded for recreational areas and therefore the community center will also house a basketball court, which can be utilized for community events.

The Community Center was designed using Autodesk Revit Architecture 2010 (Revit). This program was used to create a floor plan and three dimensional representations of the proposed building. Through the use of this program rendered drawings were made to help visualize the building after completion. Tools such as Revit are useful when describing project to investors, shareholders and the community.

3.1.2 Chapel Street Shops Design

The Chapel Street Shops were designed to satisfied credit awarded by LEED for diverse uses. The shops will include a small grocery store, dry cleaner, fitness center, restaurant and day care. It was determined that these shops would be the most beneficial due to the distance of similar facilities. The location of the shops was determined from the LEED for Neighborhood Development Guidelines.

The Chapel Street Shops were designed using Revit. This program was used to create a floor plan and three dimensional representations of the proposed building. Through the use of this program rendered drawings were made to help visualize the building after completion.

3.1.3 Recreation Area Design

LEED for Neighborhood Design awards credit for recreational areas. LEED places strict guidelines on size and location of recreational areas relative to residential areas. LEED Guidelines specify that a minimum of one acre of outdoor or 25,000 square feet of indoor recreational area must be within ¼ mile walking distance from 90% of the residential units.[22] These recreational areas could include sports fields, playgrounds, pools or any other active space.

3.1.4 Water Systems Design

LEED for Neighborhood Development offers credit points for retaining and reusing storm-water runoff. Maximum credit points are awarded if more than 95% of storm-water is retained. The design of storm-water systems will retain and reuse 100% of all storm-water under normal operating conditions. Storm-water will be retained and dispersed through rain gardens, native plant-life, porous pavement, reduction of impervious and grassed area, and a retention/irrigation system.

3.2 House Design

Housing units were designed using the LEED for New Homes Guidelines. However, *Massachusetts State Building Codes* and Leicester Town By-Laws held priority over LEED Guidelines. The *Massachusetts State Building Codes* ensured the safety and structural stability of the housing units. Leicester Zoning By-Laws limited population density that could be achieved by imposing setbacks.

Revit was used to create a floor plan and three dimensional representations of the proposed units. Through the use of this program rendered drawings were made to help visualize the units after completion.

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[22] *LEED 2009 for Neighborhood Development*, National Resources Defense Council and United States Green Building Council.

3.2.1 House Placement

House placement was determined by the Leicester Zoning By-Laws, found in Appendix F. LEED awards credit for developments with high population densities, but due to the Leicester Zoning By-Laws high population densities were not permissible. The Town of Leicester does not currently allow cluster building. However, the Leicester Master Plan states that cluster building should be allowed in the future to preserve open space.

House orientation was not governed by the Town Leicester or *Massachusetts State Building Codes*, so LEED Guidelines were followed. LEED for New Homes Guidelines and LEED for Neighborhood Development Guidelines both award points for houses that make use of passive solar heating and lighting. This is achieved by orienting the main face of the house facing south. Also, by orienting the houses facing south, maximum photovoltaic efficiencies can be obtained.

3.2.2 Building Materials

LEED for New Homes provides lists of acceptable building, framing and finishing materials. These lists are not exhaustive and use of other new sustainable materials is encouraged. One goal of this project and LEED is to maintain regional identity. When choosing building finishes care was taken to maintain a traditional New England aesthetic as much as possible.

3.2.3 Cost Estimate

The cost estimate for the units was determined by obtaining the building cost of a sample of LEED houses in the United States from the United States Green Building Council. The building costs were scaled by region; a weight of three was given to houses in Massachusetts, a weight of two was given to any project in New England and a scale of one was given to every other project. The year that the project was completed in was also taken into account. A four percent annual inflation rate was factored for all houses built before 2009. The average square foot cost was determined, and this was the cost per square foot that was used to determine the construction cost of the units. A 20% markup was then added to the construction costs for the selling cost.

The average selling cost for similar units in Leicester was determined through the use of Homes.com. From this website average selling cost and square foot of units in Leicester was determined. The average square foot selling cost was determined and multiplied by the square footage of one unit in the development, giving the approximate selling cost of a similar sized unit.

3.3 Key Points and Concepts

The LEED for Neighborhood Development Guidelines and the LEED for New Homes Guidelines were used to design a sustainable neighborhood. Since safety and public health is paramount, along with other legal issues involved, *Massachusetts State Building Codes* and Leicester Zoning Laws help priority over LEED Guidelines.

The use of Revit and AutoCAD Civil 3D allowed for the creation of site plans, building floor plans and three dimensional representations. These visual aids are highly important when presenting designs to investors, future homeowners and the community.

4.0 Neighborhood Design

One of the major goals of LEED for Neighborhood development is to reduce greenhouse gas emissions and automobile dependence. This project put emphasis on creating a community that reduces automobile dependence by offering basic essentials in the immediate vicinity and offering alternative modes of transportation. Basic needs include places such as a post office, a grocery store and a day care.

Reduced automobile dependence reduces greenhouse emissions, reduces traffic congestion and encourages walking and bike riding. As LEED suggests, this community will also offer open space and recreation areas that will encourage physical activity. The combination of reduced greenhouse gas emissions and increased physical activity is highly beneficial to public health and wellbeing. Figure 4-1 through Figure 4-3 shows the site plans for the development.

The proposed design for the community satisfied criteria for the LEED Silver certification. Appendix B includes the checklist that was used to calculate and organize potential credits earned.

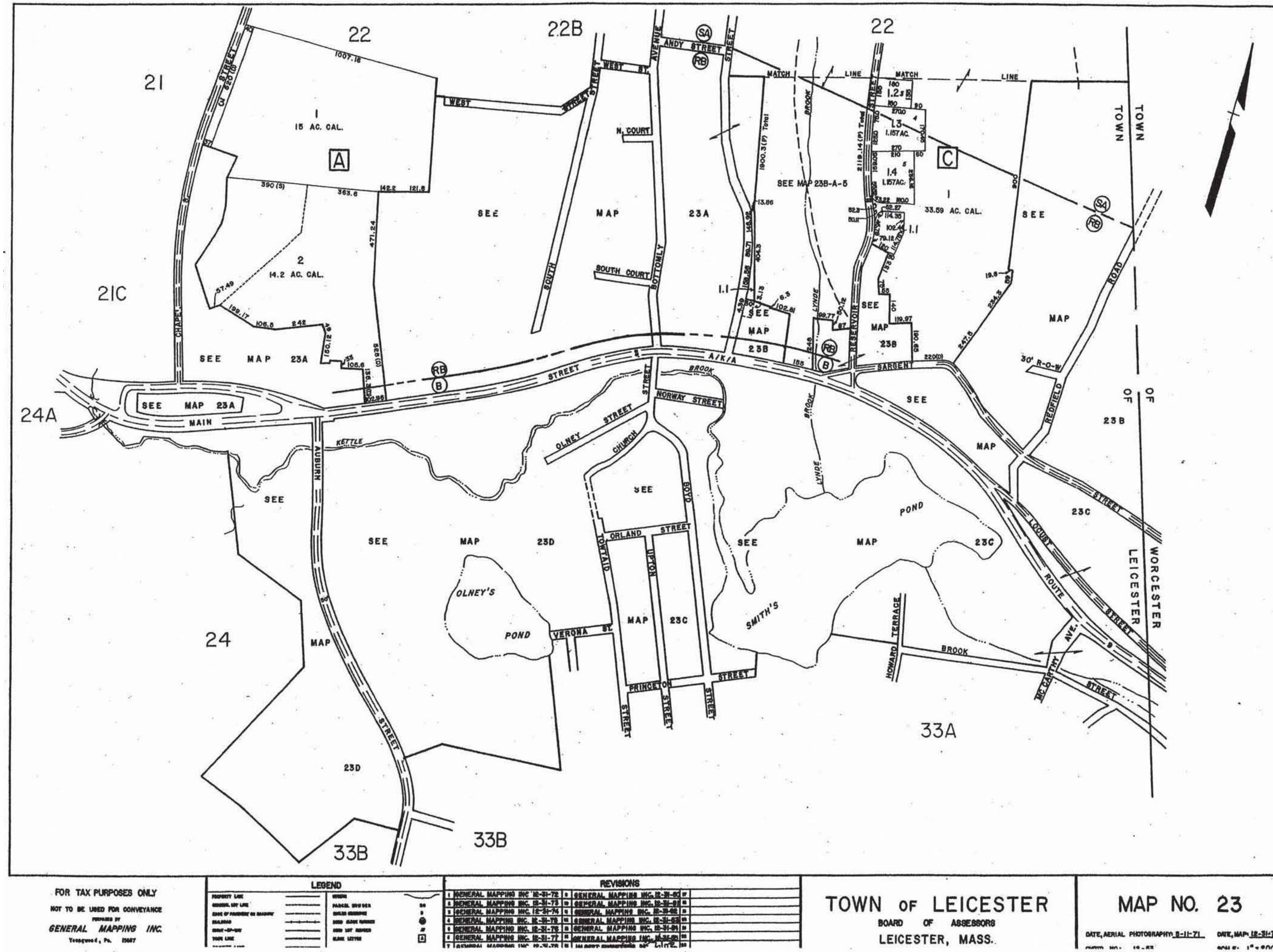

Figure 4-1: Assessor's Map

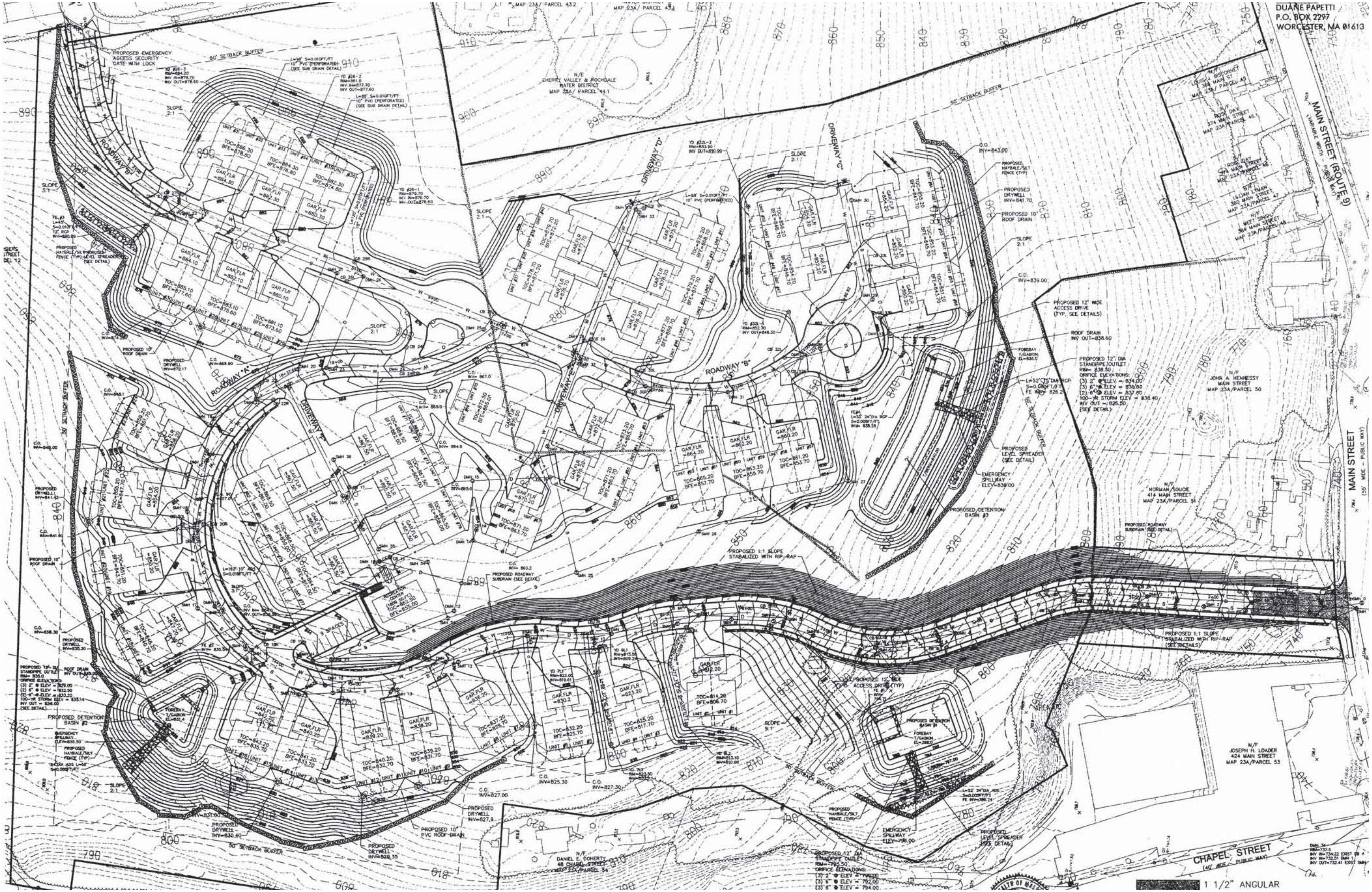

Figure 4-2: Site Plan

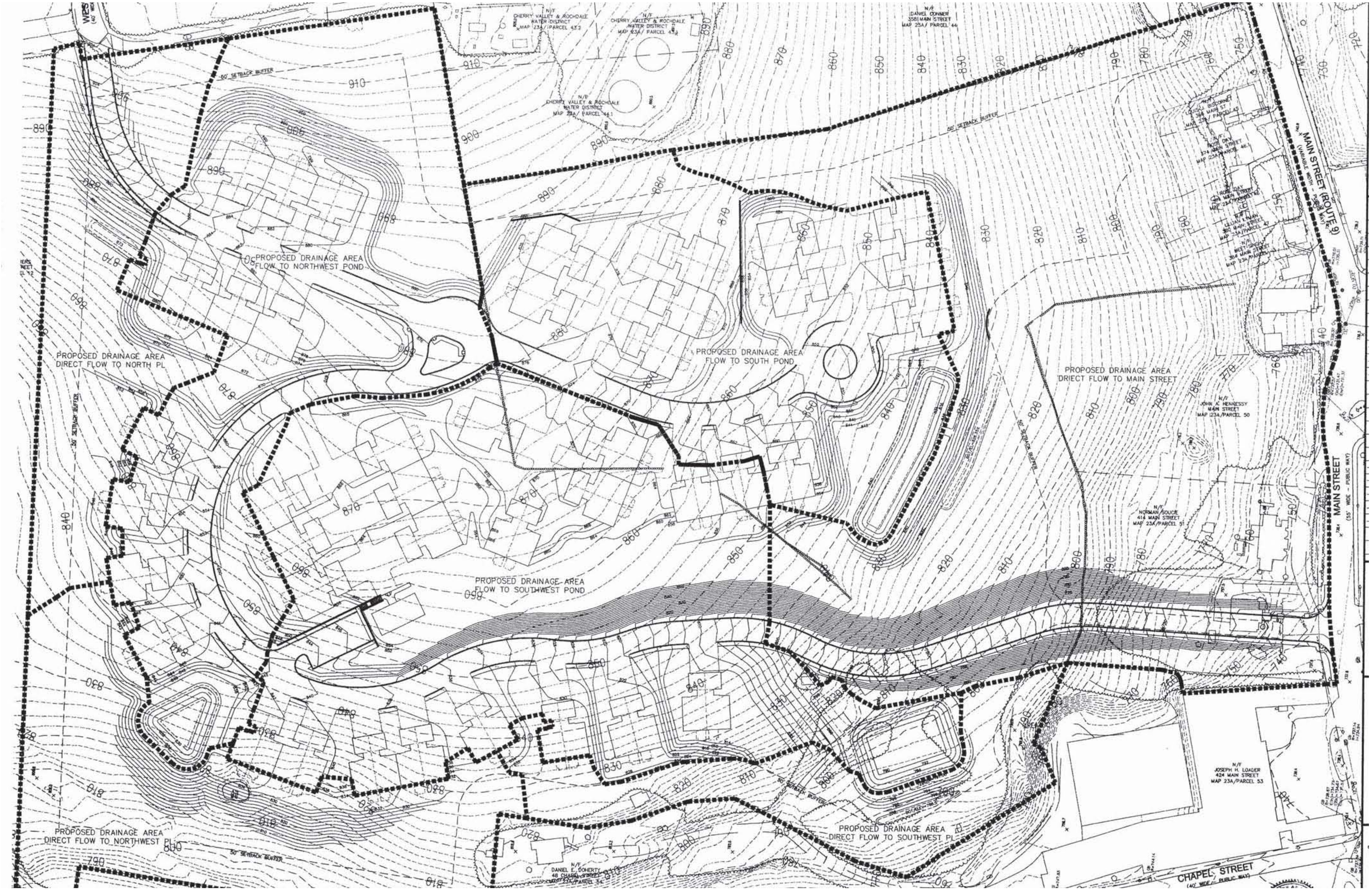

Figure 4-3: Definitive Site Plan

4.1 Parks and Recreation

The design of this community incorporates three tennis courts, one outside basketball court, one indoor basketball court, two playgrounds and a one acre open space field. The neighborhood was designed in a manner that no house is more than 1/6 mile walk from a playground, as set by LEED guidelines. The neighborhood is also set up so that no house is more than ¼ mile walking distance from the playing fields. The distances for the recreation areas are specified in the LEED for Neighborhood Development Guidelines: Neighborhood Pattern and Design section.

4.2 Community Center

LEED stresses the need for diverse uses in and around a development. This encourages walking which reduces automobile dependence and promotes a healthy lifestyle. One way to create diverse uses in the area is through the design of a community center. The community center will house a post office, gymnasium, café and various other office and meeting spaces.

The community center is planned to be a public building, which will be accessible to all Leicester residents. This will be beneficial to the surrounding community. The basketball court serves as a recreation area that can be used year round. The café will serve as a social gathering place. Figure 4-4 shows a rendered drawing of how the community center may look when complete. Figure 4-5 and Figure 4-6 show the proposed floor plan for the community center.

Figure 4-4: Community Center Design

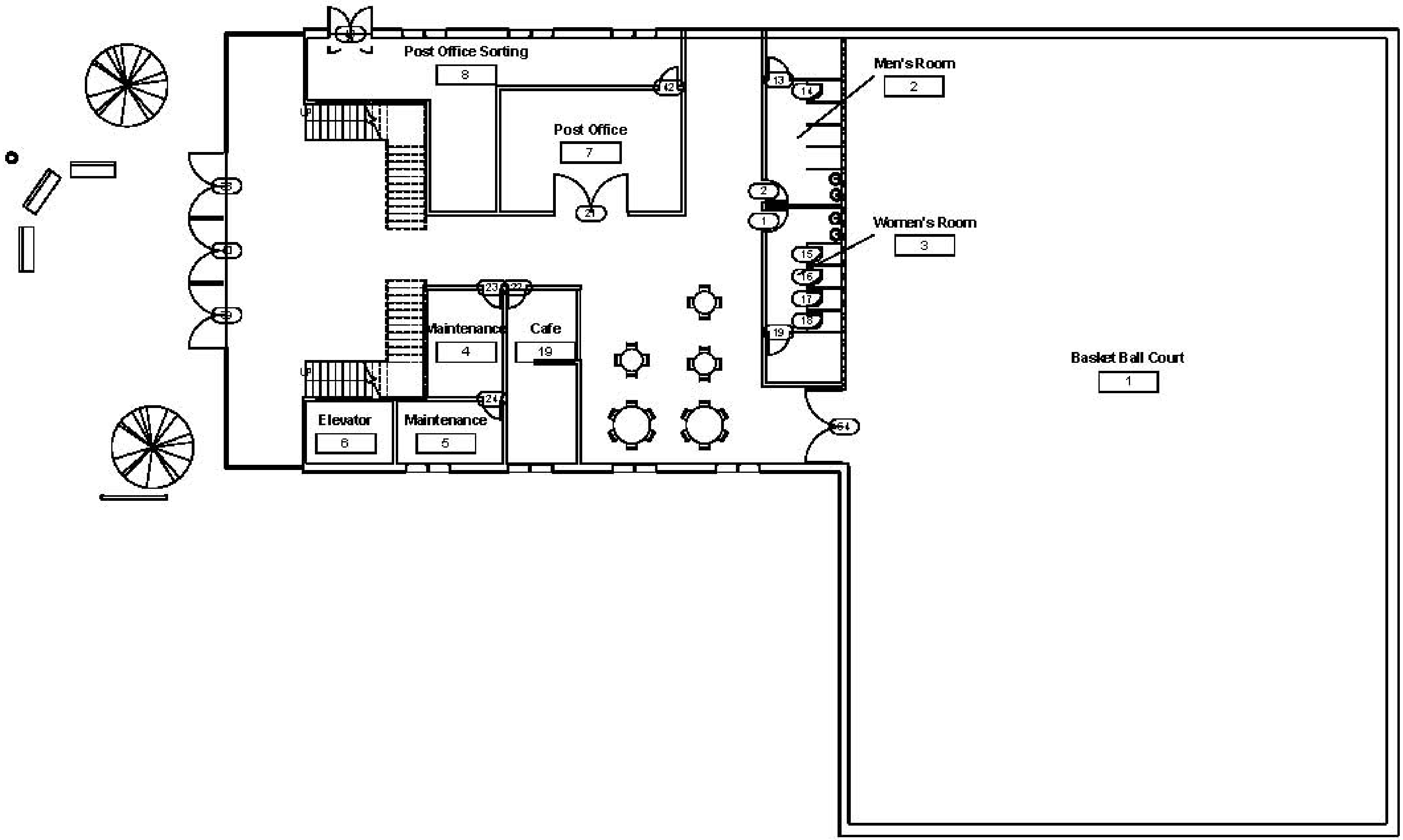

Figure 4-5: Community Center First Floor Plan

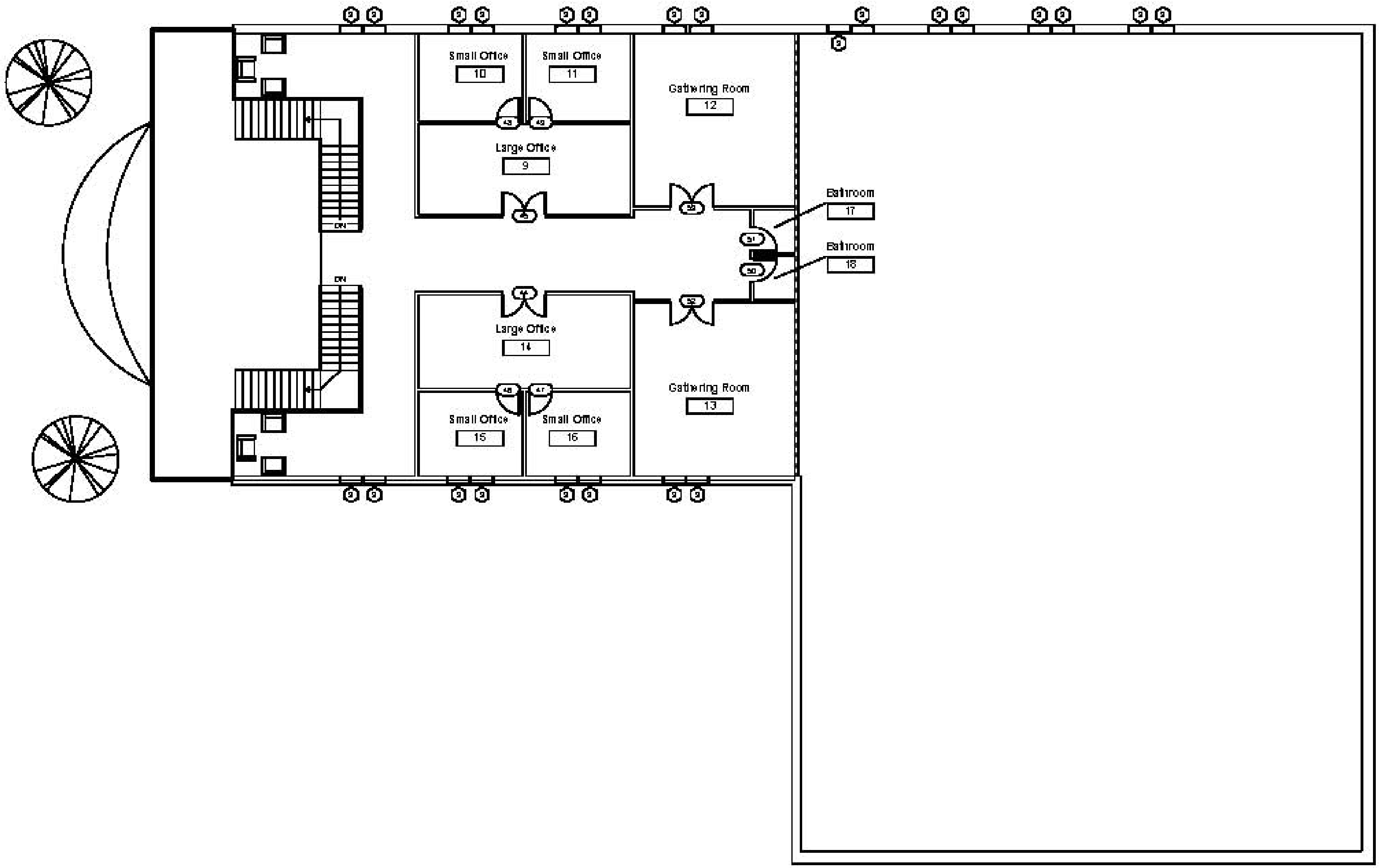

Figure 4-6: Community Center Second Floor Plan

4.3 Chapel Street Shops

One of the best strategies to reduce automobile dependence is to locate necessary amenities within walking distance of the residential dwelling units. For the design of the development, an adjacent plot of land is to be purchased for a shopping center. The shopping center will include a market, dry cleaners, health club, restaurant and day care.

The shopping center will be built on a section of land that is already cleared, reducing disturbance to the local ecology. Currently there is an old mill building on the site. The building will be demolished, but any salvageable materials will be recycled for the construction of the shopping center and community center. Figure 4-7 shows how the shops should look once they are completed. Figure 4-8 shows the proposed floor

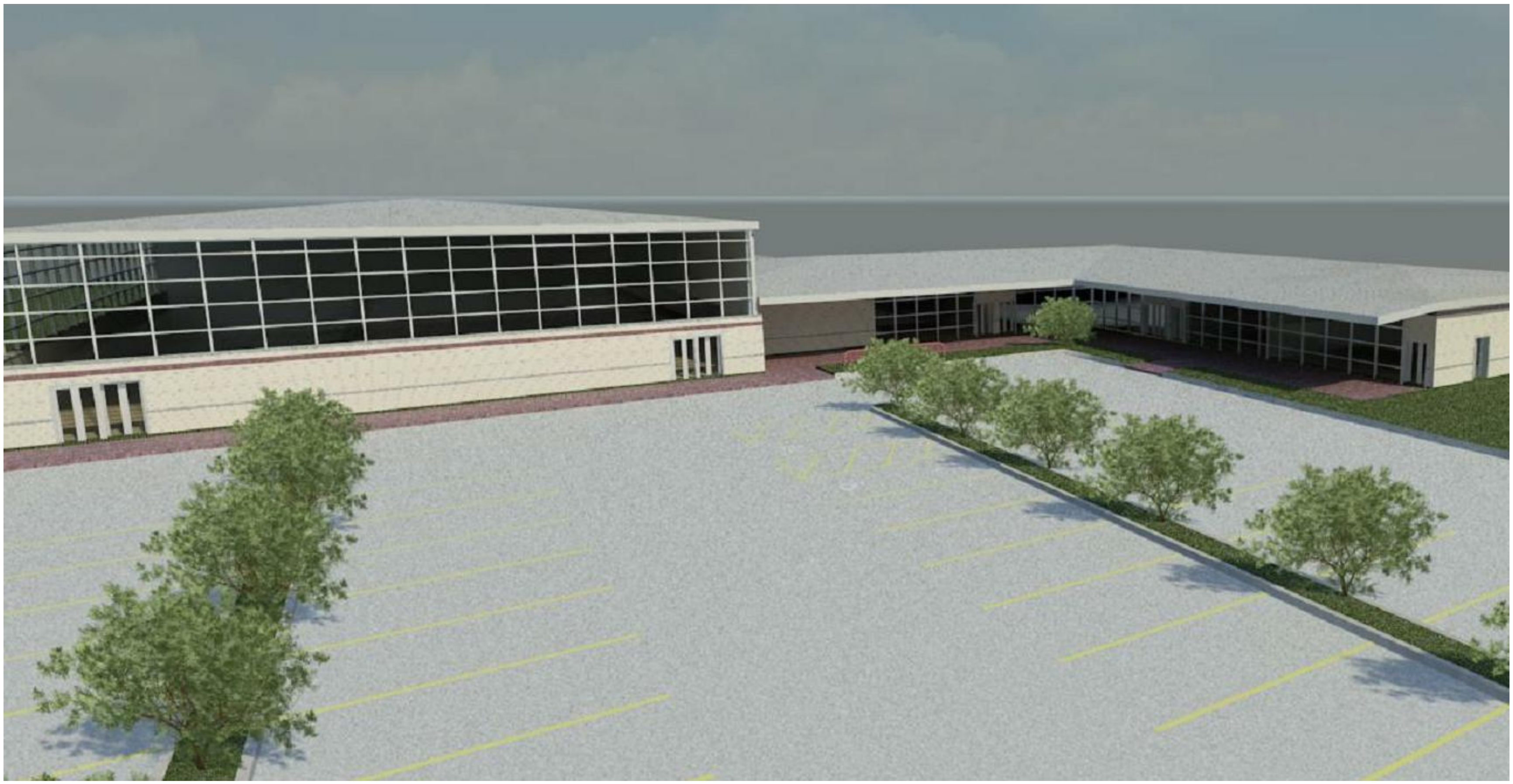

Figure 4-7: Chapel Street Shop Design

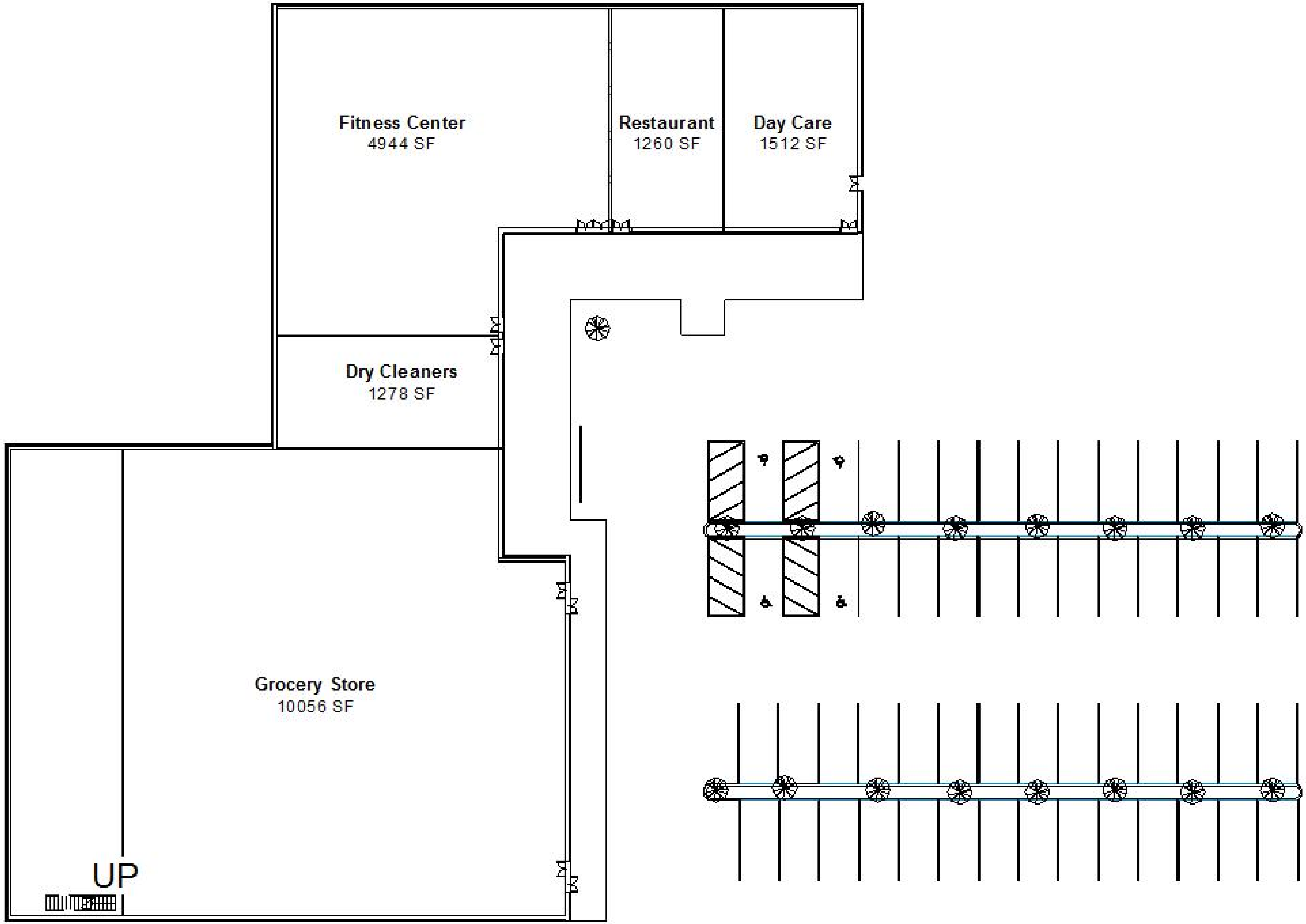

Figure 4-8: Chapel Street Shops Proposed Floor Plan

4.4 Services

The design of this neighborhood incorporates a variety of services that will help to reduce automobile dependence. LEED guidelines offer a variety of credits for reducing the need for personal vehicles. This section contains are two ways, suggested by LEED, to reduce automobile dependence: public transportation and zip cars.

4.4.1 Bus Station and Commuter Center

Providing public transportation is key to reducing automobile dependence. The Worcester Regional Transit Authority (WRTA) offers public transportation in the vicinity. An adjacent property, located along existing bus routes, will be purchased and converted into a park-and-ride. With permission of the WRTA a bus stop will be added there as well.

A covered/heated bus stop will be built on this site. A covered/heated bus stop may encourage people to ride the bus, even in inclement weather. If the bus stop produces enough passengers, plans will be made with the WRTA to create a permanent bus stop within the development in the future.

The park-and-ride will benefit the surrounding neighborhoods by helping to reduce automobile dependence, vehicle miles traveled and traffic congestion. The park-and-ride can also be used for other functions, such as providing a location for a farmer's market on the weekends.

4.4.2 Zip Cars

One service that will be provided is Zip Car. Zip Car came to the United States twelve years ago. It is a car sharing program that allows members to rent cars for short periods of time for affordable prices. The company focuses on providing electric, hybrid, compressed natural gas and other fuel efficient cars. Two zip cars will be included in the program, after a trail period an assessment of the transportation needs will be assessed and more cars can be added if deemed necessary.

Bus lines offer transportation to Worcester and the surrounding area, but buses are not always available, whether it is a time or location constraint. Zip Car will be beneficial to the neighborhood because it will provide people access to a car without have ownership costs, thereby reducing automobile dependence. According to Zip Car each vehicle removes 15 to 20 personal vehicles off the road.[23]

4.5 Storm-Water Systems

One key goal of LEED and this project is to reduce water usage and storm-water runoff. These two goals can be grouped together because the solutions to both of these problems are related. Water usage can be reduced by reusing storm water. This section details several solutions to mitigate these two problems.

[23] “green benefits,” 03/05/10, http://www.zipcar.com/is-it/greenbenefits.

4.5.1 Porous Pavement

Porous pavement is a critical tool in reducing storm-water runoff. The use of porous pavement will reduce impervious, and reduce storm-water runoff into surrounding water bodies. One major limiting factor for the use of porous pavement for this project is that porous pavement cannot be used on slopes, because water will run off instead of permeating the asphalt. Another limiting factor is that porous pavement cannot carry heavy loads, eliminating use on main roadways in the development. The final limiting factor of porous pavement is the high cost of installation and maintenance.

Due to the limiting factors porous pavement will only be used in driveways and parking lots. This reduction in imperious area is still significant.

4.5.2 Rain Gardens

Rain gardens are another critical tool for reducing storm-water runoff. Rain gardens will be strategically placed along roadways and parking lots to reduce water runoff. These gardens are only planned reduce the amount of water that enters the formal storm-water drainage system. Designs for a formal storm-water drainage system are located in the next section. These rain gardens will also reduce the problem of standing water that can occur and are aesthetically pleasing.

4.5.3 Retention and Irrigation System

The development will have to include a formal storm-water drainage system. The water from this system will be transferred to a retention pond in the south-west corner of the development, which is the lowest lying point. There will be two retention ponds in this area.

The first retention pond will retain virgin storm-water, while primary sedimentation occurs. The water will then be transferred through a filter to remove large sediments into the second retention pond.

The design of the retention pond must also include a pump house in order to redistribute the water. The water will pass through one final fine sediment filter before it passes through the pump and is redistributed. The water will be used to water landscape and for fire suppression systems. The excess water will evaporate or be redistributed to local streams.

4.6 Municipal Utilities: Water, Sewer, Gas and Electric

The Town of Leicester provides water, sewer, gas and electric to communities in the surrounding area. Due to limiting factors such as cost and feasibility, this development will make use of town water, sewer, gas and electric. The gas will be used to supplement geothermal for heating needs and the electric will be used to supplement solar for electricity demands.

4.7 Street Lighting

To provide the community with proper street lighting solar street lights will be used. The light that will be used is the SOL TSL series.[24] SOL Inc. is a leading. The lights use LED bulbs rated up to 70,000 hours, which can be more than fifteen years. Figure 4-9 shows the first per viewpoint of the SOL TSL series street light.

Another issue that arises with streetlights is light pollution. In order to reduce light pollution, streetlights will be equipped with motion sensors. If there is no activity in the vicinity of the light for 15 minutes, the light will dim to half brightness. Half brightness will be used in place of full darkness because half brightness offers significant security lighting while reducing light pollution.

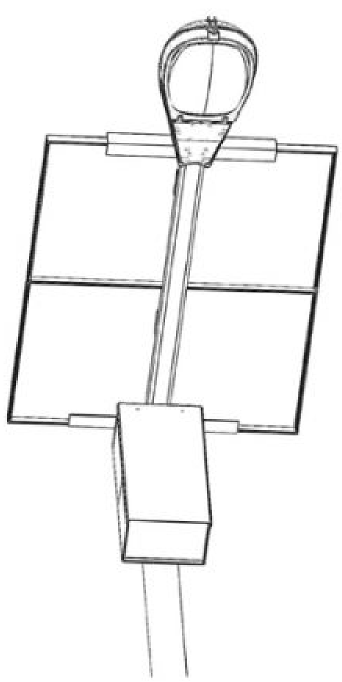

Figure 4-9: First Person View of Sol TSL Street Light (Source: www.solarlightingusa.com

[24] "TSL Series Solar Lighting," 02/10/10, Sol Inc., http://www.solarlightingusa.com/tsl-series.html.

4.8 Key Figures and Concepts

The goal for LEED for Neighborhood Development is to "successfully protect and enhance the overall health, natural environment and quality of life in our communities."[25] This section described the design for the community. The design satisfied criteria to sufficient to receive the LEED for Neighborhood Development Silver rating. In order to obtain a Silver rating a minimum of 50 credit points must be achieved.

The goal of this project was to satisfy criteria to receive the maximum credit points possible. This would rate the effectiveness of the development. A silver rating was the highest possible rating obtainable due to the site's location. LEED for Neighborhood Development awards points for population density and surrounding area density. The principles in the guidelines are applicable to all developments, but the credit points are more favorable towards urban renewal projects than suburban development projects.

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[25] "Fact Sheet," United States Green Building Council, 03/08/10, www.usgbc.com.

5.0 House Design

LEED strives to preserve regional identity; therefore one goal in the house designs is to maintain a traditional New England aesthetic in the architecture and exterior finishes. There are many aspects involved in designing a house to achieve the maximum LEED award points possible. The housing units in this neighborhood satisfied criteria for a LEED Platinum rating with 121 potential credit points. The checklist that was used to calculate and organize credit points is located in Appendix C.

One goal of this project is to create a development that is economically diverse, and therefore house design specifications will be a choice of the homeowner to fit their income. This section will provide a series of alternatives for individual house designs. The alternatives in this section are not exhaustive, but any substitute alternatives will have to comply with the specifications set forth by LEED for New Homes Guidelines. Figure 5-2, Figure 5-3, and Figure 5-4 show the design for a sample duplex.

Figure 5-1: Sample Duplex Design

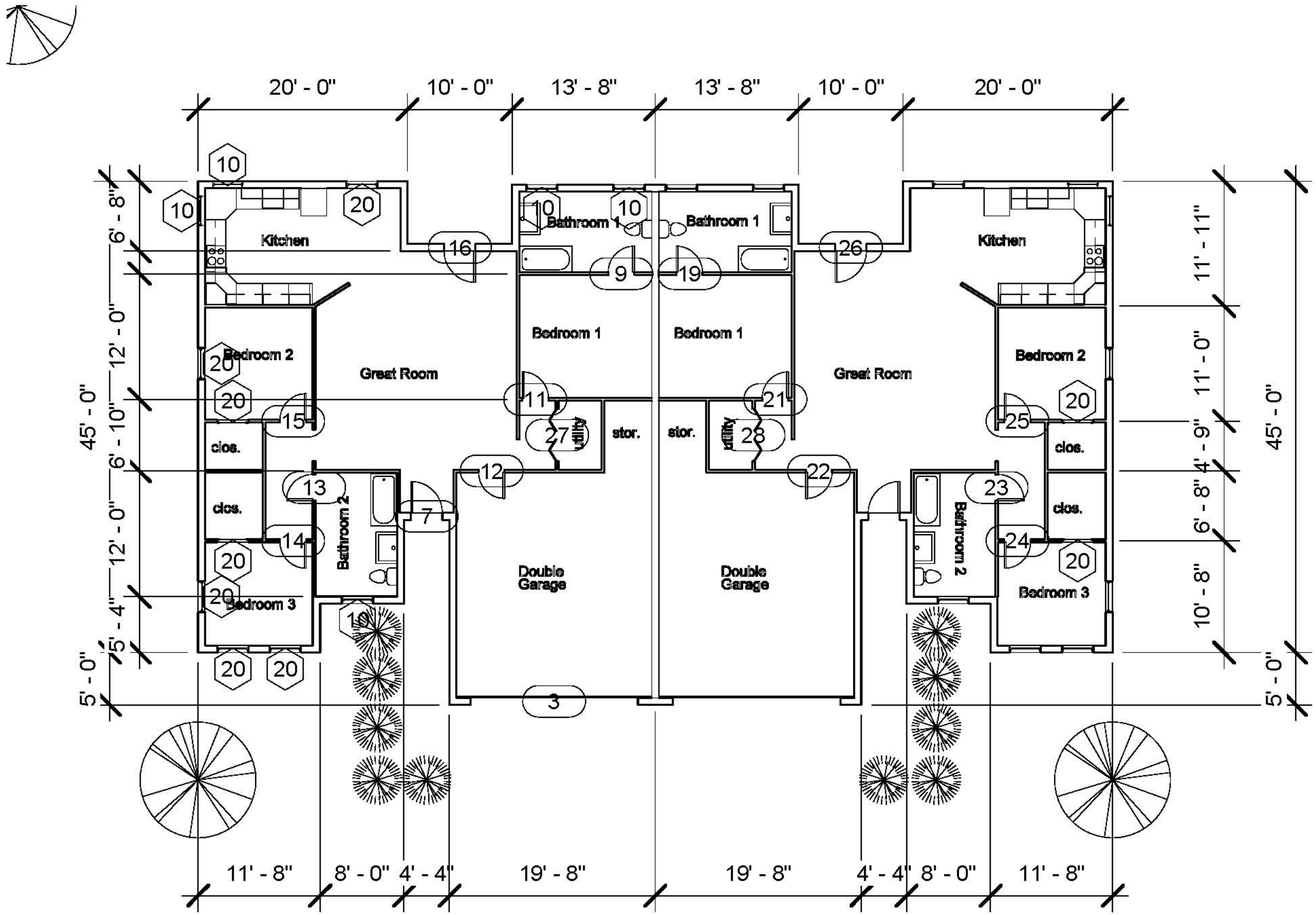
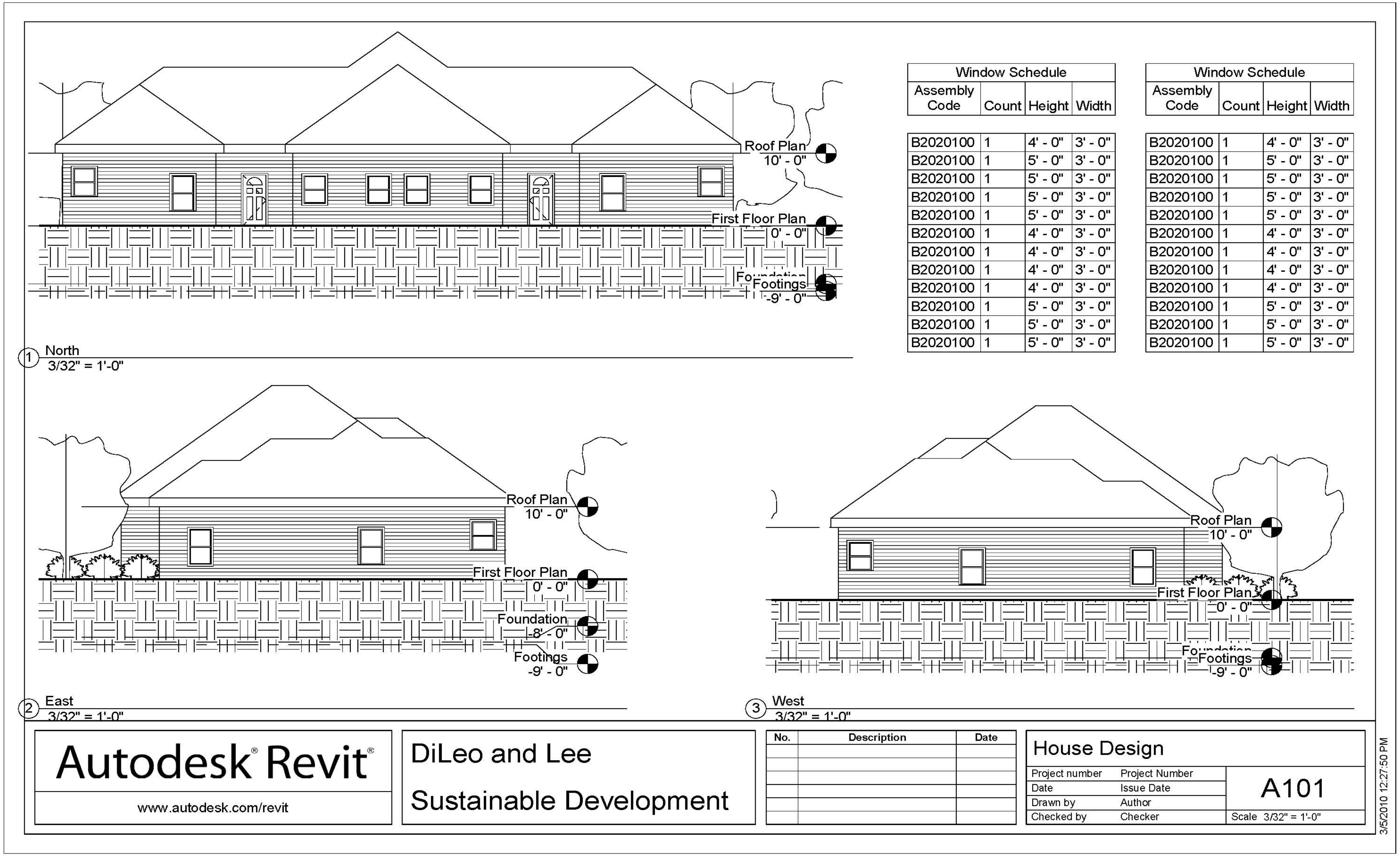


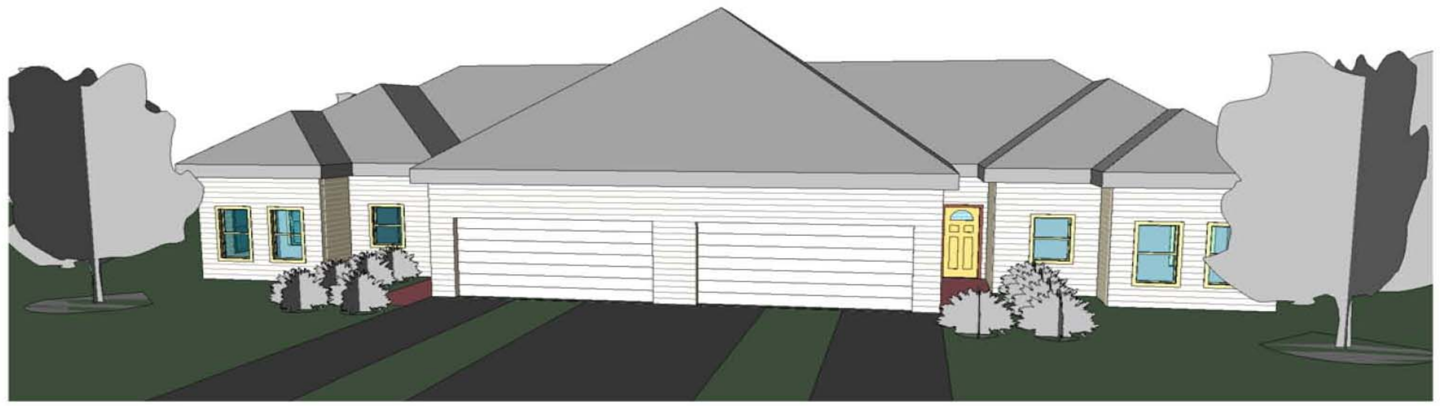
Figure 5-2: Sample Duplex Floor Plan



Window Schedule			
Assembly Code	Count	Height	Width
B2020100	1	4' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"

Window Schedule			
Assembly Code	Count	Height	Width
B2020100	1	4' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	4' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"
B2020100	1	5' - 0"	3' - 0"

Figure 5-3: Sample Duplex Elevations and Window Schedule



1 Front

2 Back

Door Schedule		
Assembly Code	Count	Height
B2030410	1	7' - 0"
C1020	1	7' - 0"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	7' - 0"
B2030410	1	7' - 0"
C1020	1	7' - 0"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	6' - 8"
C1020	1	7' - 0"
C1020	1	7' - 0"
C1020	1	7' - 0"

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DiLeo and Lee

Sustainable Development

No.	Description	Date

Unnamed

Project number	Project Number	A102
Date	Issue Date	
Drawn by	Author	
Checked by	Checker	Scale

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Figure 5-4: Sample Duplex 3-D Views and Door Schedule

5.1 House Placement

The house placement on each lot was determined by setbacks outlined in Leicester's Zoning By-laws. A table of Leicester's frontage and setback requirements is illustrated below in Table 5-1. Setback requirements govern the distance the building can be from the front, side and rear property lines.

Homes are oriented such that they will take full advantage of sunlight throughout the day. Large sized windows and living areas will be placed facing a southern direction maximizing benefits of the natural light. To increase the amount of sunlight passing into the common living areas skylight tubes, a simplified form of skylight that is not as intrusive on the roof plane, will be placed in a strategic manner along the roof. These skylight tubes do not open but reflect natural light into the room by using reflective surfaces inside the tubes to pass the sunlight through. Taking full advantage of natural light will reduce the amount of electricity used to power lighting fixtures.

Table 5-1: Business District Zoning Setbacks Requirements

District: Business (B)	
Area	15,000 square feet
Frontage	100 feet
Front	25 feet
Side	10 feet
Rear	25 feet
Max. Height of Building	35 feet
Number of Stories	2 ½ stories
Maximum Building Coverage	30%

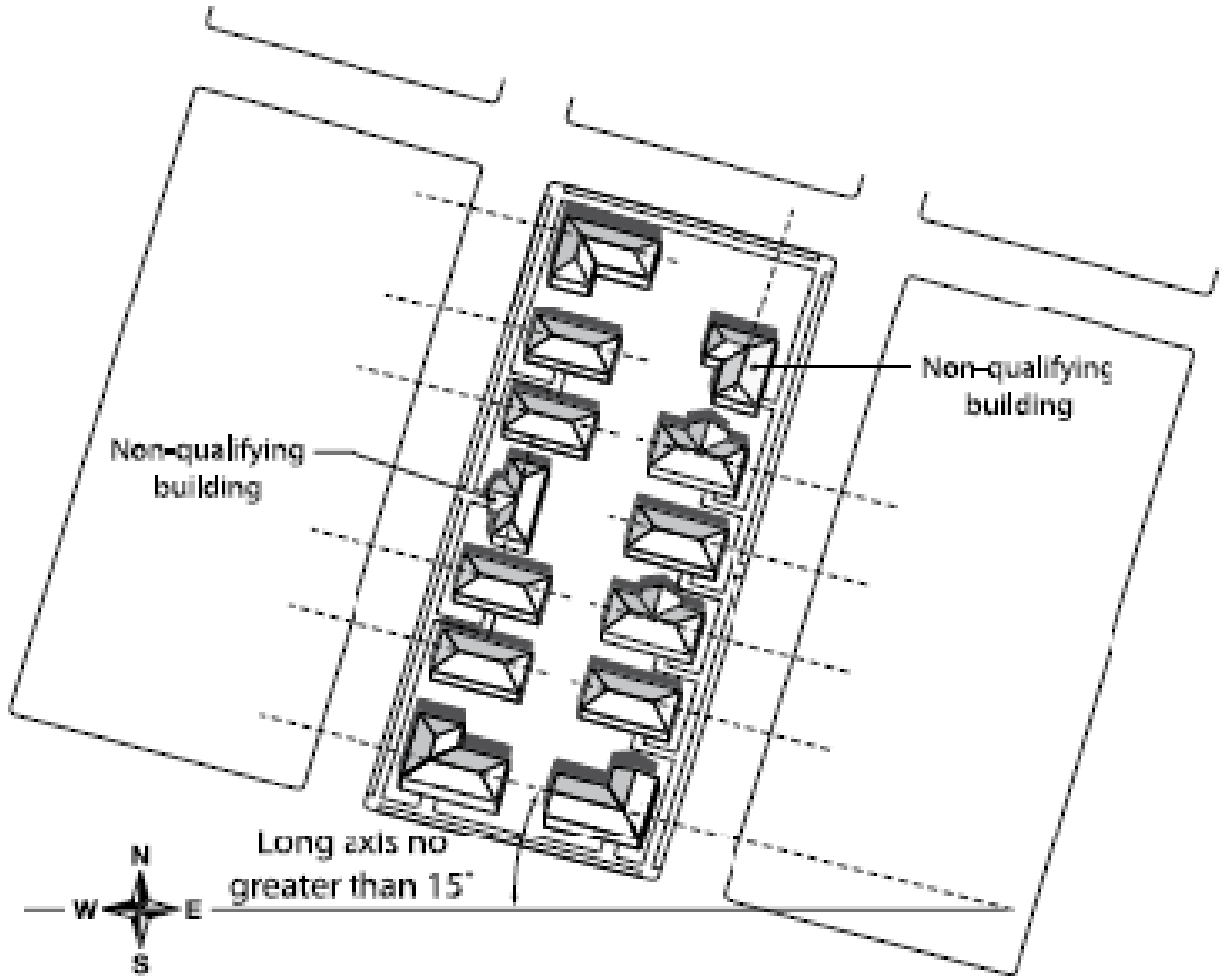


Figure 5-5: House Orientation (Source: LEED for Neighborhood Development, page 97)

5.2 Foundations

Determining what foundation system to use was dependent on the ability to withstand the severe New England climate. To emphasize the benefits of thermal blocking, Insulated Concrete Forms (ICF) were chosen. ICFs are left in place after concrete has cured. They are made from rigid plastic foam that holds the concrete in place. IFCs are lightweight and provide energy-efficient, durable construction. The insulating foam is made from expanded polystyrene (EPS) or extruded polystyrene (XPS). Depending on the material and its thickness, insulation values can range from R-17 to R-26.

There are three different types of forms: hollow foam blocks, foam planks and four foot by eight foot panels. Foam planks and panels are tied together in place by plastic clips. IFCs can accommodate either a full, eight foot ceiling height, basement or a frost-wall with a slab.

LEED for Homes credits MR 4.1 and 4.2 award points for the use of concrete made with recycled materials fly ash and slag cement. Aggregate Industries Inc., a large cement and asphalt provider in New England with plants in central Massachusetts, utilizes both products in the ready mixed concrete. According to Aggregate Industries Management Inc. website, using these recycled products, such as fly ash, actually increases the strength of the concrete, promotes proper segregation of the aggregates and creates less friction in the pumping process. Power plants and steel manufacturers generate millions of tons of by-product that would eventually be dumped in landfills and reusing the materials is a responsible solution.

5.3 Framing and Insulation

Detailed construction documents depicting proper spacing, appropriate locations and sufficient member sizes provide the team to create a detailed cut list and lumber order. Table 5-2 illustrates some possible options of efficient framing choices to decrease the amount of waste.

State building codes provide the requirements for spacing on all structural members depending on the size of the member and the dead and live loads that need to be supported. The distance between each member is greater per building code than the conventionally used sixteen inches on center. Conventional construction typically uses larger door and window headers than building code requirements for load capacity. An engineered approach to member spacing and header details reduces the amount of material used in construction and emphasizes.

Wall construction is usually built with three studs to provide sufficient material for attaching drywall, utilizing 2 stud corners with blocking between the studs or drywall clips decreases the amount of lumber needed. Using Structural Insulated Panels (SIP), foam or agriculture material core sandwiched between oriented strand board (OSB), provides significant structural and thermal performance. Detailed building drawings, one piece building components and precut framing packages will reduce construction cost by reducing labor time. Massachusetts Building Codes Seventh Edition walls stud spacing and floor joist requirements can be found in Appendix G.

LEED for Homes credits the use of FSC Certified Tropical Wood, which is wood harvested between the Tropics of Cancer and the Tropics of Capricorn. The lumber is harvested from forests that are managed with awareness of and responsibility to the social, economical, ecological, cultural and spiritual needs of generations to follow.

Using SIPs for the walls, floor and roof increases the thermal break provided from the core. The R-value, or measure of thermal resistance, of each panel increases as the thickness of the panel increases. Table 5-3 illustrates average R-values of the panels. The table provides generalized values and respective manufacturers should be contacted for actual values. Typically fiberglass batt insulation, traditionally used in construction, provides an R-value of 3.14 per inch of insulation. A two-by-four stud wall sheathed with plywood generally has an R-value of 13. A two-by-ten roof system with batt insulation has an R-value of 30. Combined similar foam and plywood construction can reach R-values of above 48.

Table 5-2: Efficient Framing Methods (Source: LEED for Homes, page 78)

Precut framing packages
Open web floor trusses
Structural insulated panel (SIP) walls
SIP roof
SIP Floors
Stud spacing greater than 16” o.c.
Floor joist spacing greater than 16 o.c.
Roof rafter greater than 16 o.c.

Table 5-3: SIP-R Values (Source: www.sips.org)

SIP Panel Thickness	**4 1/2"**	**6 1/2"**	**8 1/4"**	**10 1/4"**	**12 1/4"**
EPS	14.4	21.6	27.9	35.1	45.9
XPS	19.5	29.5	38.3	48.3	58.3
Polyurethane	21.7	32.9	N/A	N/A	N/A
Consult the panel manufacturer to verify R-values. R-values can vary between SIP manufacturers.					
Calculated R-values for generic structural insulated panel (SIP), including 7/16” oriented strand board (OSB) on each side. Expanded polystyrene (EPS) is Type I per ASTM C578-07. Extruded polystyrene (XPS) is Type IV – Type X per ASTM C578-06. Polyurethane information is derived from the range of products offered by SIPA Member manufacturers. Please consult SIP manufacturers for actual R-value information. R-values do not include wall coverings (interior or exterior) and/or air film values. All listed R-values are at mean temperature of 75° F.					

5.4 Construction Waste Management

Conventional home construction generates significant amounts of construction waste. According to Oikos® (www.oikos.com) wood, drywall and cardboard generate 60 to 80 percent of waste generated on a jobsite. Per weight wood makes up nearly half of the waste generated from a new home project. Plastic and metal materials are a small percentage but are easily recyclable. Proper designing and ordering of materials can greatly reduce the amount of waste generated. Table 5-4 lists construction waste materials by weight per square foot. Figure 5-6 illustrates the average amount of waste generated from a construction site, sorted my material type.

Recycling of construction products greatly reduces the amount of material sent to landfills. Sorting of construction waste on the job site and sending it to respective recyclers is a responsible means of sustainable building.

Table 5-4: Construction Waste - Types and Quantities (Source: http://www.oikos.com/library/waste/types.html)

Material	Lbs./Sq.Ft.
Wood	1.3 – 2.1[1]
Drywall	1.0 – 1.2
Cardboard	0.1 – 0.5[2]
Metals	0.02 – 0.13
Other (plastic, shingle, etc.)	0.50 – 0.13
Total	3.0 – 5.2

[1] Range for wood waste depends on material used for wall sheathing, siding, trim, and roofing.
[2] Range for cardboard depends on type of siding and whether windows, doors, and cabinetry are locally manufactured.

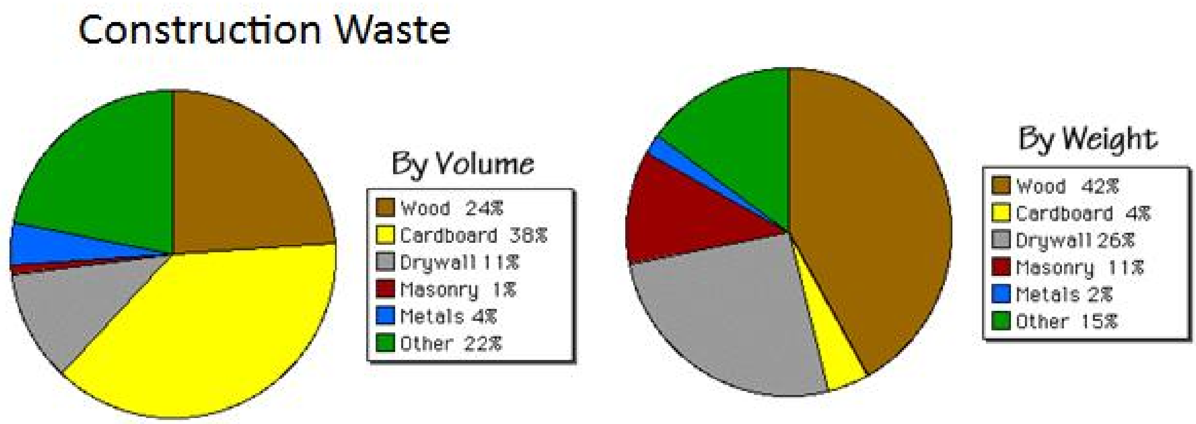


Figure 5-6: Construction Waste – Types and Quantities (Source: www.oikos.com)

5.5 Doors and Windows

The home owner will have the choice of style window they want to use in their home. Window options include vinyl, wood and aluminum. Most popular choices are wood and vinyl. The style and characteristics vary between manufacturers but the National Fenestration Rating System (NRFC), an organization of construction professionals that developed a rating system based on window and door performance, needs to be met or exceed these standards in LEED and Energy Star requirements. Figure 5-7 shows a NFRC rating label provided on all doors and windows illustrating its performance. Table 5-5 Illustrates LEED and Energy star requirements for U-factors of windows and glass doors. U-factor of windows and doors is the measurement of heat loss. A low u-factor means greater resistance to heat flow.

Table 5-5: Energy Star Requirements for Windows and Glass Doors (Source: LEED for Homes)

	Metric	Northern	North Central	South Central	Southern
EA 4.1 Good Windows (prerequisite)	U-factor SHGC	≤0.35 Any	≤0.40 ≤0.45	≤0.40 ≤0.40	≤0.55 ≤0.35
EA 4.2 Enhanced Windows (optional, 2 points)	U-factor SHGC	≤0.31 Any	≤0.35 ≤0.40	≤0.35 ≤0.35	≤0.55 ≤0.33
EA 4.3 Enhanced Windows (optional, 2 points)	U-factor SHGC	≤0.28 Any	≤0.32 0.40≤	≤0.32 ≤0.30	≤0.55 ≤0.30

Figure 5-7: Sample Window Efficiency Label (Source: www.efficientwindows.org/nfrc)

Home owners will also have a choice of door styles. Exterior doors come in a wide variety of options. Any door choice that has glass must meet the standards depicted in Table 5-5. Environmentally preferable door materials include fiberglass and steel. These doors are hollow with insulation inside creating a beneficial thermal break from the outside climate.

Interior doors do not need to meet any performance standards, therefore options are endless. Solid wood doors require FSC certified wood as well as FSC certified wood door casings. Generally hollow core doors are discouraged because they are less durable, require more frequent replacement and do not offer the same sound reducing qualities as solid wood doors. Recycled doors will be encouraged.

5.6 Siding

Various siding options including cement fiber siding, FSC certified wood siding and environmentally friendly sustainable wood-based material siding will be provided to homeowners. Vinyl, however low-cost and easy to install, has environmental and health concerns and therefore will be avoided. The vinyl chloride monomer from which vinyl siding is made is a known carcinogen. When heated vinyl siding can warp and releases toxic fumes.

Cement fiber siding products such as James Hardie siding is made of sand, cement and cellulose fibers. Cement materials can be replaced with fly ash making the product a sustainable solution for siding. Cement fiber siding is highly durable. The siding can be painted either before or after installation.

A traditional look for homes in New England is wood shake siding. Keeping this look and using sustainable products, FSC certified wood siding is an available option to the homeowner. The cost of cedar shakes is comparable to vinyl siding for material but the wood siding is more labor intensive and installation cost generally run more.

Sustainable wood based siding products such as EcoClad[26] is made of FSC certified wood fibers, recycled paper products and recycled wood fibers. The product is extremely durable and is manufactured in several shapes and colors. According to the manufacturer Ecoclad is VOC free and satisfies seven of the LEED for Homes credits.

[26] "EcoClad," 03/08/10, KlipTech Klip BioTechnologies, http://www.kliptech.com/index.html.

Figure 5-8: James Hardie Cement fiber Siding (Source: Missouri Windows and Siding, www.mossouriwindows.com)

Figure 5-9: FSC Certified Hardwood Floor

5.7 Flooring

There are many sustainable flooring options on the market today. To maximize LEED credits awarded for each unit, choices will be limited to FSC Certified wood flooring, SCS Floor Score Certified products and tile made from recycled products. .

Table 5-6 illustrates several choices of flooring products that the homeowner can choose to put in their unit. The Scientific Certification Systems (SCS) combined with the Resilient Floor Covering Institute (RFCI), "tests and certifies flooring products for compliance with indoor air quality emission requirements adopted nation-wide. A flooring product bearing the FloorScore® seal has been independently certified by SCS to comply with the volatile organic compound (VOC) emissions criteria of the California Section 01350 standard".[27] Figure 5-9 shows a floor covered with FSC certified hardwood.

Table 5-6: Sustainable Flooring Options

FSC Certified Wood Flooring	SCS Floor Score Certified	Tile
Bamboo	Vinyl	Recycled Glass
Cork	Polymeric Flooring	Recycled Ceramic
Eucalyptus	Linoleum	Recycled Porcelain
Maple	Laminate Flooring	Recycled Cement Products
Oak	Engineered Hardwood Flooring	Natural Stone
Pine	Ceramic Flooring	
Teak	Rubber Flooring	

In areas such as bedrooms, living rooms and hallways, wood-type floors are recommended. In the areas susceptible to water penetration such as bathrooms, kitchens and entrance ways, tile or linoleum flooring is suggested. Tile floors are durable and longest lasting floor covering. Wood and wood type floors are less durable than tile but are warmer to the

[27] "Floor Score: What and Why," 02/26/10, http://www.rfci.com/int_FloorScore.htm

touch in the winter and provide better noise reduction. Flooring options with a longer warranty will be selected ensure that the quality of the material will withstand many years.

5.8 Solar

The solar system that was determined to be the most economical and effective for this development was a grid-tied system. No battery back-up will be installed, meaning that excess electricity generated will be sold to the local electric utility for fair market value.

According the EIA, in 2008 the average household in Massachusetts consumed approximately 20 kWh a day. The required system size is determined by dividing electricity consumed by solar isolation value, to produce the number of kW consumed daily. Solar isolation is a value that determines effective daily sunlight. Table 5-7 shows the average solar isolation for various Massachusetts communities. The solar isolation values that were used were for design calculations were from the town of Natick, MA. This value was used because Natick is the community city to Leicester that had provided solar isolation values.

Table 5-7: Solar Isolation for Massachusetts City, organized by distance from Leicester, MA (Source: www.solar4power.com)

MA Locations	High	Low	Average
Natick	4.62	3.09	3.99
Blue Hill	4.37	3.33	4.05
Boston	4.27	2.99	3.84
Lynn	4.60	2.33	3.79
East Wareham	4.48	3.06	3.99

The solar systems will be designed for peak summer solar isolation, which is 4.62 in Natick. According to the EIA electricity consumption is significantly higher during the summer months. Each photovoltaic cell is capable of providing 0.07 Watt-hours per square inch. Therefore to obtain full solar capacity approximately 25,000 square inches or 175 square feet of PV cells are required to offset electricity usage for one household, or 350 square feet for one two-family home. The average southern exposure on a two family home in this development is over 1000 square feet with a roof pitch of 9:12. It was interpolated from **Error! Reference ource not found.** that the solar orientation value for this set up would be approximate 0.99, meaning that the system would function at 99% maximum efficiency. Solar Isolation Values accommodate for regional climate and geographical location. Maximum solar efficiencies can be obtained from a southern facing Photovoltaic panel at thirty degrees from horizontal. If panels cannot face due south they can still obtain 95 percent efficiency if they are within twenty degrees east or west of south.[28]

5.9 Geothermal

With small lot sizes the ideal geothermal system would use a vertical pipe configuration in which a hole is drilled about fifty feet into the ground, and pipes are looped to bring water into the ground and back through the home, capturing the temperature of the earth. To reduce the cost of each home a lateral piping system will be implemented. Pipe loops will be buried under each home's foundation. Polyethylene pipe is used for ground loops because of its

[28] "Solar Electricity for Massachusetts Residents," Commonwealth Solar, 03/08/10, www.masstech.org/renewableenergy/comonwealth_solar/docs/PVResGuide.pdf.

durability. According to Advanced Drainage Systems (ADS), the world's largest manufacturer of polyethylene pipe, the pipes are guaranteed with a fifty year warranty. Pipe connections will be place outside the foundation's perimeter to make future maintenance less destructive. Utilizing this configuration excess blasting beyond what may be required for the foundation will be eliminated. Eliminating blasting for this situation will greatly reduce construction cost and pass the savings on to the homeowner. Burying the networks of pipes beneath the foundations decreases the amount of area that needs to be disturbed satisfying LEED credits. Figure 5-10 shows the proper placement of geothermal ground loops under a foundation.

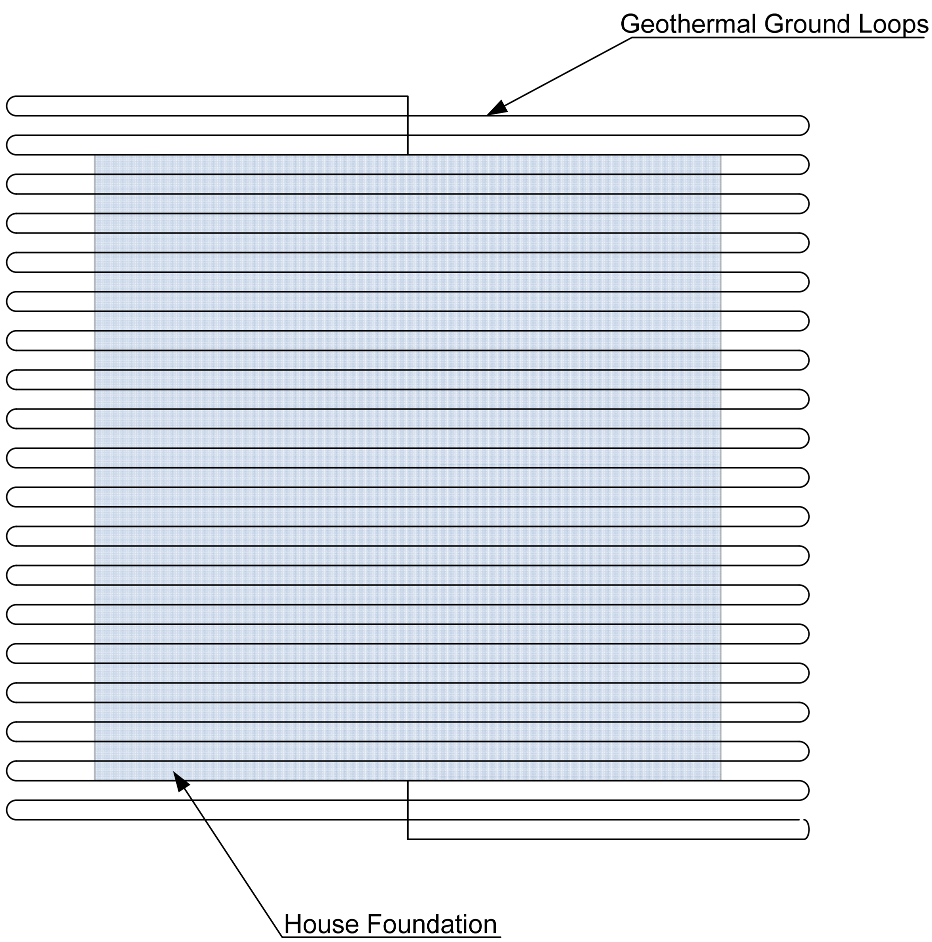
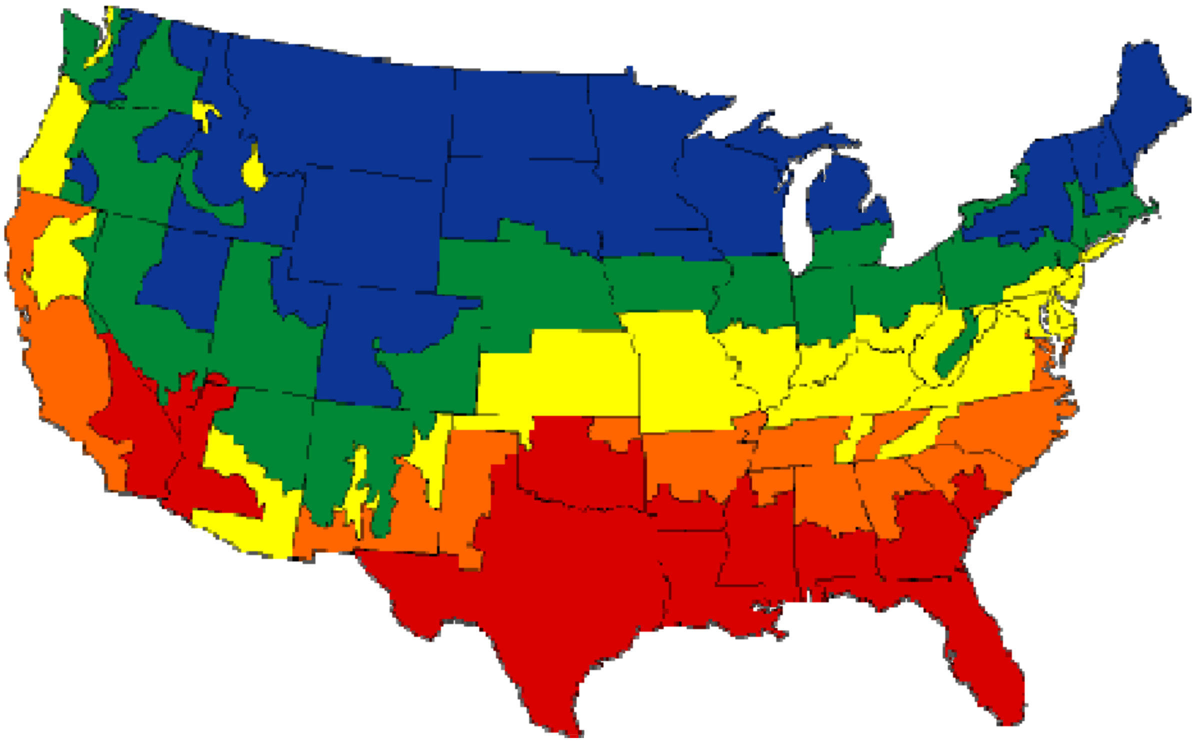


Figure 5-10: Geothermal Ground Loop Placement

Geothermal systems generally cost around $3000.00 per ton to install for the units. The cost per ton is based on the capacity size of the heating and cooling unit. Installation cost range from about $10,000 to $30,000 for excavation and labor.[29] Since the excavation will already be taking place the cost will be closer to $10,000 for each unit.

Determining the size units needed depended on the square footage of each unit, heating and cooling needs are measured in British thermal units (Btu). Using the calculated Btu the appropriate sized system can be determined. The average conversion uses 12,000 Btu per 1 ton unit. Figure 5-11 illustrates unit sizes per square footage of structure by each region in the United States. From Figure 5-11 it was determined that a 2.5 ton system would be adequate. This system would produce 30,000 Btu.

[29] "Geothermal and Ground Source Heat Pumps," 03/08/10, http://www.consumerenergycenter.org/home/heating_cooling/geothermal.html



Air Conditioning Square Footage Range by Climate Zone					
	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5
1.5 Tons	600- 900 sf	600 - 950 sf	600 - 1000 sf	700 - 1050 sf	700 - 1100 sf
2 Tons	901-1200 sf	951 - 1250 sf	1001 - 1300 sf	1051 - 1350 sf	1101 - 1400 sf
2.5 Tons	1201 - 1500 sf	1251 - 1550 sf	1301 - 1600 sf	1351 - 1600 sf	1401 - 1650 sf
3 Tons	1501 - 1800 sf	1501 - 1850 sf	1601 - 1900 sf	1601 - 2000 sf	1651 - 2100 sf
3.5 Tons	1801 - 2100 sf	1851 - 2150 sf	1901 - 2200 sf	2001 - 2250 sf	2101 - 2300 sf
4 Tons	2101 - 2400 sf	2151 - 2500 sf	2201 - 2600 sf	2251 - 2700 sf	2301 - 2700 sf
5 Tons	2401 - 3000 sf	2501 - 3100 sf	2601 - 3200 sf	2751 - 3300 sf	2701 - 3300 sf

Figure 5-11: Geothermal System Sizing Aid Map (Source: www.acdirect.com)

5.10 Trim, Finishes and Paint

Interior finishes are available in a wide range of patterns and materials. The most preferable option is reclaimed trim pieces from demolished buildings and homes. Specific, used construction materials are collected by re-sell stores and sold at economical prices. Not only do these stores provide construction materials at a discounted price, but also reduce waste that would otherwise be placed in a landfill. The second option for interior trim is using FSC certified wood products that can be cut into any pattern the customer chooses. Wood trim allows the consumer to choose a wide variety of wood species, each with an individual aesthetic appeal. The third option that the homeowner may select is composite materials. Composite trim is made from bonding recycled wood fiber and plastic. LEED requirements state that the use of composites is acceptable only if they are made of non-urea formaldehyde products. These are adhesives that off-gas formaldehyde, which can be harmful to people with prolonged exposure.

LEED has specified standards for VOCs limits in paint and coatings, shown in Table 5-8. VOCs may cause lung irritation and exacerbate asthma and/or allergy problems and therefore LEED awards points for utilizing VOC-free materials.

Table 5-8: Standards for Environmentally Preferable Paint and Coatings (Source: LEED for Homes, page 81)

Component	Applicable standard (VOC content)	Reference
Architectural paints, coatings and primers applied to interior walls and ceilings	Flats: 50 g/L Nonflats: 150 g/L	Green Seal Standard GS-11, Paints, 1st Edition, May 20, 1993
Anticorrosive and antirust paints applied to interior ferrous metal substrates	250 g/L	Green Seal Standard GC-03, Anti-Corrosive Paints, 2nd Edition, January 7, 1997
Clear wood finishes	Varnish: 350 g/L Lacquer: 550 g/L	South Coast Air Quality Management District Rule 1113, Architectural Coatings
Floor coatings	100 g/L	
Sealers	Waterproofing: 250 g/L Sanding: 275 g/L All others: 200 g/L	
Shellacs	Clear: 730 g/L Pigmented: 550 g/L	
Stains	250 g/L	

5.11 Key Points and Concepts

As the need for sustainable technologies increases, house construction needs to follow suit. Many product manufacturers are leaning towards the use of recycled, environmentally safe and natural products. State, local and private associations are providing awards and accreditations to “Green” homes. These credits emphasize to builders, designers, and home buyers that the house, in relationship to traditionally built houses, is of superior quality.

Conventional home construction relies on standard construction methods that reduce need for design and make for easier constructability and quicker construction schedules. This generates large amounts of waste and excessive costs. In conventional stud built home placing effort towards using maximum spacing and minimum sized members allowed by state building codes assures for the most sustainable and safe home. Another sustainable construction option is making use of pre-engineered and pre-fabricated structural building materials. With proper design this alternative reduces waste and decreases construction time. Using pre-engineered panels for walls, floors and roofs can accommodate layers of foam insulation that has greater R-values than commonly used fiberglass insulation.

6.0 Unit Cost Analysis

A cost analysis for a single unit was performed. The cost for new units in the development was estimated from case studies for similar constructions in the United States.

Table 6-2 shows a list of the average cost per square foot, square footage and total cost of specified LEED-certified houses in the United States. The costs shown reflect a regional priority weight and annual inflation rate of four percent from the year that the project was constructed, Appendix H shows the full worksheet that was prepared for cost estimate purposes. Projects in New England received a regional priority weight of two and projects in Massachusetts received a weight of three. From the table it was determined that the average square footage cost for a LEED house was $163.The average cost of a unit in the development was determined by multiplying the average square footage building cost of a LEED house by the square footage of a unit by a 20% markup cost. The cost for a 1500 square foot unit was determined to be $283,500. The average purchase cost per square foot for a unit in this development is $196.

Table 6-1 shows the average cost of a town house or condo in Leicester, MA as listed on Homes.com (www.homes.com/Real_Estate/MA/City/LEICESTER/). The average cost per square foot for a condo in Leicester is $189, which is a 3% difference from the LEED homes. The cost of a 1500 square foot condo in Leicester was estimated to $283,500, compared to $293,500 for a house in the development.

Table 6-1: Average Condo/Townhouse Costs in Leicester, MA (Source: www.homes.com/Real_Estate/MA/City/LEICESTER/)

Sample House Number	Cost / Square Foot	Square Feet	Total Cost
1	$ 195	1386	$ 269,900
2	$ 158	1650	$ 259,500
3	$ 187	1544	$ 289,000
4	$ 189	1480	$ 279,720
5	$ 181	1544	$ 279,000
6	$ 199	1400	$ 279,000
7	$ 222	1210	$ 269,000
8	$ 157	1650	$ 259,000
9	$ 214	1210	$ 259,000
10	$ 192	1400	$ 269,000
Average	$ 189	1447	$ 271,302

Table 6-2: Average Cost for LEED Houses in the United States

Location	Square Feet	Cost/ Sq. Ft.	Total Cost
Freeport, ME	3200	$ 517.44	$ 827,900
Charolette, VT	2700	$ 423.99	$ 572,383
South Glastonbury, CT	2966	$ 520.00	$ 771,160
Waitsfield, VT	2000	$ 194.69	$ 194,688
Saxapahaw, NC	2498	$ 170.89	$ 426,890
Columbus, OH	1495	$ 156.00	$ 233,220
Urbana, IL	1200	$ 118.94	$ 142,728
Weatherford, TX	2038	$ 136.87	$ 278,948
Dexter, MI	4010	$ 267.72	$ 1,073,548
Blacksburg, VA	1038	$ 110.24	$ 114,426
Blacksburg, VA	1360	$ 110.24	$ 149,922
Chino Valley, AZ	3202	$ 105.29	$ 337,130
Redding, CT	3489	$ 442.86	$ 772,572
Chebeague Island, ME	2478	$ 433.13	$ 536,646
East Falmouth, CC, MA	1041	$ 379.60	$ 131,720
Campton, NH	3180	$ 223.86	$ 355,944
Epping, NH	2270	$ 140.38	$ 159,335
Groton, NH	3132	$ 389.20	$ 609,492
Chicago, IL	1830	$ 213.84	$ 391,325
Bloomington, IN	4300	$ 145.60	$ 626,080
Silver Springs, MD		$ 122.74	$ -
Bowie, MD	1900	$ 111.85	$ 212,523
Duluth, MN	2000	$ 243.39	$ 486,773
Lonsdale, MN	2700	$ 182.50	$ 492,744
Philadelphia, PA	1680	$ 157.48	$ 264,568
Taylorstown, VA	1900	$ 177.91	$ 338,037
Lansing, MI	1400	$ 116.33	$ 162,860
Perkiomenvill, PA	2016	$ 202.48	$ 408,191
Charleston, RI	2600	$ 156.56	$ 203,534
Average	2344	$ 163	$ 388,803

7.0 Conclusions

The goal of this project was to design an affordable community using the LEED for Neighborhood Development Guidelines. The LEED for Neighborhood Guidelines includes prerequisites for buildings to be certified under the LEED for Homes, LEED for New Construction or LEED for Commercial Interior Guidelines.

The LEED guidelines served as a basis for the design of the community and houses. The neighborhood design fell within specifications for the prestigious LEED Silver rating with 51 potential credit points. The houses fell within specification for the LEED Platinum rating with 121 potential points.

The community was designed in a manner that promoted an active lifestyle and encouraged social interactions. The proposed community center, shopping plaza and recreation areas will benefit the surrounding communities as well as the development. Services such as the Zip Car, park-and-ride, and heated bus stop will help to reduce automobile dependence which will have positive effects on air quality and traffic congestion. A higher LEED for Neighborhood Development rating may not be possible in this location due to zoning laws. LEED awards points for high population densities and is more applicable for urban developments.

The selling price for a unit in the neighborhood was determined to be three percent more than similar conventional unit in the town of Leicester. The three percent cost increase is well within affordable limits since the neighborhood offers a great variety of amenities and services that may not be available at other locations which benefit quality of life.

The homes were designed to be accessible to a diverse income group, even with each unit being built to above average standards. The affordability was achieved by providing sustainable alternatives of varying cost to each aspect of the house design. Solar panels and geothermal pumps were incorporated into the house design to offset energy needs.

Original plans included a wind turbine to offset electricity needs of the community. However, due to spatial constrains the wind turbine was not feasible. Due to the proximity of abutting properties, there was not sufficient space to provide the required setbacks for safe operation of a wind turbine. The Federal Aviation Administration (FAA) regulations state that wind turbines must be a minimum of five miles from any air field. Due to the proximity of the site to the Worcester Regional Airport, the wind turbine could not be legally constructed.

The community and house designs both achieved LEED certification. In our opinion this confirms that this project achieved the goals that it set forth. We hope that this project provides sufficient evidence that a community of this nature is feasible.

Appendices

Appendix A: Proposal

Introduction and Problem Statement

With growing awareness of the impact that human development has on the environment there has been great deal of attention paid to sustainable building and living. Sustainable living is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[30] This requires that we as humans only consume resources at or below the same rate that they can be replenished. It is debatable whether or not societies are living beyond what the Earth can supply, but with growing populations and dwindling or invariable resources it seems evident that we are living beyond nature's means. However, the goal of this project is not to predict or hypothesize about the eventual consumption of the Earth's resources, nor is this project going to solve all environmental problems. The goal of this project is to compile modern technologies to develop awareness of the feasibility of sustainable practices, in hopes of making progress toward the greater goal of a sustainable society.

The goal of this project is to design a community using the LEED (The Lead in Energy and Environmental Design) standards for neighborhood development. The LEED standards will be used as an outline for the design of a new type of community in the town of Leicester, MA. The design will incorporate various pre-existing and experimental alternative and renewable energy

[30] B Brundtland, H. *Our Common Future*, (Oxford: Oxford University Press, for the World Commission on Environment and Development, 1987), (p. 43).

sources. Emphasis will be placed on the use of sustainable building and construction materials and methods whenever possible. It is also crucial to this project that the development will incorporate the needs of the town of Leicester to become an interactive part of the town. After designing the community, a cost analysis will be performed and compared against that of a traditional community, which will be defined.

Scope

The development will consist of 40 dwelling units; this includes a variety of houses, condos, duplexes and apartments. There will be a community center that provides a multipurpose indoor recreations center, convenience store, post office and day care. The design will reflect the importance of outdoor recreation areas by incorporating basketball and tennis courts, playing fields and playgrounds, within walking distance to all the residences. To reduce the impact of personal vehicles and encourage the use of public and shared transportation, the design will incorporate a bus station and a park-and-ride. The intentions are that the park-and-ride will be a multiuse area that can be used for events such as a farmer's market on the weekends.

Proper design of the utilities and infrastructure are paramount to creating a sustainable community. Porous pavement and rain gardens will be used as a means of minimizing storm water runoff wherever possible. The excess storm water runoff will be collected in one of two retention ponds, where it will be stored for later use with items such as outdoor sprinklers and fire suppression systems. A small pump house will be built provide the means to move the water from the retention ponds. For economic and feasibility reasons, the development will make use of the town drinking water, sewer system and gas lines.

There will be a variety of community and household supplemental alternative electricity sources. All the supplemental energy sources will be grid-tied, meaning that excess energy will be sold back to the electric company. The electric company will then credit the accounts and the credits will be used to offset the cost of electricity usage during peak hours, where usage is greater than the amount being created. Community energy sources include a solar panels on community center and solar streetlamps. Household energy sources include solar panels and geothermal heating tubes.

Sample houses and dwelling units will be designed. This will be done through a combination of design of new or experimental technologies and case studies of existing and well-documented technologies, materials and construction methods. At least one sample unit will be design for the following dwelling units: house, condo/duplex and apartment building.

Methodology

The first steps that will be taken are to itemize the features in the design and create a preliminary layout. The design features will be first and foremost contingent upon the LEED standards for Neighborhood Development. All buildings in the development would also be designed to LEED New Construction standards. After completing the preliminary design, the designs will be presented to a representative of the Town of Leicester. The town representative will have the chance to review the designs and have input into existing and potential aspects of the design that would be beneficial to the town.

The design will potentially incorporate a variety of alternative and renewable energy resources. Prior to incorporating these elements into the design feasibility and case studies will be performed. The project will be designed in accordance of all federal, state and town regulations, building codes and zoning laws; under the assumption that all permits and licenses have been granted. Items that require variances will be designed twice: once with the assumption that variance was granted and once with an alternative if the variance was not granted.

Deliverables

The main deliverable for this project will be the MQP report, which will be a written compilation of all work and findings that occurred during the course of the project. The project will also include a variety of site plans that include utility information, house lots, community buildings and all other site features. In addition to site plans, there will be drawings and layouts of the individual sample dwelling units and community buildings. The final deliverable will be a comparison between the construction costs and selling costs of a residential unit in this development and similar units in the town.

Conclusions

This design is expected to have higher construction costs when compared against a traditional community, but will offer a better quality of life. This cost analysis will prove the feasibility of community with sustainable features. By following the LEED standards, the development should obtain certification. The development will also show the possibility of creating communities that are affordable and incorporate a diversity of households with various incomes.

Appendix B: LEED for Neighborhood Development Checklist

LEED 2009 for Neighborhood Development
Project Scorecard

Project Name:
Date:

Smart Location and Linkage — 27 Points Possible

Yes	?	No			
7	0	0		Smart Location and Linkage	27 Points Possible
Y			Prereq 1	Smart Location	Required
Y			Prereq 2	Imperiled Species and Ecological Communities	Required
Y			Prereq 3	Wetland and Water Body Conservation	Required
Y			Prereq 4	Agricultural Land Conservation	Required
Y			Prereq 5	Floodplain Avoidance	Required
1			Credit 1	Preferred Locations	10
0			Credit 2	Brownfield Redevelopment	2
1			Credit 3	Locations with Reduced Automobile Dependence	7
1			Credit 4	Bicycle Network and Storage	1
0			Credit 5	Housing and Jobs Proximity	3
1			Credit 6	Steep Slope Protection	1
1			Credit 7	Site Design for Habitat or Wetland and Water Body Conservation	1
1			Credit 8	Restoration of Habitat or Wetlands and Water Bodies	1
1			Credit 9	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1

Neighborhood Pattern and Design — 44 Points Possible

Yes	?	No			
23	0	0		Neighborhood Pattern and Design	44 Points Possible
Y			Prereq 1	Walkable Streets	Required
Y			Prereq 2	Compact Development	Required
Y			Prereq 3	Connected and Open Community	Required
7			Credit 1	Walkable Streets	12
1			Credit 2	Compact Development	6
2			Credit 3	Mixed-Use Neighborhood Centers	4
1			Credit 4	Mixed-Income Diverse Communities	7
1			Credit 5	Reduced Parking Footprint	1
1			Credit 6	Street Network	2
1			Credit 7	Transit Facilities	1
2			Credit 8	Transportation Demand Management	2
1			Credit 9	Access to Civic and Public Spaces	1
1			Credit 10	Access to Recreation Facilities	1
1			Credit 11	Visitability and Universal Design	1
2			Credit 12	Community Outreach and Involvement	2
1			Credit 13	Local Food Production	1
1			Credit 14	Tree-Lined and Shaded Streets	2
0			Credit 15	Neighborhood Schools	1

Green Infrastructure and Buildings — 29 Points Possible

Yes	?	No			
20	0	0		Green Infrastructure and Buildings	29 Points Possible
Y			Prereq 1	Certified Green Building	Required
Y			Prereq 2	Minimum Building Energy Efficiency	Required
Y			Prereq 3	Minimum Building Water Efficiency	Required
Y			Prereq 4	Construction Activity Pollution Prevention	Required

Green Infrastructure and Buildings, Continued

Yes	?	No			
5			Credit 1	Certified Green Buildings	5
2			Credit 2	Building Energy Efficiency	2
1			Credit 3	Building Water Efficiency	1
1			Credit 4	Water-Efficient Landscaping	1
0			Credit 5	Existing Building Use	1
1			Credit 6	Historic Resource Preservation and Adaptive Reuse	1
0			Credit 7	Minimized Site Disturbance in Design and Construction	1
4			Credit 8	Stormwater Management	4
0			Credit 9	Heat Island Reduction	1
0			Credit 10	Solar Orientation	1
2			Credit 11	On-Site Renewable Energy Sources	3
0			Credit 12	District Heating and Cooling	2
1			Credit 13	Infrastructure Energy Efficiency	1
2			Credit 14	Wastewater Management	2
0			Credit 15	Recycled Content in Infrastructure	1
1			Credit 16	Solid Waste Management Infrastructure	1
1			Credit 17	Light Pollution Reduction	1

Innovation and Design Process — 6 Points

Yes	?	No			
1	0	0		Innovation and Design Process	6 Points
0			Credit 1.1	Innovation and Exemplary Performance: Provide Specific Title	1
0			Credit 1.2	Innovation and Exemplary Performance: Provide Specific Title	1
0			Credit 1.3	Innovation and Exemplary Performance: Provide Specific Title	1
0			Credit 1.4	Innovation and Exemplary Performance: Provide Specific Title	1
0			Credit 1.5	Innovation and Exemplary Performance: Provide Specific Title	1
1			Credit 2	LEED® Accredited Professional	1

Regional Priority Credit — 4 Points

Yes	?	No			
0	0	0		Regional Priority Credit	4 Points
0			Credit 1.1	Regional Priority Credit: Region Defined	1
0			Credit 1.2	Regional Priority Credit: Region Defined	1
0			Credit 1.3	Regional Priority Credit: Region Defined	1
0			Credit 1.4	Regional Priority Credit: Region Defined	1

Project Totals (Certification estimates) — 110 Points

Yes	?	No		
51	0	0	Project Totals (Certification estimates)	110 Points

Certified: 40-49 points, Silver: 50-59 points, Gold: 60-79 points, Platinum: 80+ points

Appendix C: LEED for New Homes Checklist

LEED for Homes Simplified Project Checklist

for Homes

Builder Name:	
Project Team Leader (if different):	
Home Address (Street/City/State):	

Project Description:

Building type: Project type:

\# of bedrooms: *0* Floor area: *0*

Adjusted Certification Thresholds

Certified: *45.0* Gold: *75.0*

Silver: *60.0* Platinum: *90.0*

Project Point Total Prelim: 0 + 0 maybe pts Final: 0

Final Credit Category Total Points ID: 0 SS: 0 EA: 0 EQ: 0 LL: 0 WE: 0 MR: 0 AE: 0

Certification Level Prelim: Not Certified Final: Not Certified

Min. Point Thresholds Not Met for Prelim. OR Final Rating

date last updated :

last updated by :

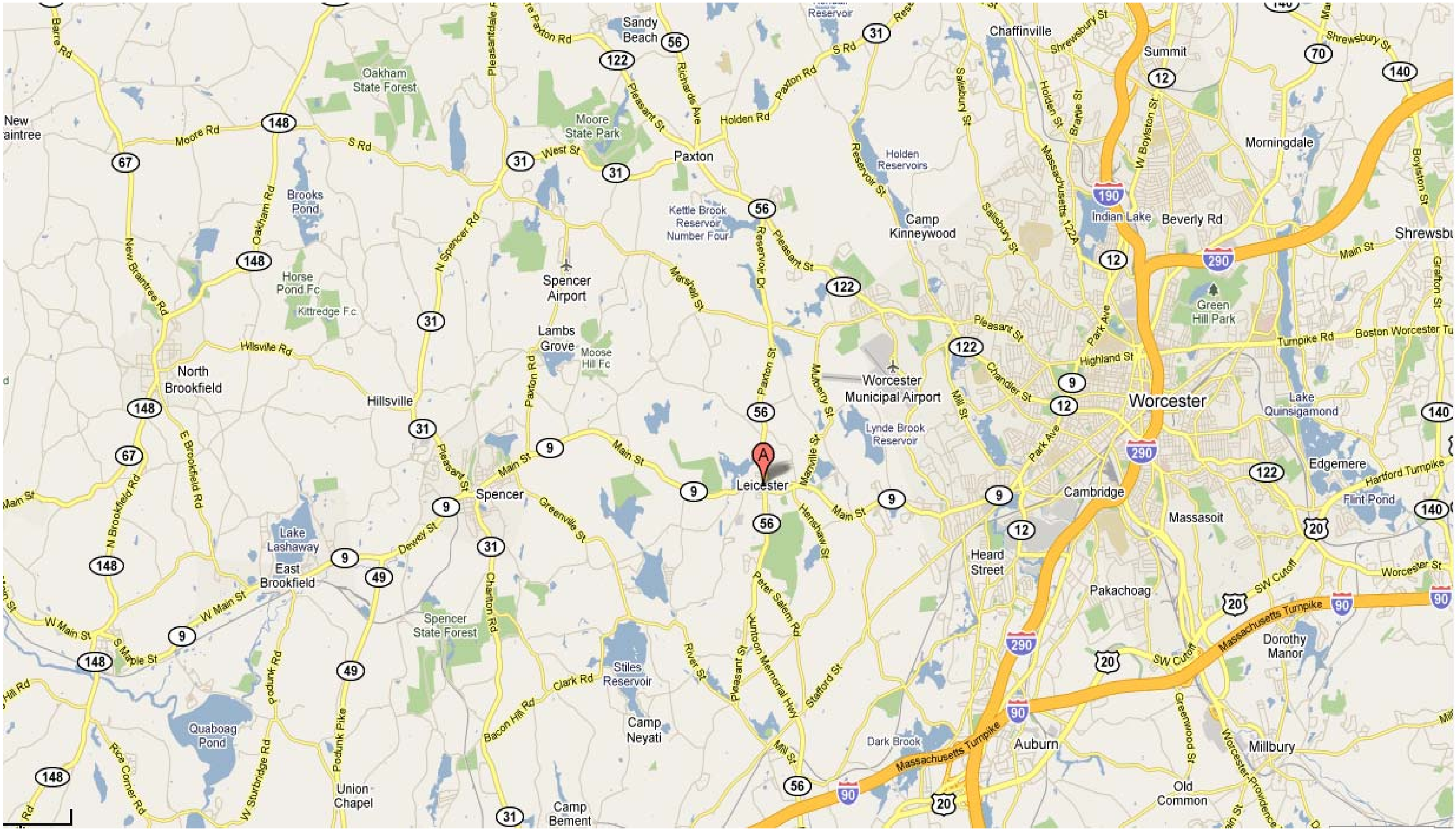
	No.	Credit		Max Points	Preliminary Y/Pts	Preliminary Maybe	Preliminary No	Final Y/Pts
Innovation and Design Process (ID)		(No Minimum Points Required)		Max	Y/Pts	Maybe	No	Y/Pts
1. Integrated Project Planning	1.1	Preliminary Rating		Prereq				
	1.2	Integrated Project Team		1	1			
	1.3	Professional Credentialed with Respect to LEED for Homes		1	1			
	1.4	Design Charrette		1	1			
	1.5	Building Orientation for Solar Design		1	1			
2. Durability Management Process	2.1	Durability Planning		Prereq				
	2.2	Durability Management		Prereq				
	2.3	Third-Party Durability Management Verification		3	3			
3. Innovative or Regional Design	3.1	Innovation #1 Innovative Design Request		1	1			
	3.2	Innovation #2 Geothermal Heating & cooling		1	1			
	3.3	Innovation #3 Porous Pavement		1	1			
	3.4	Innovation #4 Recycled Greywater		1	1			
		Sub-Total for ID Category:		11	11	0		0
Location and Linkages (LL)		(No Minimum Points Required)	OR	Max	Y/Pts	Maybe	No	Y/Pts
1. LEED ND	1	LEED for Neighborhood Development	LL2-6	10	10			
2. Site Selection	2	Site Selection		2				
3. Preferred Locations	3.1	Edge Development	LL 3.2	1				
	3.2	Infill		2				
	3.3	Previously Developed		1				
4. Infrastructure	4	Existing Infrastructure		1				
5. Community Resources/ Transit	5.1	Basic Community Resources / Transit	LL 5.2, 5.3	1				
	5.2	Extensive Community Resources / Transit	LL 5.3	2				
	5.3	Outstanding Community Resources / Transit		3				
6. Access to Open Space	6	Access to Open Space		1				
		Sub-Total for LL Category:		10	10	0		0
Sustainable Sites (SS)		(Minimum of 5 SS Points Required)	OR	Max	Y/Pts	Maybe	No	Y/Pts
1. Site Stewardship	1.1	Erosion Controls During Construction		Prereq				
	1.2	Minimize Disturbed Area of Site		1	1			
2. Landscaping	2.1	No Invasive Plants		Prereq				
	2.2	Basic Landscape Design	SS 2.5	2	1			
	2.3	Limit Conventional Turf	SS 2.5	3	1			
	2.4	Drought Tolerant Plants	SS 2.5	2	1			
	2.5	Reduce Overall Irrigation Demand by at Least 20%		6	3			
3. Local Heat Island Effects	3	Reduce Local Heat Island Effects		1	1			
4. Surface Water Management	4.1	Permeable Lot		4	2			
	4.2	Permanent Erosion Controls		1				
	4.3	Management of Run-off from Roof		2	2			
5. Nontoxic Pest Control	5	Pest Control Alternatives		2	2			
6. Compact Development	6.1	Moderate Density	SS 6.2, 6.3	2				
	6.2	High Density	SS 6.3	3				
	6.3	Very High Density		4				
		Sub-Total for SS Category:		22	14	0		0

LEED for Homes Simplified Project Checklist (continued)

				Max Points	Project Points Preliminary			Final
Water Efficiency (WE)		(Minimum of 3 WE Points Required)	OR	Max	Y/Pts	Maybe	No	Y/Pts
1. Water Reuse	1.1	Rainwater Harvesting System	**WE 1.3**	4	4			
	1.2	Graywater Reuse System	**WE 1.3**	1	1			
	1.3	Use of Municipal Recycled Water System		3				
2. Irrigation System	2.1	High Efficiency Irrigation System	**WE 2.3**	3	3			
	2.2	Third Party Inspection	**WE 2.3**	1	1			
	2.3	Reduce Overall Irrigation Demand by at Least 45%		4				
3. Indoor Water Use	3.1	High-Efficiency Fixtures and Fittings		3	[illegible]			
	3.2	Very High Efficiency Fixtures and Fittings		6	6			
			Sub-Total for WE Category:	*15*	*0* 15	*0*		*0*
Energy and Atmosphere (EA)		(Minimum of 0 EA Points Required)	OR	Max	Y/Pts	Maybe	No	Y/Pts
1. Optimize Energy Performance	1.1	Performance of ENERGY STAR for Homes		Prereq	34			
	1.2	Exceptional Energy Performance		34				
7. Water Heating	7.1	Efficient Hot Water Distribution		2				
	7.2	Pipe Insulation		1				
11. Residential Refrigerant Management	11.1	Refrigerant Charge Test		Prereq				
	11.2	Appropriate HVAC Refrigerants		1	1			
			Sub-Total for EA Category:	*38*	*0* 35			*0*
Materials and Resources (MR)		(Minimum of 2 MR Points Required)	OR	Max	Y/Pts	Maybe	No	Y/Pts
1. Material-Efficient Framing	1.1	Framing Order Waste Factor Limit		Prereq				
	1.2	Detailed Framing Documents	**MR 1.5**	1				
	1.3	Detailed Cut List and Lumber Order	**MR 1.5**	1				
	1.4	Framing Efficiencies	**MR 1.5**	3				
	1.5	Off-site Fabrication		4	4			
2. Environmentally Preferable Products	2.1	FSC Certified Tropical Wood		Prereq				
	2.2	Environmentally Preferable Products		8	8			
3. Waste Management	3.1	Construction Waste Management Planning		Prereq				
	3.2	Construction Waste Reduction		3	3			
			Sub-Total for MR Category:	*16*	*0* 15			*0*
Indoor Environmental Quality (EQ)		(Minimum of 6 EQ Points Required)	OR	Max	Y/Pts	Maybe	No	Y/Pts
1. ENERGY STAR with IAP	1	ENERGY STAR with Indoor Air Package		13	13			
2. Combustion Venting	2.1	Basic Combustion Venting Measures	**EQ 1**	Prereq				
	2.2	Enhanced Combustion Venting Measures	**EQ 1**	2				
3. Moisture Control	3	Moisture Load Control	**EQ 1**	1				
4. Outdoor Air Ventilation	4.1	Basic Outdoor Air Ventilation	**EQ 1**	Prereq				
	4.2	Enhanced Outdoor Air Ventilation		2	2			
	4.3	Third-Party Performance Testing	**EQ 1**	1	1			
5. Local Exhaust	5.1	Basic Local Exhaust	**EQ 1**	Prereq				
	5.2	Enhanced Local Exhaust		1				
	5.3	Third-Party Performance Testing		1				
6. Distribution of Space Heating and Cooling	6.1	Room-by-Room Load Calculations	**EQ 1**	Prereq				
	6.2	Return Air Flow / Room by Room Controls	**EQ 1**	1				
	6.3	Third-Party Performance Test / Multiple Zones	**EQ 1**	2				
7. Air Filtering	7.1	Good Filters	**EQ 1**	Prereq				
	7.2	Better Filters	**EQ 7.3**	1				
	7.3	Best Filters		2				
8. Contaminant Control	8.1	Indoor Contaminant Control during Construction	**EQ 1**	1				
	8.2	Indoor Contaminant Control		2	2			
	8.3	Preoccupancy Flush	**EQ 1**	1				
9. Radon Protection	9.1	Radon-Resistant Construction in High-Risk Areas	**EQ 1**	Prereq				
	9.2	Radon-Resistant Construction in Moderate-Risk Areas	**EQ 1**	1				
10. Garage Pollutant Protection	10.1	No HVAC in Garage	**EQ 1**	Prereq				
	10.2	Minimize Pollutants from Garage	**EQ 1, 10.4**	2				
	10.3	Exhaust Fan in Garage	**EQ 1, 10.4**	1				
	10.4	Detached Garage or No Garage	**EQ 1**	3				
			Sub-Total for EQ Category:	*21*	*0* 18			*0*
Awareness and Education (AE)		(Minimum of 0 AE Points Required)		Max	Y/Pts	Maybe	No	Y/Pts
1. Education of the Homeowner or Tenant	1.1	Basic Operations Training		Prereq				
	1.2	Enhanced Training		1	1			
	1.3	Public Awareness		1	1			
2. Education of Building Manager	2	Education of Building Manager		1	1			
			Sub-Total for AE Category:	*3*	*0* 3			*0*

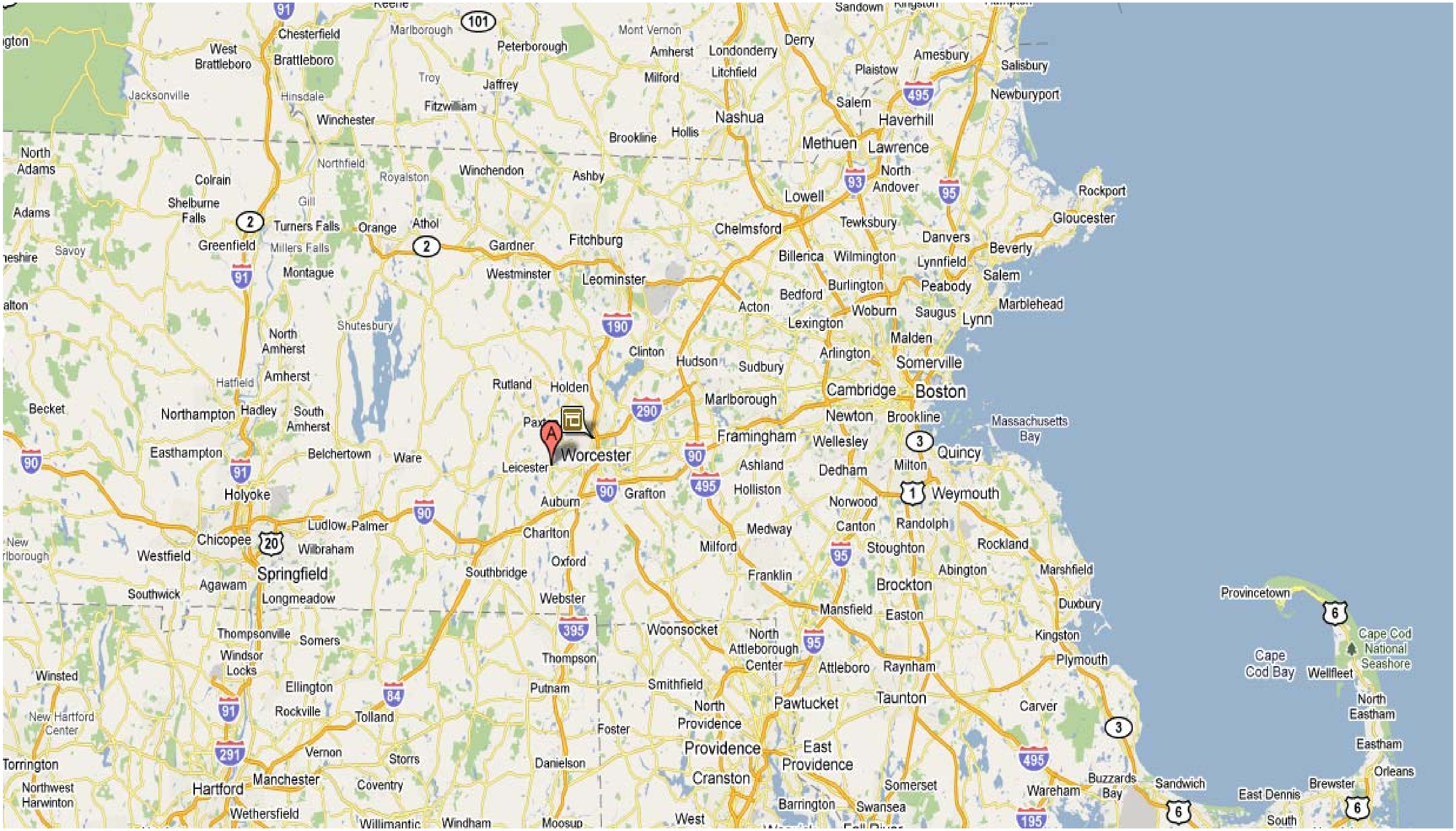
Appendix D: Area and Maps

Source: Google Earth



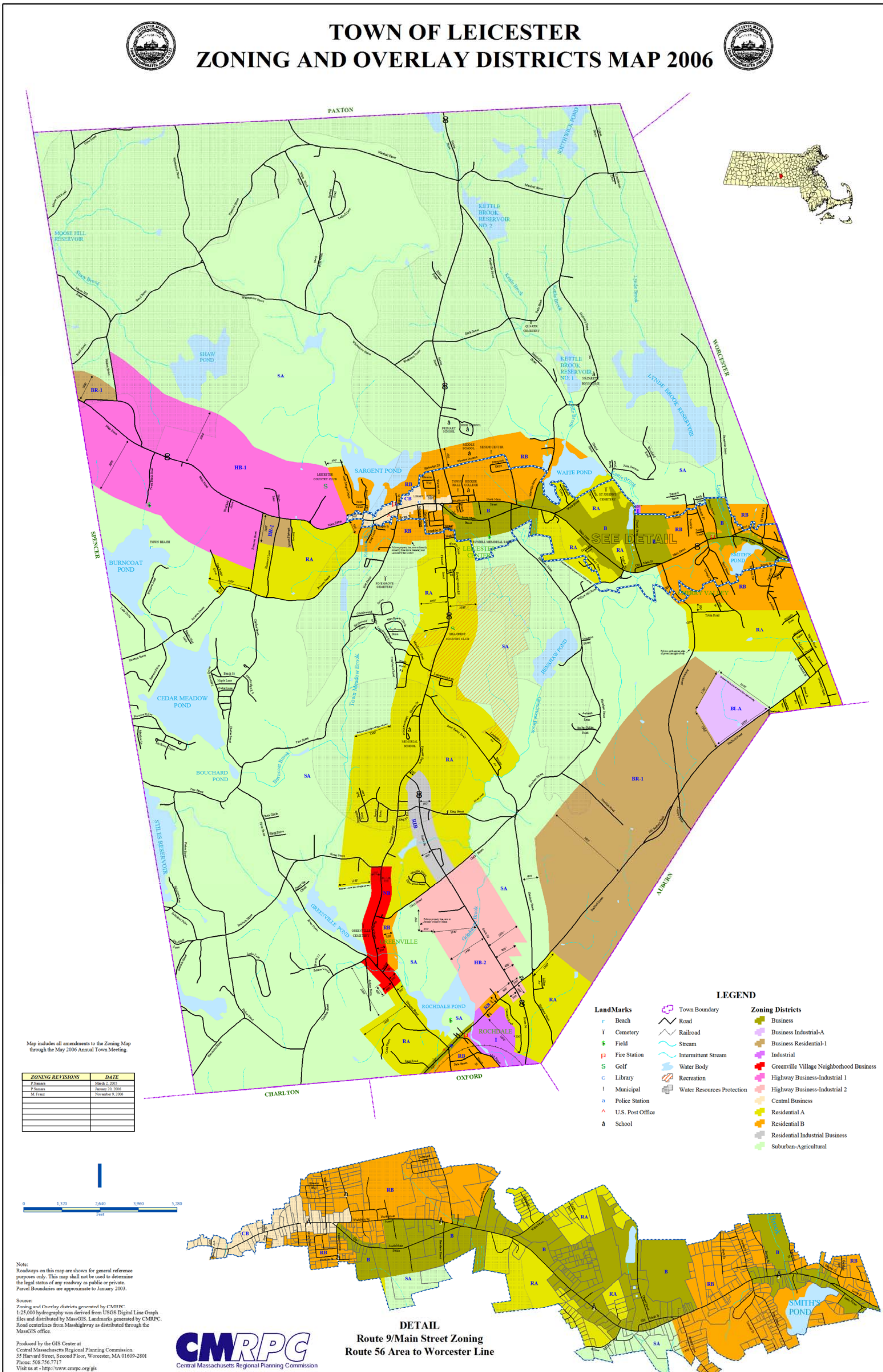
Source: Google

X



Source: Google

Appendix E: Zoning Map



Appendix F: Zoning Bylaws

SECTION 2
ESTABLISHMENT OF DISTRICTS

2.1 TYPES OF DISTRICTS
For the purpose of this by-law, the Town of Leicester is hereby divided into the following types of use districts:

FULL NAME	SHORT TERMS	FULL NAME	SHORT TERMS
Residential 1	R1	Recreational Development	RD
Residential 2	R2	Business Residential-1	BR-1
Suburban-Agricultural	SA	Residential Industrial Business	RIB
Business	B	Highway Business-Industrial District 1	HB-1
Industrial	I	Highway Business-Industrial District 2	HB-2
Business-Industrial-A	BI-A	Greenville Village Neighborhood Business Dist	NB
		Central Business	CB

2.2 LOCATIONS OF DISTRICTS: Said districts are established as shown, defined and bounded on the map entitled. "Zoning Map of Leicester, Massachusetts". Said map and all explanatory matter thereon are hereby made a part of this by-law.

2.3 DISTRICT BOUNDARIES

2.3.01 Where the boundary of a district is shown on a map to follow the course of a street or road, the center line of such a way shall be the boundary line.

2.3.02 A boundary line located outside of such a street or road and shown on the map as approximately parallel to the center line and distances shown on the map between such a boundary line and the street or road are the distances in feet from the boundary line to the center line of the street or road, such distances being measured at right angles to the center line unless otherwise indicated.

2.3.03 In all cases which are not covered by the forgoing provisions of this section, the location of boundary lines shall be determined by the distances in feet, if given, from other lines upon said map, by use of identifications as shown on the map, and by directions and distances as they may be scaled and measured from the map.

2.3.04 Where a district boundary line divides any lot existing at the time such line is adopted, the regulations for the less restricted portion of such lot may extend not more than thirty (30) feet into the more restricted portion, provided only that such lot has the required minimum frontage on a street in the less restricted portion for the existing or intended use of the premises.

SECTION 2.3.05 RECREATIONAL DEVELOPMENT

(A)	Intent	(F)	Planning Principles and Requirements
(B)	Definitions	(G)	Natural Features Protection
(C)	Objectives	(H)	Recreation Areas
(D)	Uses	(I)	Non-Residential Uses
(E)	Location and Density	(J)	Administration

(A). INTENT The intent of this section is to provide recreational opportunities for the residents of Leicester, to allow more effective and efficient use of large tracts of land in the rural areas of Leicester, and to minimize Town service responsibilities.

(B). DEFINITIONS "**Recreational Area**" is a parcel(s) of land or an area(s) of water, or a combination of land and water within the site designated for a Recreational Development, maintained and preserved for active or passive recreational uses (such as a park, tennis courts, ball fields, swimming pools, golf courses, etc.), or for buffer areas, and designed and intended for the use or enjoyment of occupants of the Recreational Development and, in certain circumstances, the general public. Recreational Areas may contain such structures and improvements as are appropriate under the provisions of this Section. "**Recreational Development**" (RD) is an area of land, designed and developed as a unit, with Recreational Areas as integral characteristics and which departs from the zoning regulations conventionally required in the Residential 1, Residential 2 or Suburban-Agricultural Districts concerning use of land or buildings, lot size, bulk or type of structures, or other requirements. Unless specifically prescribed, any combination of residential and compatible uses may be allowed.

(C) OBJECTIVES (1) To preserve natural topography and provide useable space for recreational facilities. (2) To insure appropriate, high quality design and site planning and a high level of environmental amenity. (3) To eliminate Town service responsibilities for streets and utilities. (4) To allow flexibility and creativity in the design of developments through a carefully controlled Special Permit process of negotiation of particular plans.

SECTION 4

DIMENSIONAL REQUIREMENTS

4.1 BASIC REQUIREMENTS

No building or structure erected in any district shall be located on a lot having less than the minimum requirements set forth in Table I and II, and no more than one dwelling shall be built upon such lot, except in the case of Business, or combination of Business and Residential areas (B, BR-1, and RIB) when used as Business. No existing lot shall be changed as to size or shape so as to result in the violation of the requirements set forth in Table I and II.

4.2 SCHEDULE OF DIMENSIONAL REQUIREMENTS - TABLE I

District		Area (SQ.ft)	Frontage (FT)	Front (FT)	Side (FT)	Rear (FT)	Max height of building in feet	No. of stories	Maximum Building Coverage(%)
RESIDENTIAL 1	(R1)	50,000†	150	25	15	25	35	2½	30
RESIDENTIAL 2	(R2)	20,000	125	25	15	25	35	2½	30
SUB-AGRICULTURE	(SA)	80,000	200	40	40	40	35	2½	30
BUSINESS structure	(B)	15,000	100	25	10	25	35	2½	30
BI-A single family	(BI-A)	30,000	175	40	40	40	55	5½	30
BI-A structure	(BI-A)	20,000	150	50	40	40	55	5½	30
BUSINESS RESIDENTIAL-1 single family	(BR-1)	50,000	200	40	40	40	55	5½	30
BUSINESS RESIDENTIAL -1 structure	(BR-1)	20,000	150	50	40	40	55	5½	30
INDUSTRIAL single family	(I)	40,000	100	25	10	25	55	5½	30
INDUSTRIAL structure	(I)	10,000	100	25	10	25	55	5½	50
RESIDENTIAL INDUSTRIAL BUSINESS single family	(RIB)	30,000	175	40	40	40	55	5½	33
RESIDENTIAL INDUSTRIAL BUSINESS Two family*	(RIB)	30,000	175	25	25	25	55	5½	33
RESIDENTIAL INDUSTRIAL BUSINESS Multi-family* - Three Apts.	(RIB)	30,000	250	25	15	25	55	5½	33
RESIDENTIAL INDUSTRIAL BUSINESS Multi-family* Each add'l apt. up to and include 5	(RIB)	10,000	250	25	15	25	55	5½	33
RESIDENTIAL INDUSTRIAL BUSINESS Multi-family* Each add'l apt after 5th apt.	(RIB)	2,500	250	25	15	25	55	5½	33
HIGHWAY BUSINESS-INDUSTRIAL DISTRICT 1 (HB-1)	(HB-1)	60,000	200	50	50	50	55	5½	40
HIGHWAY BUSINESS-INDUSTRIAL DISTRICT 2 (HB-2)	(HB-2)	45,000	200	50	50	50	55	5½	40
GREENVILLE VILLAGE NEIGHBORHOOD BUSINESS DISTRICT	(NB)	20,000	100	25†	15	25	25	2	40

† = The minimum lot size in the R1 district shall be 40,000 square feet for lots served by public water and sewer.
* = Special Permit
† = In Neighborhood Business Districts (NB), if the alignment of existing principal buildings on adjacent lots on each side of a lot fronting the same street in the same district is nearer to the street line than the required front setback, the average of the existing alignments of all such buildings within 500 feet of said lot shall be the required front setback.

4.2 SCHEDULE OF DIMENSIONAL REQUIREMENTS - TABLE II

District		Area (SQ.ft)	Frontage (FT)	Front (FT)	Side (FT)	Rear (FT)	Max height of building in feet	No. of stories	Maximum Building Coverage(%)
BUSINESS Multi-family, 1st apt	(B)	15,000	100	25	15	25	35	2½	30
BUSINESS Multi-family, each add'l apt. up to & include. 5	(B)	7,500	100	25	15	25	35	2½	33
BUSINESS Multi-family, each add'l apt. after 5th apt.	(B)	2,000	100	25	15	25	35	2½	30

4.2.01 A lot or parcel of land having an area or a frontage of lesser amounts than required by this table may be considered as coming within the area and frontage requirements of this section, provided such lot or parcel of land was shown on a plan or described in a deed duly recorded or registered at the time of the adoption of this by-law and did not at the time of such adoption adjoin other land of the same owner available for use in connection with such lot or parcel.

4.2.02 To be measured at right angles to the principal structure. Measurement is from the right-of-way line where a plan of the way is on file with the Registry of Deeds or, in the absence of such a plan, from a line 25 feet from and parallel with the center line of the traveled way.

4.2.03 The limitations on height of buildings shall not apply in any district to chimneys, ventilators, towers, spires or other ornamental features of buildings which features are in no way used for living purposes.

4.2.04 Side yard dimension will be fifty (50) feet when adjacent to a Residential District or a Suburban-Agricultural District.

4.2.05 Rear yard dimension will be fifty (50) feet when adjacent to a Residential District or a Suburban-Agricultural District.

4.2.06 Height Restriction for Habitation. No building over 35 feet in height shall be used for human or animal habitation.

4.3 MODIFICATIONS TO DIMENSIONAL REQUIREMENT

4.3.01 No existing lot shall be changed as to size or shape so as to result in the violation of the requirements set forth in Section 4.2.

4.3.02 Upon granting of a Special Permit by the Planning Board, the dimensional requirements of this bylaw shall not apply to any uninhabited structures for public utilities owned by the Town of Leicester or Municipalities within the Town.

Section 4.4

A lot in the BR-1, and RIB Zones shall not contain more than two-third (2/3) impervious area and not less than 1/3 for greenery. The greenery must extend 20' from boundary of lot. All business and/or multiple family uses set forth in the BR-1, and RIB Zones shall be subject to the Site Plan Review By-Law.

Appendix G: Floor and Wall Spacing Codes

780 CMR TABLE 5602.3(3)
ALLOWABLE STUD SPACING FOR WOOD STRUCTURAL PANEL WALL SHEATHING

PANEL SPAN RATING	PANEL NOMINAL THICKNESS (inch)	MAXIMUM STUD SPACING (inches) Siding nailed to:[a]	
		Stud	Sheathing
12/0, 16/0, 20/0, or wall —16 o.c.	$^5/_{16}$, ⅜	16	16[b]
24/0, 24/16, 32/16 or wall—24 o.c.	⅜, $^7/_{16}$, $^{15}/_{32}$, ½	24	24[c]

For SI: 1 inch = 25.4 mm.

a. Blocking of horizontal joints shall not be required.

b. Plywood sheathing $^3/_8$-inch thick or less shall be applied with long dimension across studs.

c. Three-ply plywood panels shall be applied with long dimension across studs.

780 CMR TABLE 5602.3(4)
ALLOWABLE SPANS FOR PARTICLEBOARD WALL SHEATHING[a]

THICKNESS (inch)	GRADE	STUD SPACING (inches)	
		When siding is nailed to studs	When siding is nailed to sheathing
⅜	M-1 Exterior glue	16	—
½	M-2 Exterior glue	16	16

For SI: 1 inch = 25.4 mm.

a. Wall sheathing not exposed to the weather. If the panels are applied horizontally, the end joints of the panel shall be offset so that four panels corners will not meet. All panel edges must be supported. Leave a $^1/_{16}$-inch gap between panels and nail no closer than ⅜ inch from panel edges.

780 CMR TABLE 5602.3(5)
SIZE, HEIGHT AND SPACING OF WOOD STUDS[a]

STUD SIZE (inches)	BEARING WALLS					NONBEARING WALLS	
	Laterally unsupported stud height[a] (feet)	Maximum spacing when supporting roof and ceiling only (inches)	Maximum spacing when supporting one floor, roof and ceiling (inches)	Maximum spacing when supporting two floors, roof and ceiling (inches)	Maximum spacing when supporting one floor only (inches)	Laterally unsupported stud height[a] (feet)	Maximum spacing (inches)
2× 3[b]	—	—	—	—	—	10	16
2× 4	10	24	16	—	24	14	24
3× 4	10	24	24	16	24	14	24
2× 5	10	24	24	—	24	16	24
2× 6	10	24	24	16	24	20	24

For SI: 1 inch = 25.4 mm.

a. Listed heights are distances between points of lateral support placed perpendicular to the plane of the wall. Increases in unsupported height are permitted where justified by analysis.

b. Shall not be used in exterior walls.

780 CMR TABLE 5502.3.1(1)
FLOOR JOIST SPANS FOR COMMON LUMBER SPECIES
(Residential Sleeping Areas, Live Load = 30 psf, L/Δ = 360)

JOIST SPACING (inches)	SPECIES AND GRADE		DEAD LOAD = 10 psf				DEAD LOAD = 20 psf			
			2×6	2×8	2×10	2×12	2×6	2×8	2×10	2×12
			Maximum floor joist spans							
			(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)
	Douglas fir-larch	SS	12- 6	16- 6	21- 0	25- 7	12- 6	16- 6	21- 0	25- 7
	Douglas fir-larch	#1	12- 0	15-10	20- 3	24- 8	12- 0	15- 7	19- 0	22- 0
	Douglas fir-larch	#2	11-10	15- 7	19-10	23- 0	11- 6	14- 7	17- 9	20- 7
	Douglas fir-larch	#3	9- 8	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
	Hem-fir	SS	11- 10	15- 7	19-10	24- 2	11- 10	15- 7	19-10	24- 2
	Hem-fir	#1	11- 7	15- 3	19- 5	23- 7	11- 7	15- 2	18- 6	21- 6
	Hem-fir	#2	11- 0	14- 6	18- 6	22- 6	11- 0	14- 4	17- 6	20- 4
	Hem-fir	#3	9- 8	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
	Southern pine	SS	12- 3	16- 2	20- 8	25- 1	12- 3	16- 2	20- 8	25- 1
	Southern pine	#1	12- 0	15-10	20- 3	24- 8	12- 0	15-10	20- 3	24- 8
	Southern pine	#2	11- 10	15- 7	19-10	24- 2	11- 10	15- 7	18- 7	21- 9
	Southern pine	#3	10- 5	13- 3	15- 8	18- 8	9- 4	11- 11	14- 0	16- 8
	Spruce-pine-fir	SS	11- 7	15- 3	19- 5	23- 7	11- 7	15- 3	19- 5	23- 7
	Spruce-pine-fir	#1	11- 3	14-11	19- 0	23- 0	11- 3	14- 7	17- 9	20- 7
	Spruce-pine-fir	#2	11- 3	14-11	19- 0	23- 0	11- 3	14- 7	17- 9	20- 7
12	Spruce-pine-fir	#3	9- 8	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
	Douglas fir-larch	SS	11- 4	15- 0	19- 1	23- 3	11- 4	15- 0	19- 1	23- 0
	Douglas fir-larch	#1	10- 11	14- 5	18- 5	21- 4	10- 8	13- 6	16- 5	19- 1
	Douglas fir-larch	#2	10- 9	14- 1	17- 2	19-11	9- 11	12- 7	15- 5	17-10
	Douglas fir-larch	#3	8- 5	10- 8	13- 0	15- 1	7- 6	9- 6	11- 8	13- 6
	Hem-fir	SS	10- 9	14- 2	18- 0	21-11	10- 9	14- 2	18- 0	21-11
	Hem-fir	#1	10- 6	13- 10	17- 8	20- 9	10- 4	13- 1	16- 0	18- 7
	Hem-fir	#2	10- 0	13- 2	16-10	19- 8	9- 10	12- 5	15- 2	17- 7
	Hem-fir	#3	8- 5	10- 8	13- 0	15- 1	7- 6	9- 6	11- 8	13- 6
	Southern pine	SS	11- 2	14- 8	18- 9	22-10	11- 2	14- 8	18- 9	22-10
	Southern pine	#1	10- 11	14- 5	18- 5	22- 5	10- 11	14- 5	17-11	21- 4
	Southern pine	#2	10- 9	14- 2	18- 0	21- 1	10- 5	13- 6	16- 1	18-10
	Southern pine	#3	9- 0	11- 6	13- 7	16- 2	8- 1	10- 3	12- 2	14- 6
	Spruce-pine-fir	SS	10- 6	13- 10	17- 8	21- 6	10- 6	13- 10	17- 8	21- 4
	Spruce-pine-fir	#1	10- 3	13- 6	17- 2	19-11	9- 11	12- 7	15- 5	17-10
	Spruce-pine-fir	#2	10- 3	13- 6	17- 2	19-11	9- 11	12- 7	15- 5	17-10
16	Spruce-pine-fir	#3	8- 5	10- 8	13- 0	15- 1	7- 6	9- 6	11- 8	13- 6
	Douglas fir-larch	SS	10- 8	14- 1	18- 0	21-10	10- 8	14- 1	18- 0	21- 0
	Douglas fir-larch	#1	10- 4	13- 7	16- 9	19- 6	9- 8	12- 4	15- 0	17- 5
	Douglas fir-larch	#2	10- 1	12- 10	15- 8	18- 3	9- 1	11- 6	14- 1	16- 3
	Douglas fir-larch	#3	7- 8	9- 9	11- 10	13- 9	6- 10	8- 8	10- 7	12- 4
	Hem-fir	SS	10- 1	13- 4	17- 0	20- 8	10- 1	13- 4	17- 0	20- 7
	Hem-fir	#1	9- 10	13- 0	16- 4	19- 0	9- 6	12- 0	14- 8	17- 0
	Hem-fir	#2	9- 5	12- 5	15- 6	17-1	8- 11	11- 4	13- 10	16- 1
	Hem-fir	#3	7- 8	9- 9	11- 10	13- 9	6- 10	8- 8	10- 7	12- 4
	Southern pine	SS	10- 6	13- 10	17- 8	21- 6	10- 6	13- 10	17- 8	21- 6
	Southern pine	#1	10- 4	13- 7	17- 4	21- 1	10- 4	13- 7	16- 4	19- 6
	Southern pine	#2	10- 1	13- 4	16- 5	19- 3	9- 6	12- 4	14- 8	17- 2
	Southern pine	#3	8- 3	10- 6	12- 5	14- 9	7- 4	9- 5	11- 1	13- 2
	Spruce-pine-fir	SS	9- 10	13- 0	16- 7	20- 2	9- 10	13- 0	16- 7	19- 6
	Spruce-pine-fir	#1	9- 8	12- 9	15- 8	18- 3	9- 1	11- 6	14- 1	16- 3
	Spruce-pine-fir	#2	9- 8	12- 9	15- 8	18- 3	9- 1	11- 6	14- 1	16- 3
19.2	Spruce-pine-fir	#3	7- 8	9- 9	11- 10	13- 9	6- 10	8- 8	10- 7	12- 4
	Douglas fir-larch	SS	9- 11	13- 1	16- 8	20- 3	9- 11	13- 1	16- 2	18- 9
	Douglas fir-larch	#1	9- 7	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
	Douglas fir-larch	#2	9- 1	11- 6	14- 1	16- 3	8- 1	10- 3	12- 7	14- 7
	Douglas fir-larch	#3	6- 10	8- 8	10- 7	12- 4	6- 2	7- 9	9- 6	11- 0
	Hem-fir	SS	9- 4	12- 4	15- 9	19- 2	9- 4	12- 4	15- 9	18- 5
	Hem-fir	#1	9- 2	12- 0	14- 8	17- 0	8- 6	10- 9	13- 1	15- 2
	Hem-fir	#2	8- 9	11- 4	13- 10	16- 1	8- 0	10- 2	12- 5	14- 4
	Hem-fir	#3	6- 10	8- 8	10- 7	12- 4	6- 2	7- 9	9- 6	11- 0
	Southern pine	SS	9- 9	12- 10	16- 5	19-11	9- 9	12- 10	16- 5	19-11
	Southern pine	#1	9- 7	12- 7	16- 1	19- 6	9- 7	12- 4	14- 7	17- 5
	Southern pine	#2	9- 4	12- 4	14- 8	17- 2	8- 6	11- 0	13- 1	15- 5
	Southern pine	#3	7- 4	9- 5	11- 1	13- 2	6- 7	8- 5	9- 11	11- 10
	Spruce-pine-fir	SS	9- 2	12- 1	15- 5	18- 9	9- 2	12- 1	15- 0	17- 5
24	Spruce-pine-fir	#1	8- 11	11- 6	14- 1	16- 3	8- 1	10- 3	12- 7	14- 7

	Spruce-pine-fir #2	8- 11	11- 6	14- 1	16- 3	8- 1	10- 3	12- 7	14- 7
	Spruce-pine-fir #3	6- 10	8- 8	10- 7	12- 4	6- 2	7- 9	9- 6	11- 0

For SI: 1 inch – 25.4 mm, 1 foot – 304.8 mm, 1 pound per square foot – 0.0479kN/m^2. **NOTE:** Check sources for availability of lumber in lengths greater than 20 feet.

780 CMR TABLE 5502.3.1(2)
FLOOR JOIST SPANS FOR COMMON LUMBER SPECIES
(Residential living areas, live load = 40 psf, L/Δ = 360)

JOIST SPACING (inches)	SPECIES AND GRADE	DEAD LOAD = 10 psf				DEAD LOAD = 20 psf			
		2×6	2×8	2×10	2×12	2×6	2×8	2×10	2×12
		Maximum floor joist spans							
		(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)	(ft.- in.)
	Douglas fir-larch SS	11- 4	15- 0	19- 1	23- 3	11- 4	15- 0	19- 1	23- 3
	Douglas fir-larch #1	10- 11	14- 5	18- 5	22- 0	10- 11	14- 2	17- 4	20- 1
	Douglas fir-larch #2	10- 9	14- 2	17- 9	20- 7	10- 6	13- 3	16- 3	18-10
	Douglas fir-larch #3	8- 8	11- 0	13- 5	15- 7	7- 11	10- 0	12- 3	14- 3
	Hem-fir SS	10- 9	14- 2	18- 0	21-11	10- 9	14- 2	18- 0	21-11
	Hem-fir #1	10- 6	13- 10	17- 8	21- 6	10- 6	13- 10	16-11	19- 7
	Hem-fir #2	10- 0	13- 2	16-10	20- 4	10- 0	13- 1	16- 0	18- 6
	Hem-fir #3	8- 8	11- 0	13- 5	15- 7	7- 11	10- 0	12- 3	14- 3
	Southern pine SS	11- 2	14- 8	18- 9	22-10	11- 2	14- 8	18- 9	22-10
	Southern pine #1	10- 11	14- 5	18- 5	22- 5	10- 11	14- 5	18- 5	22- 5
	Southern pine #2	10- 9	14- 2	18- 0	21- 9	10- 9	14- 2	16-11	19-10
	Southern pine #3	9- 4	11- 11	14- 0	16- 8	8- 6	10- 10	12- 10	15- 3
	Spruce-pine-fir SS	10- 6	13- 10	17- 8	21- 6	10- 6	13- 10	17- 8	21- 6
	Spruce-pine-fir #1	10- 3	13- 6	17- 3	20- 7	10- 3	13- 3	16- 3	18-10
	Spruce-pine-fir #2	10- 3	13- 6	17- 3	20- 7	10- 3	13- 3	16- 3	18-10
12	Spruce-pine-fir #3	8- 8	11- 0	13- 5	15- 7	7- 11	10- 0	12- 3	14- 3
	Douglas fir-larch SS	10- 4	13- 7	17- 4	21- 1	10- 4	13- 7	17- 4	21- 0
	Douglas fir-larch #1	9- 11	13- 1	16- 5	19- 1	9- 8	12- 4	15- 0	17- 5
	Douglas fir-larch #2	9- 9	12- 7	15- 5	17-10	9- 1	11- 6	14- 1	16- 3
	Douglas fir-larch #3	7- 6	9- 6	11- 8	13- 6	6- 10	8- 8	10- 7	12- 4
	Hem-fir SS	9- 9	12- 10	16- 5	19-11	9- 9	12- 10	16- 5	19-11
	Hem-fir #1	9- 6	12- 7	16- 0	18- 7	9- 6	12- 0	14- 8	17- 0
	Hem-fir #2	9- 1	12- 0	15- 2	17- 7	8- 11	11- 4	13- 10	16- 1
	Hem-fir #3	7- 6	9- 6	11- 8	13- 6	6- 10	8- 8	10- 7	12- 4
	Southern pine SS	10- 2	13- 4	17- 0	20- 9	10- 2	13- 4	17- 0	20- 9
	Southern pine #1	9- 11	13- 1	16- 9	20- 4	9- 11	13- 1	16- 4	19- 6
	Southern pine #2	9- 9	12- 10	16- 1	18-10	9- 6	12- 4	14- 8	17- 2
	Southern pine #3	8- 1	10- 3	12- 2	14- 6	7- 4	9- 5	11- 1	13- 2
	Spruce-pine-fir SS	9- 6	12- 7	16- 0	19- 6	9- 6	12- 7	16- 0	19- 6
	Spruce-pine-fir #1	9- 4	12- 3	15- 5	17-10	9- 1	11- 6	14- 1	16- 3
	Spruce-pine-fir #2	9- 4	12- 3	15- 5	17-10	9- 1	11- 6	14- 1	16- 3
16	Spruce-pine-fir #3	7- 6	9- 6	11- 8	13- 6	6- 10	8- 8	10- 7	12- 4
	Douglas fir-larch SS	9- 8	12- 10	16- 4	19-10	9- 8	12- 10	16- 4	19- 2
	Douglas fir-larch #1	9- 4	12- 4	15- 0	17- 5	8- 10	11- 3	13- 8	15-11
	Douglas fir-larch #2	9- 1	11- 6	14- 1	16- 3	8- 3	10- 6	12- 10	14-10
	Douglas fir-larch #3	6- 10	8- 8	10- 7	12- 4	6- 3	7- 11	9- 8	11- 3
	Hem-fir SS	9- 2	12- 1	15- 5	18- 9	9- 2	12- 1	15- 5	18- 9
	Hem-fir #1	9- 0	11- 10	14- 8	17- 0	8- 8	10- 11	13- 4	15- 6
	Hem-fir #2	8- 7	11- 3	13- 10	16- 1	8- 2	10- 4	12- 8	14- 8
	Hem-fir #3	6- 10	8- 8	10- 7	12- 4	6- 3	7- 11	9- 8	11- 3
	Southern pine SS	9- 6	12- 7	16- 0	19- 6	9- 6	12- 7	16- 0	19- 6
	Southern pine #1	9- 4	12- 4	15- 9	19- 2	9- 4	12- 4	14-11	17- 9
	Southern pine #2	9- 2	12- 1	14- 8	17- 2	8- 8	11- 3	13- 5	15- 8
	Southern pine #3	7- 4	9- 5	11- 1	13- 2	6- 9	8- 7	10- 1	12- 1
	Spruce-pine-fir SS	9- 0	11- 10	15- 1	18- 4	9- 0	11- 10	15- 1	17- 9
	Spruce-pine-fir #1	8- 9	11- 6	14- 1	16- 3	8- 3	10- 6	12- 10	14-10
	Spruce-pine-fir #2	8- 9	11- 6	14- 1	16- 3	8- 3	10- 6	12- 10	14-10
19.2	Spruce-pine-fir #3	6- 10	8- 8	10- 7	12- 4	6- 3	7- 11	9- 8	11- 3
	Douglas fir-larch SS	9- 0	11- 11	15- 2	18- 5	9- 0	11- 11	14- 9	17- 1
	Douglas fir-larch #1	8- 8	11- 0	13- 5	15- 7	7- 11	10- 0	12- 3	14- 3
	Douglas fir-larch #2	8- 1	10- 3	12- 7	14- 7	7- 5	9- 5	11- 6	13- 4
	Douglas fir-larch #3	6- 2	7- 9	9- 6	11- 0	5- 7	7- 1	8- 8	10- 1
	Hem-fir SS	8- 6	11- 3	14- 4	17- 5	8- 6	11- 3	14- 4	16-10[a]
	Hem-fir #1	8- 4	10- 9	13- 1	15- 2	7- 9	9- 9	11- 11	13- 10
	Hem-fir #2	7- 11	10- 2	12- 5	14- 4	7- 4	9- 3	11- 4	13- 1
	Hem-fir #3	6- 2	7- 9	9- 6	11- 0	5- 7	7- 1	8- 8	10- 1
	Southern pine SS	8- 10	11- 8	14-11	18- 1	8- 10	11- 8	14-11	18- 1
24	Southern pine #1	8- 8	11- 5	14- 7	17- 5	8- 8	11- 3	13- 4	15-11

	Southern pine	#2	8- 6	11- 0	13- 1	15- 5	7- 9	10- 0	12- 0	14- 0
	Southern pine	#3	6- 7	8- 5	9- 11	11- 10	6- 0	7- 8	9- 1	10- 9
	Spruce-pine-fir	SS	8- 4	11- 0	14- 0	17- 0	8- 4	11- 0	13- 8	15-11
	Spruce-pine-fir	#1	8- 1	10- 3	12- 7	14- 7	7- 5	9- 5	11- 6	13- 4
	Spruce-pine-fir	#2	8- 1	10- 3	12- 7	14- 7	7- 5	9- 5	11- 6	13- 4
	Spruce-pine-fir	#3	6- 2	7- 9	9- 6	11- 0	5- 7	7- 1	8- 8	10- 1

NOTE: Check sources for availability of lumber in lengths greater than 20 feet.
For SI: 1 inch 25.4 mm, 1 foot 304.8 mm, 1 pound per square foot 0.0479kN/m^2. a. End bearing length shall be increased to 2 inches.

Appendix H: Cost Analysis Worksheet

Location	Cost/SF	SF	Year	Cost/SF (w/Inflation)	Regional Weight	Weigted Cost/SF	Total Cost
Freeport, ME	$ 230.00	3200	2006	$ 258.72	2	$ 517.44	$ 827,900
Charolette, VT	$ 196.00	2700	2007	$ 211.99	2	$ 423.99	$ 572,383
South Glastonbury, CT	$ 250.00	2966	2008	$ 260.00	2	$ 520.00	$ 771,160
Waitsfield, VT	$ 90.00	2000	2007	$ 97.34	2	$ 194.69	$ 194,688
Saxapahaw, NC	$ 158.00	2498	2007	$ 170.89	1	$ 170.89	$ 426,890
Columbus, OH	$ 150.00	1495	2008	$ 156.00	1	$ 156.00	$ 233,220
Urbana, IL	$ 94.00	1200	2003	$ 118.94	1	$ 118.94	$ 142,728
Weatherford, TX	$ 117.00	2038	2005	$ 136.87	1	$ 136.87	$ 278,948
Dexter, MI	$ 238.00	4010	2006	$ 267.72	1	$ 267.72	$ 1,073,548
Blacksburg, VA	$ 98.00	1038	2006	$ 110.24	1	$ 110.24	$ 114,426
Blacksburg, VA	$ 98.00	1360	2006	$ 110.24	1	$ 110.24	$ 149,922
Chino Valley, AZ	$ 90.00	3202	2005	$ 105.29	1	$ 105.29	$ 337,130
Redding, CT	$ 175.00	3489	2003	$ 221.43	2	$ 442.86	$ 772,572
Chebeague Island, ME	$ 178.00	2478	2004	$ 216.56	2	$ 433.13	$ 536,646
East Falmouth, CC, MA	$ 100.00	1041	2003	$ 126.53	3	$ 379.60	$ 131,720
Campton, NH	$ 92.00	3180	2004	$ 111.93	2	$ 223.86	$ 355,944
Epping, NH	$ 60.00	2270	2005	$ 70.19	2	$ 140.38	$ 159,335
Groton, NH	$ 173.00	3132	2006	$ 194.60	2	$ 389.20	$ 609,492
Chicago, IL	$ 169.00	1830	2003	$ 213.84	1	$ 213.84	$ 391,325
Bloomington, IN	$ 140.00	4300	2008	$ 145.60	1	$ 145.60	$ 626,080
Silver Springs, MD	$ 97.00		2003	$ 122.74	1	$ 122.74	$ -
Bowic, MD	$ 85.00	1900	2002	$ 111.85	1	$ 111.85	$ 212,523
Duluth, MN	$ 171.00	2000	2000	$ 243.39	1	$ 243.39	$ 486,773
Lonsdale, MN	$ 150.00	2700	2004	$ 182.50	1	$ 182.50	$ 492,744
Philadelphia, PA	$ 140.00	1680	2006	$ 157.48	1	$ 157.48	$ 264,568
Taylorstown, VA	$ 130.00	1900	2001	$ 177.91	1	$ 177.91	$ 338,037
Lansing, MI	$ 85.00	1400	2001	$ 116.33	1	$ 116.33	$ 162,860
Perkiomenvill, PA	$ 180.00	2016	2006	$ 202.48	1	$ 202.48	$ 408,191
Charleston, RI	$ 55.00	2600	2000	$ 78.28	2	$ 156.56	$ 203,534
Average	$ 138	2344	2005	$ 162	41	$ 163	$ 388,803