



# Green Infrastructure: The Landscape of Urban EcoHousing

# Green Infrastructure: The Landscape of Urban EcoHousing

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in partial fulfillment of the requirements for the degree of

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design for sun and wind, green roof, urban forestry, impervious surface

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# Abstract

## Green Infrastructure: The Landscape of Urban EcoHousing

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Cities are facing environmental crises like never before, with problems of excess water runoff, degraded water quality, air pollution, and energy use reaching critical levels. The development of urban areas and the built environment is the primary cause of these problems and the built environment needs to be a part of the solution. This design thesis project produces a prototype design for the Urban EcoHousing development on a city block in Alexandria, Virginia. Design goals for the project connect the “Ecological Services of the Urban Landscape” to the “Rights of the Urban EcoHousing Resident” to create livable green spaces that can serve ecological functions and give the residents spaces to use. A comparison study with a conventional housing development at the same location illustrates that ecohousing can meet the requirements of the conventional development while providing superior results for the residents and the environment.



## Acknowledgements

To my mother, for being my first garden teacher and giving me great encouragement to change my path in life.

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# Introduction

## Green Infrastructure: The Landscape of Urban EcoHousing

# Introduction

This document is a record of the thesis design project completed for a Masters in Landscape Architecture. The document describes the process of the project and the evolution of thoughts and ideas through the project.

The project goal and thesis statement is “Design the urban landscape as the green infrastructure providing ecological services to sustain people in the built environment.” The urban landscape is designed for a housing site in Alexandria, Virginia that has recently been built with a conventional housing development. The project design involves a process methodology to achieve the green infrastructure design.

Section 1 gives an overview of the concepts and background information for the project. Green Infrastructure is described in its early definition and current applications. The ecological services provided by the urban landscape are outlined in the areas of water quantity, water quality, air quality, and energy conservation. Design methods for green infrastructure, such as low impact development, green roofs, and urban forestry are described. Current directions in urban ecological landscape design and analysis show applications, design frameworks, and research that is taking place in the United States.

Section 2 gives an overview of the project. The site location is on four blocks in Alexandria, Virginia. The history of the site shown in maps, gives the evolution of the site from swamp to housing over two hundred years. The Urban EcoHousing project is introduced in this section. The Rights of the Urban EcoHousing Resident are described. Project goals and constraints are outlined. The comparison study with the conventional housing development is introduced in this section.

Section 3 steps through the design analysis for the project. A block form study of Old Town Alexandria shows comparisons and evolution of the block through the towns’ development. Analysis of sun, wind, and water gives a baseline for directional design based on the elements. A density analysis and block configuration study shows the evolution of the building design for urban ecohousing. Floor space and unit requirements are significant limiting factors in the design process. The final block configuration and unit layout is presented and compared with the conventional housing development.

# Introduction

Section 4 illustrates and describes the Urban EcoHousing project. The design overview shows the site plans at the ground level, garage level, and rooftop and canopy level. Sections, models, and 3d views enhance the understanding of the design. This section is organized by the five design goals of the project and the design implementation to achieve each goal. The five goals are:

- Provide Natural Heating and Cooling

- Maximize Green Space

- Minimize Impervious Surface

- Control Water Quantity and Quality

- Create Livable Green Space

Each goal section gives the methods to achieve the goal, and links the goal to ecological services and the resident's rights. Plans, sections, and 3d views illustrate the design. The comparison study with the conventional housing development and the ecohousing development shows differences in impervious surface, green space, winter shading, wind flow, tree canopy, and water runoff.

The conclusion shows a conceptual illustration of the single prototype Urban EcoHousing block design implemented over the four block site. Block comparisons and analysis diagrams complete the conventional and ecohousing comparison study. The simple methods and implementation of ecohousing are pondered to determine why more of these types of sites are not built.

# Thesis Concepts

Green Infrastructure  
Ecological Services of the Urban Landscape  
Design Implementation Methods  
Current Design and Analysis Examples  
From Concept to Design

# Thesis Concepts

Design the urban landscape as the green infrastructure providing ecological services to sustain people in the built environment.

## Urban Environmental Problems

The rapid growth and development of urban and suburban areas in the last half of the twentieth century has caused environmental problems like never before. Large areas of impervious surface, such as buildings, roads, and parking lots, cause vast amounts of storm water to runoff. The water runoff collects pollutants such as oil, salt, fertilizers, pesticides, animal waste, and general debris that flows into local streams and contributes to degraded water quality.

Air quality has deteriorated due to pollution emissions from cars and industry. The paved and built environment has created the 'Urban Heat Island' effect where temperatures in the city are higher than in surrounding suburban and rural areas. Energy use is increased and more demand is placed on mechanical air and heating to keep building temperatures comfortable. Providing solutions to these problems are critical to the environmental sustainability of our cities.

The landscape can and should play an integral role in the solution to these environmental problems. The value of landscape in cities has been known for centuries. Through time that understanding has been forgotten and revived in numerous iterations.

The landscape can be designed to ameliorate many urban problems and function as a green infrastructure. The landscape can help slow and absorb stormwater, protect buildings and outdoor areas from the heating rays of the sun and chilling winter winds, and help filter particles from the air around us. These functions of the landscape can provide a future cost savings to the property owner and municipality. The property owner will benefit from energy cost savings. The municipality will realize savings to stormwater management costs and future infrastructure capacity needs.

Cities must achieve certain air quality and water quality requirements under federal mandates. The Chesapeake Bay 2000 Agreement calls for water pollution reductions of 24% in nitrogen, 17% in phosphorus, and 13% in sediment loads by 2010 in urban areas. To achieve that reduction, stormwater management shall be implemented on 950,000 acres of existing developed urban land, 26% of the total watershed land area (Koroncai). The landscape can play a role in achieving these quality levels and must be considered more than an accessory or decoration. The landscape must be seen as a critical infrastructure that will realize long term benefit savings and value to water, air, and energy needs.

## The Green Infrastructure Movement

A recent movement considers the landscape as the 'green infrastructure' of a city. This movement is raising the value and significance of landscape in urban areas. Green infrastructure is a new way to express concerns that have been around for decades and even centuries. In this version it is the coalescence of many movements of the last few decades including rising environmental concern, need for smart growth and sustainable development, rising energy costs, and the acknowledgement of air and water quality needs in public planning. By defining the green spaces as infrastructure, it places green on equal level with other infrastructure, such as transportation, communication, energy, and water supplies.

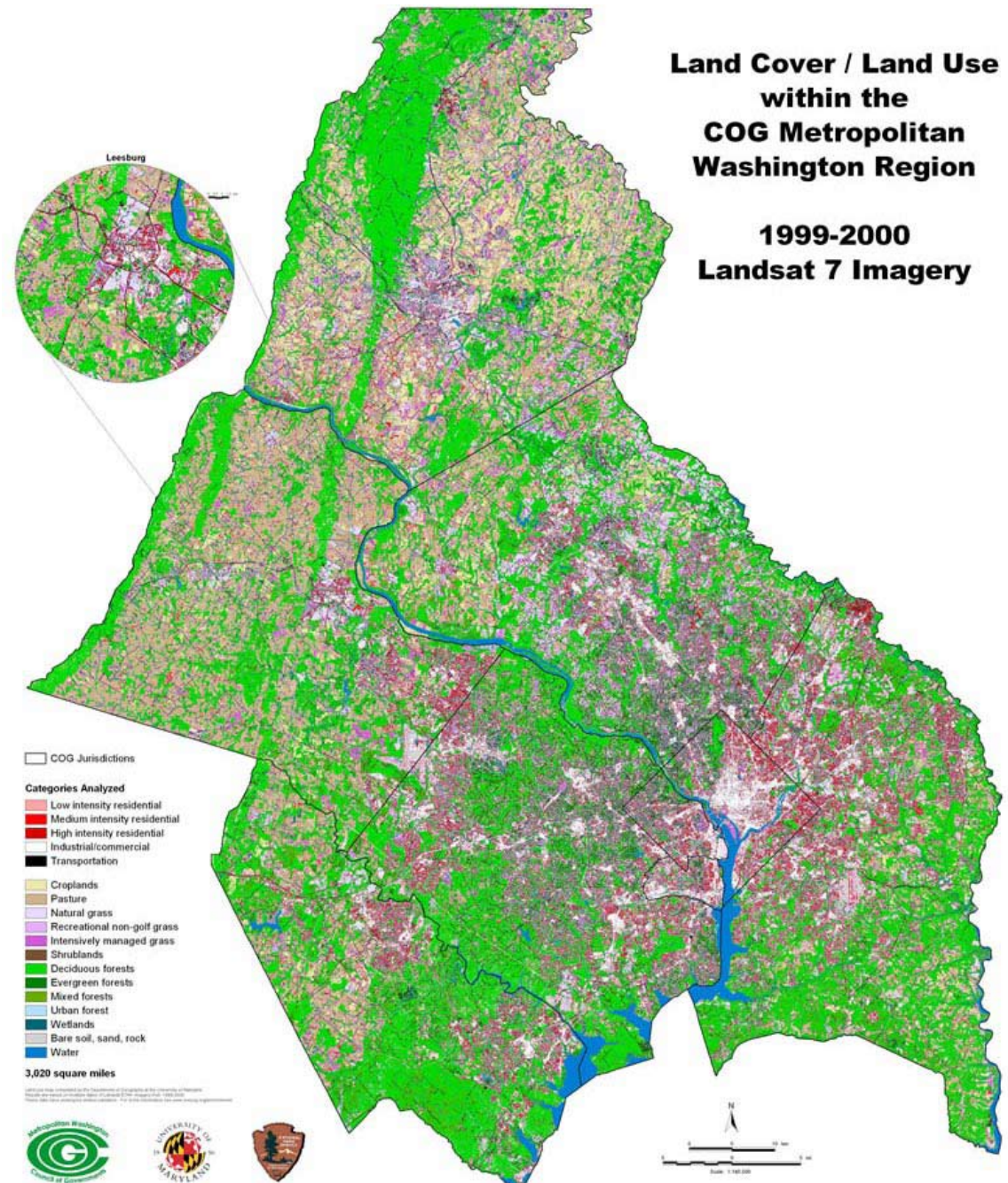
One green infrastructure movement is being led by the USDA Forest Service and promoted to local governments to look at the large-scale landscape. They promote the value of existing green space and the need to preserve green space prior to development. The definition for green infrastructure evolved from the President's Council on Sustainability and a working group formed by The Conservation Fund and the Forest Service in 1999. Their definition of green infrastructure is as follows (Benedict, 12):

“Our Nation’s natural life support system - an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks and other conservation lands; working farms, ranches, and forests of conservation value; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for America’s communities and people.”

Current green infrastructure efforts include regional, county and citywide mapping of existing green space. Local planning can aim to connect urban and suburban parks with waterways and natural areas. Mapping efforts allow local governments to determine which lands are valuable for preservation and which lands may be more suitable for development (Bolton).

## Washington D. C. Green Infrastructure Project

The Metropolitan Washington Green Infrastructure Demonstration project has goals to make green spaces an important part of land use planning in communities (Eugster). A mapping project created a green infrastructure and land cover map of the metropolitan region. The map was developed from Landsat satellite imagery data and displays twelve land cover types. This land cover map will show existing green space connections and enable analysis to determine potential future connections (LeCouteur). The Washington map project also produced a map of impervious surface cover and a map showing the increase in developed land from 1986 to 2000.



Washington Region Green Infrastructure Map  
(Metropolitan Washington Council of Governments  
and National Park Service, 2004)

## Ecological Services of the Urban Landscape

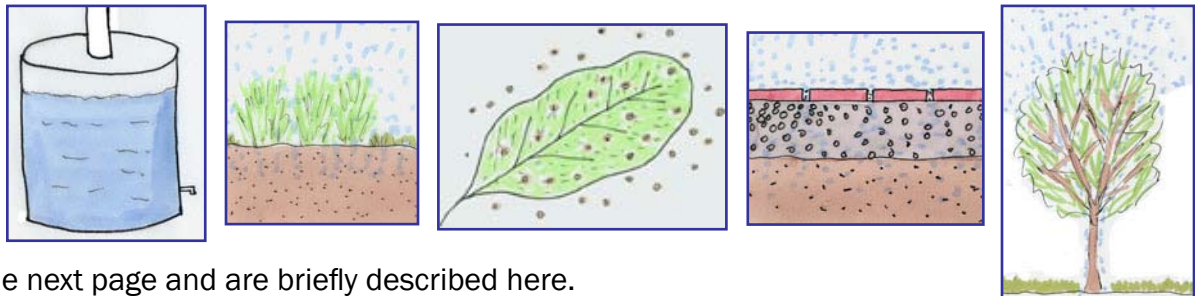
### Green Infrastructure Applied to the Small-scale Site

The treatment of the landscape as a green infrastructure also applies to the site-scale and individual land parcels in a city. The landscape can function in a critical way as other infrastructure of a city – roads, water, sewer, gas, electric, and communication lines. The landscape can be viewed as a series of components and processes that serve functions and provide services. The ecological services of the urban landscape can be categorized by water quantity, water quality, energy conservation, and air quality. The components of the landscape exist at each site and perform functions at that site. The ecological services of the urban landscape can apply to the site or to the larger urban area. Larger scale effects of ecological services will be seen once many small-scale implementations of green infrastructure occur. The ecological services of the urban landscape are listed in the boxes on this and the next page and are briefly described here.

Ecological Services of the Urban Landscape

Water Quantity  
 Reduce excess runoff through capture and infiltration  
 Capture water on site and reuse  
 Capture water in vegetation and release to air through evapotranspiration  
 Infiltrate water into ground through planted and pervious areas

Water Quality  
 Plants and soil act as filter to clean water  
 Plants capture particulates in leaves and stems  
 Soil captures particulates as water passes through



### Water Quantity & Water Quality

The urban landscape can provide services to control water quantity and improve water quality. The landscape can reduce excess runoff through capture and infiltration. Water can be captured on site and reused. Water is captured in vegetation and released to the air through evapotranspiration. Water that falls on the ground infiltrates into the soil and is absorbed by plant roots. Special areas can be designed to infiltrate the water. Water quality is improved as it passes through the landscape and is filtered by plants and soil. Plants capture particulates in leaves and stems and soil captures particulates as water passes through it.

## Energy Conservation

The urban landscape provides services for energy conservation. Desired affects are reduced energy use to cool in the summer and heat in the winter, and a pleasant outdoor environment at most times of the year. Landscape cools the surrounding areas through shade from trees and reflection of sunlight, providing lower temperatures under the tree canopy. As plants release moisture through evapotranspiration, the surrounding air is cooled. These cooling effects help reduce the urban heat island effect in cities. Vegetated layers, such as green roofs and green walls, provide insulation to buildings, lowering both heating and cooling needs. Winds can have large effects on heating and cooling, and plant placement can be designed to deflect or allow wind through a site.

## Air Quality

The urban landscape provides services for air quality. Air quality issues involve particulates and excess carbon dioxide, sulfur oxide, nitrous oxide, and other gaseous pollutants. Plants can capture particulates in leaves and stems which are then washed to ground and absorbed in soil. Plants can absorb SO<sub>x</sub>, NO<sub>x</sub>, and other gaseous pollutants in leaves during photosynthesis. Plants and soil can store carbon from CO<sub>2</sub> during photosynthesis process. This process is known as carbon sequestration.

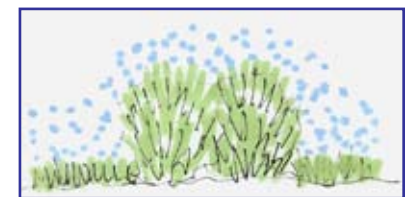
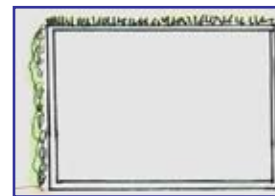
## Ecological Services of the Urban Landscape

### Energy Conservation

- Reduce Urban Heat Island effect
- Trees provide shade and reflect sunlight
- Temperatures reduced under tree canopy
- Plants cool surrounding air through evapotranspiration
- Vegetated layers provide insulation to buildings
- Plants can deflect or allow wind

### Air Quality

- Plants capture particulates in leaves and stems
- Particulates are washed to ground and absorbed in soil
- SO<sub>x</sub>, NO<sub>x</sub>, other gaseous pollutants are absorbed in leaves during photosynthesis
- Plants and soil store carbon from CO<sub>2</sub> during photosynthesis process



## Implementation Methods for Green Infrastructure Design

### Site Analysis

The landscape functions within basic earth conditions. The soil type allows different uses and supports various plant types. A site receives sunlight from different directions through the day and year. Winds flow through the site, in somewhat predictable directions. Water falls on the site in rain and snow, flows through the site in streams, and flows below ground through the soil. A landscape must be designed based on the soil, sun, wind, and water conditions that exist. Placing a building on a site may alter the conditions on-site and off-site and may create needs to protect the building from or expose it to those conditions.

To design in conjunction with the earth's conditions means that a site can be functional within its ecosystem. The soil should be analyzed to understand its structure, nutrient levels, water permeability and absorption capacity. Precipitation data should be used to know how much water a site will receive and when, how much can be captured, and how much should be treated to improve water quality. The landscape can be used to slow water as it reaches the ground, absorb water to be transpired into the air, and hold water so it can permeate to the ground. Hardscape elements can be used to capture or direct water in a site, allow water to permeate the soil, and reduce sunlight absorption or reflection.

Solar conditions should be analyzed to know what areas need shading in summer and sunlight in winter. Wind conditions will determine areas that need blocking or deflecting from cold winter winds or exposure to cooling summer winds. Soil, water, and light conditions should be critical in making plant choices for a site. The benefits to air quality and wildlife habitat are the indirect results of landscape implementation for other considerations.

Anne Whiston Spirn brought many of these issues into the mainstream in her 1984 book, *The Granite Garden*. She promotes public spaces designed for human comfort, because so many places exist where it is not pleasant due to temperature extremes or wind conditions. If landscapes are designed with the soil, sun, wind, and water conditions as a critical component, comfort to humans can be realized as a result.

These methods can be considered basic site analysis and principles of good landscape architecture. They need to be seen holistically as contributing to the functioning of a site. However my observations are that these basic principles are not always the foundation of every design. More often, projects are cited for how they use the sun, wind, and water conditions in designs as an exceptional part of the design, rather than a standard practice.

## **Design Methods**

What are the methods to implement a landscape design as green infrastructure? The site analysis inputs of soil, sun, water, and wind conditions give important baseline information. The landscape methods used should target enhancement of the landscape's capability to perform ecological services. Reducing impervious surface, increasing pervious area, and increasing green space enables several of the ecological services. Landscape methods to control stormwater runoff, quantity and quality are predominant in this category.

## **Low Impact Development**

A relatively new design philosophy, from about the last ten years, is low impact design or low impact development, known as LID. The intention of LID is to control stormwater runoff at the site instead of sending it through pipes to be collected, treated, and distributed elsewhere. In undeveloped and very low density areas, the goal is infiltrate water into the ground and to control runoff to predevelopment levels. In urban high density areas, the goals are to capture water runoff, slow the runoff from the site, and clean the water before it leaves the site. Methods are used to achieve these goals as space and conditions allow.

Water can be captured on site in storage containers, commonly known as cisterns, and reused in the landscape or building. Water can be absorbed in vegetated areas on the roof and ground, capturing some of the water, and slowing runoff. Water can be collected from roofs, sidewalks, roads, and parking areas and diverted to bioretention areas. Bioretention areas have deep layers of soil and aggregate planted with moisture loving plants to absorb water, infiltrate it into the ground, and filter nutrients and pollutants out of the water before it flows into a water way. Some bioretention areas have under drains to release excess water, and some do not. If the infiltration capability of the soil is sufficient, an under drain may not be needed.

Water can also be infiltrated into trenches filled with aggregate to absorb into the soil. Water can be collected in underground storage containers to be released after the peak flow of a rain storm has passed. Paved areas can be made permeable through the use of paving blocks, permeable concrete, and permeable asphalt. Permeable paving blocks can be special shapes with large areas between the blocks, or brick and stone pavers, with gaps between the blocks to allow the water to flow through. Permeable asphalt and concrete are aggregate mixes that allow water to flow through, and which meet weight and durability requirements.

## **Green Roofs**

Green roofs are vegetated areas on the roof of a building. Green roofs can absorb stormwater, reduce runoff from the roof, provide an insulation layer to the building which reduces energy costs, and provide a place for wildlife to nest. Green roofs can be classified as extensive or intensive. Extensive green roofs have thin layers of soil planted with low growing drought tolerant plants, and minimal weight loads on the roof (< 20 lbs). Intensive green roofs have larger amounts of soil to support trees, shrubs, and herbaceous plants, and larger weight load requirements. Intensive green roofs are often called roof gardens, and may be occupied by people. Extensive green roofs may have space for people to gather, but that is not their primary goal.

## **Urban Forestry**

Urban Forestry is the practice, establishment, maintenance, and study of trees in cities and developed areas. Trees in the built environment exist in very different conditions and must be managed in different ways than trees in natural or dedicated forest areas. As green space is squeezed out of the urban environment, trees have less area for their roots to grow. Analysis by Jim Urban shows that the ultimate size of a tree is directly related to the amount of root space the tree has to grow. A tree's roots will fill a four foot by four foot (4' x 4') planting box in four years. "To grow a tree 25 inches in diameter, more than 1000 cubic feet of rooting space is needed" (Moll & Urban 134). This is equivalent to a twenty foot by twenty foot (20' x 20') growing area. A tree grown in a typical urban space will never reach a size where it can give the shade and ecological services it is capable of giving. Urban trees must be given more root growing space to grow to larger sizes.

Since roads and sidewalks surround most urban trees, the only way to give the trees extra growing space is to provide it beneath the hardscape. Continuous trench plantings or root path trenches are construction methods that provide growing space beneath sidewalks. The continuous trench provides a soil growing area beneath a reinforced paved sidewalk. Root path trenches provide small trench areas for the roots to expand beyond the tree box and allow water and air to reach the roots. Structural soil is a planting medium that can be used with the continuous trench without the need for reinforced paving (Thompson & Sorvig, 120-21). Nina Bassuk and others at Cornell University Urban Horticulture Institute developed a structural soil mix (CU-Soil) that uses crushed rock to provide the load bearing capacity needed for sidewalks. The compacted rock provides pore space for soil, air, and water, and allows the tree roots to grow through the spaces (Bassuk, 1999). All of these methods allow the trees more root space to grow, thus allowing the tree to grow larger and provide more ecological services.

## Current Design and Analysis Examples

### **Landscape Valued as Economic Benefit**

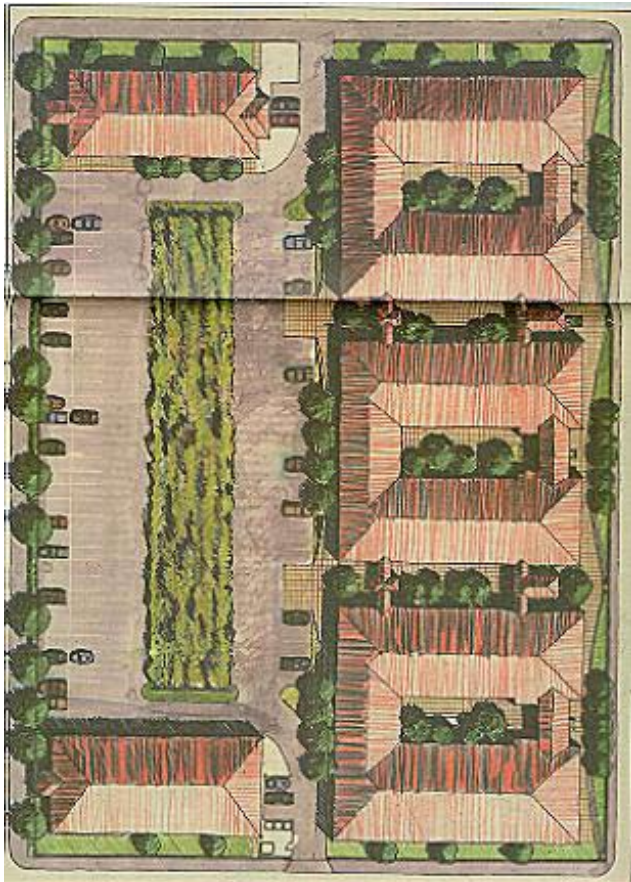
To promote the value of the landscape as a green infrastructure, the value must be measured in economic terms. Landscape architects need to be able to quantify the cost savings and economic benefits to promote the value of the landscape. This can give a value and purpose to the landscape that developers and municipalities might not otherwise have. Research is being conducted by federal organizations, universities, professional organizations, and environmental advocacy groups. Research areas include the urban forest and trees, vegetated and other low impact design stormwater management methods, and green roofs.

The researchers are looking at quantifying the amount of stormwater that is captured or infiltrated, the pollutants that are removed from stormwater, air particles that are captured by vegetation, and temperature changes from vegetated structures. These quantifications can be converted to a dollar value in terms of the cost of mechanically capturing and cleaning stormwater and air particles, and mechanically heating or cooling. These benefits on the site or per component will be on a small scale and can be extrapolated to a larger scale. The cost and benefits are the arguments that must be made to the government and developers for small-scale implementations to be done.

A companion project to this Landscape Architecture thesis is a major paper for a Masters in Natural Resources. This paper will examine the research that these organizations are conducting, the methods and models they are using, and the results being produced. The coalescence of design methods with economic benefits will be the impetus to preserve and revive the urban landscape. This movement is at the early stages and it has tremendous potential. The examples from the Los Angeles Tree People and the American Forests Urban Ecosystem Analysis show that the design of green infrastructure can give significant economic benefits. The design methods from Sustainable Urban Landscapes and Community Greens show how green space can be designed in urban areas. Landscape architects can use the ecological quantification and economic benefit data to promote their profession and the importance of the landscape in urban areas.

## Los Angeles Second Nature Design Charrette

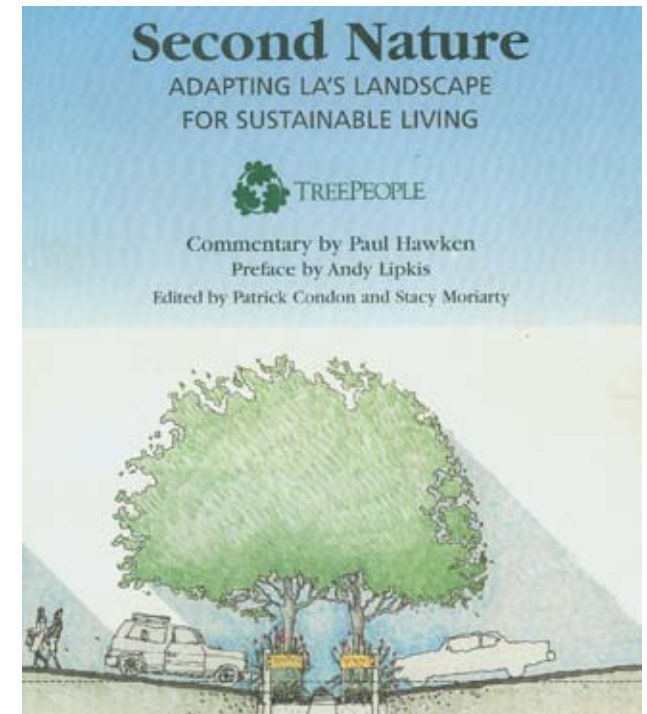
TreePeople is a Los Angeles group aimed at bringing citizen involvement into the improvement and care of the urban forest. They have recognized the value of the landscape and its benefits at the site scale. TreePeople organized a project to bring together local, regional, and federal agencies to promote a systematic approach to integrating resource management and building a sustainable environment. Their project goals included looking at sites “as miniature urban forest watersheds” and emphasizing the “economic viability” of the redesign approaches (Condon, 1999, 12).



Multi-Family Housing Site Plan, Second Nature Design Charrette  
(Copyright © 1999 by Andy Lipkis, TreePeople)

TreePeople sponsored the Second Nature Design Charrette in Los Angeles in May 1997. It brought together multi-disciplinary teams from landscape architecture, architecture, civil engineering, horticulture, and urban forestry. The teams created conceptual designs for five sites: single-family home, multi-family complex, commercial and retail center, industrial site, and public school. (Condon, 1999)

The teams addressed five environmental challenges for Los Angeles: excessive consumption of potable water, flood management, water pollution, building energy use, and green waste. Site solutions included reduced paved areas, increased plant cover, cisterns for water collection, graywater irrigation, vegetated swales and filter strips, bioretention, subsurface infiltration, trees and vine covered trellis over parking area, and semi permeable paving blocks. The single-family home design was implemented and it is used as a demonstration site. The other designs remain conceptual ideas to be used as templates for future designs. (Condon, 1999)



Second Nature Design Charrette, Book Cover  
(Copyright © 1999 by Andy Lipkis, TreePeople)

The Second Nature Design Charrette addressed the cost-effectiveness of the solutions in each of its five design proposals. They addressed several areas of cost savings for the multi-family development as shown in the chart below, including irrigation water use, flood management, water pollution, air pollution, and green waste. Domestic water use is beyond the scope of this thesis project, but did contribute 43% of the overall cost savings. The design proposal was able to quantify a 2.4 million dollar value over thirty years versus \$900K of construction and design fees upfront (Condon, 1999, 62-63). This shows tremendous value for implementing these practices on the multi-family housing site.

Issue	Amount Changed	Value / year	Value / 30 years
Irrigation water use	80% reduction From 75 gal/day/dwelling unit to 15 gal/day/dwelling unit. <sup>25</sup>	\$28,700	\$861,000
Domestic water use	40% reduction From 181 gal/day/dwelling unit to 109 gal/day/dwelling unit	\$34,700	\$1,041,000
Flood management	30% reduction (By holding 0.84 acre feet on-site during a 133-yr. flood emergency) <sup>26</sup>	\$3,320	\$33,200
Water pollution	Capture and treat 100% of first-flush rain	\$1,760	\$52,800
Air pollution	Tree canopy increased from 7.5% to 29% (35 trees @ 16' canopy diameter)	\$3,530	\$105,900
Green waste	100% reduction All green waste recycled on-site	\$10,640 <sup>27</sup>	\$319,200
Total Value of all remediation for 3.37 acre site over a thirty-year period =			\$2,413,100

Benefit Analysis, Multi-Family Site Plan, Second Nature Design Charrette (Copyright © 1999 by Andy Lipkis, TreePeople)

### **American Forests Urban Ecosystem Analysis**

A national organization, American Forests, is working to “protect, restore, and enhance” trees and forests and has a special program for urban forests. They have conducted urban ecosystem analysis in more than forty cities in the last several years. The urban ecosystem analysis documents tree cover loss at the city or regional scale and determines the ecological services of the urban forest and other vegetated landscapes. American Forests has created the CITYgreen software to calculate the economic value of trees for stormwater control, water quality, air pollution reduction, carbon storage, and energy conservation.

The CITYgreen software is an application of the ArcView geographic information system software and uses models developed by or adapted from federal agencies and universities. The software calculates the volume of storm water the tree cover intercepts and what the dollar cost would be to retain that water. It calculates the amount of pollutants and particles that can be captured by tree canopy from stormwater and air flow. The amount of atmospheric carbon that is converted and stored annually in the urban forest is calculated. Energy savings is calculated for buildings based on the size and proximity of a tree to a building and how much shade it will provide. The software models are used in the urban ecosystem analysis to show the value of the urban green infrastructure at a larger scale. The methods and software can be used to calculate landscape value on a small-scale site. These concepts, models, and quantification of the landscape as green infrastructure are an important progression in the movement to place an economic value on the landscape. (AF, Citygreen)

American Forests conducted an Urban Ecosystem Analysis on Washington, D.C. in 1999 and 2002. The 1999 analysis used satellite imagery to determine that tree canopy in the District of Columbia declined from 37% in 1973 to 21% in 1997. This analysis determined overall value of trees to stormwater management and air quality in the city (AF, 1999). The 2002 analysis looked at the metropolitan regional area of 636 square miles. It evaluated tree cover and ecological benefits for 102 communities in the area. Alexandria was determined to have 34% tree canopy, 6% urban land use, 44% impervious surface, 14% open space, and 2% water. Alexandria’s trees are estimated to provide \$868K to air quality services and \$44 million to storm water management services (AF, DC, 2002).

## Sustainable Urban Landscapes

*Sustainable Urban Landscapes*, a site design manual developed by Patrick Condon and others at the University of British Columbia, is a compendium of design charrettes and design methods used to create design guidelines for urban communities. The manual addresses design methods and approaches at four scales of a site: the district, corridor, block, and parcel. The design philosophy addresses green infrastructure, social infrastructure, movement, and cost as the tenets of sustainability. The design principles to create a center, layer the systems, connect the flows, and make it home, give an integrated approach to sustainable communities. (Condon, 2003)

The design guidelines, especially at the corridor, block, and parcel scale, inspire the design goals and methods used in this thesis project. The design guidelines used in corridor and block design to encourage social infrastructure, include public space on each block and centering neighborhoods around social space. To address green infrastructure, guidelines include managing stormwater on the block and moving it along the street, and creating urban forests and urban gardens. Guidelines for movement encourage safe and comfortable streets, with a sense of enclosure, encouraging the flow of people within blocks, and wise placement of parking. Sites can achieve multiple purposes by layering functions in the open space. (Condon, 2003)

Design guidelines at the parcel scale direct both the building and site structure and function. The design should provide a variety of housing types, layer the living space within a parcel, and provide a structure that fits within the community. To support social infrastructure, houses shall have a front door on the street and provide semi-private open space for each unit. To support green infrastructure, the guideline to minimize hard surface includes building up, not out, and reducing driveways. Sites can be designed as smart parcels, which control stormwater on site with trees, infiltration areas, and green roofs. Smart parcels can reduce energy use and provide energy production on site. (Condon, 2003)



Initial Design Ideas for Blocks Designed as Green Infrastructure

### **Community Greens**

Community Greens are shared green spaces in urban blocks that are used by the residents of the block. An organization of the same name is working with local governments and neighborhoods to help create or transform urban spaces into community amenities. Community greens can be created through shared spaces from existing back yards, from converted alleys, or by design in new communities (Herrod). Community greens can be described by three defining characteristics: the green is at least partially enclosed by the housing units, the green is not a public space and is owned or managed by the residents, and the green is easily accessible to all residents (Inerfeld).

At Chandler's Yard in Baltimore Maryland, a common courtyard was created at the new development by merging some of the backyard spaces of the surrounding houses. At Stoney Creek Apartments in Livermore, California, the units are oriented to interconnected courtyards, with patios and balconies on the courtyards. Montgomery Park in Boston is a century old park that was reconnected to the houses in the 1970's. The residents converted the alley to create green connections from the backyards of eighty-five houses to the one-third acre park. The residents maintain the park, and it is a popular play area (Community Greens).

The Community Greens organization cites many benefits to the residents, neighborhood, and city by creating common green spaces. Community greens create strong neighborhoods by providing a shared space where residents can interact. They can contribute to a cohesively aesthetic block and give the residents access to natural areas. Children have a safe and nearby place to play and residents have spaces to relax alone or with other people (Herrod).

## From Concept to Design

These concepts form the basis for a landscape design project. The landscape will be designed as the green infrastructure at the site scale. The ecological services of the urban landscape will be used as guidelines for what the urban landscape can achieve. The site will be investigated through the green infrastructure site analysis methods of sun, wind, earth, and water. The site design implementation methods of low impact development, green roofs, and urban forestry will be included where appropriate. The case studies in urban environmental design inspire a systematic and comprehensive approach to the site design.

I choose to design Urban EcoHousing in Alexandria, Virginia. Housing has sparked my interest through my education because of the complex views people have toward housing. American society is moving toward bigger houses that cost more to build and maintain, yet also separating people from their neighbors. People want to have a large space to live, but do not want to care for the surrounding land. Urban housing is getting larger, but also being spaced closer together. As more houses or units are placed on smaller pieces of land, the green space loses out. Areas where back patios or small gardens used to occupy are now given to paved parking and driveways.

In landscape architecture, residential landscape design is often seen as a simplified application of skill, and delegated to those without a full degree. Yet people spend the most time in the place they live. Parks, plazas, and shared urban and natural spaces are wonderful. However, in the busy lives people live today, some people never get beyond their immediate surroundings. I had not seen any landscape projects that dealt with housing in my graduate school experience, so I felt this was an important topic to address.

The following sections will show a methodical approach to green infrastructure design. The unique attributes and requirements of urban housing will be addressed and resolved. To show the differences and benefits of an ecohousing design, a comparative analysis will be done. The ecohousing design will be evaluated against a conventional housing design, typical of many current and new urban housing developments. The design methods will be described such that they can be used in other similar urban landscape and housing design projects.

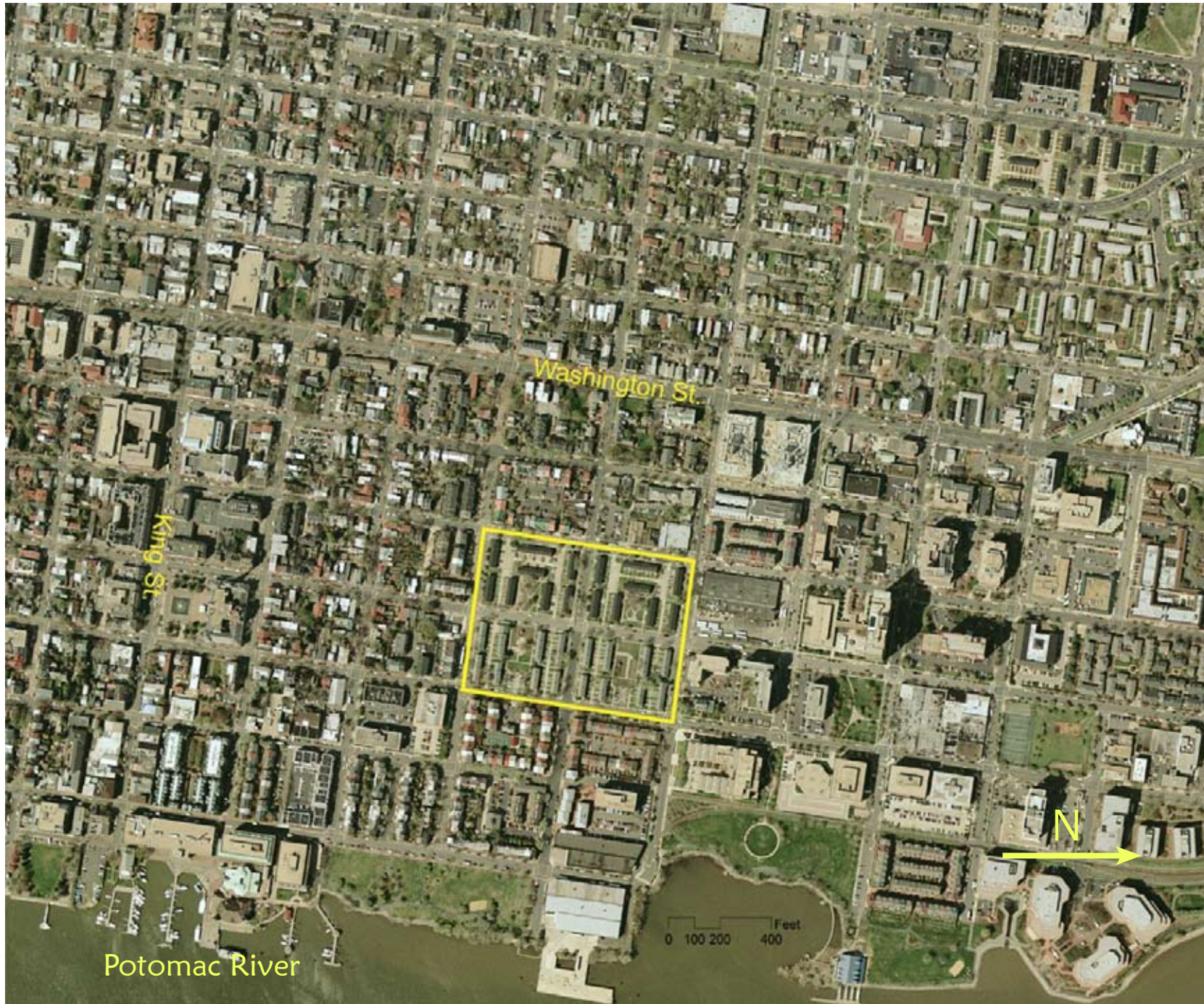
Design the urban landscape as the green infrastructure providing ecological services  
to sustain people in the built environment.

# Project Overview

Site Location

Site History

Urban EcoHousing



### Alexandria, Virginia

The project site is a four block area in the Old Town section of Alexandria, Virginia. The Old Town area is a popular area to live, with quiet tree lined streets, many historical buildings, and several parks along the Potomac River. The area attracts many visitors to its upscale shops and restaurants. The site is in a highly desirable area just a few blocks from the Potomac River and the vibrant central district of Old Town along King and Washington Streets.

Orthographic image,  
(City of Alexandria GIS Data)



Orthographic image, (City of Alexandria GIS Data)

## Site Context

The site is bounded by Princess Street, North Pitt Street, Pendleton Street, and North Fairfax Street. The surrounding blocks are primarily residential. The houses vary in size and age, from two and three story eighteenth century townhouses, to larger three story units from the 1970's and 1980's, and tall four story townhouses built in the last ten years. Surrounding blocks also contain small retail business, city government buildings, mid-rise apartment buildings, and a Metro bus depot.

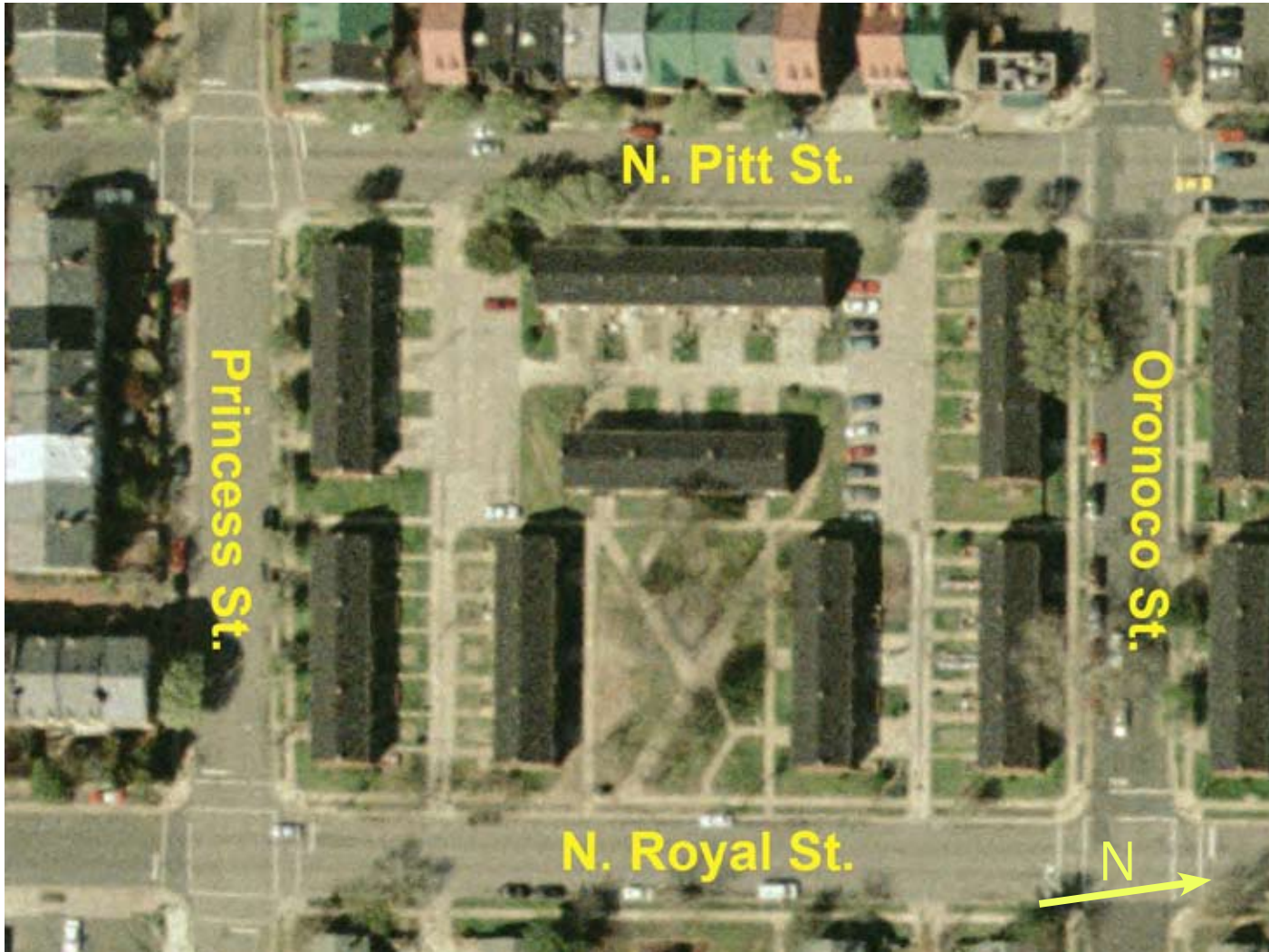


Princess Street

N. Fairfax St.

N. Royal St.

N. Pitt St.



Orthographic image, (City of Alexandria GIS Data)

### Block Development

The site has been used for housing and business for over two hundred years. Federal Housing projects were built in the 1940's and 50's on the four blocks of the site. In 2003, the two western blocks were cleared to build a new townhouse development with market rate sale units and affordable rental units.

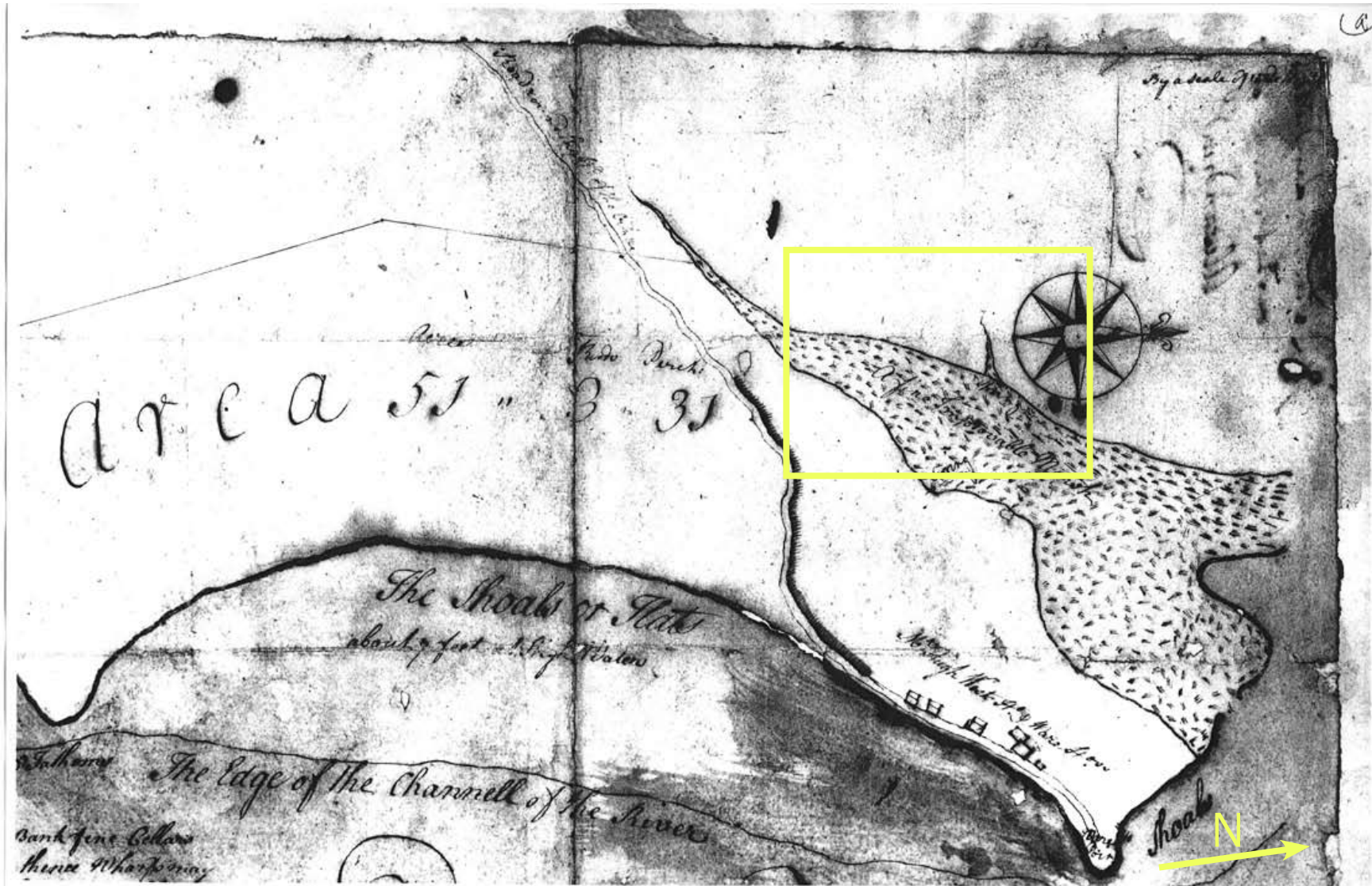
### North Pitt Street



Princess St.

Oronoco St.

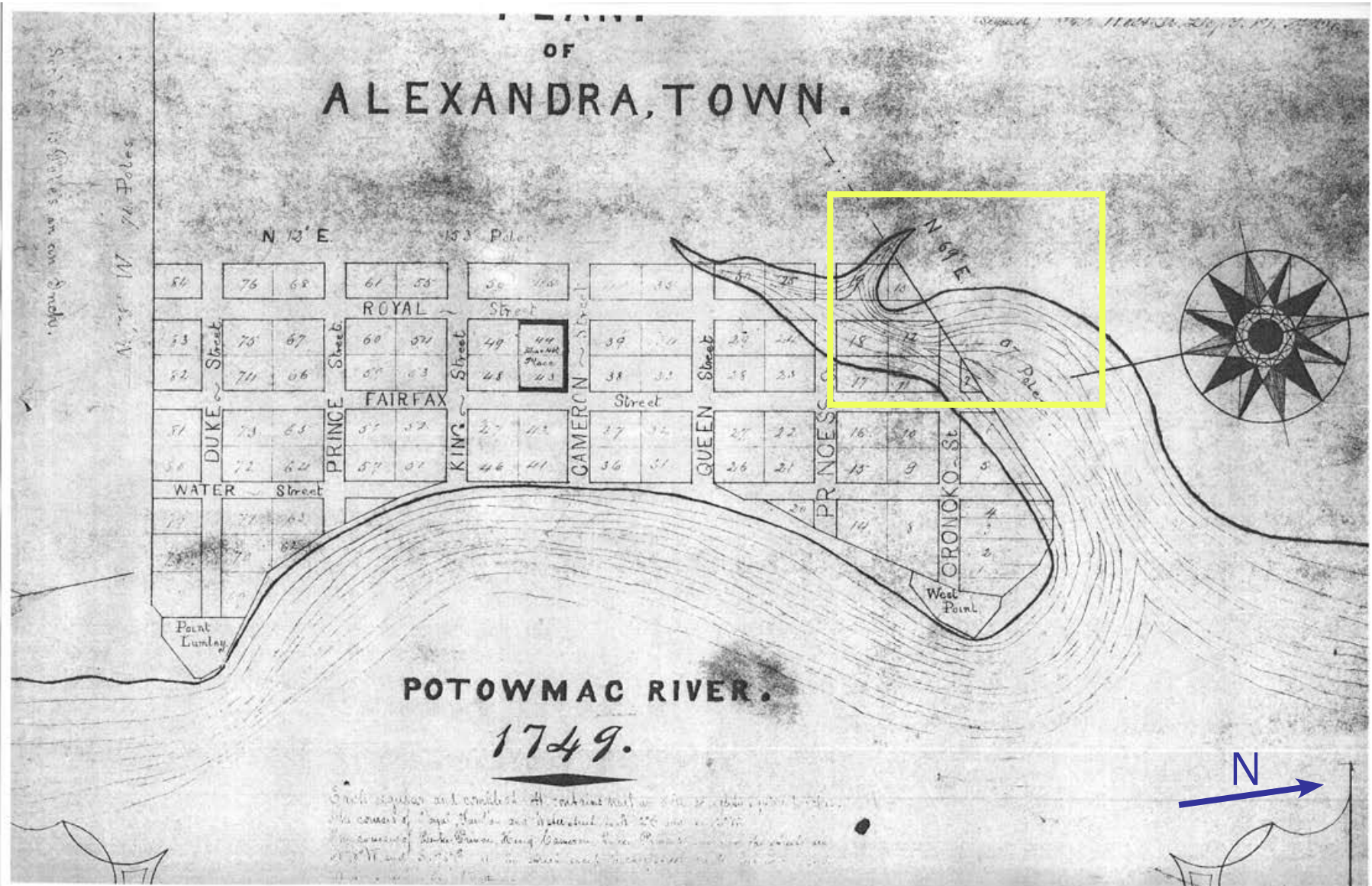
Pendleton St.



*Plat of land where on stands the town of Alexandria, 1748*

## Prior to Settlement

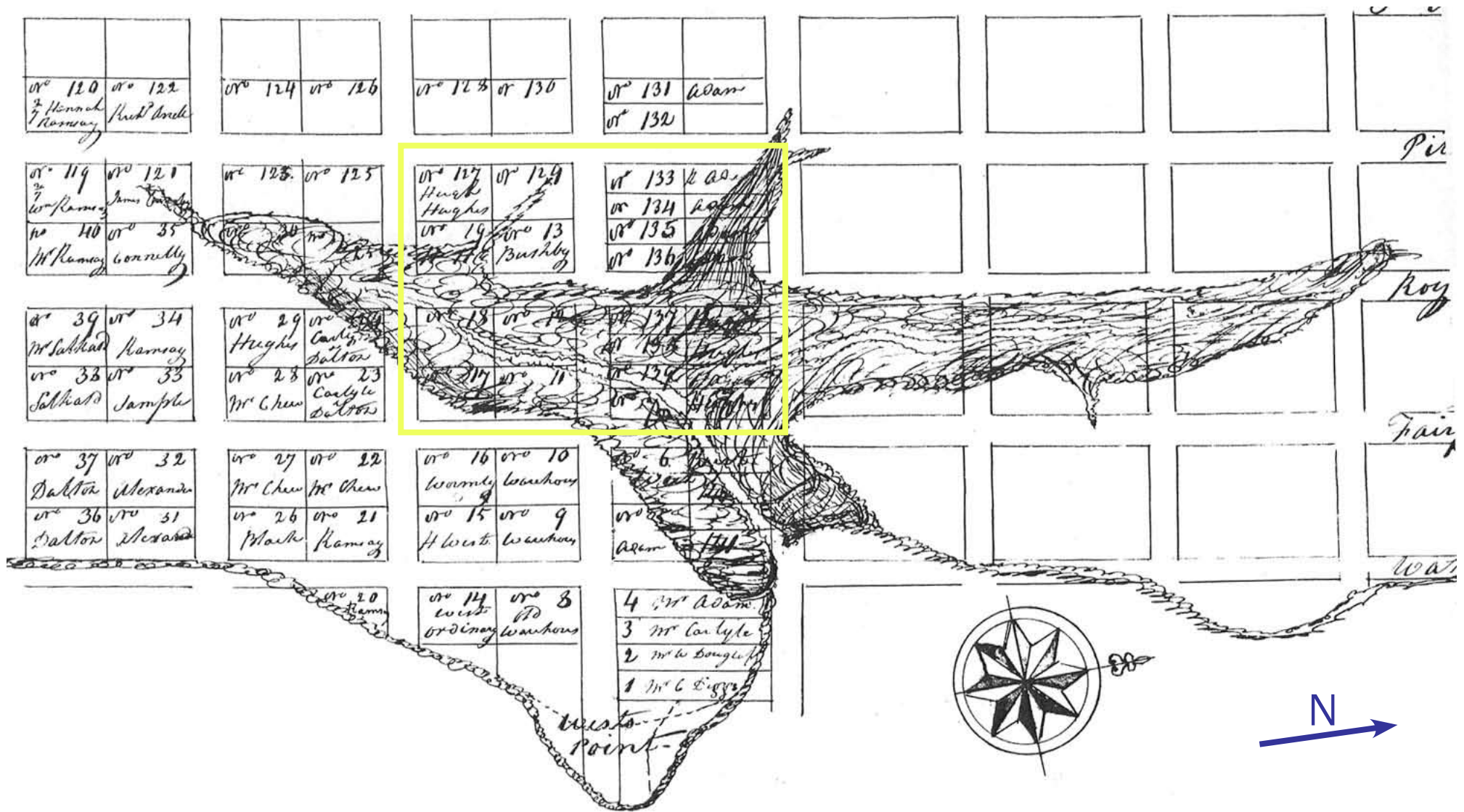
The City of Alexandria was settled along the Potomac River in Virginia. This map from 1748 shows the area prior to development. The map notes “a fine improvable marsh” in the area of Oronoco, the general area of the project site. The marsh and streams will be problematic for development for nearly two hundred years.



Plan of Alexandria Town, Potowmac River, 1749.

## Original Town Layout 1749

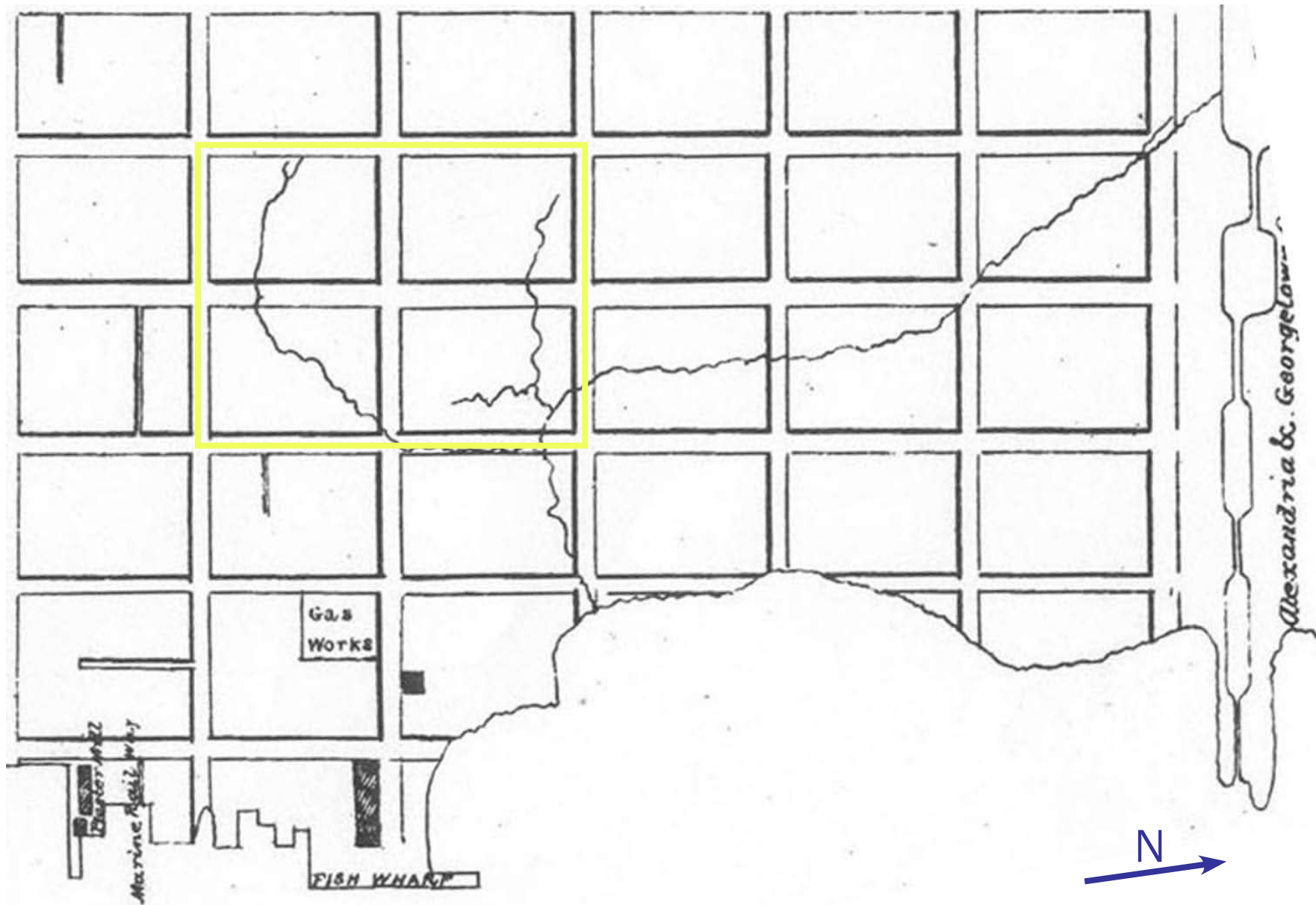
The City of Alexandria was laid out in 1749. The two southern blocks of the project site were part of the original 1749 city plan. The site is inland of Oronoco Bay and shows the water flow through the site.



Copy of the Original Plot of the Town of Alexandria, 1790?

1790's

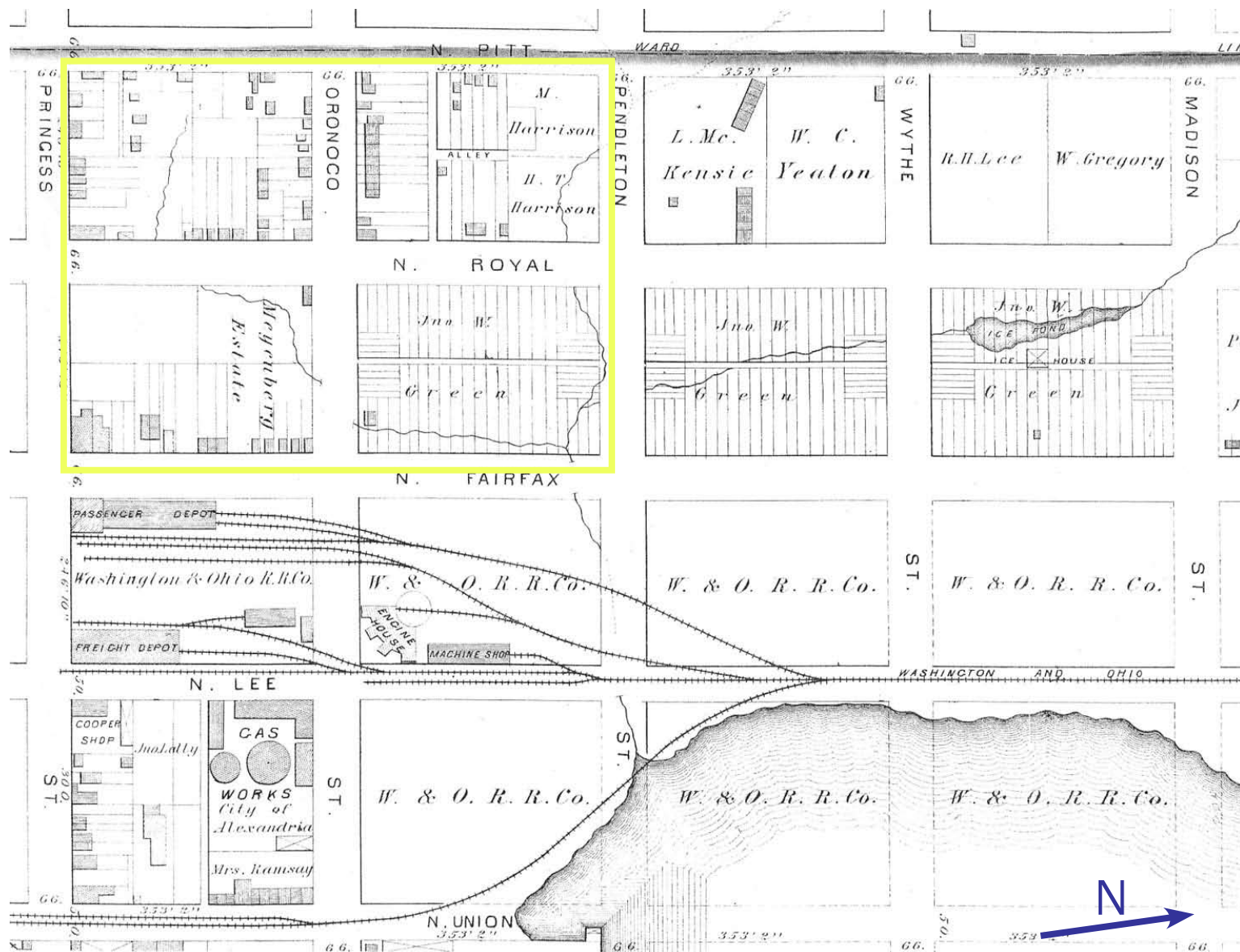
The map from the 1790's shows the extended town plan and new allotments. The four blocks of the site of have lots laid out, although the area is shown as marsh with streams running through the site.



Plan of Alexandria showing the end of the Alexandria Canal, 185?

### 1850's

This map from the 1850's shows streams flowing through the site into Oronoco Creek, which flows into the Potomac. The site blocks were home to African American freed people during and after the Civil War (Cressey).



Part of Ward 2, City of Alexandria, Plate K. (C.M. Hopkins, 1877)

### 1877

The 1877 Hopkins map shows streams flowing through the site and describes buildings on the site as “cheap residences”. The 1920 Sanborn map (not shown) shows the northeastern block as a city dumping ground. Federal housing projects were built on the four block site in the 1940’s. This is the first notable structure built on the swampy northeastern block.

As older housing is removed and new housing built in the City of Alexandria and cities everywhere, there is an opportunity to make great changes in the way people live. Housing can be designed in a way to make better buildings and surroundings in which people live, and lessen the impact of built structures on our natural environment. Unless this is done by a proactive developer or required by the municipality, buildings will continue to exist as disconnected structures from their surroundings, and vast areas of impervious surface.

The new conventional housing development on Princess St. and N. Pitt Street in Alexandria contains fifty market rate sale townhouses and twenty-six affordable rental units per block. The sale unit sizes vary from 1900 to 2200 square feet, with two 2700 and two 3500 square foot units. The rental units range in size from 800 to 1300 square feet. The units have little or no green space outside the units and some units do not have any private outdoor space. There is a small common green area on the interior of the block. One set of buildings has units built back to back, providing windows only on one side of the units. Parking is primarily in under the structure with two access drives (similar to alleys) on the block. The access drives contribute to the sites' 86% impervious surface rate.

The new development is built on two of the four block site. It is anticipated that the two remaining blocks of federal housing will be replaced in the near future with a similar townhouse development. This project looks at the entire four block site as an area for redevelopment in the hopes that future building will follow the green infrastructure and urban ecohousing methods.

Observation of the conventional housing design triggered several questions and issues about how people can and should live in a city. The "Rights of the Urban EcoHousing Resident" is a list of items or abilities that a resident should have living in an urban area. This list of rights is by no means all inclusive, but limited to what a landscape design for green infrastructure can accomplish.

### Rights of the Urban EcoHousing Resident

All Housing units shall have:

Winter sun in their window

Shading from summer sun

Natural air circulation

Views to common green space

Private outside space

Air circulation through housing site

Common green space near unit

A place for children to play

Ground level space is free from cars

## Project Goals

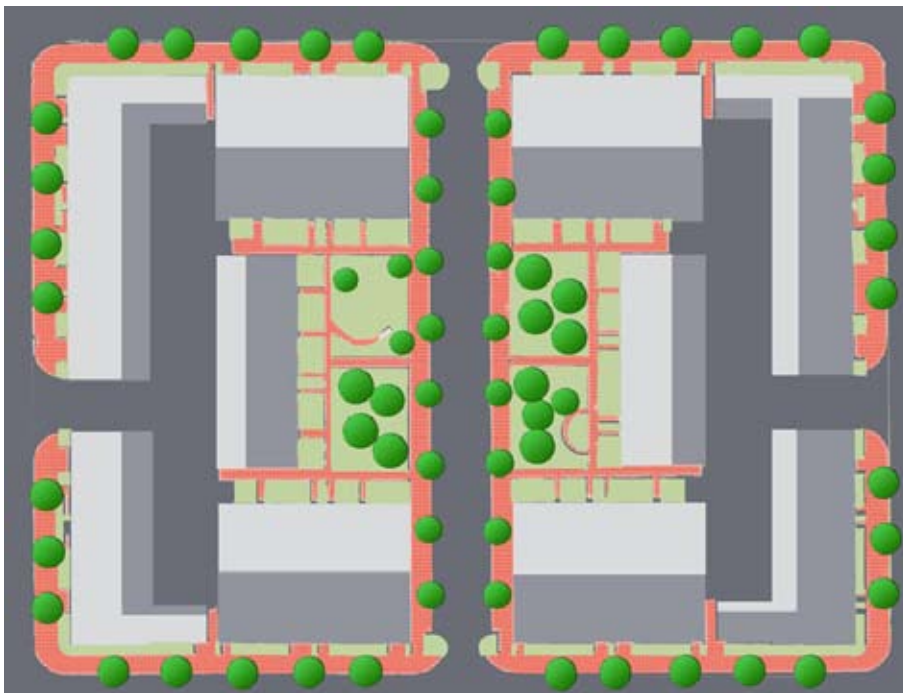
- Design a housing development on a block in Alexandria with landscape as green infrastructure
- Design a single block as a design prototype
- Show comparisons of Urban EcoHousing to the conventional housing development
- Implement the block design conceptually over a four block site
- Develop design goals using Ecological Services of the Urban Landscape and Rights of the Urban EcoHousing Resident

Parameters of the design project will provide several constraints and limitations. The Urban EcoHousing design will meet the square foot and unit requirements of the conventional housing development and provide equivalent parking spaces. The project includes designing the building placement, but the building interior layouts and building facades will not be designed.

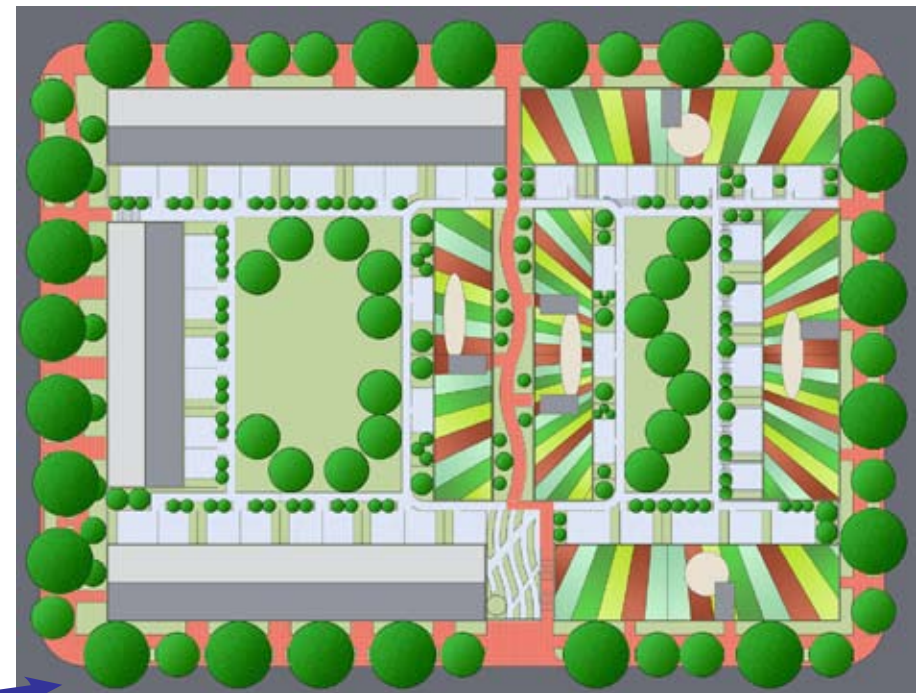
## Urban EcoHousing Requirements

- 142,000 Square Feet Unit Space
- 76 Units of Equivalent Size and Number to the Conventional Development
- 188 Parking Spaces

### Conventional Housing

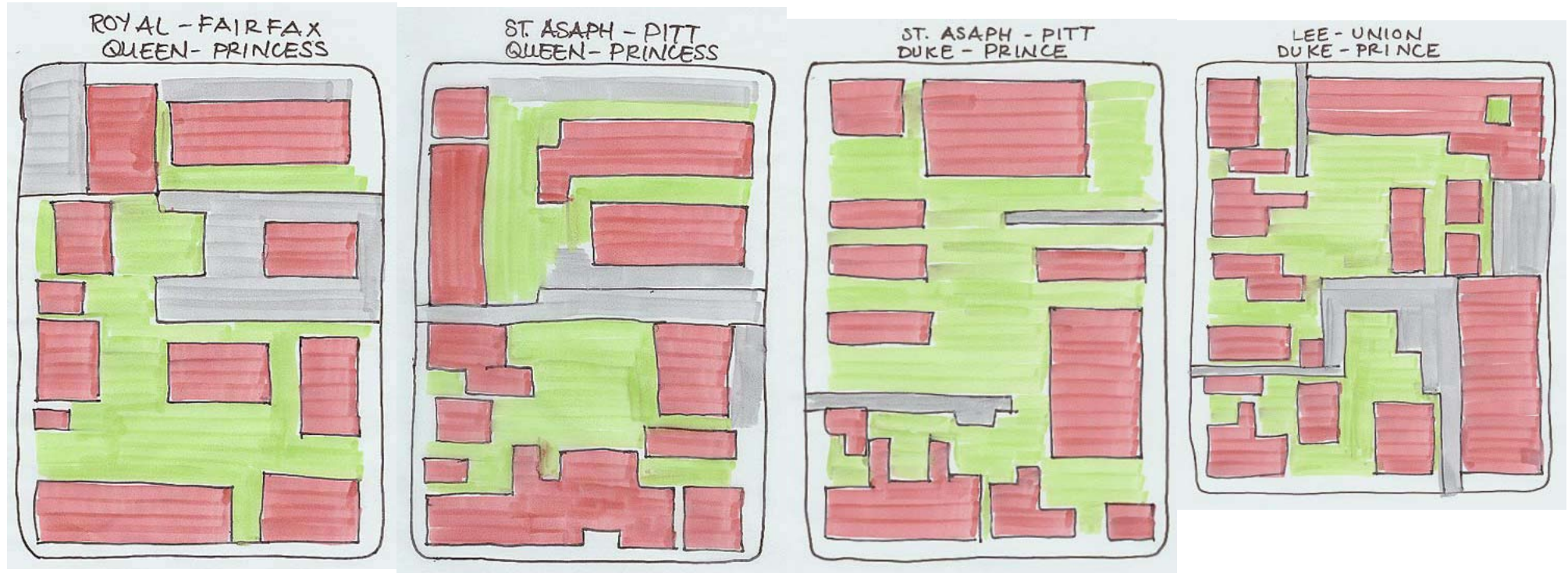


### Urban EcoHousing



# Design Analysis

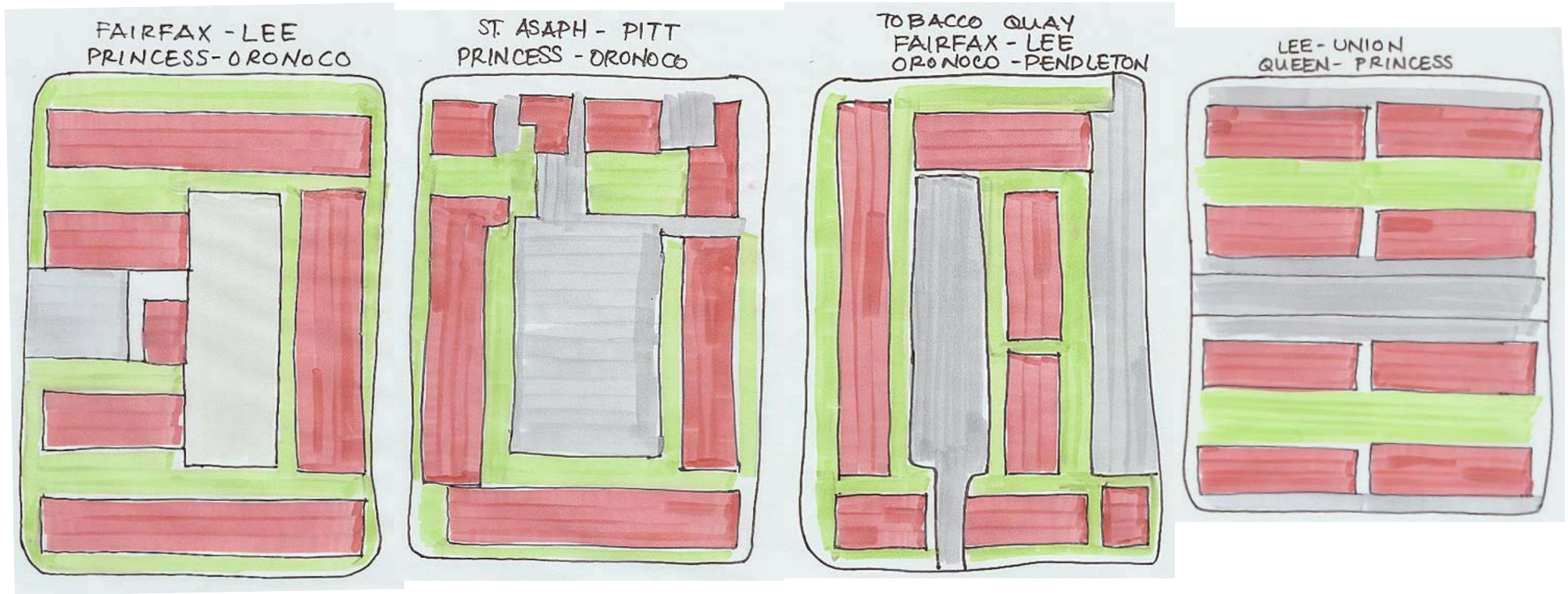
Alexandria Block Study  
Sun Wind Water  
Block Configurations  
Final Building Configuration



## 18th and 19th Century Housing

The Alexandria block study looks at the configuration of several blocks throughout the old town area. The study examines building layout, green space, alleys, and parking lots to gain an understanding of the typical layout of residential blocks in Alexandria. Results show there are vast differences between block layouts in the Old Town, but blocks grouped by the eras in which they were established show similar characteristics.

Blocks established prior to the 20th century, typically contain two or three story attached or detached row houses on narrow, deep lots. Parking is generally on the street, although there are alleys to access the interior of the block and the rear of properties, some with small parking areas or garages. There is lots of green space and each house has some outside private space. The blocks are very irregular in the spacing of buildings and alleys.



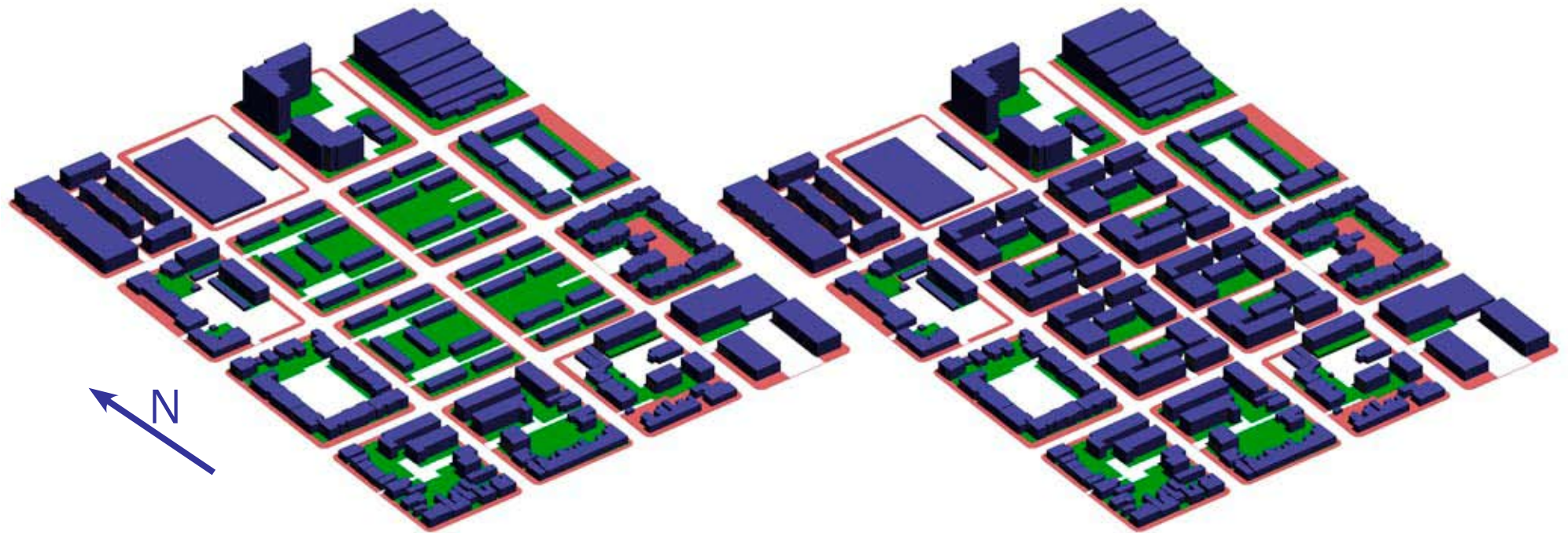
## 1970's and 1980's Housing

Blocks with housing built in the 1970's to 1980's typically have two or three story attached row houses in an orderly linear organization. Parking is in first floor unit garages, accessed by a driveway from the street, or in a surface lot within the block. Each townhouse generally has a small private green space behind the unit.



## Housing from 1990's to present

Blocks built from the 1990's to the present typically have three or four story attached row houses in a linear organization. There may be a multiple rows of houses within each block. Parking is usually in under unit garages, accessed by alleys running through the block. There is minimal green space on the block and the units may have no private outdoor space.

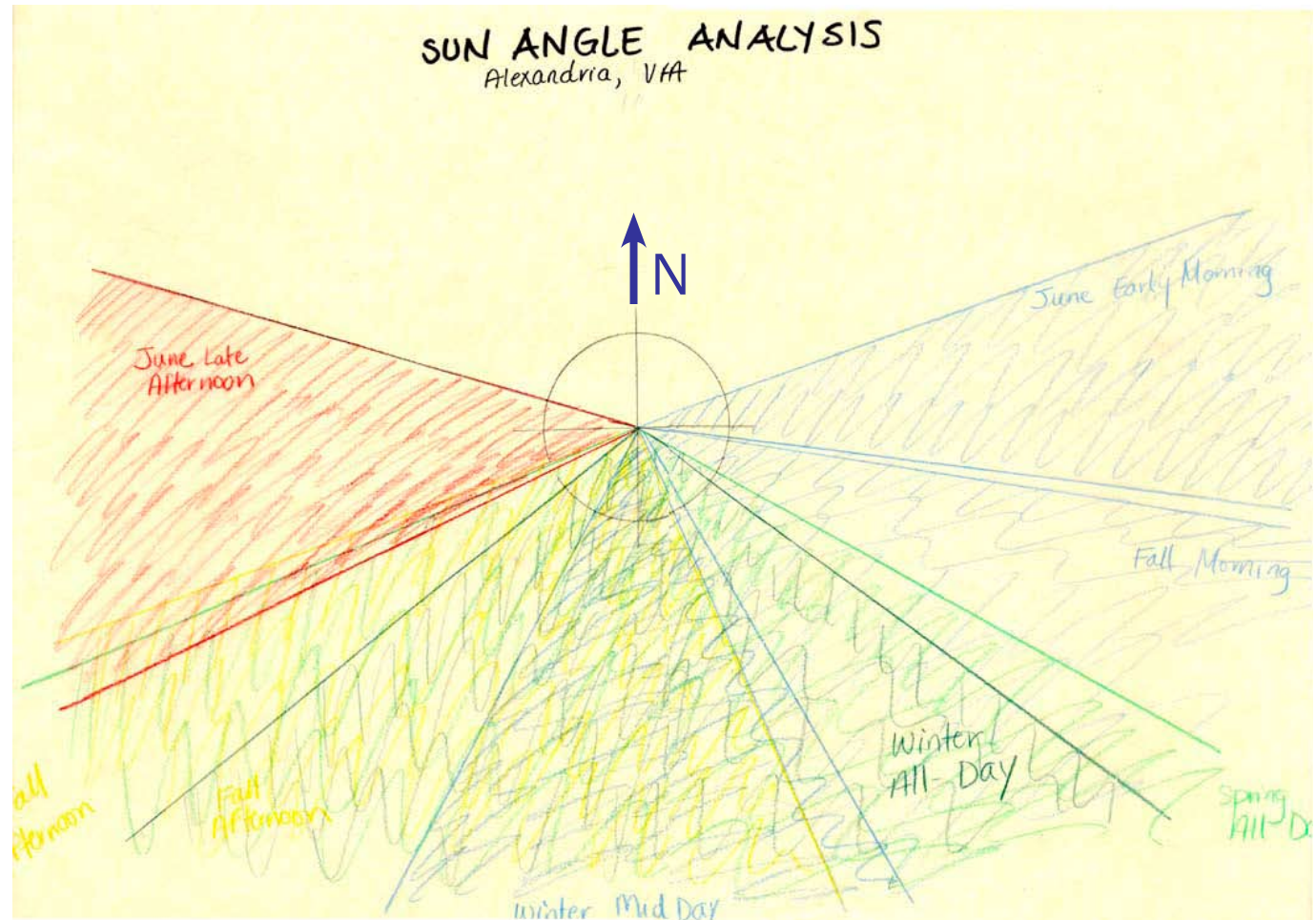
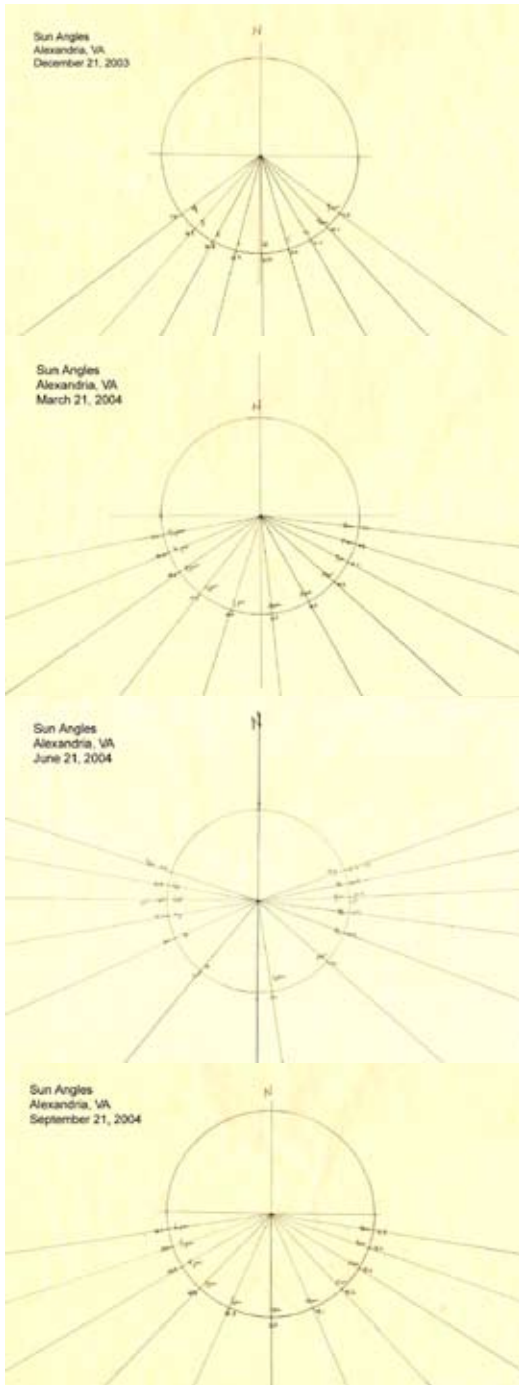


Site Density Prior to Development

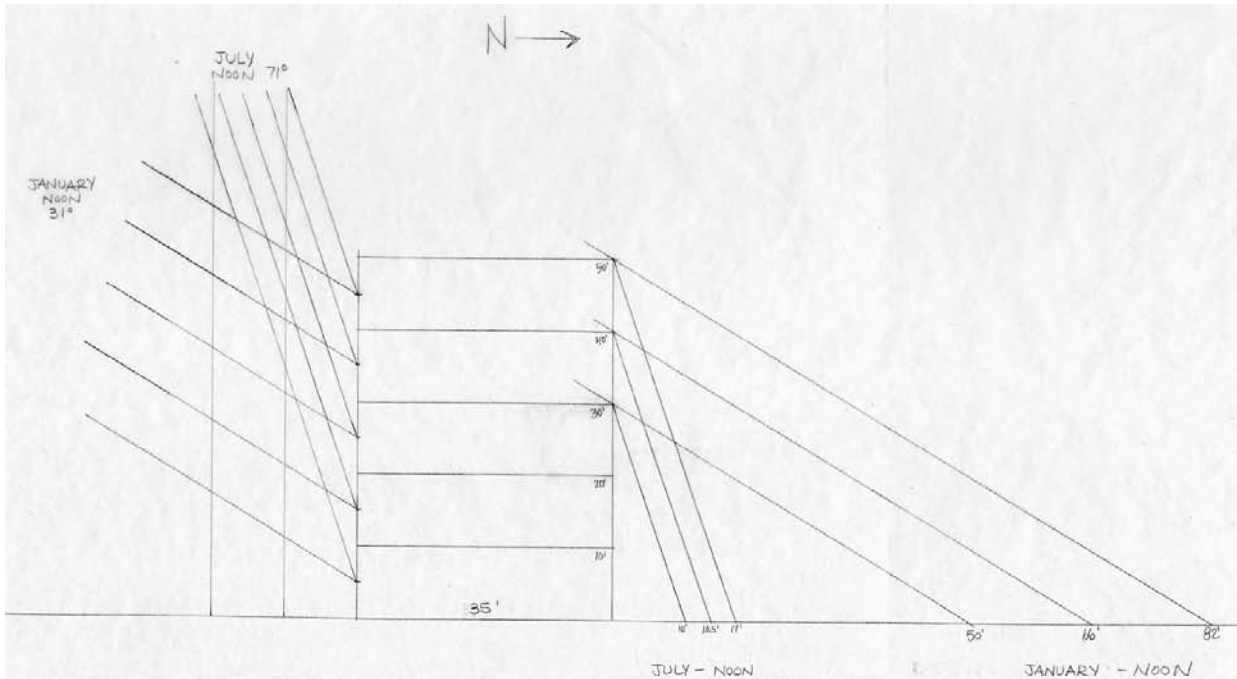
Site Density with Conventional Housing

The evolution of housing and block development raises several concerns. Housing density is increasing, impervious surface is increasing, and green space is decreasing. The project site is changing from a low density urban site as federal housing to a high density site. The buildings are changing from two story units to four story units. The super-sized urban row houses tower over their older neighbors. How does that impact the surrounding area? Can anything be done differently to make the new housing fit better?

The sun and how it lightens or shades areas is an important component of green infrastructure design. A study of the sun angles in Alexandria, Virginia through the year show the sun low in the southern sky during winter and high overhead during the summer. The sun rises in the northeast and sets in the northwest during the peak days of summer, but is limited to the southeastern and southwestern range in the winter.

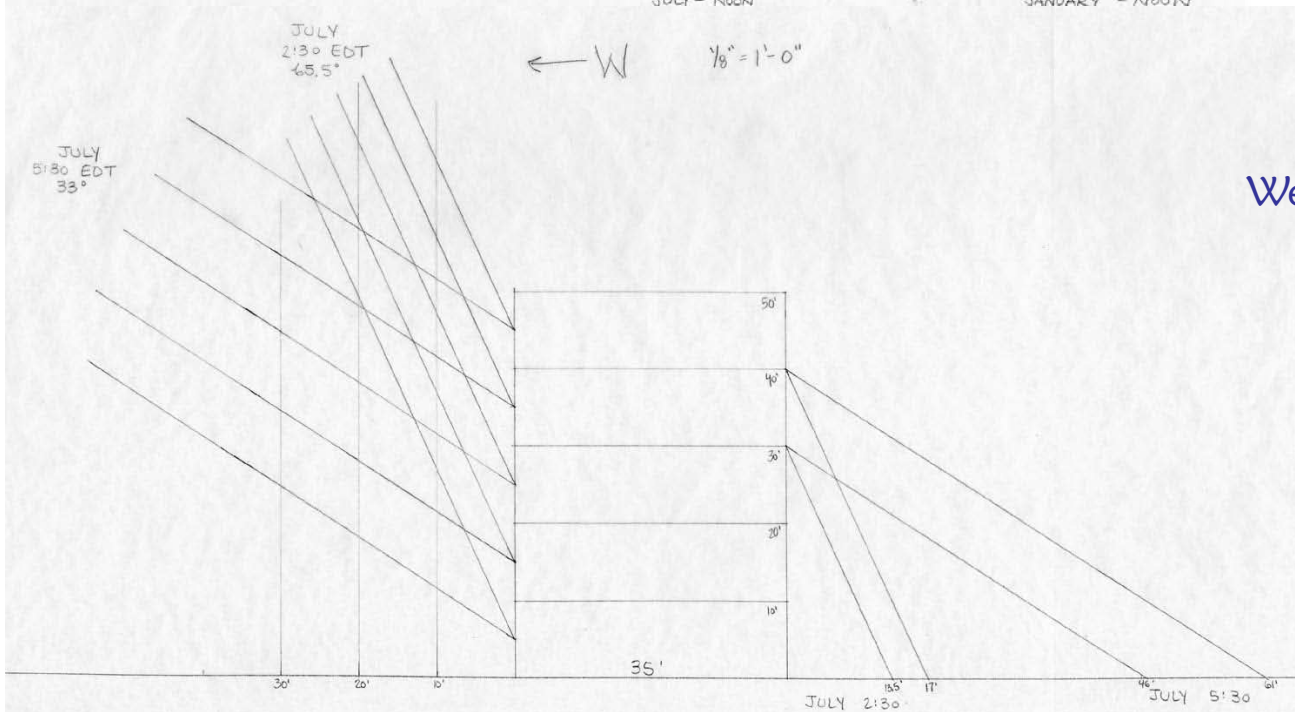


The sun angle analysis is used to determine where shading is needed and where the sun needs to shine for temperature moderation and human comfort. The morning sun in the east is always desired, and the southern sun in the winter is very important for natural heating. The southern and western summer sun and the southwestern fall sun should be blocked where possible to help cooling.



### Southern Summer and Winter Sun Angles

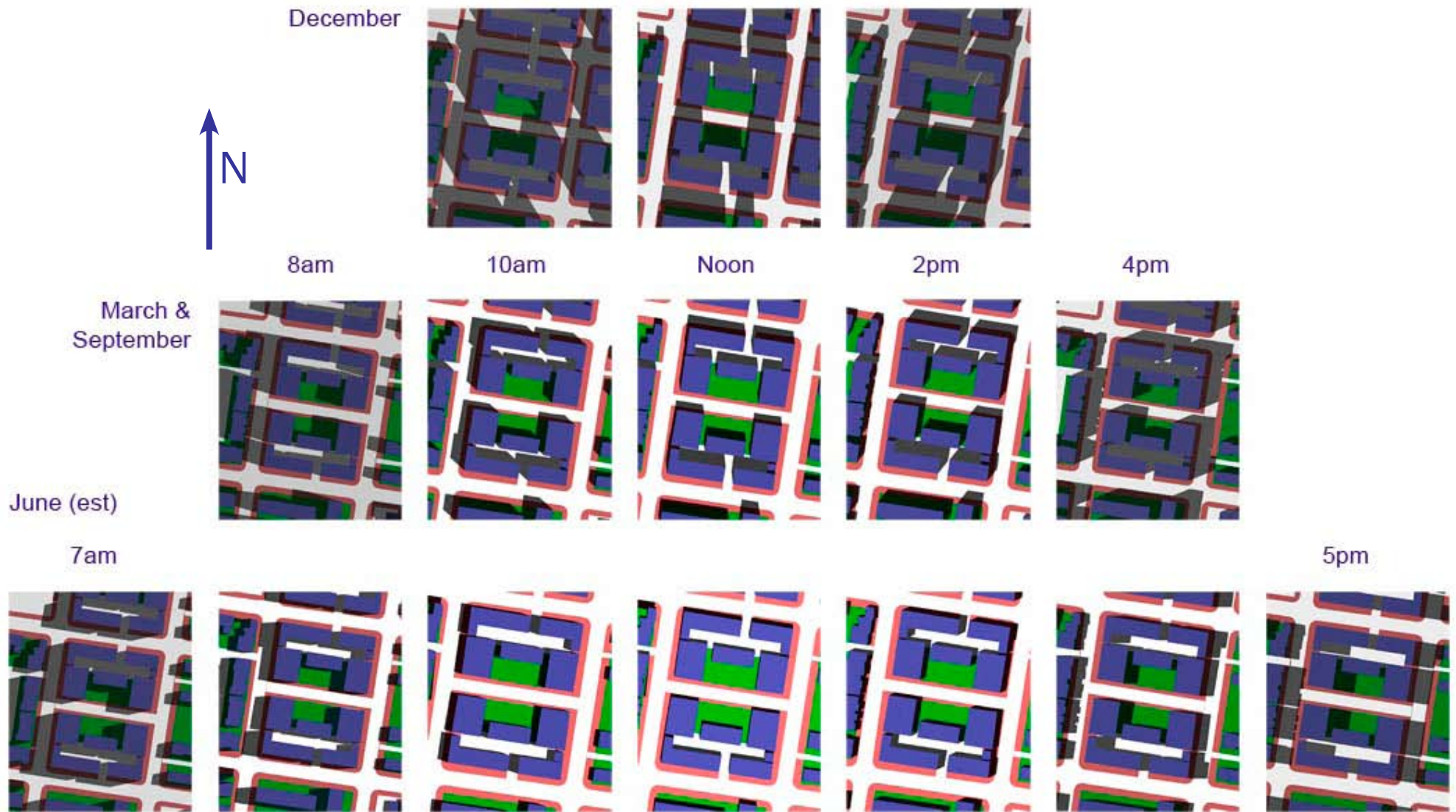
The southern sun angles show the difference in elevation between the winter and summer sun. Buildings cast a much larger shadow during the winter than in summer as shown in the diagram. Devices can be used to block the high angle of the summer sun, and allow the low angle of the winter sun.



### Western Summer Sun Angles

The western summer sun diagram show the range of elevation angles that need to be blocked from the heat of the summer sun. Shading devices need to provide for both high and low elevation angles.

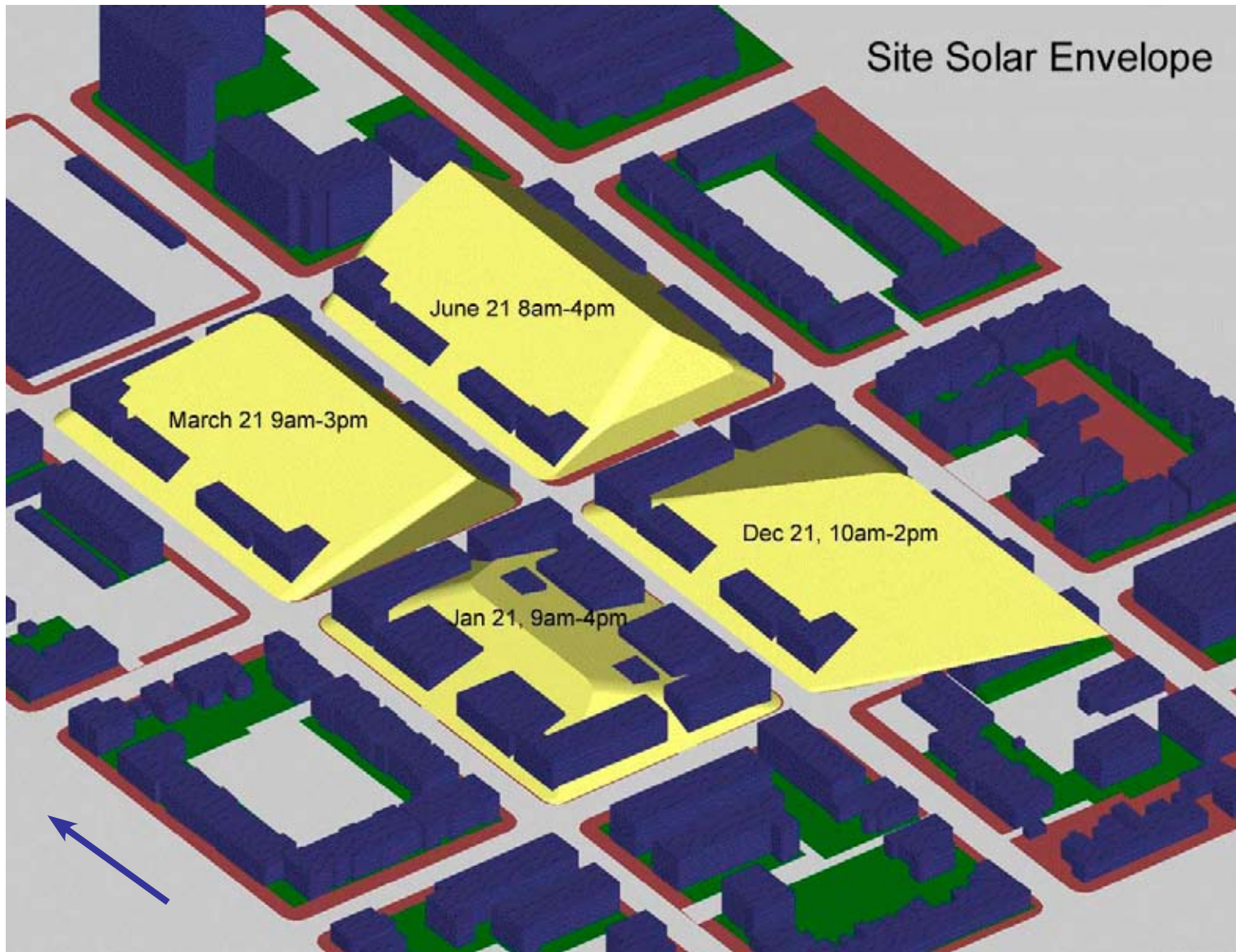
Shade Study at Conventional Development



A shade study of the conventional housing development shows the areas of the block shaded by buildings throughout the year and at different times of day. The close proximity of buildings leads to shading of several areas on the block for much of the year. The alleys and one common area are shaded all of winter. Both common areas receive sun only during the peak of spring, summer, and fall days. This study is used to design the building placement for urban ecohousing that will allow sun into the site at all times of the year.

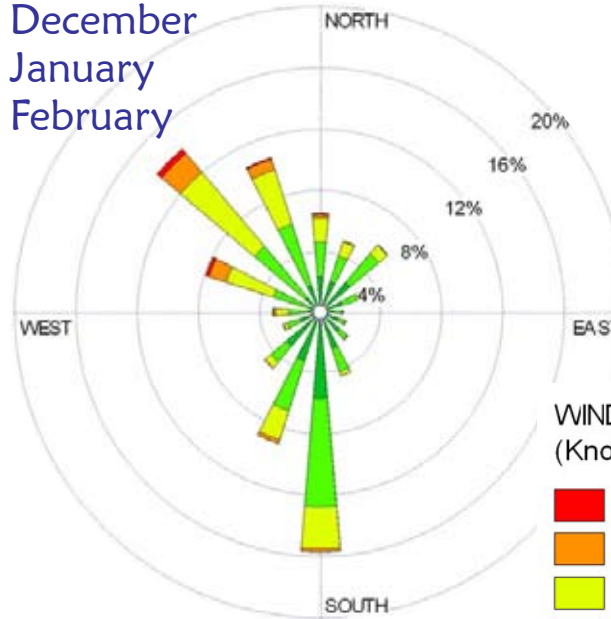
### Solar Envelope

Ralph Knowles, from the University of Southern California, developed the concept of a solar envelope in the late 1970's. The concept is derived from solar access and the problem that "our buildings are undifferentiated by orientation to the sun" (Knowles, 1999). The solar envelope describes the volume which buildings can occupy and not shade the surrounding space. The solar envelope can be used as a zoning tool to regulate building placement and height, ensuring both solar access to all buildings and creating the possibility for creative architecture. "The solar envelope regulates development within imaginary boundaries derived from the sun's relative motion" (Knowles, 1999).

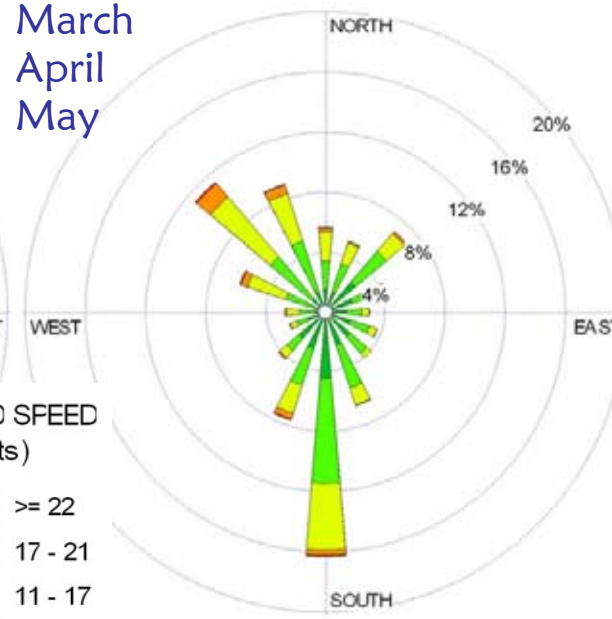


The images shown here are the solar envelopes created for the site in Alexandria with the conventional development. Solar vectors at different times of the year and time of day are used to create a volume at the block boundaries. The building volumes outside of the solar envelope will create shade outside the block boundary during the hours listed. The solar envelope concept will be used in the design of the ecohousing buildings.

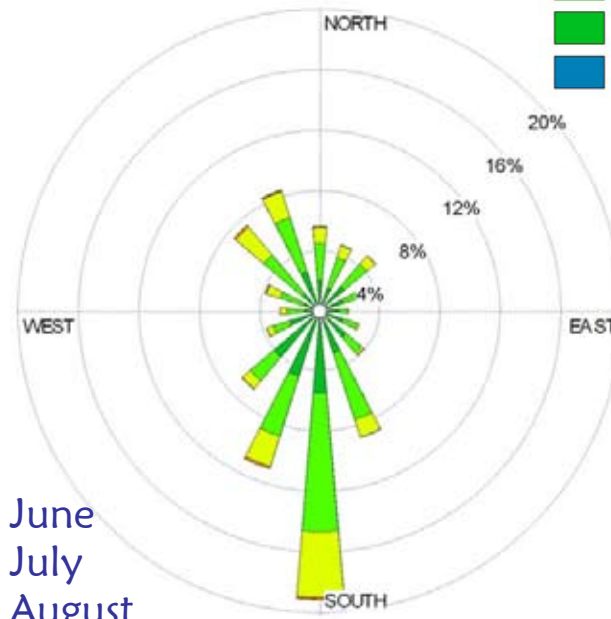
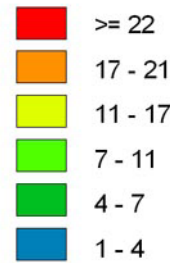
December  
January  
February



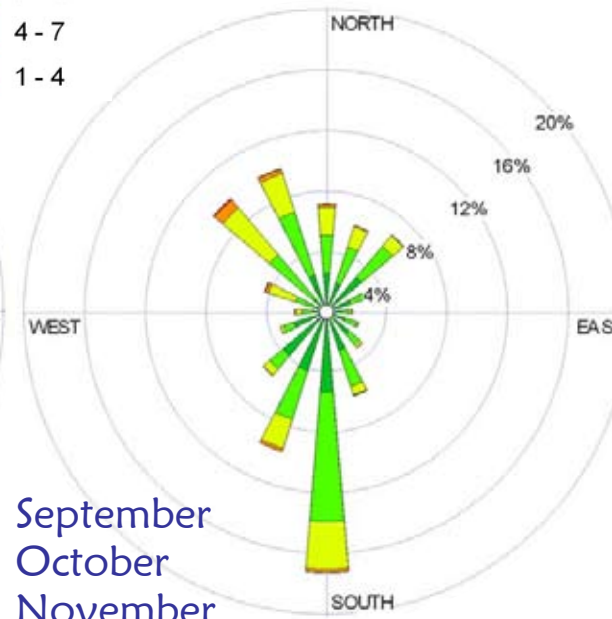
March  
April  
May



WIND SPEED  
(Knots)



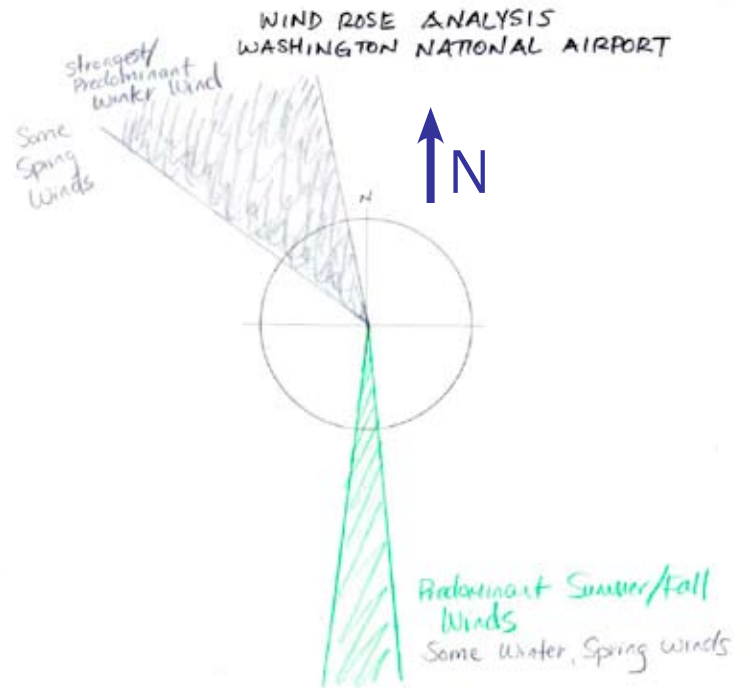
June  
July  
August



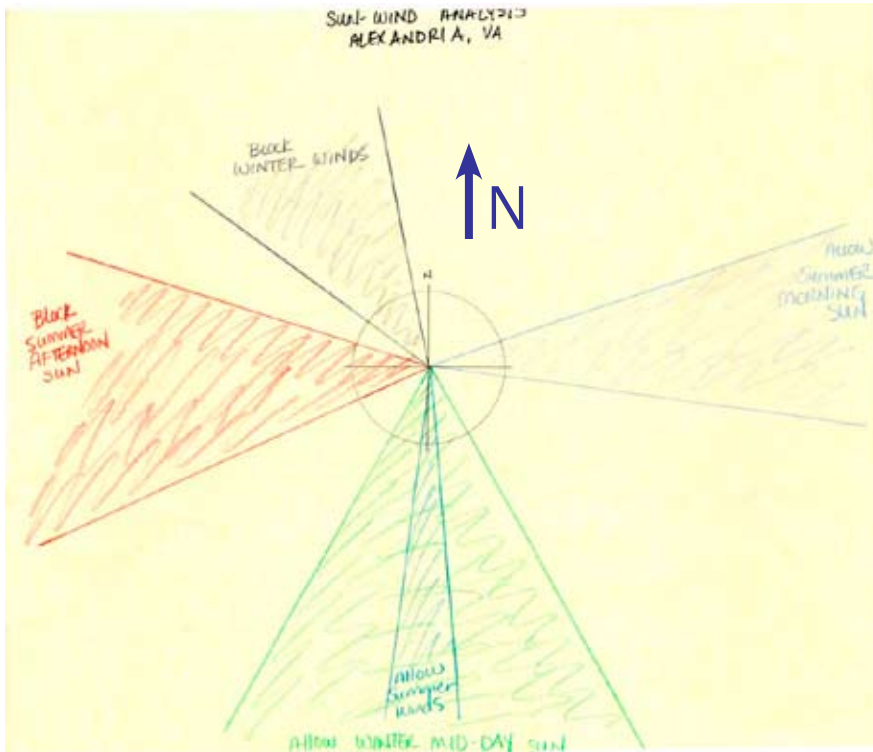
September  
October  
November

## Wind Direction Analysis

Wind data is collected at Washington D.C. National Airport, just north of Alexandria along the Potomac River. Eight years of wind data is plotted using the WRPLOT View software from Lakes Environmental. The wind rose graph shows the percentage of winds from all directions and strengths of wind over four seasons of the year.



The dominant patterns are winds from the northwest and the south. The strongest winter winds and some spring winds come from the northwest. The predominant summer and fall winds come from the south.



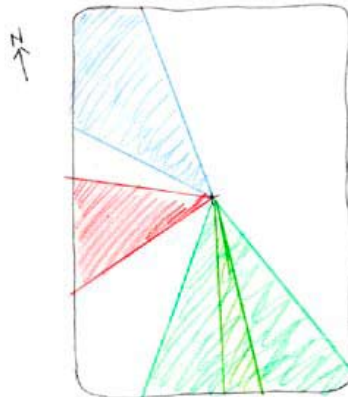
### Consolidated Sun and Wind Analysis

The consolidated sun and wind analysis is used to determine where sun and wind should be blocked and where it should be allowed to pass. In the east, the summer morning sun is desired. To the south, the winter sun is desired for heating and the summer winds should be allowed to flow through the site for cooling. The western summer and fall sun should be blocked to prevent excess heating. The northwestern winter winds should be blocked.

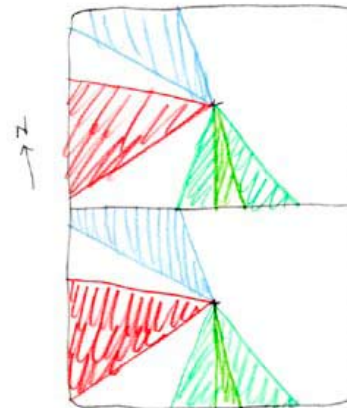
The sun and wind analysis will be used to design building placement and openings to allow natural heating and cooling and air circulation through the site. The block diagrams are early concept ideas to explore how buildings and openings may be placed on the entire block, or the block divided in half, in either a north-south or east-west direction.

Block Diagrams, Designing for Sun & Wind, Alexandria, VA

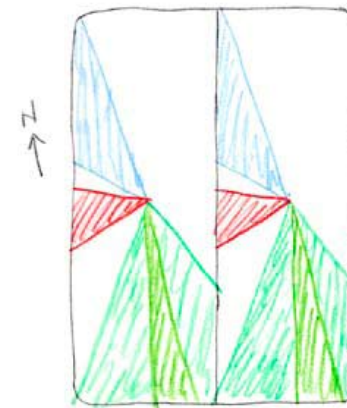
Design from Center of Block

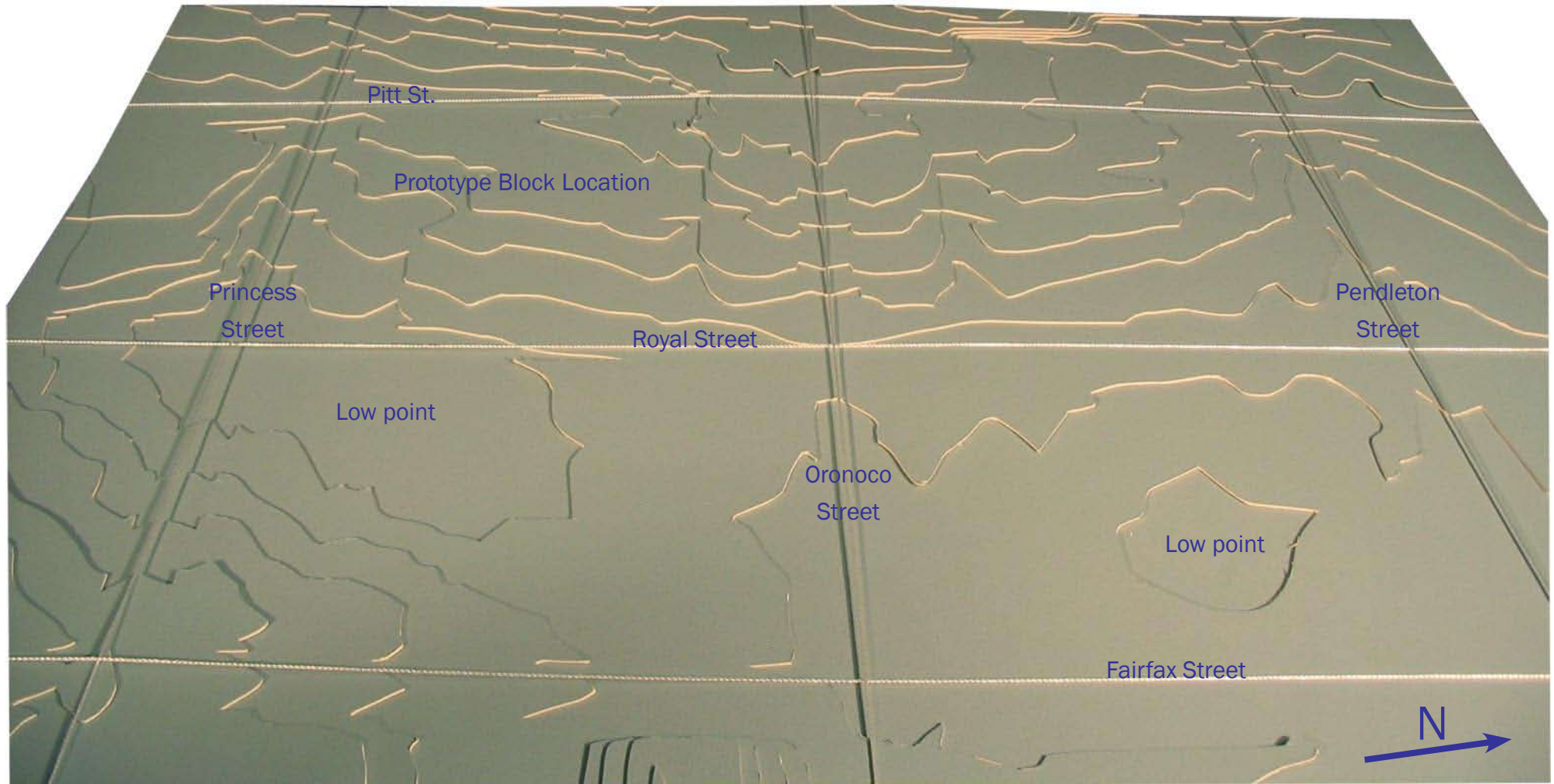


Design for block in two sections, north & south



Design for block in two sections, east & west


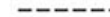




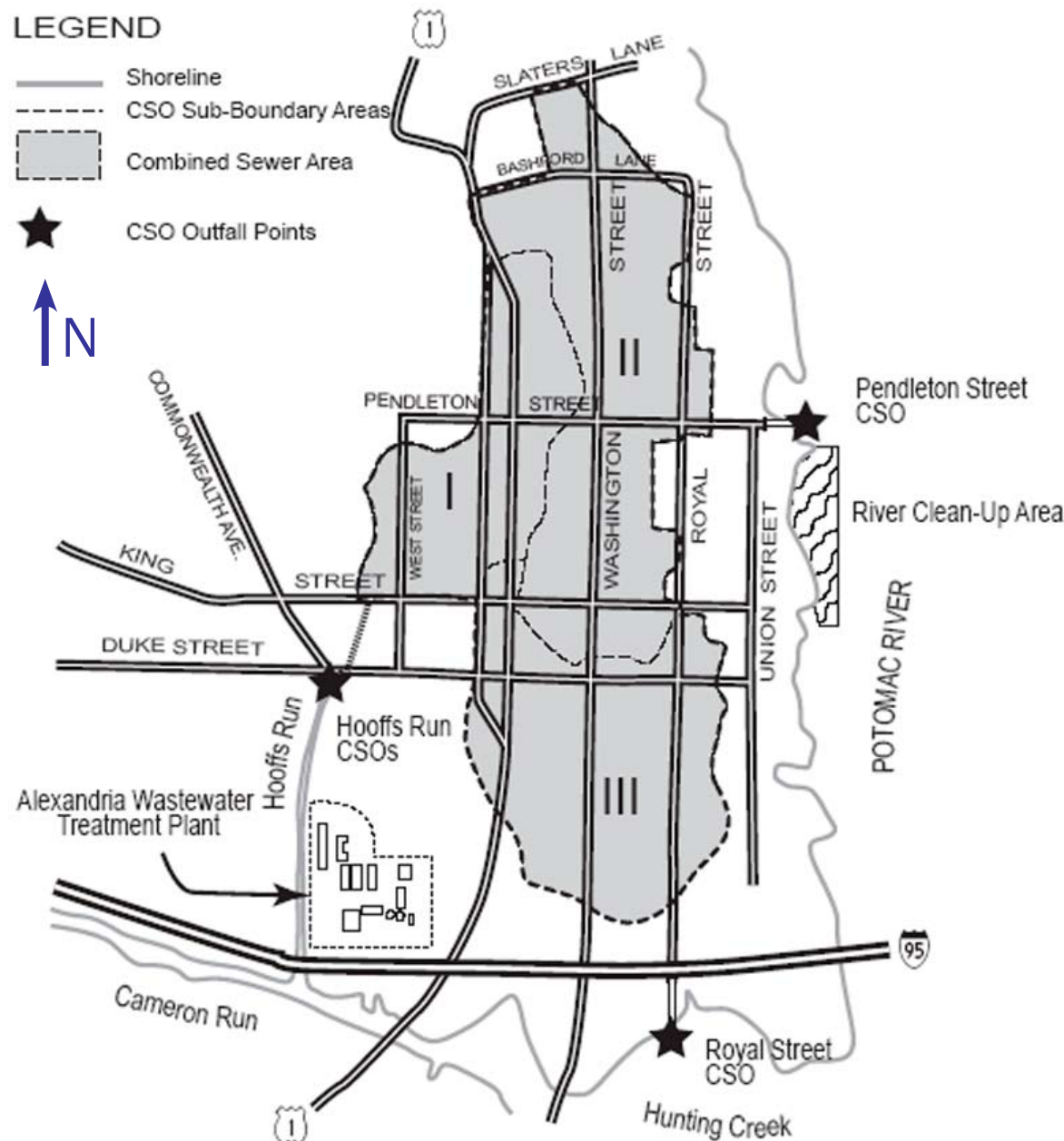


## Topography Model

The marsh, streams, and drainage areas seen in the historical maps are revealed in the current topography of the site. A site topography model shows low points at the mid section of the four block site. This area is at the edge of the marsh and water shown in the 1749 and 1797 maps. The western edges of the site are at higher elevations as expected from the natural topography, and the eastern edges were built up as part of the railroad.

## LEGEND

-  Shoreline
-  CSO Sub-Boundary Areas
-  Combined Sewer Area
-  CSO Outfall Points



Alexandria, Virginia Combined Sewer System  
(City of Alexandria, Water Quality Management Supplement to the Master Plan)

## Combined Sewer System

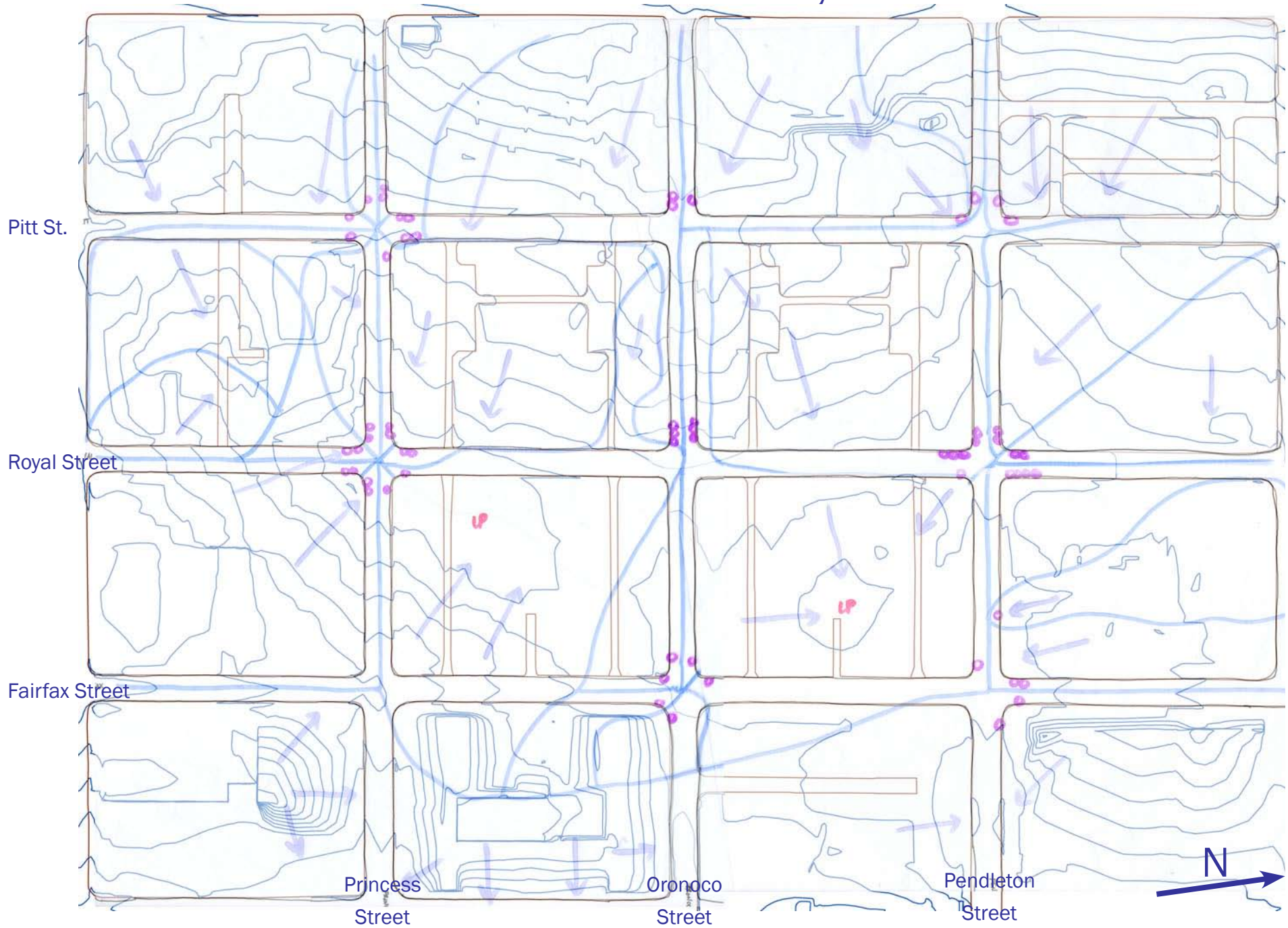
This area of Alexandria has a combined sewer system where wastewater and stormwater flow in a single sewer system. During storm events, the sewers can be overloaded with stormwater and overflow the excess capacity. This is known as combined sewer overflow (CSO). The CSO outfall for this area is at the end of Pendleton Street, on the north edge of the project site (City of Alexandria, 2001). In heavy rain storms, the sewer overflow will deposit sanitary sewer waste into the Potomac River. Reducing stormwater runoff through site design can help reduce the water flow to the sewers during storm events, and reduce the occurrence of CSO's.

## Urban Watershed Study

A mini-urban watershed study is shown on the following page. The water flow analysis divides the four block site and its twelve surrounding blocks into drainage areas. Water flow direction is indicated by bold blue arrows. The site is analyzed to the smallest areas (outlined in bold turquoise lines) to determine where water will flow and into which storm drains (shown as magenta circles).

The water flow analysis will be used as design of the block and the site progresses. The design will include management of water flow and water quality mitigations.

Urban Watershed Study



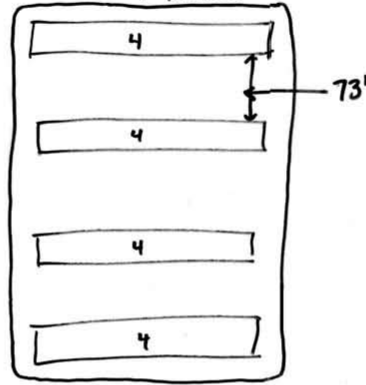
DENSITY - What volume of space required on site - 142,000 SF  
How much, How tall, # Units - 68 Townhouse Spaces - Block 280' x 380'

single level

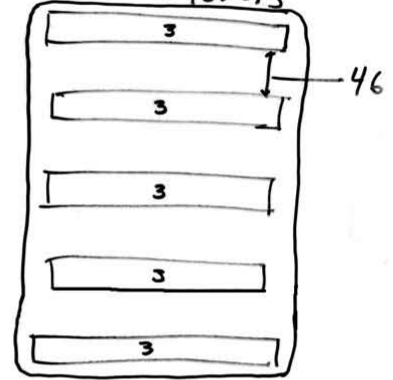


Linear Rows

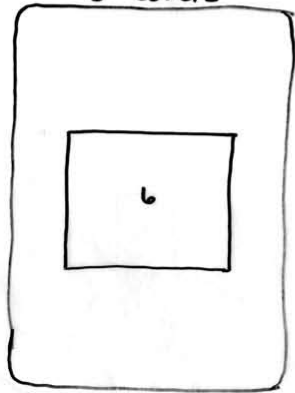
4 levels



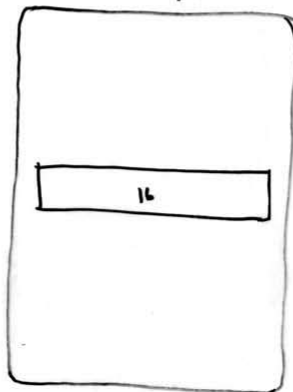
3 levels



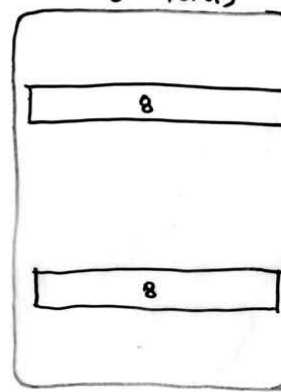
Large Mass 6 levels



single tower 16 levels

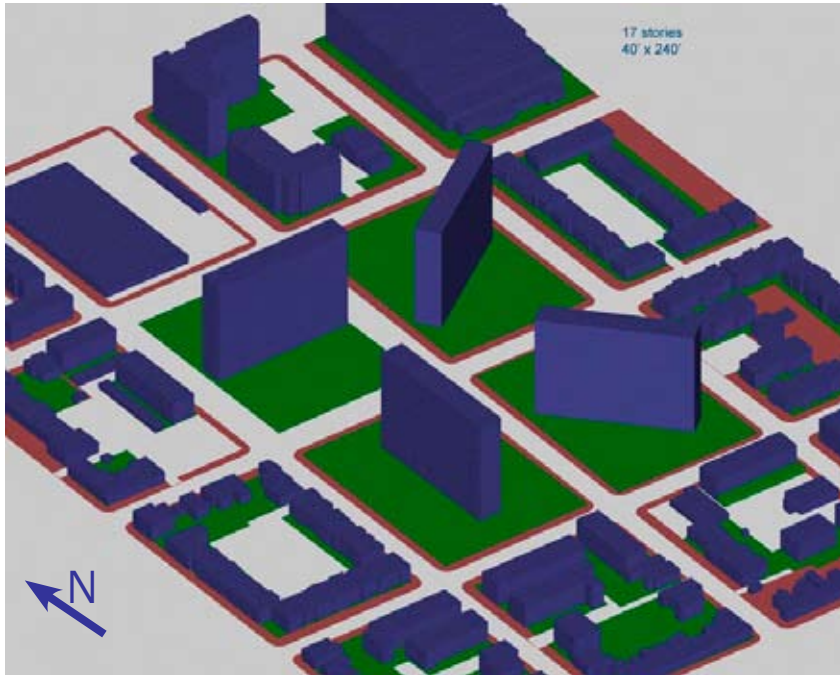


Two Towers 8 levels



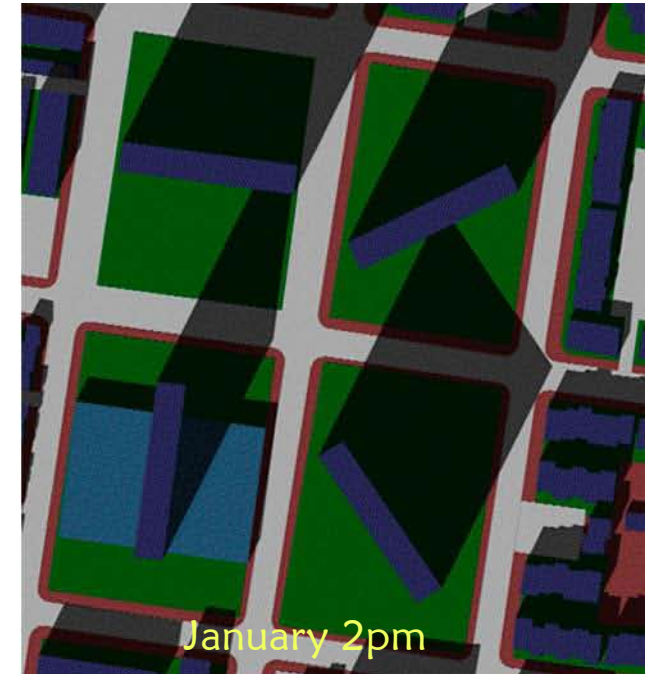
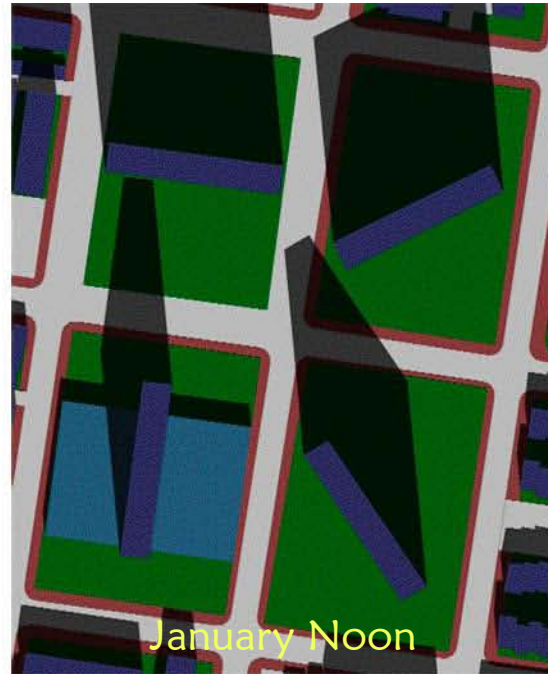
Density Analysis

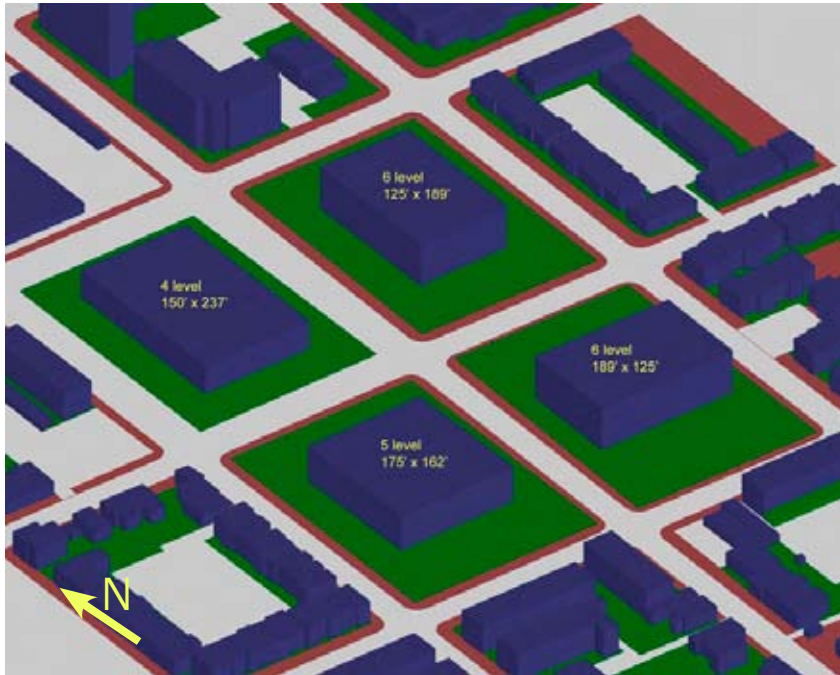
The constraints of the project require that 142,000 square feet of housing space and seventy-six (76) units be placed on a block that is 280 feet by 380 feet, a total 106,400 square feet in size. The analysis diagrams show how different volumes can fit in this space. The required volume laid over the entire block takes one and one-half story. Other block configurations are three or four story row houses, a block building, and towers of different heights. Each of these cases is examined further using the density analysis and shade study to analyze how it fits in the neighborhood. The shade study will show how the building shades the site and surrounding area in winter for the worst case shadows of the year. This process will lead to the final design for Urban EcoHousing.



### Mid-Rise Buildings

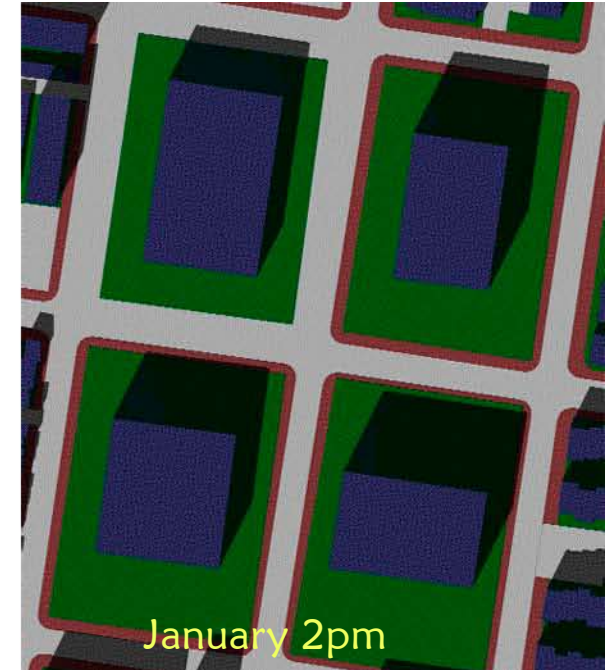
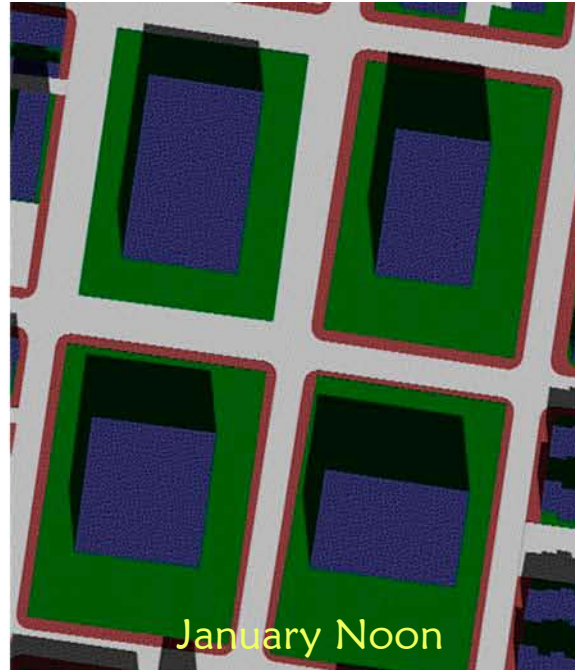
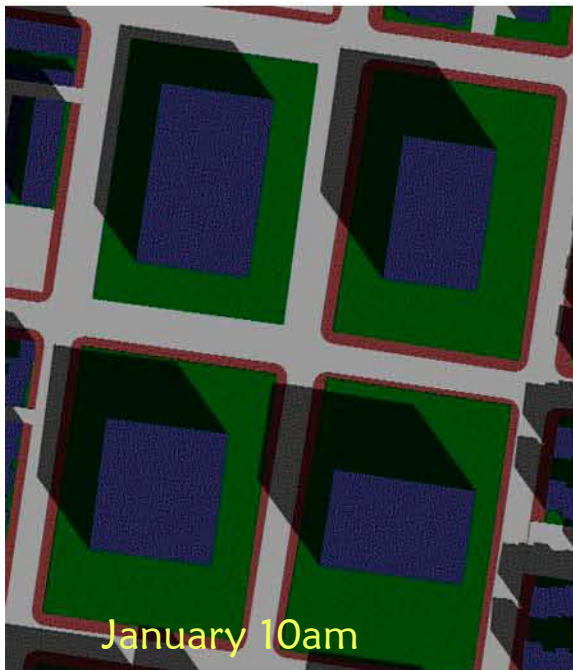
The first building configuration examined is a mid-rise building of seventeen (17) stories. The building is 40 feet by 240 feet and is shown placed on the block in several different configurations. The January shade study shows how the buildings shade much of the block, but can leave large areas of sun as well. The shades cast on the surrounding areas and the out of context scale of this building are reasons to reject this building type for these blocks.

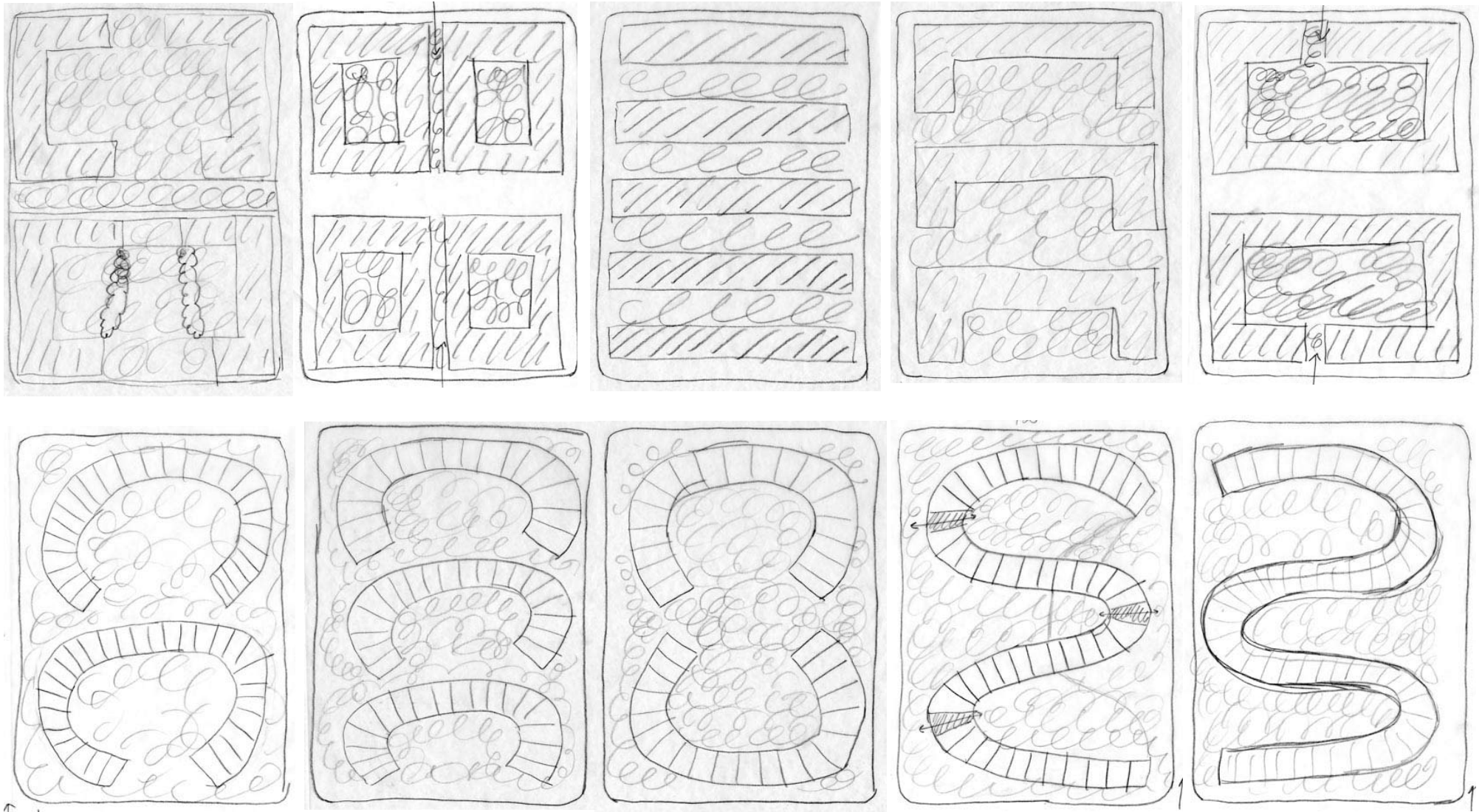




## Block Buildings

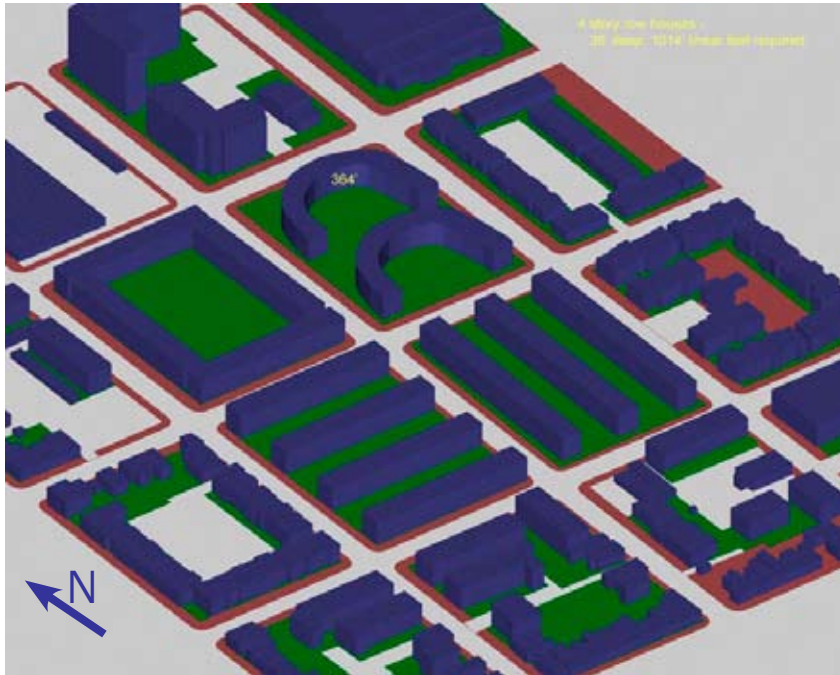
A block building that is four to six stories shows the large mass required to fulfill the square foot requirement. While the block buildings can cast considerable shade in January, they can also allow large areas of sun. A block building poses larger problems with unit layout, air circulation, and sunlight access to the units, and is not acceptable.





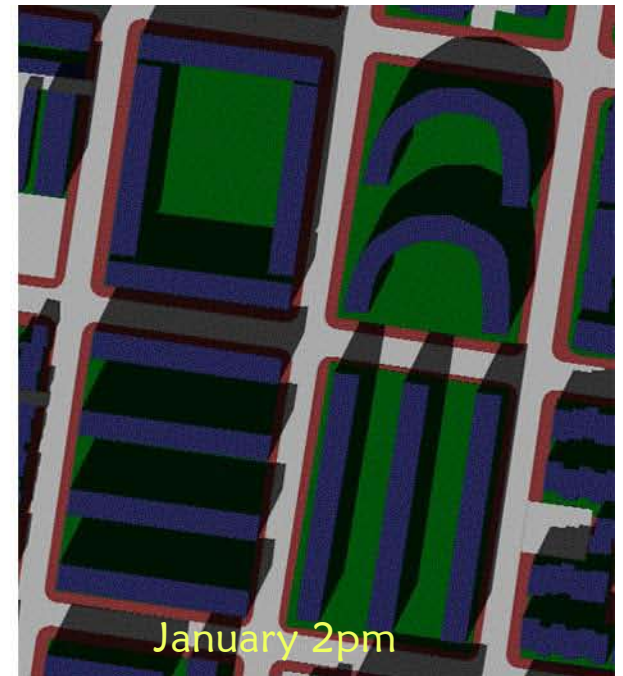
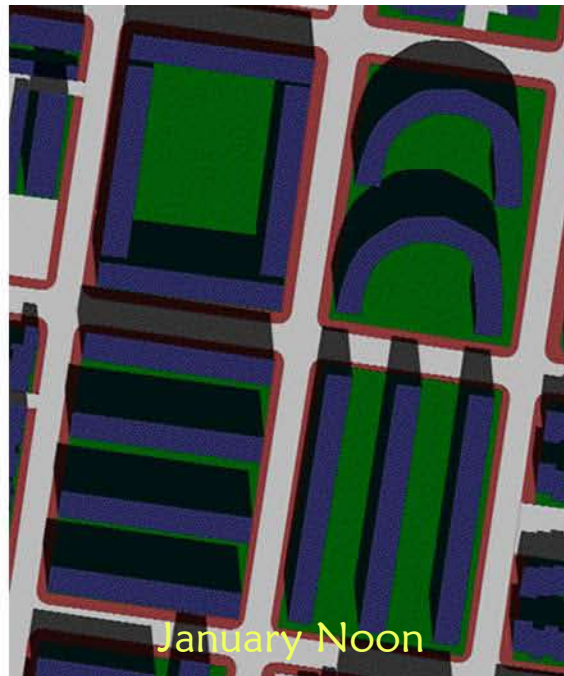
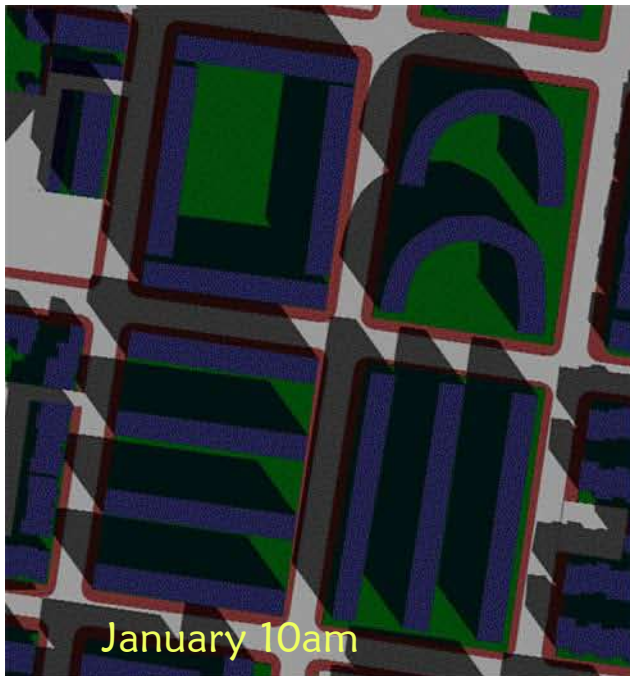
### Unconventional Row House Designs

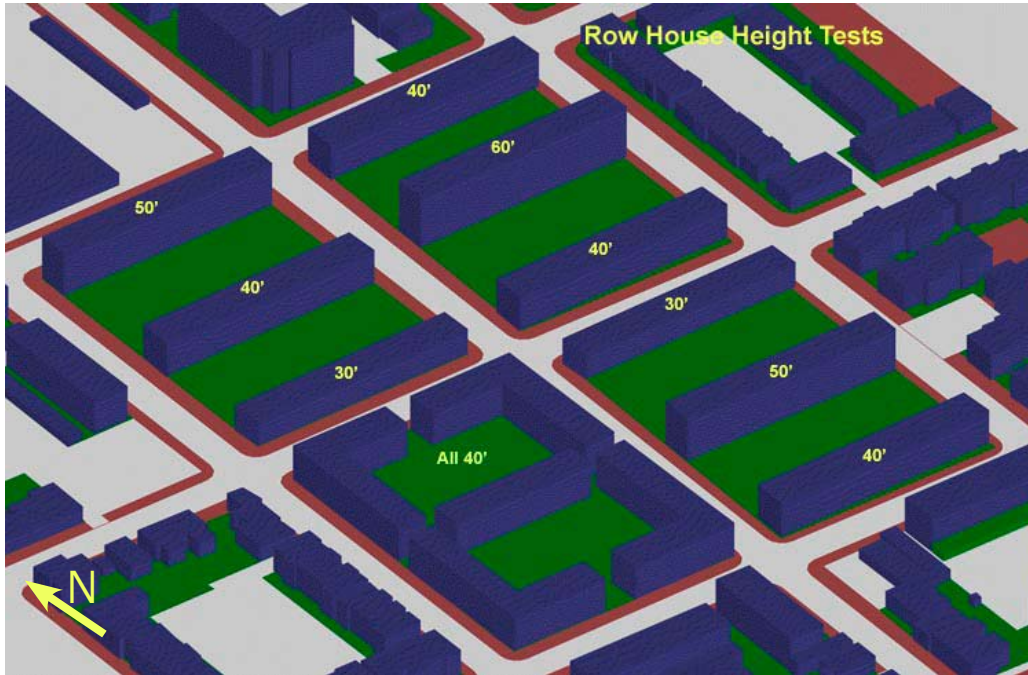
The design process urges creativity where possible. A desire to move beyond the typical rectangular row house prompted these sketches on other layouts. Design ideas attempt to maximize common green space areas. To meet the area requirement, 1014 linear feet of building is required, where the buildings are thirty-five feet (35') deep and four stories tall. Ultimately, the area space requirement ruled out most of these ideas.



## Row Building Configurations

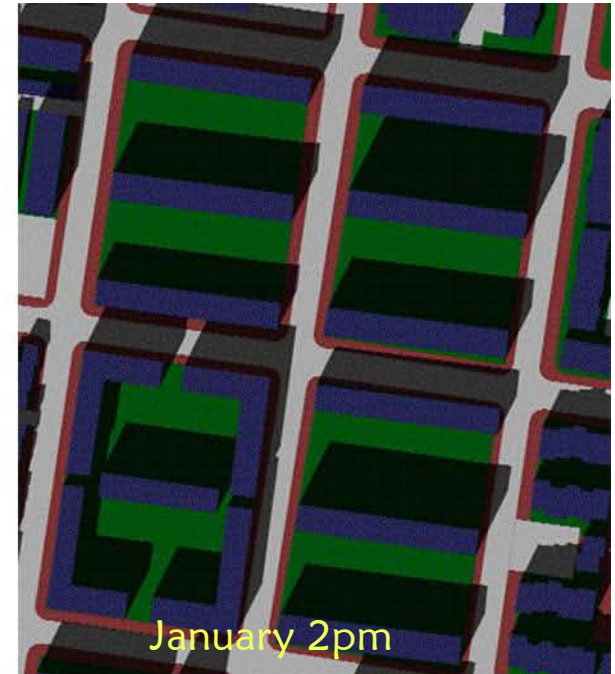
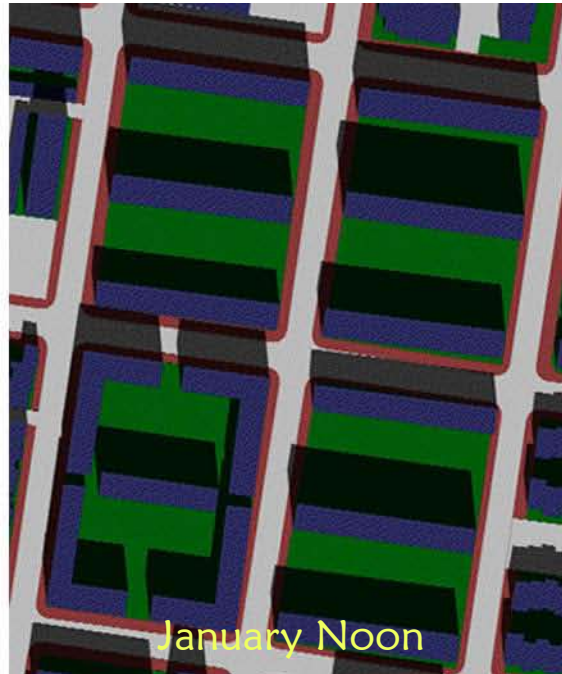
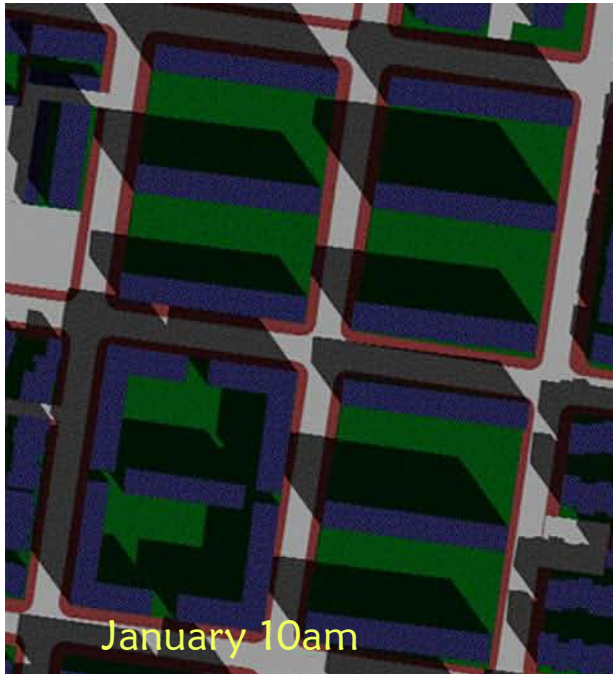
Various row building configurations are tested on the block to determine if they meet the area requirement. Row buildings that are thirty-five feet (35') deep and four stories tall must have 1014 linear feet of building to meet the area requirement. The "C" shaped buildings fall well short of the building length requirement at just 728 feet. The three rectangular configurations all meet the building area requirement. The block is 280 feet by 380 feet giving 1036 linear feet at the block perimeter with minimal setbacks and distance between buildings. Shade analysis shows the merits and drawbacks of these configurations. They will be used to further refine the design.

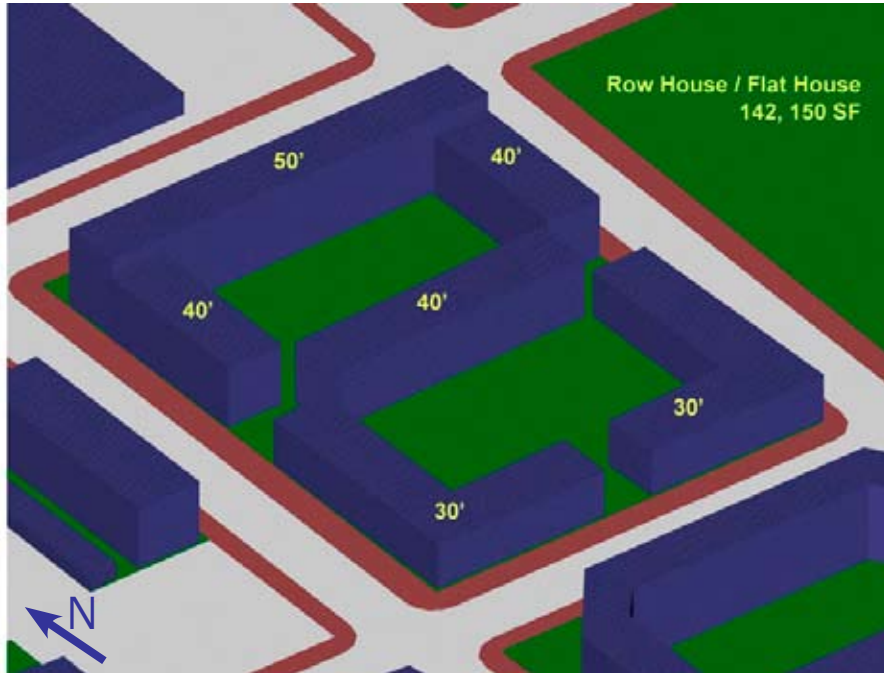




### Testing Row Building Heights

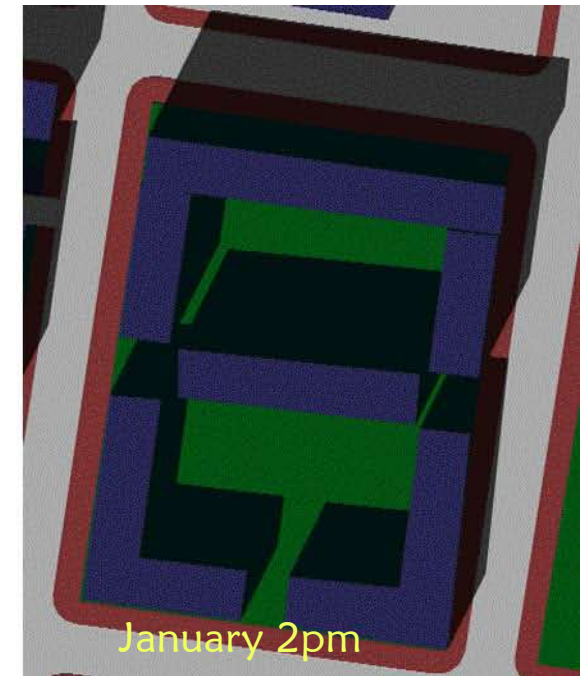
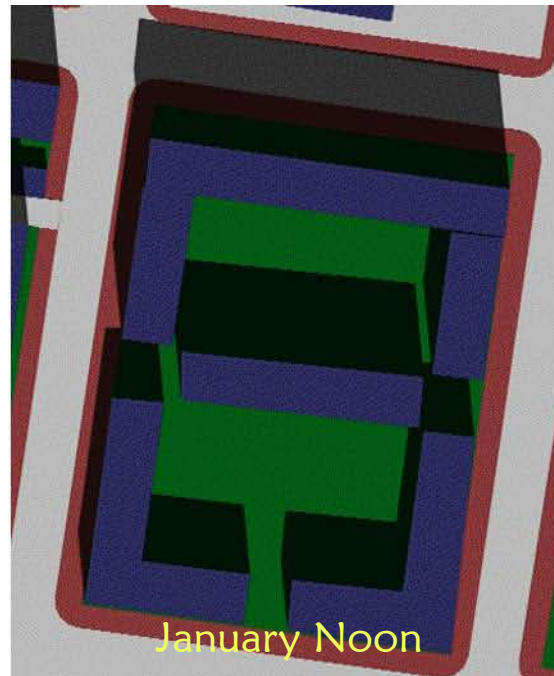
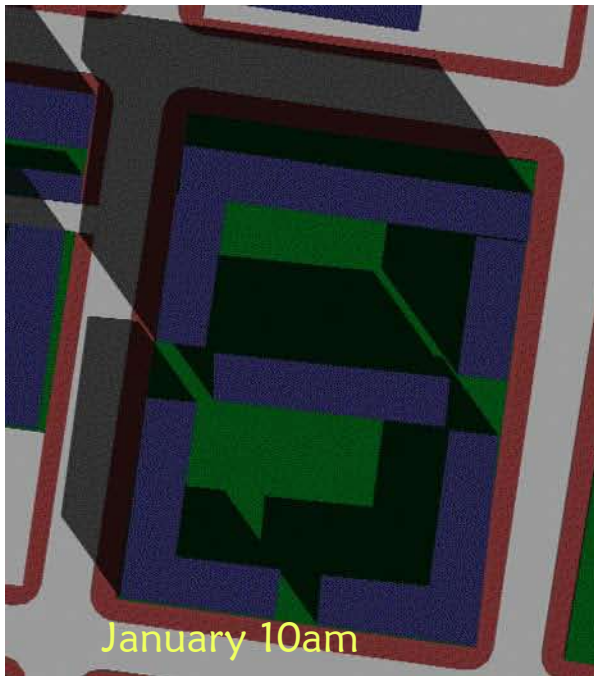
Various row building heights are tested to examine shading. All buildings are thirty-five feet (35') deep and heights of three to six stories are tested. The shadows cast are used to determine the required distance needed between buildings to prevent shading and the effect on surrounding blocks.

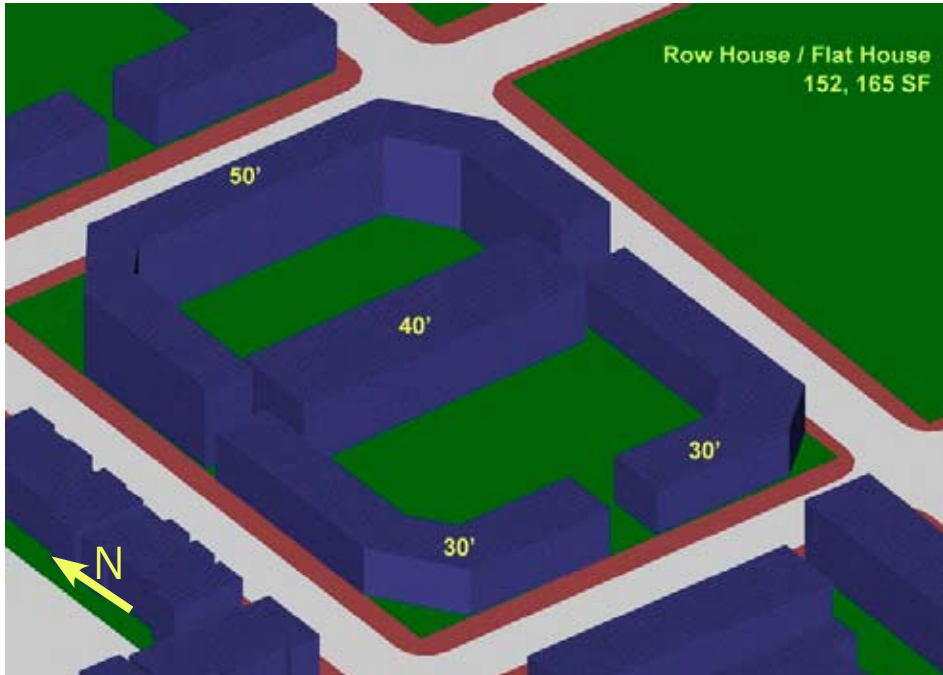




## Row Building Design

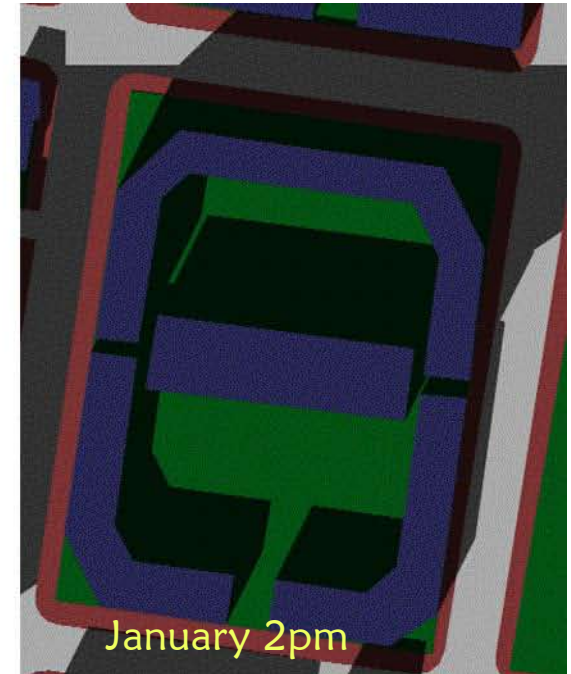
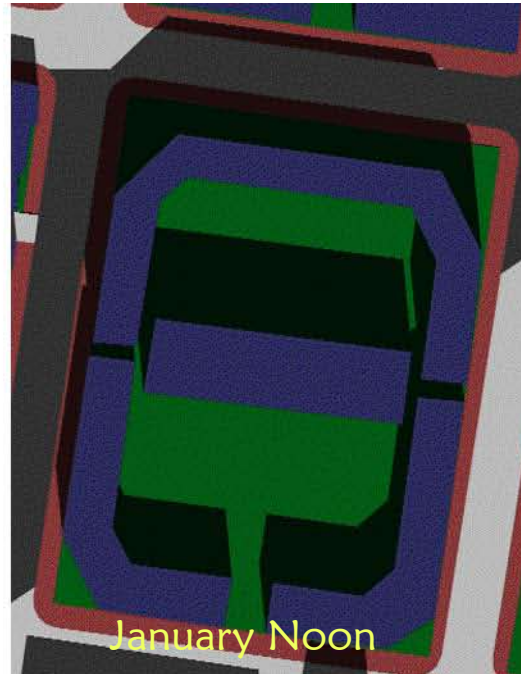
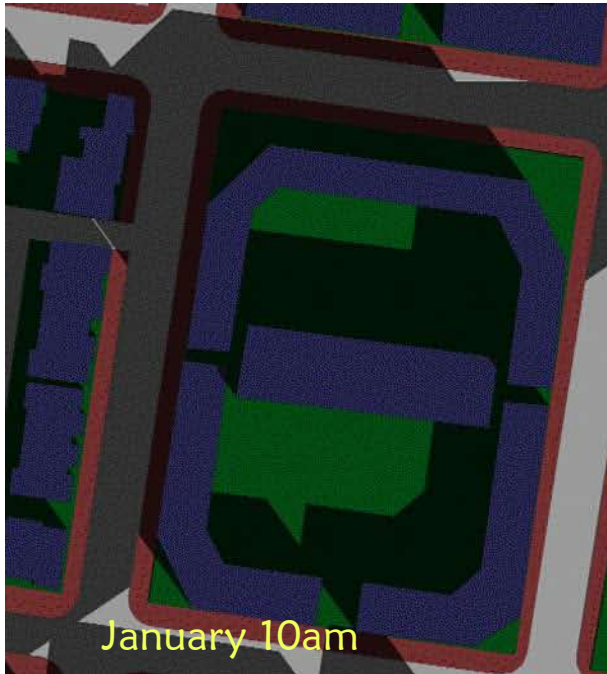
Row buildings at the edges and interior of the block allow for large common areas on the interior of the block. A variety of building heights can serve multiple housing needs, from single family town houses to stacked flats. Openings in the row buildings can provide sun and air circulation to the interior of the block. This configuration meets the area requirement with one building set at five stories tall.

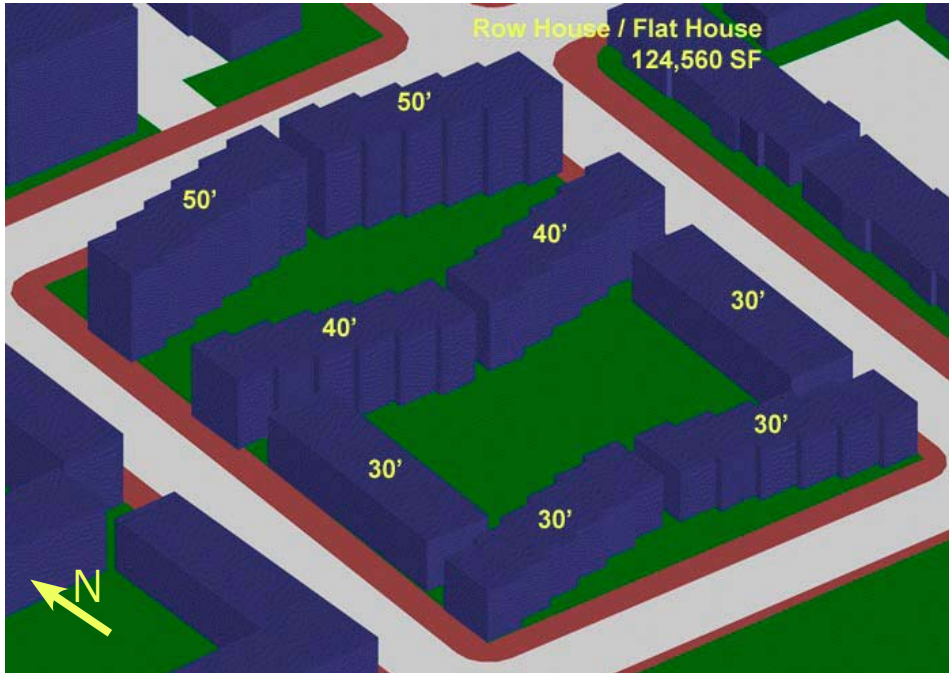




### Row Buildings with Chamfered Corners

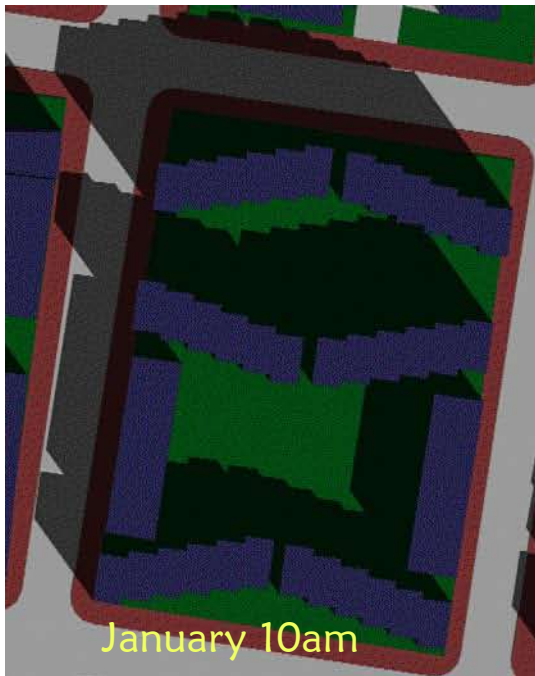
Buildings with chamfered corners can provide public space on the corners of the block. This configuration exceeds the square foot requirement with one building set at five stories tall. This option is not pursued further due to the height of buildings and challenge to unit layout.



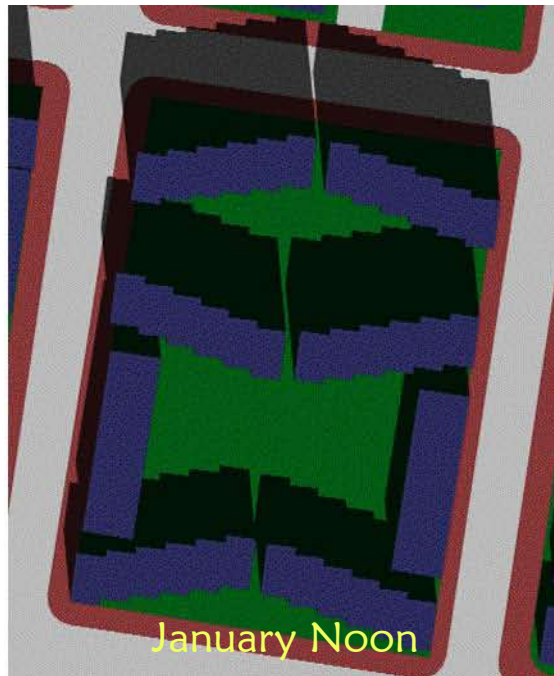


## Staggered Row Buildings

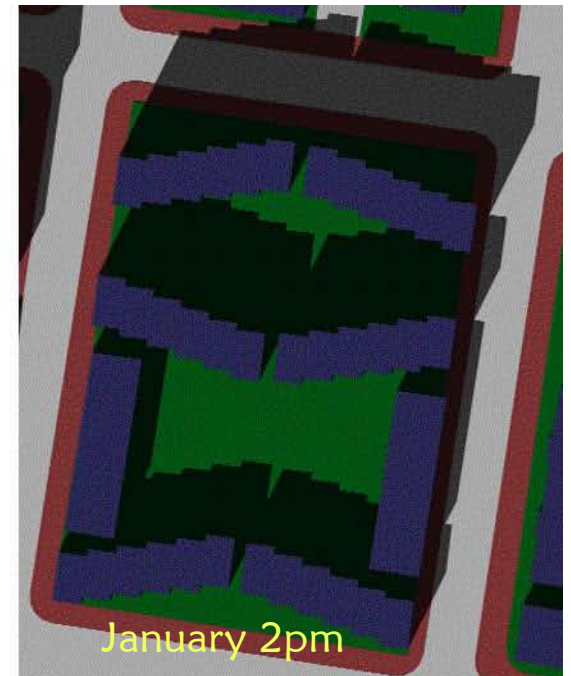
Staggered row buildings can provide variety to the sidewalks and the rear private space of the units. This configuration does not meet the area requirement and ultimately reduces the available interior common space. This option is not pursued further.



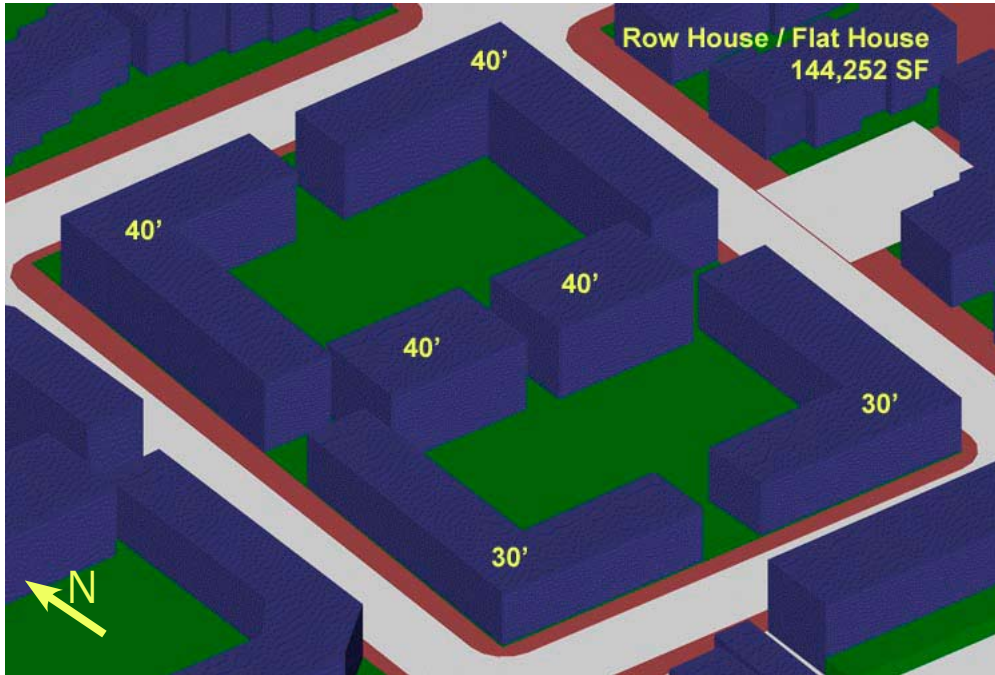
January 10am



January Noon

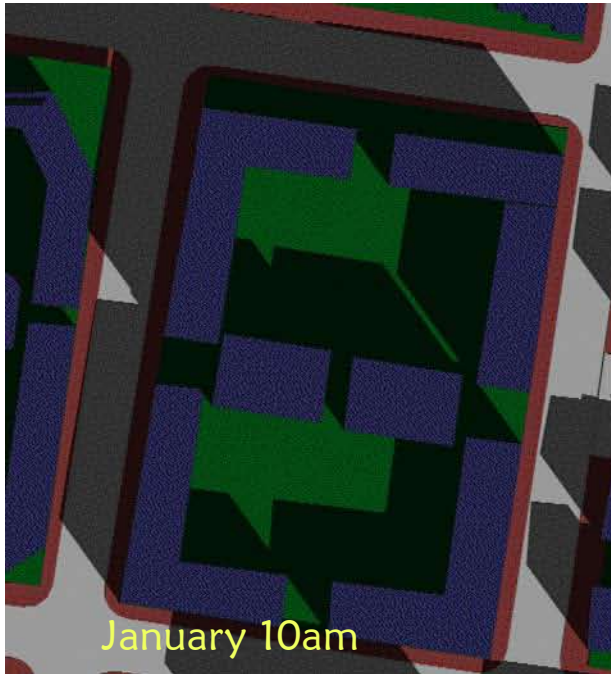


January 2pm

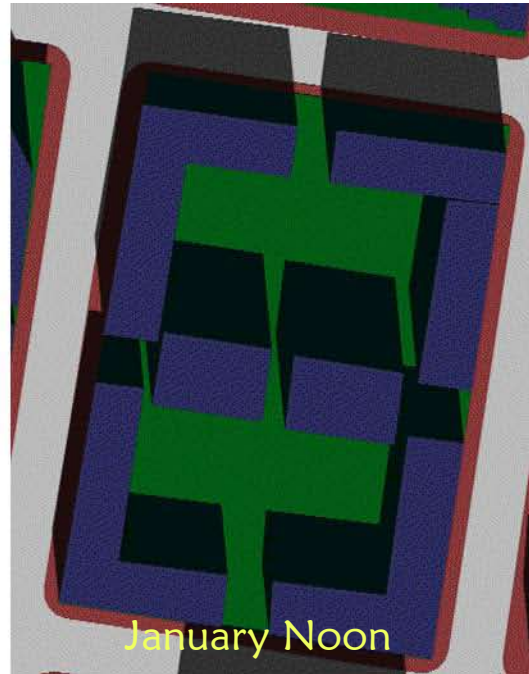


### Row Building Design

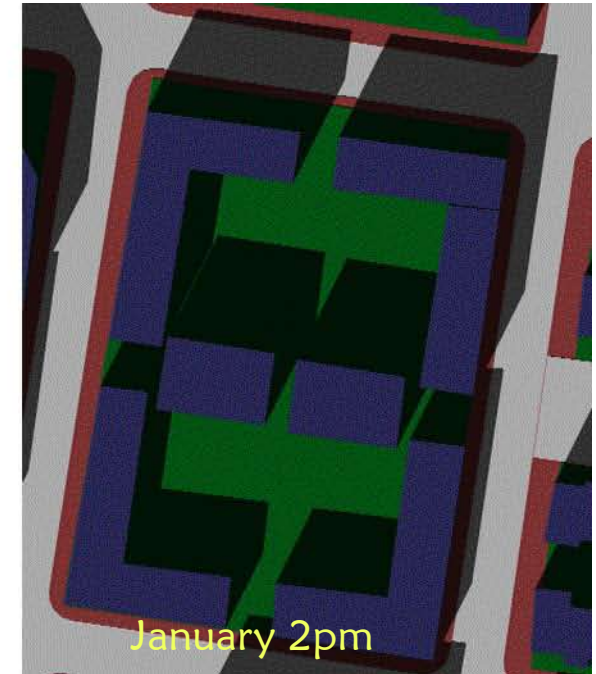
The design moves toward an optimum solution. This option shows row buildings on the street edge of the block with wide openings on each street. Three story buildings on the southern half of the block are allocated as single family townhouses. Four story buildings on the northern half of block will be two story units. Interior buildings are wider and will be used as one level units. Building openings on the north-south axis allow the southern summer wind open access through the block.



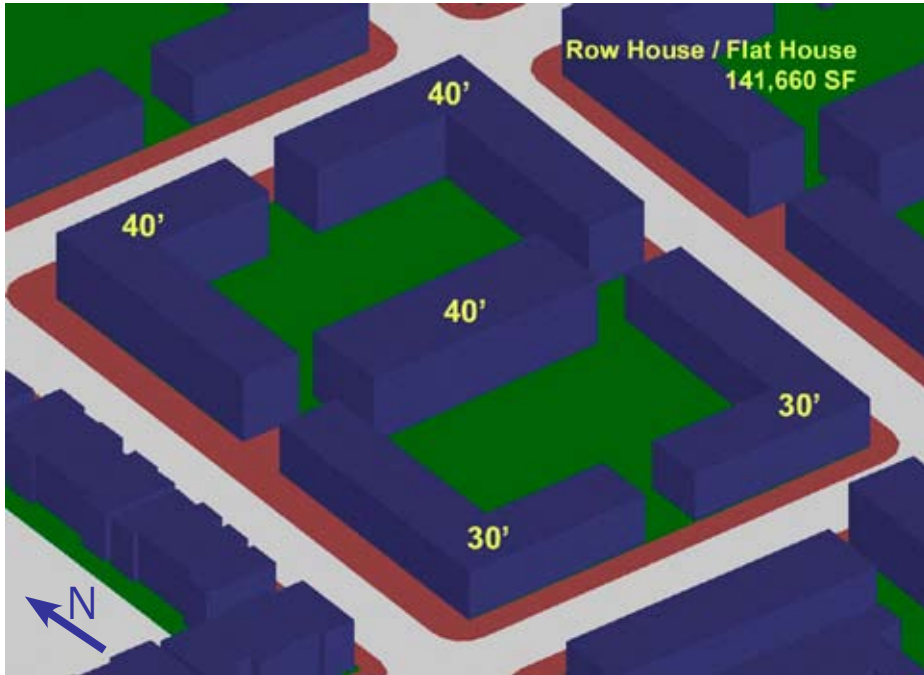
January 10am



January Noon

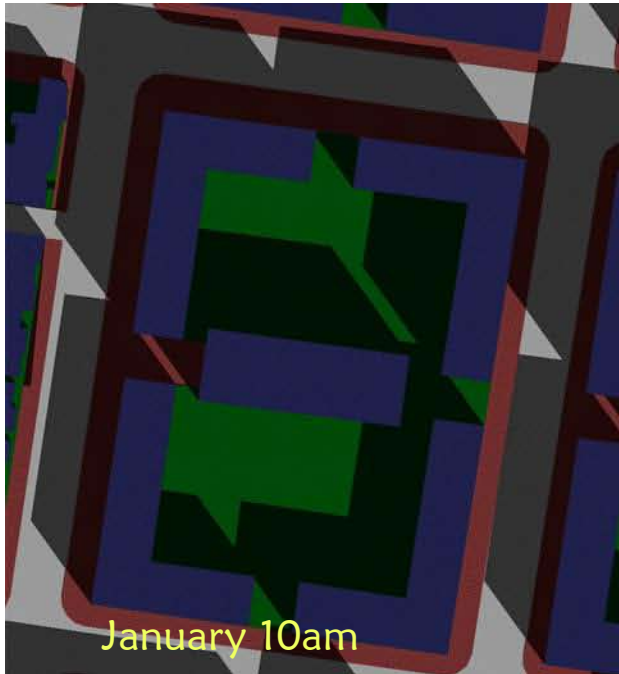


January 2pm

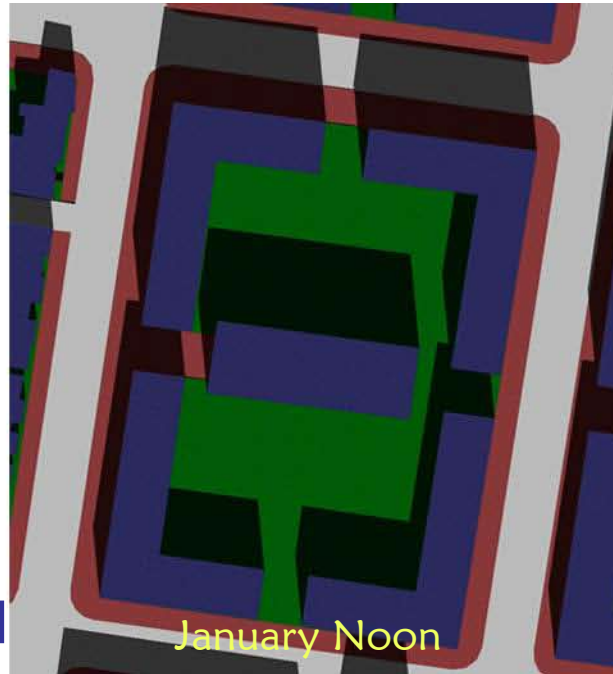


### Row Building Design

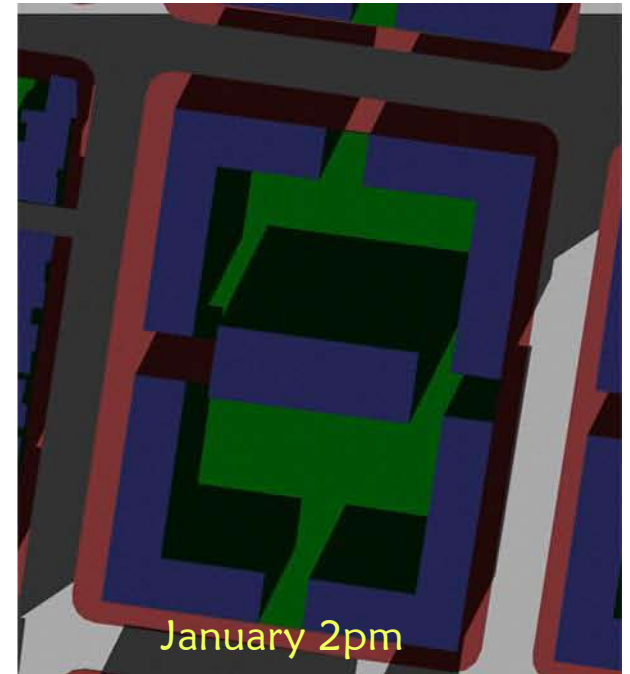
This row building design is similar to the previous option. A single building on the block interior allows more space on the eastern and western side between the buildings. This option will be used to start unit layouts.



January 10am



January Noon

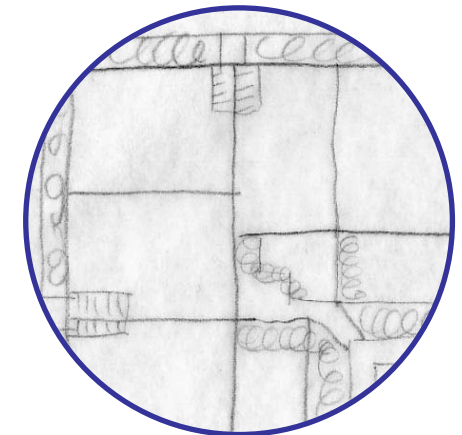
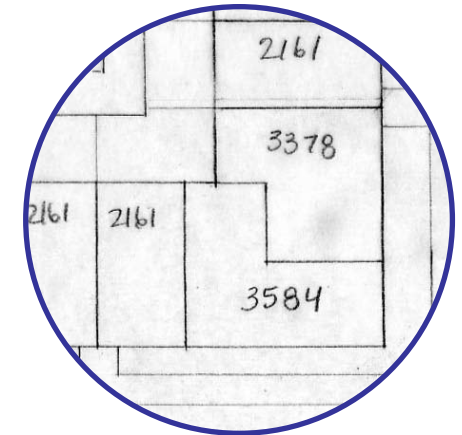
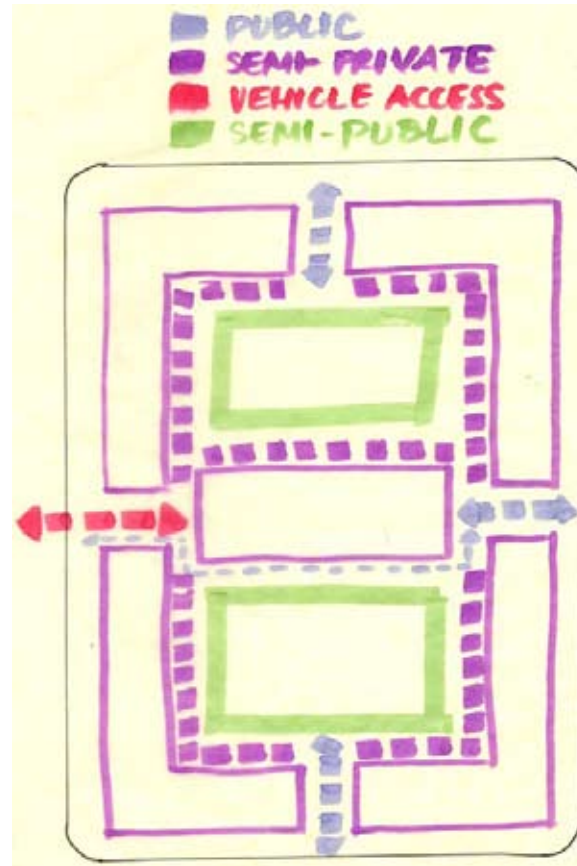
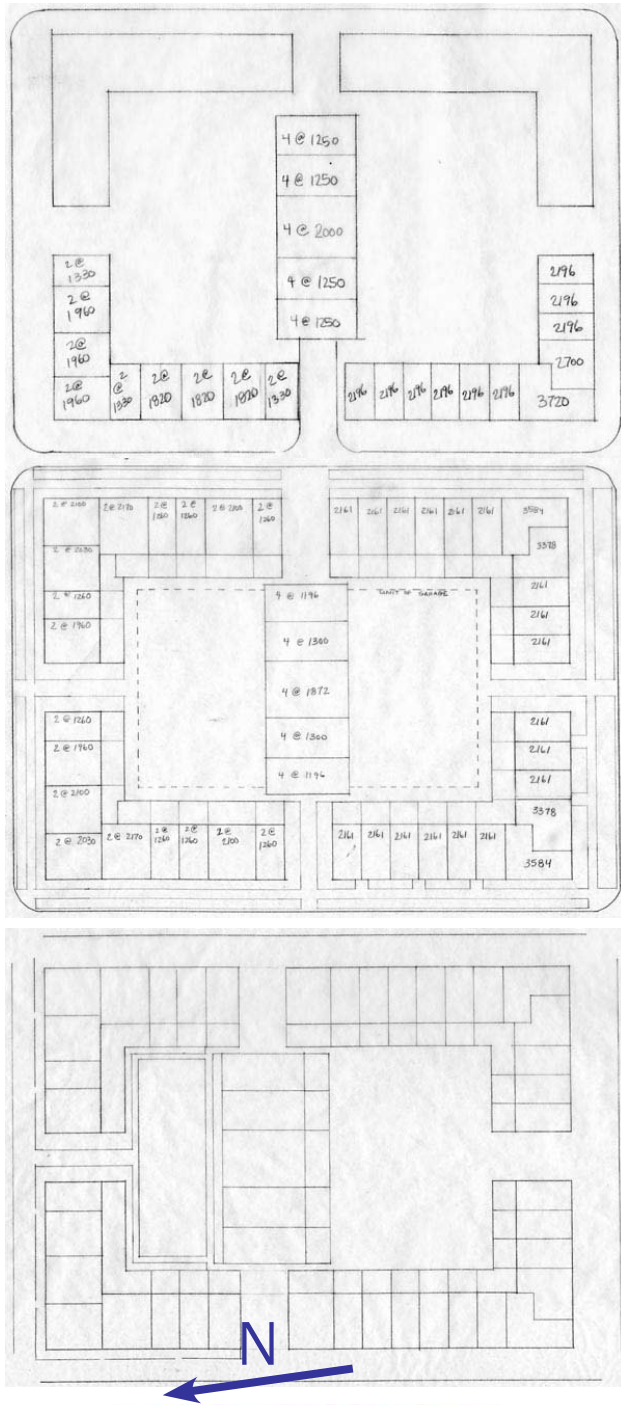


January 2pm

## Unit Layout

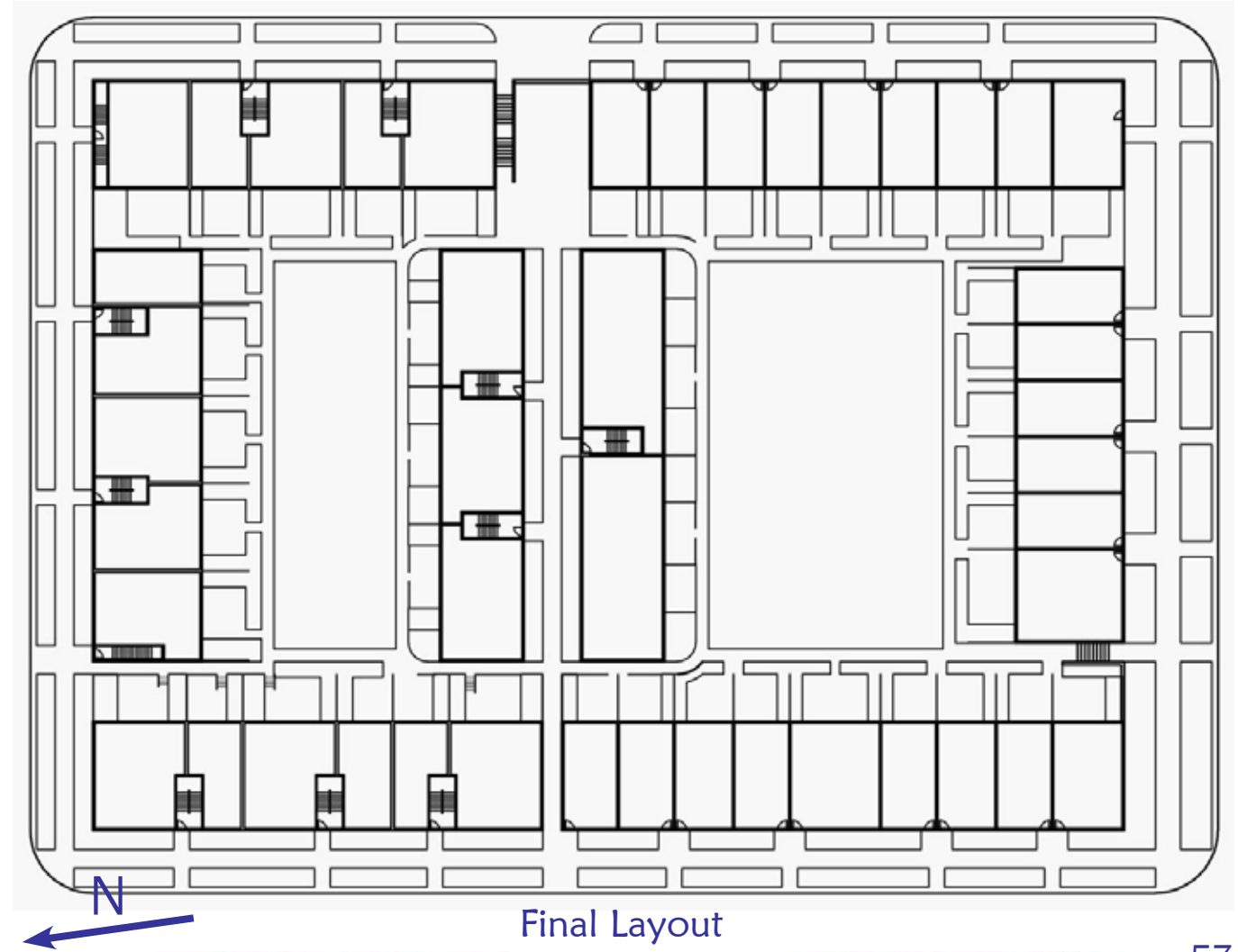
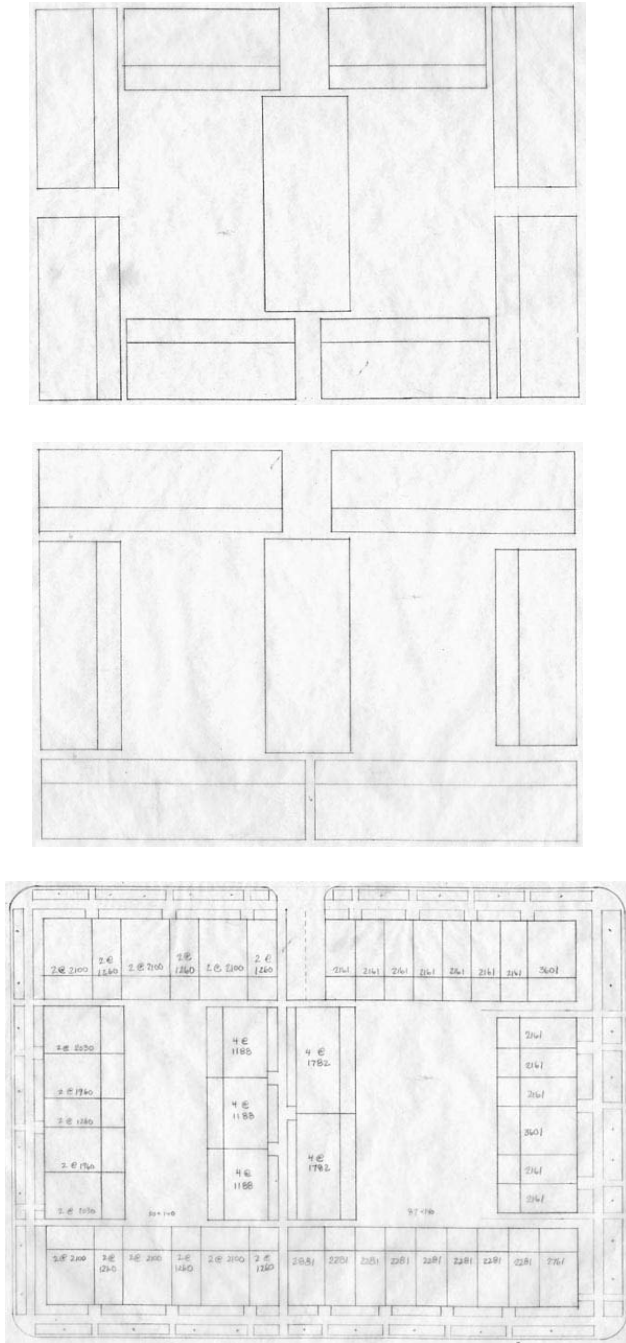
The block configuration with three story townhouses, four story buildings with two level units, and an interior four story building with one level units will be used to start layout of the required unit sizes.

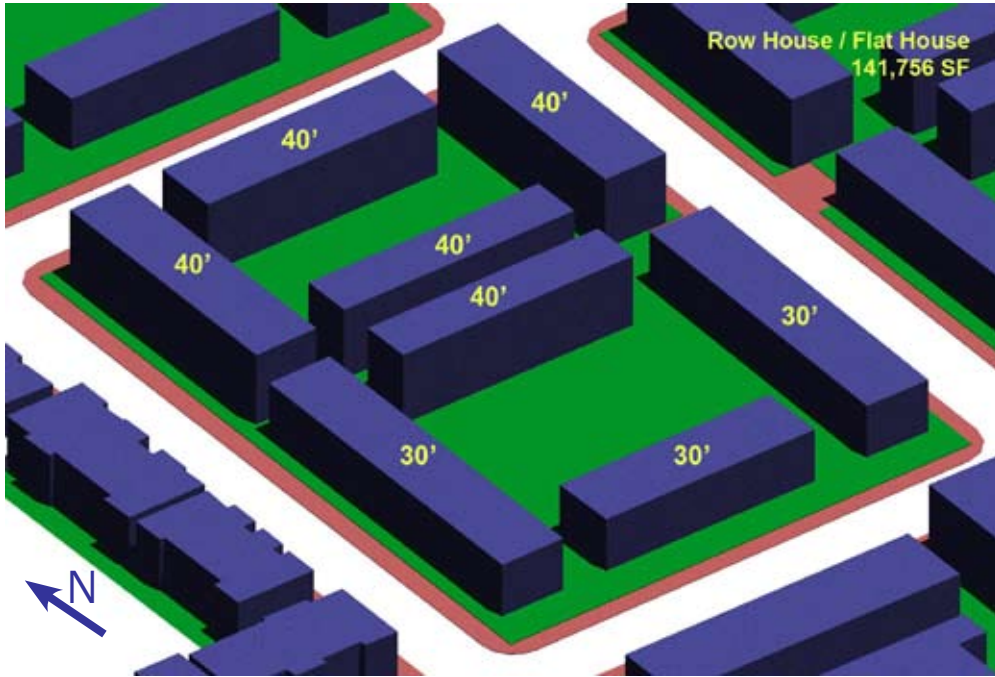
Several questions arise during the unit layout process. This design poses problems with the corner units. How are corner units divided to provide both sides a front door area and a rear private area? The single interior building raises questions about where the front and back doors are located. Will the front doors for this building be facing the rear areas of the other units? This can give confusion in the hierarchy of space and which areas are public or private.



## Refining Building and Unit Layout

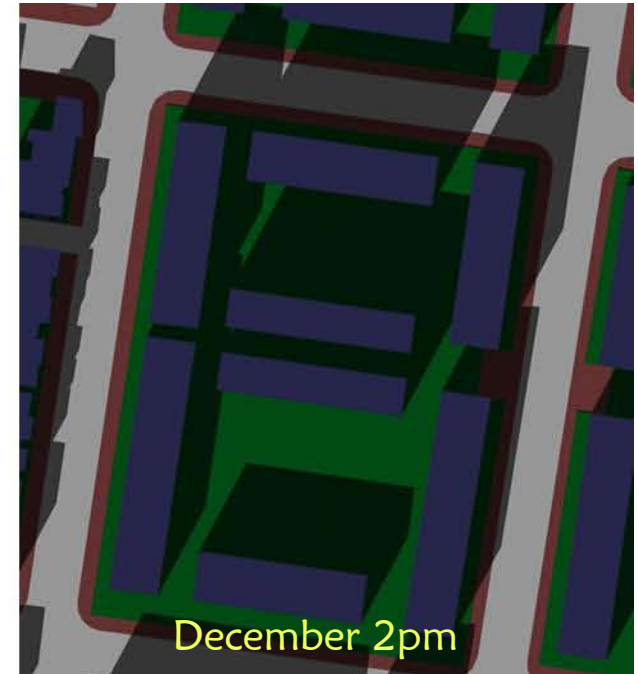
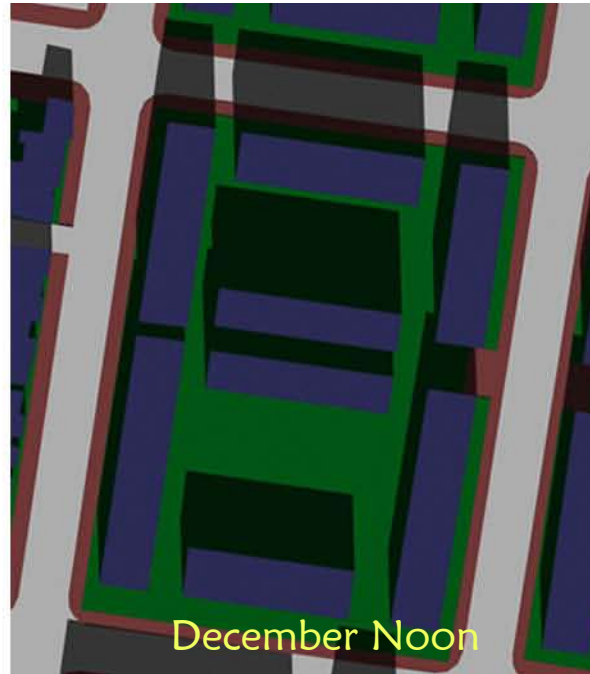
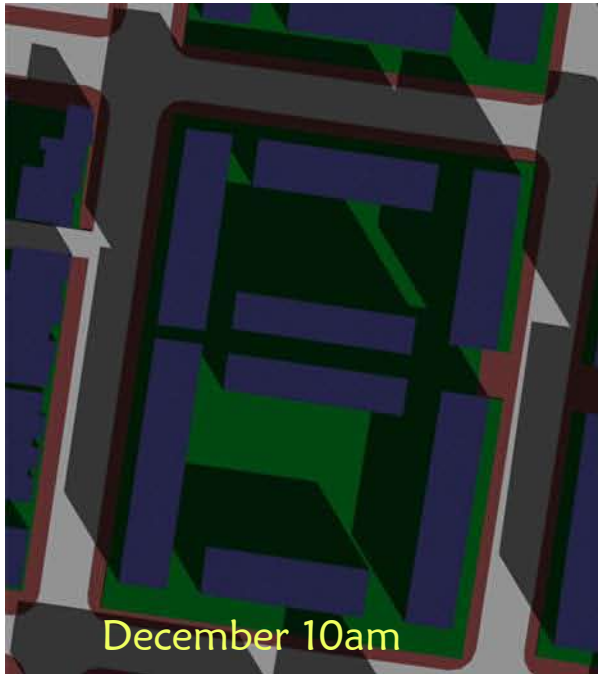
Problems with the corner units and interior building lead to a refinement of the design. Buildings are reorganized to be single row buildings along the street edge with no corners. Each unit has private space on the interior side of the block. The interior building is converted into two buildings with an entry way between the buildings. The private spaces for the interior buildings face the interior of the block. The garage entrance moves to the eastern side of the block along N. Royal St. where the elevation is lowest.



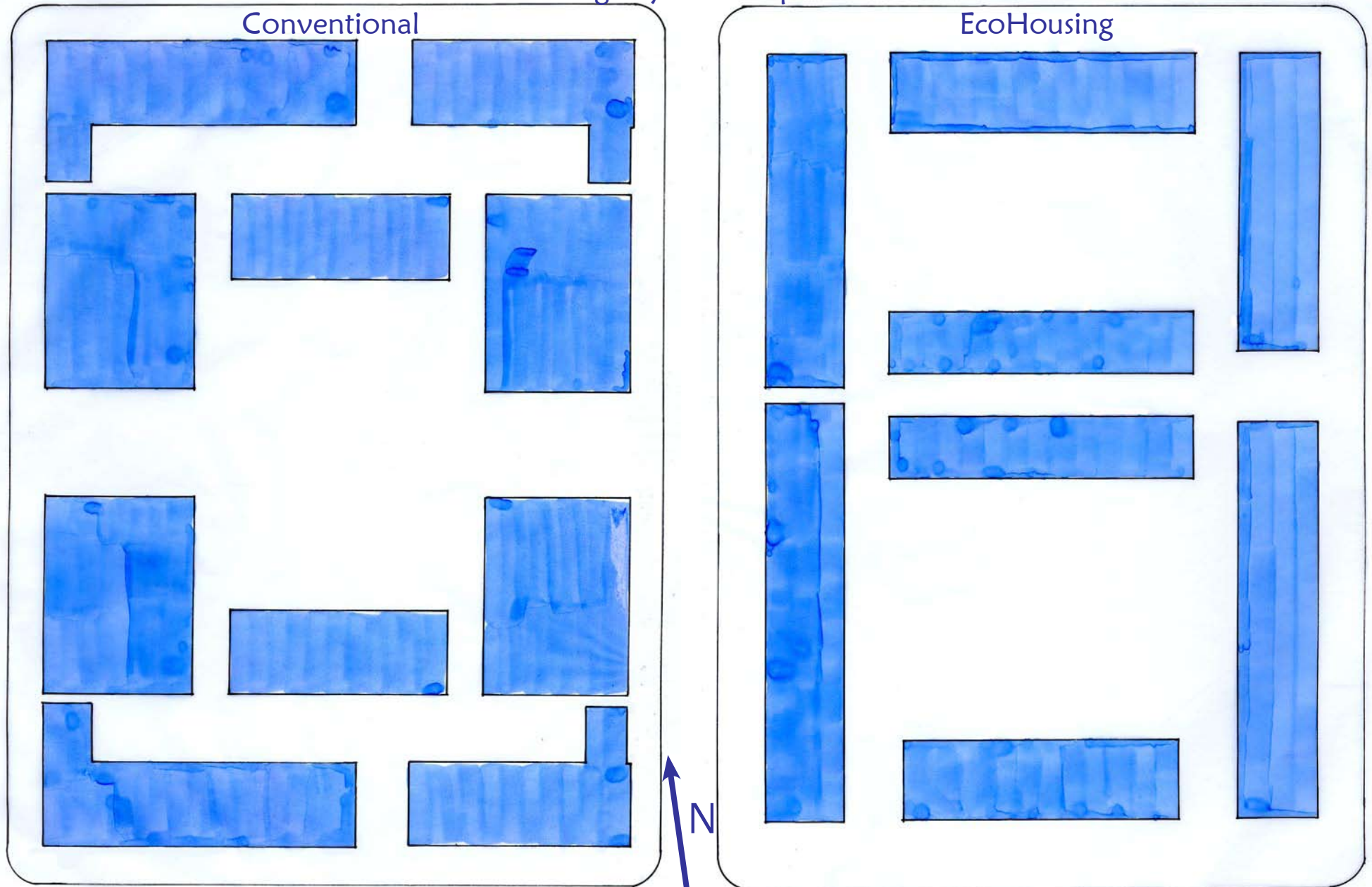


## Final Block Configuration

The final block configuration and shade analysis is shown. Dual openings in the north-south axis of the block allow southern winter sun and southern summer wind open access through the block. Further block design is discussed in the next section.



## Building Layout Comparison

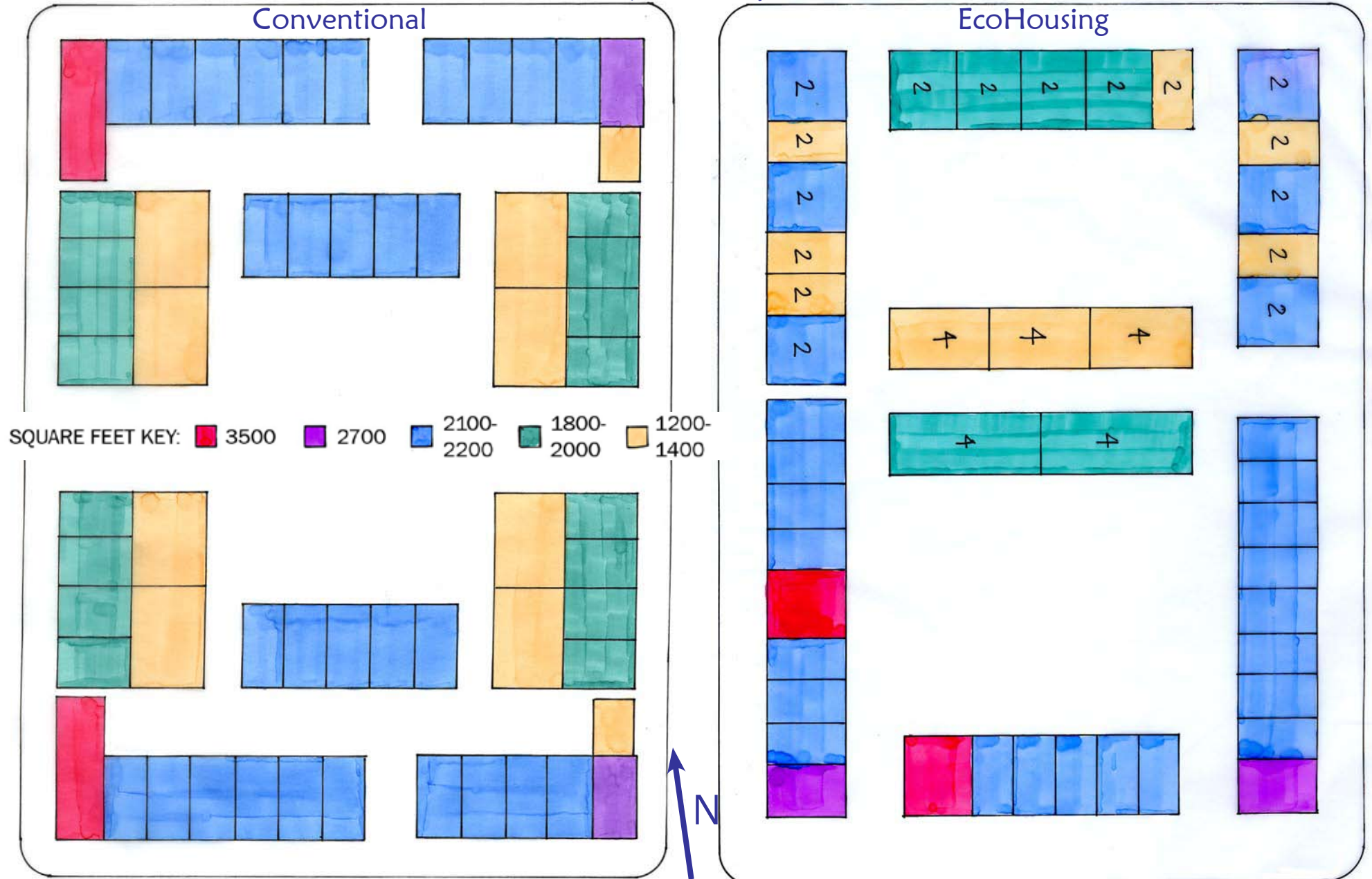


The building layout for Urban EcoHousing is compared to the Conventional Development. Single depth buildings allow better air circulation for ecohousing units. Building setbacks and spacing reduce shading effects and will be discussed in a later section.

# Design Analysis

## Unit Layout Comparison

# Final Building Configuration



The unit layout for Urban EcoHousing is compared to the Conventional Development and is shown to meet unit size and number requirements. Ecohousing consolidates building space by using one and two level units in buildings that are one story higher than the conventional development.

# Urban EcoHousing

Design Overview

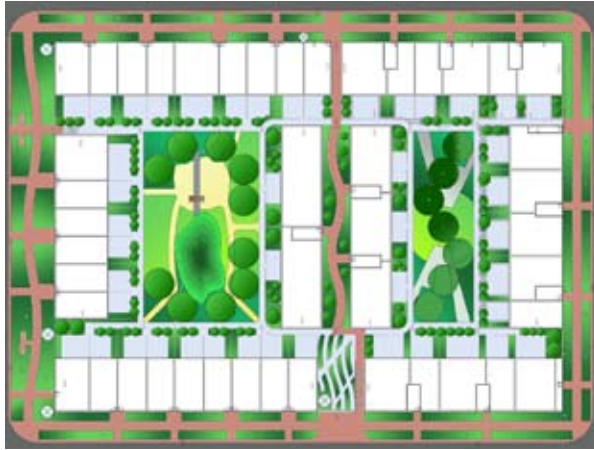
Design Goal: Maximize Green Space

Design Goal: Minimize Impervious Surface

Design Goal: Provide Natural Heating and Cooling

Design Goal: Control Water Quantity and Quality

Design Goal: Create Livable Green Space



## Ground Level Plan Garage Level Plan Roof and Tree Canopy Plan

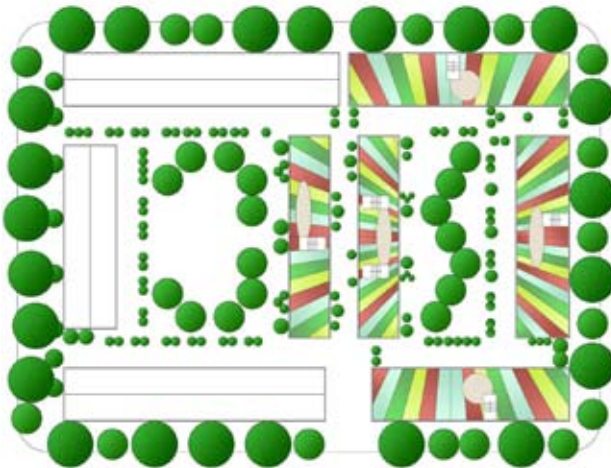
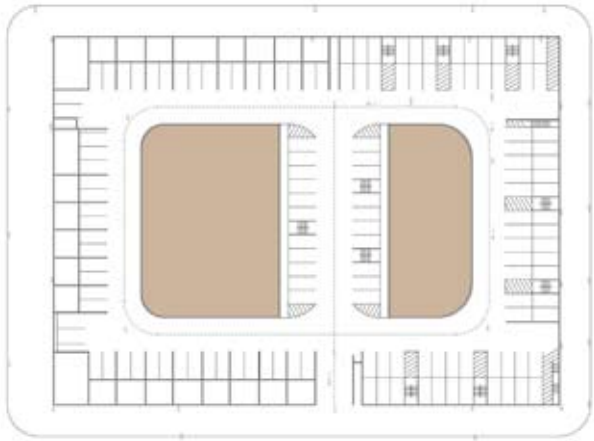
Thus far, this document has introduced the concept of the Green Infrastructure and Urban EcoHousing project, analyzed the site, and worked through building configuration design. I now address the site design for the Urban EcoHousing project.

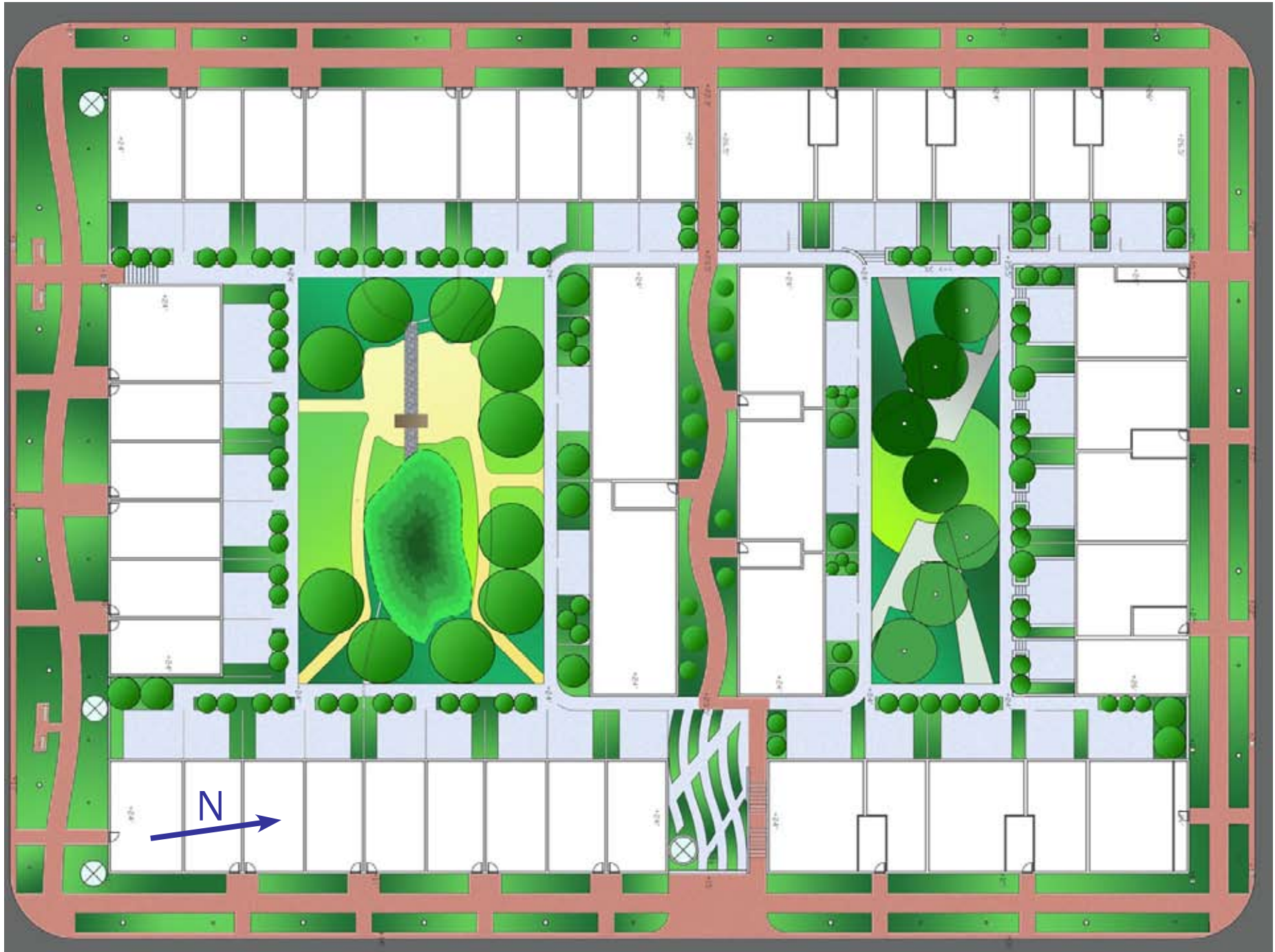
The plan for Urban EcoHousing must be designed at three levels. The ground level plan shows the building footprints, the sidewalk landscape and building entrances, private patio space and common interior courtyards.

A lower level parking garage contains parking spaces below the units and common buildings. Earth wells contained within the lower level garage provide permeable ground for the two large courtyard spaces.

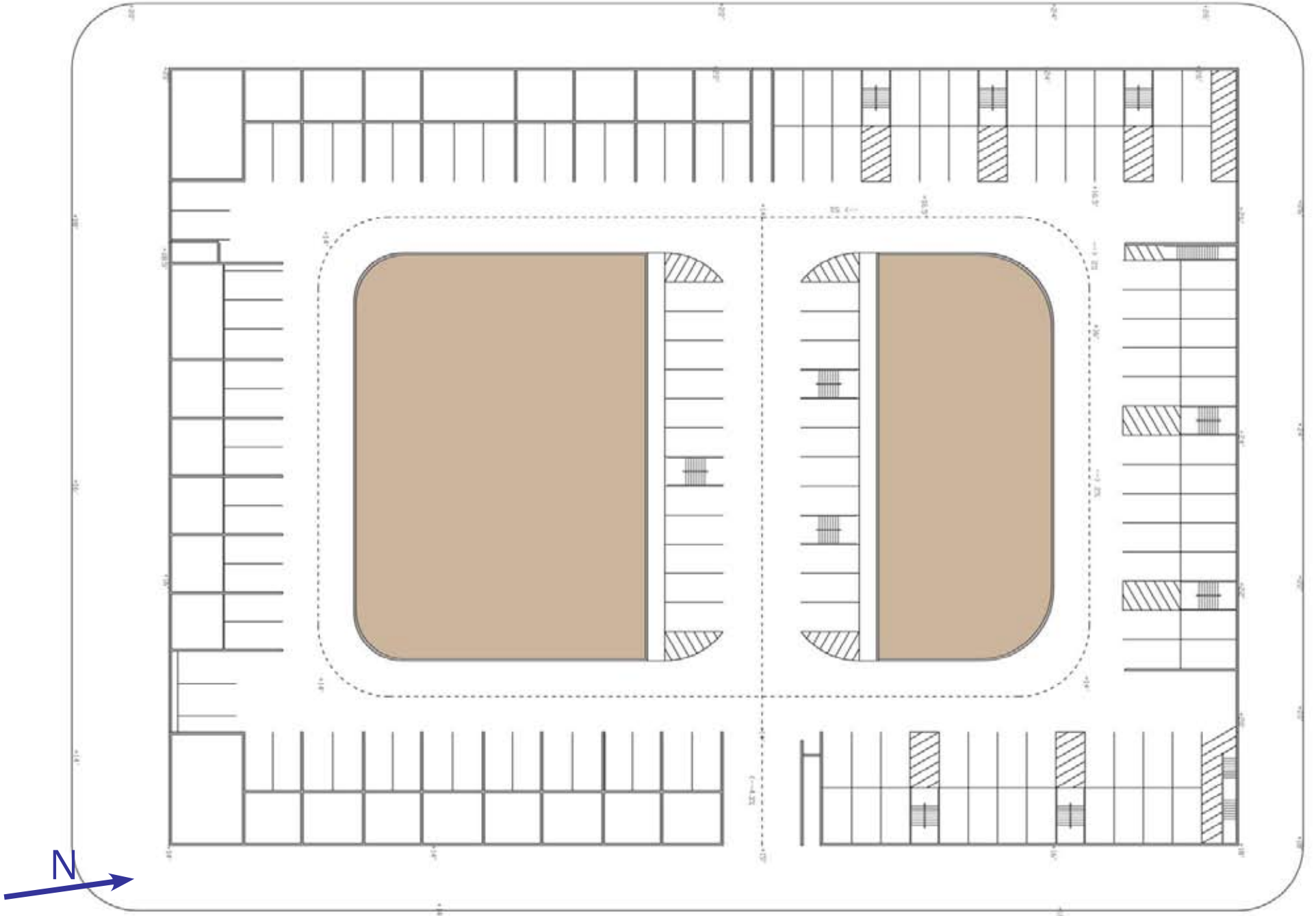
The roof and canopy plan shows green roofs and tree canopy. Each level is an important part of the Urban EcoHousing design and shows distinct features of the design. Larger images of each plan are shown on the following pages.

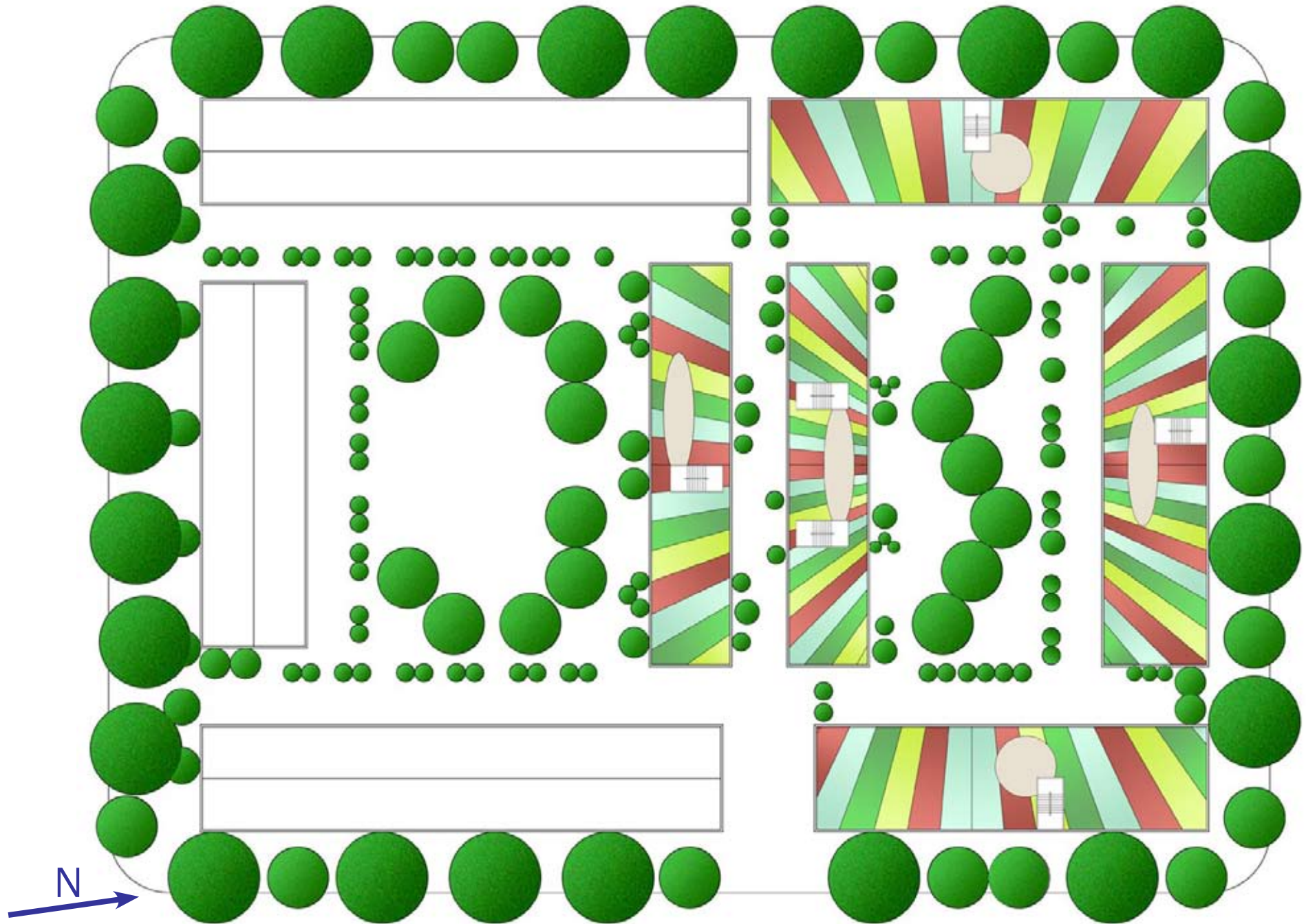
The site design is based on the themes of sun, wind, and water. Sun and wind were a critical factor in designing the placement of the buildings. The rays of the sun and the flow of water are used as design form generators for the courtyards, sidewalk space, and planting areas. These ideas will be further discussed and demonstrated in the section titled 'Creating Livable Green Space'.





Garage Level Plan

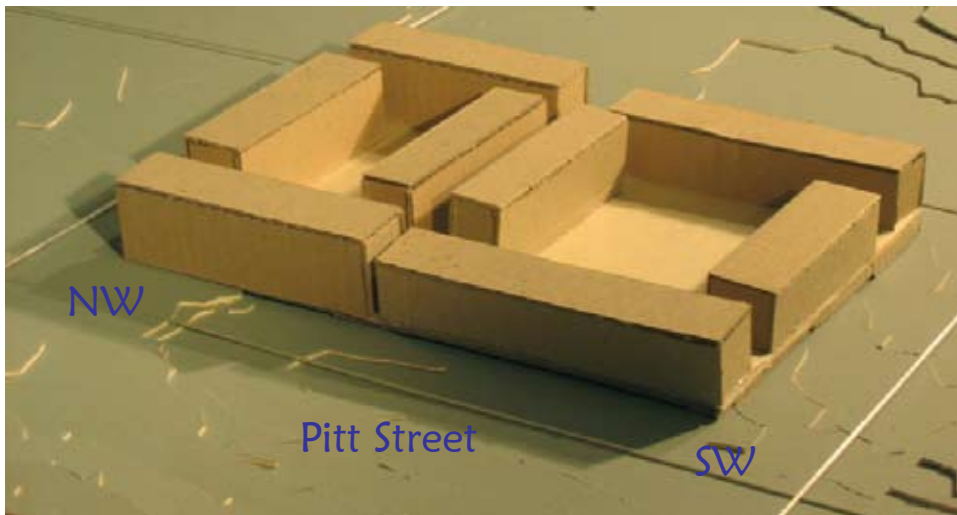
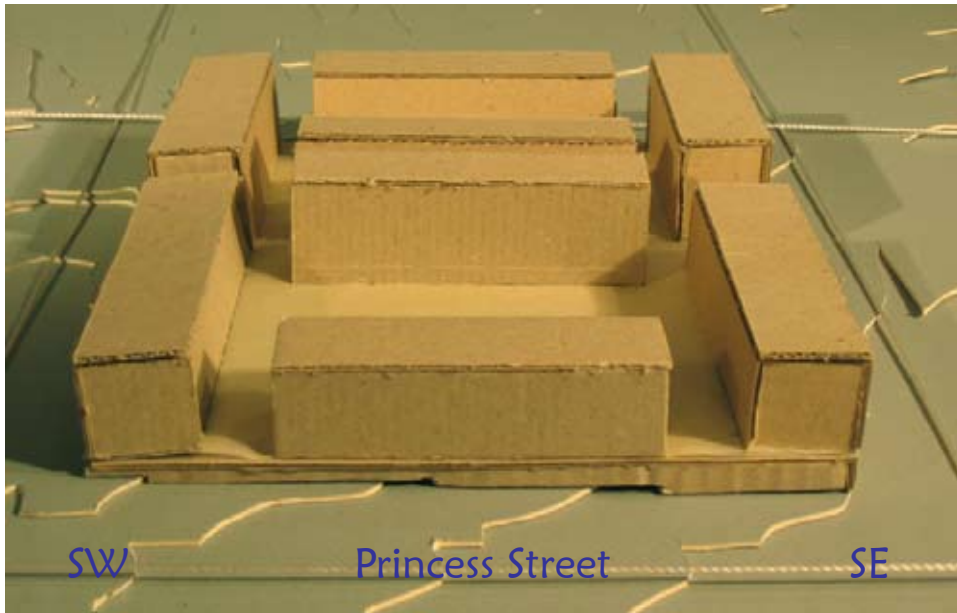




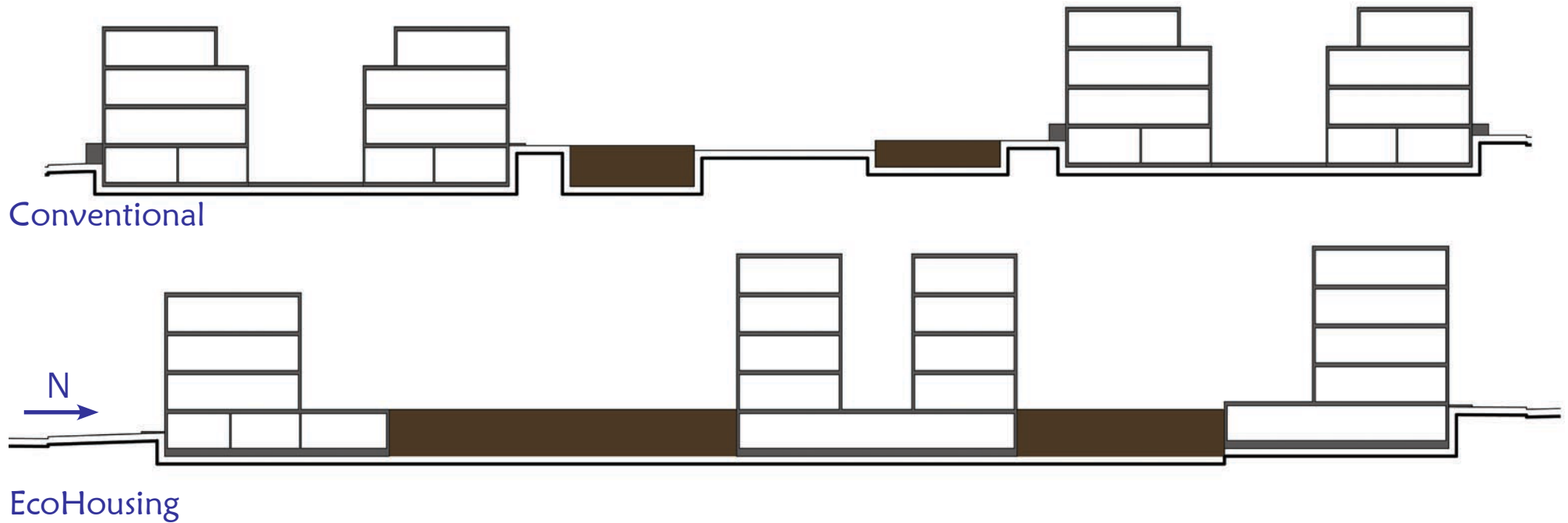
## Site Elevations and Study Model

The elevation of the block changes from fourteen feet (14') at the southeastern corner to twenty-six feet (26') at the northwestern corner. This grade change added challenge to the design of the buildings, garage, and common courtyard spaces. This study model shows the grade differences at the corners and street level. Contours are spaced every two feet (2'). The garage is entered at grade level of fifteen feet (15') on the eastern side of the block. The garage floor level is fourteen feet (14') on most of the block, except the northwestern corner where the floor level is sixteen feet (16').

Buildings are entered at grade level of the sidewalk, ranging from fourteen to twenty-six feet (14' - 26'). Interior stairs give access to the main level of buildings, at twenty-four, twenty-six, or twenty-six and one-half feet (24', 26', or 26.5') elevation. Private patios are above the garage at the same grade as the main level of the building. Interior common courtyards are above the garage at twenty-four feet (24') elevation. Each of these conditions will be explored further in the following sections.

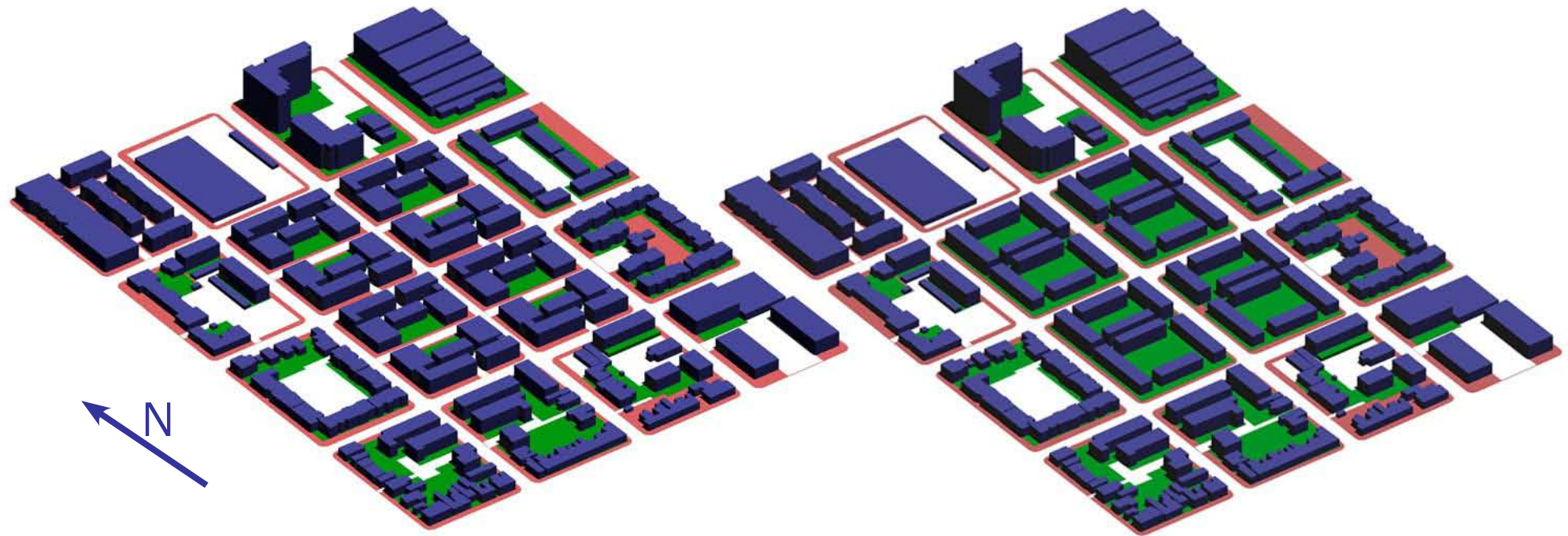


## North-South Section Comparison



This section through the north-south direction of the block shows the difference between the placement, height, and depth of the conventional housing and ecohousing. The buildings are similar in how they meet the block perimeter sidewalk at grade or mid-way between the garage and first floor levels. Differences are seen in the increase of open and pervious surface in the ecohousing. Several of the buildings in ecohousing are one floor higher than the conventional development, which allows for consolidation of building area space.

## Site Density Comparison



Conventional

Ecohousing

The site density of ecohousing is now compared to the conventional development. Issues from the comparison with the sites' previous density remain. The buildings are larger than the previous site structures and they may sit high over the existing neighborhood. In order to meet the density of current development, this is a necessary consequence.

However, in comparison to the conventional development, ecohousing shows several improvements. The buildings are compacted in such a way to give more space between the buildings and more open space. Placement of the parking and alleys below the ground level gives more livable green space and significantly reduces impervious surfaces. Residents in most units can enjoy a view to a landscaped courtyard out their window, instead of a paved alley or a view directly to their neighbors' window.

The inputs to Urban EcoHousing are ‘Ecological Services of the Urban Landscape’ and the ‘Rights of the Urban EcoHousing Resident’. To design the landscape as green infrastructure, design goals are developed to integrate these ideas. How can an urban landscape be designed to ensure that it will provide the most ecological services it can? What are the pieces of a landscape design that fulfill the rights of the urban resident? The Urban EcoHousing design goals connect ecological services to the resident’s rights in the realm of what a landscape architect can do.

The first design goal is to maximize green space. This goal derives from the need to maximize the surface area of the landscape so it can provide the most ecological services possible. Resident’s rights to have views and access to common green space, and shading from the summer sun also lead to this goal.

The second design goal is to minimize impervious surface. This goal is derived from the ecological services to control the quantity and quality of water runoff and to reduce heat gathering and reflection from pavement. This goal is also focused at taking cars off of valuable ground level space and providing views and access to common green space near housing units.

The third design goal is to provide natural heating and cooling. This goal is developed from the resident’s rights to have winter sun in their window, shading from summer sun, and natural air circulation through their house and through the housing site. This goal is directly related to the landscapes’ ability to provide ecological services for energy conservation.

The fourth design goal is to control water quantity and quality. The ecological services of water quantity and water quality are the origination of this goal. Storm water runoff and the impaired quality of our rivers are important issues in today’s landscape. Mitigating these problems must be a primary goal in the landscape design.

The fifth design goal is to create livable green space. The resident’s right to be able to passively or actively use the area outside of their units is the primary driver of this goal. Residents need common green space, private outside space, places for children to play, and shade from the summer sun. The landscape’s ability to reduce temperatures and improve air quality will make the livable green spaces a more pleasant place to be.

Each goal is now explored further. Design strategies and implementations to achieve each goal are illustrated and discussed.

## Design Goals

Maximize Green Space

Minimize Impervious Surface

Provide Natural Heating and Cooling

Control Water Quantity and Quality

Create Livable Green Space

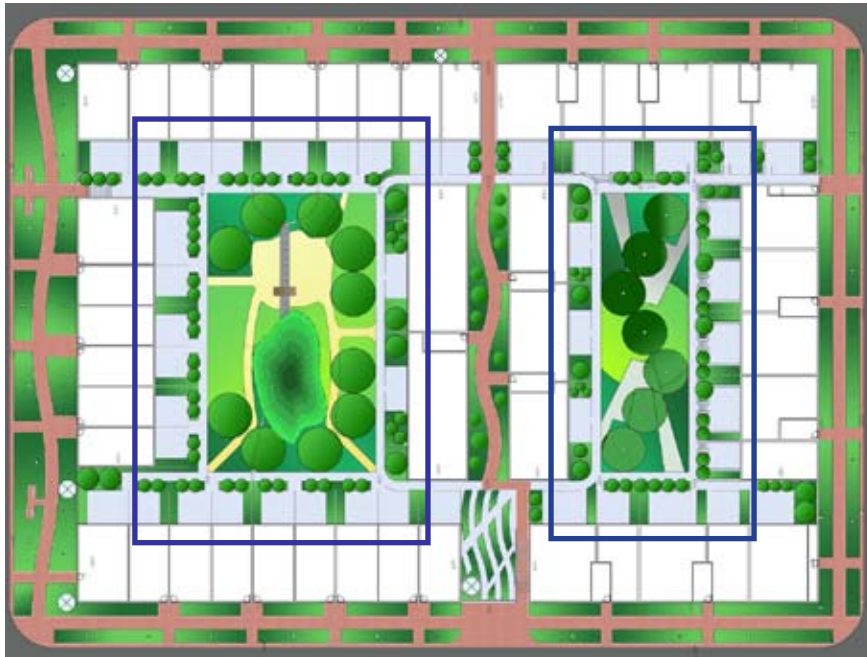
# Maximize Green Space

Interior Courtyard Space  
Garage Rooftop Gardens  
Street Trees with Continuous Planting Areas  
Green Roofs

Maximizing green space is at the heart of the green infrastructure concept. For the landscape to function well and perform ecological services, it needs sufficient soil depth and as much growing area as possible. In cities the area for the landscape is very constrained, so each space must be designed carefully. Maximizing green space has been a primary goal from the first layout and iterations of building placement in this project. The need of the urban ecohousing resident for living, moving around, and keeping their cars must be balanced with the needs of space for landscape.

The goal to maximize green space produces results that tie very closely with the goal to minimize impervious surface. Each goal is distinctive and needs to be treated separately. However there is significant overlap and many issues will be discussed in both sections.

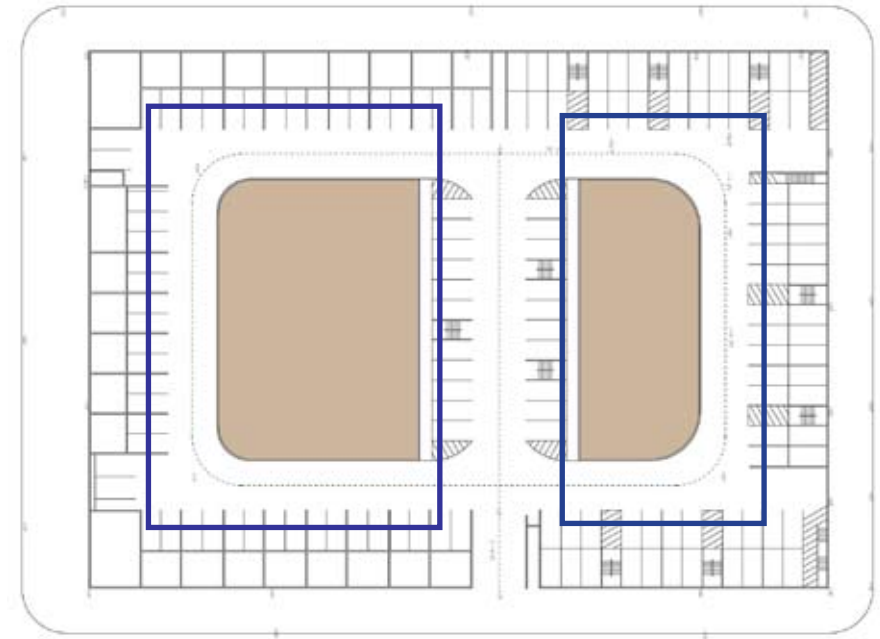
The ecohousing design maximizes green space through several methods. Interior courtyard areas are made possible by placing parking and access drives below the ground level. Private outside spaces and planting buffers are on the ground level above the garage. Planting areas between the sidewalk and road are designed as continuous strips with special sidewalk techniques to maximize the growing space for trees. Green roofs provide additional green space to the tops of the five buildings with one and two story units.



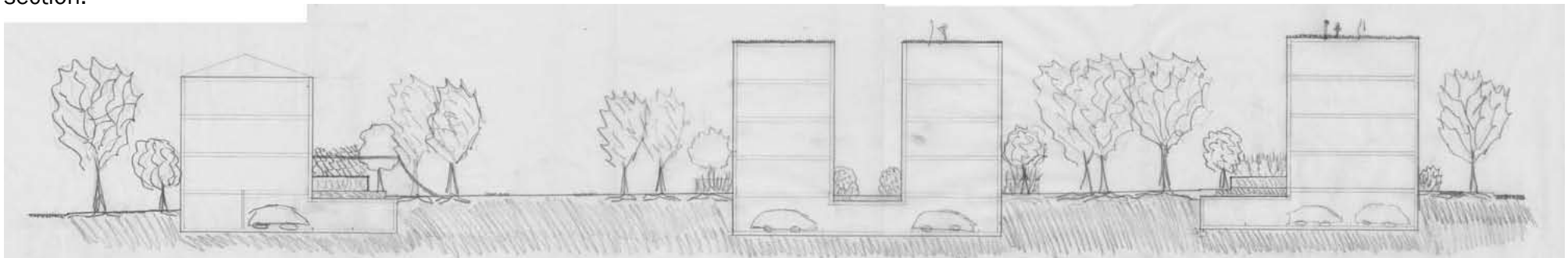
### Courtyard Spaces and Garage Rooftop Gardens

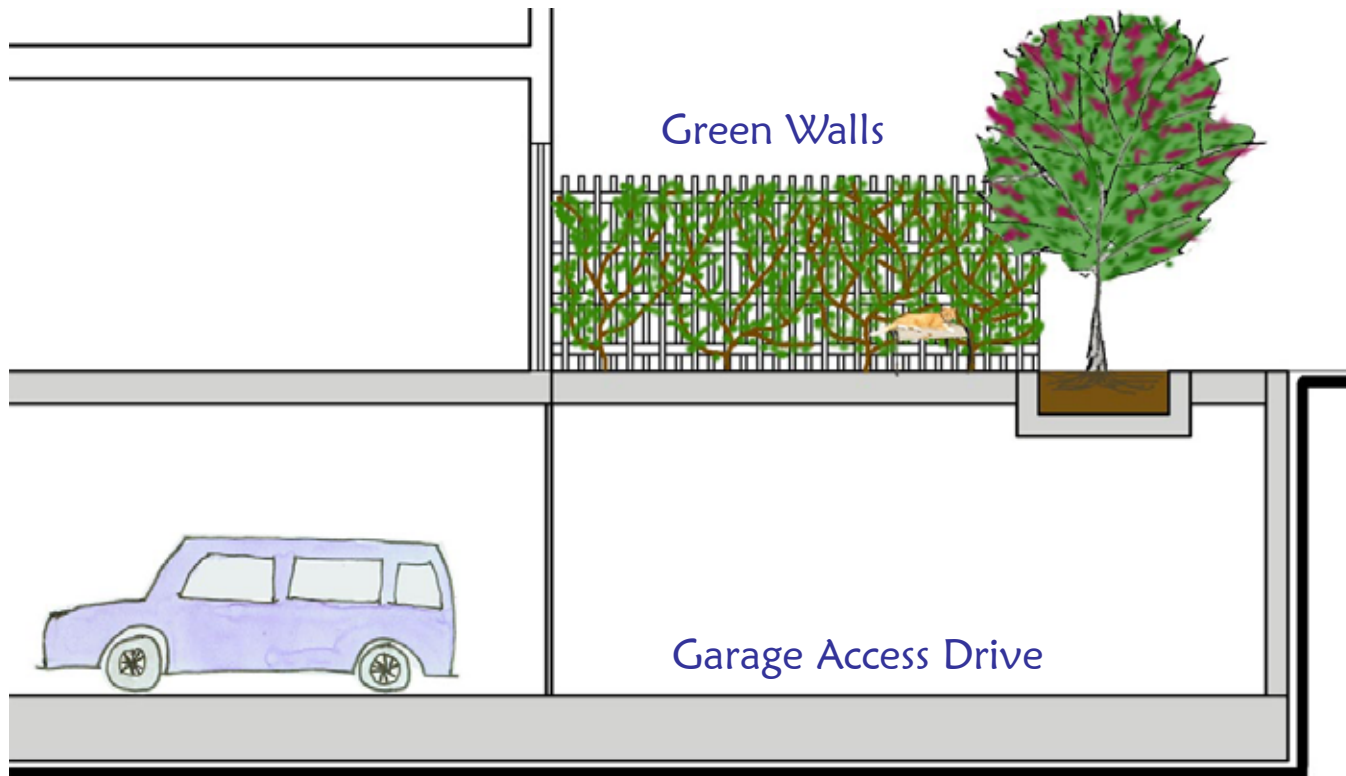
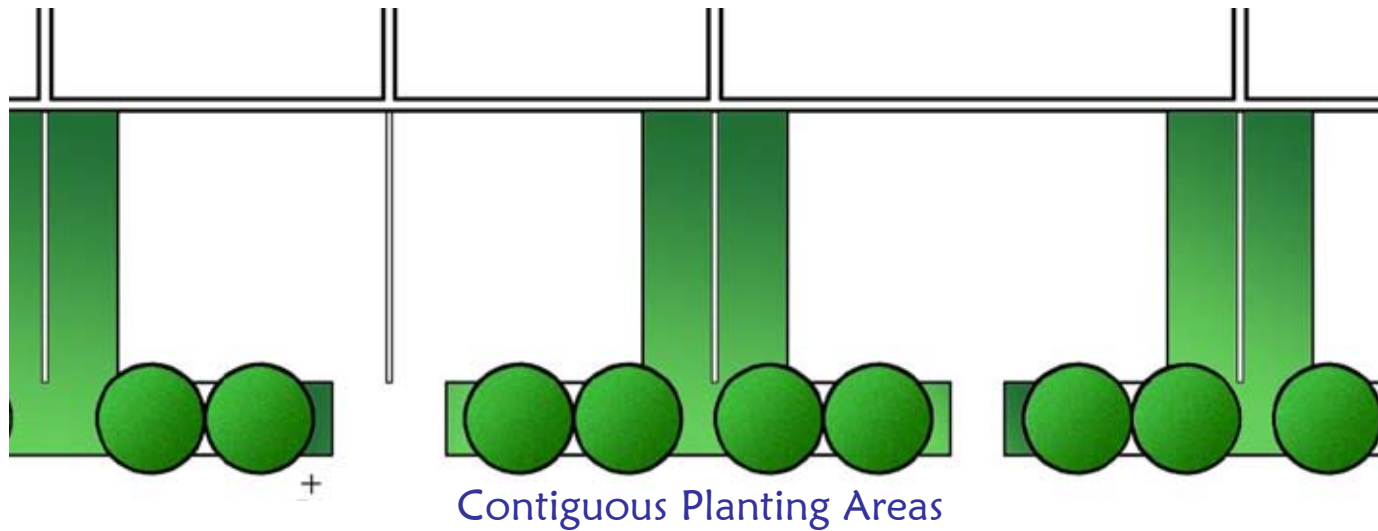
The lack of green space in the conventional design is noticeable. Access drives to the parking garages take up significant space that could be used as green space. A solution is to build the garage and access drives below the surface level and reclaim the space above as livable green space.

The ecohousing design has below ground access drives with parking under the buildings and a single access point to the street. The access drives are designed so that the center of the garage contains earth wells in the courtyard locations. With areas for deep soil, the courtyards can support larger plantings and water infiltration, and avoid the rooftop condition typical in this situation. Private patios, planting areas, and a community garden are located in the space above the access drives. The garage will be further described in the 'Minimize Impervious Surface' design goal section.



### Below Grade Garage with Earth Well

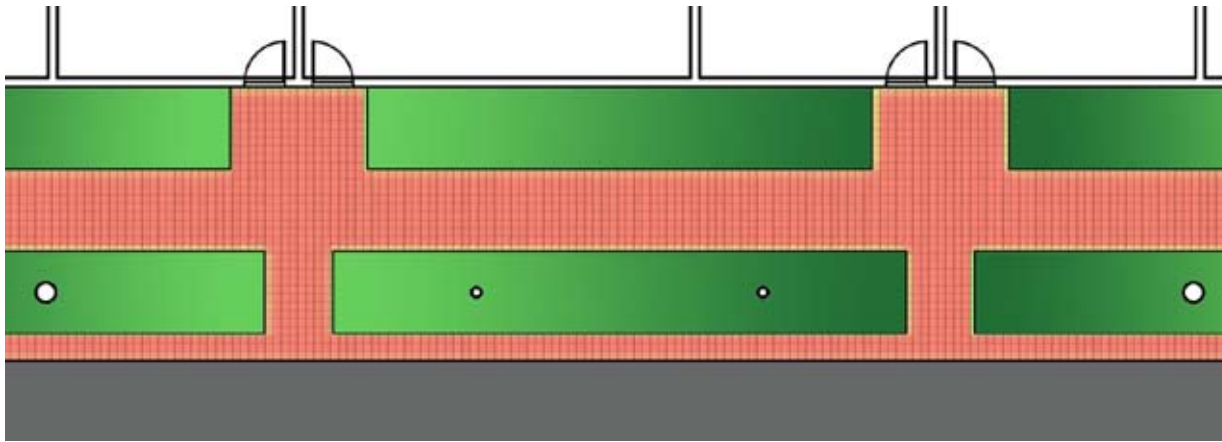




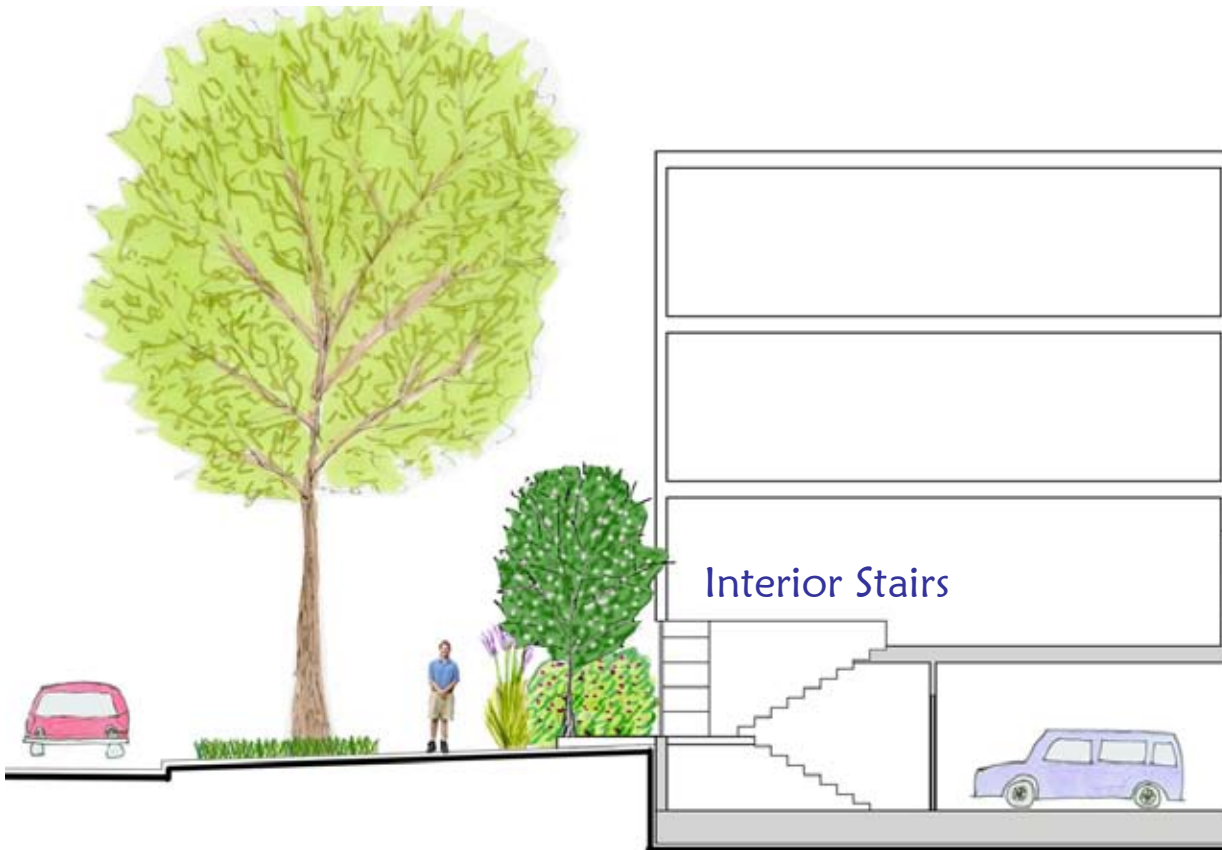
## Garage Rooftop Gardens

Private outdoor space and planting buffers are located above the access drives. Plants are limited in size by their growing space, and the more root space they have the larger they can grow. To maximize the green space, planting areas are collocated between units. Where space allows for only one planting area, it is paired with the planting area for the adjacent unit.

The private areas are also separated by green walls wherever possible. Green walls are plants grown on a vertical surface, in this case, a wooden or metal trellis. A soil base in the planting area or a container is required for a green wall



Continuous Sidewalk Planting Areas



## Street Trees

Trees are a critical part of green space, but the reality is that most street trees live on average seven years. Urban trees typically do not have enough root space to grow to a mature size. With a short life span, and under potential size, street trees will never be able to serve their purpose and provide ecological services and enjoyment to people. The ecohousing design is focused on proving street trees the right kind of conditions to grow to a mature size.

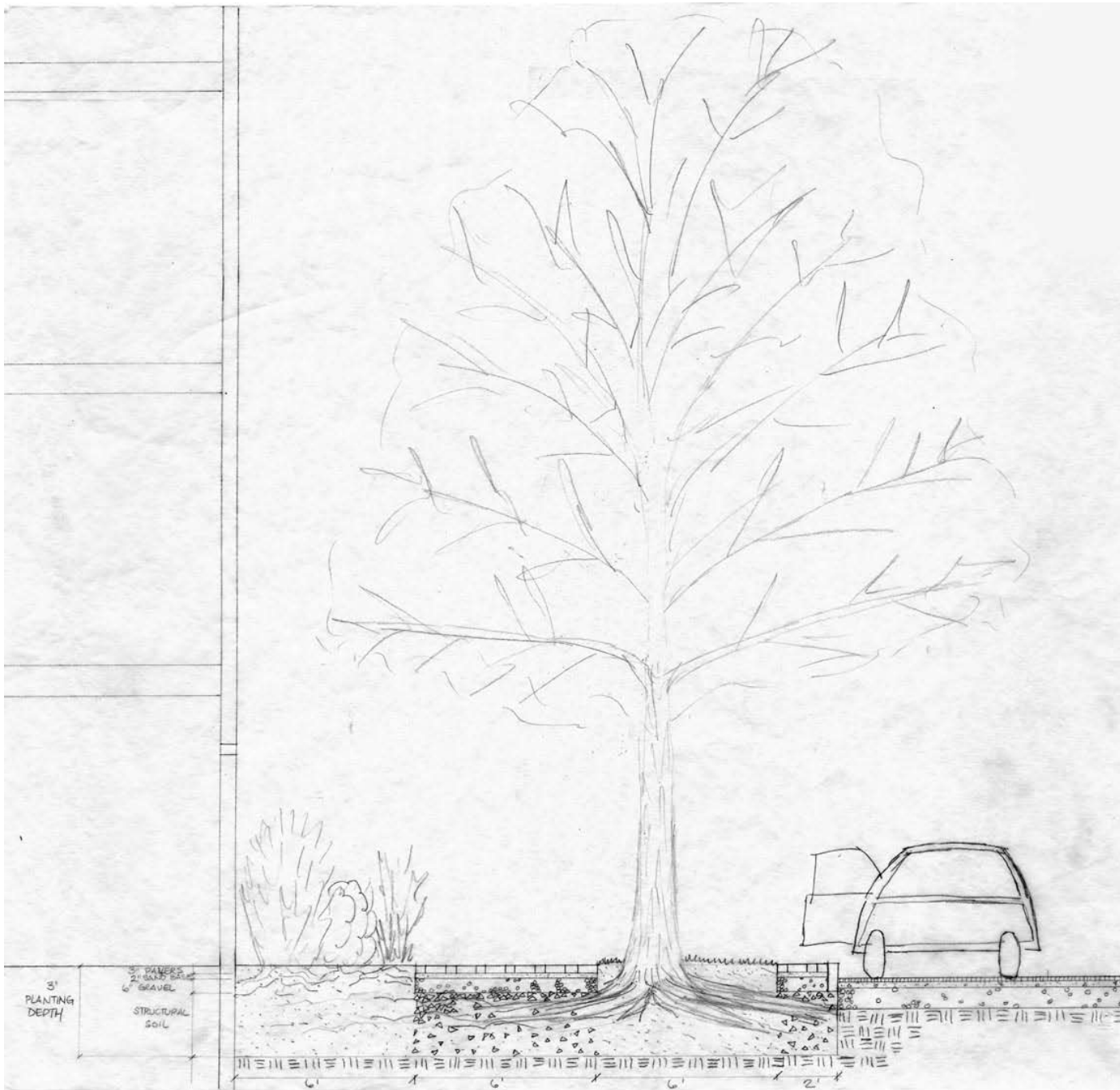
The sidewalk design has a significant impact on how trees can grow. Continuous planting strips allow more soil for tree roots to grow, and more green space between the houses and street. Access points at regular intervals through the planting area, allow residents to reach the sidewalk and house from the street. Entrances to houses are grouped in pairs to reduce the number of access points needed. Green space and growing area is also located between the house and the sidewalk.

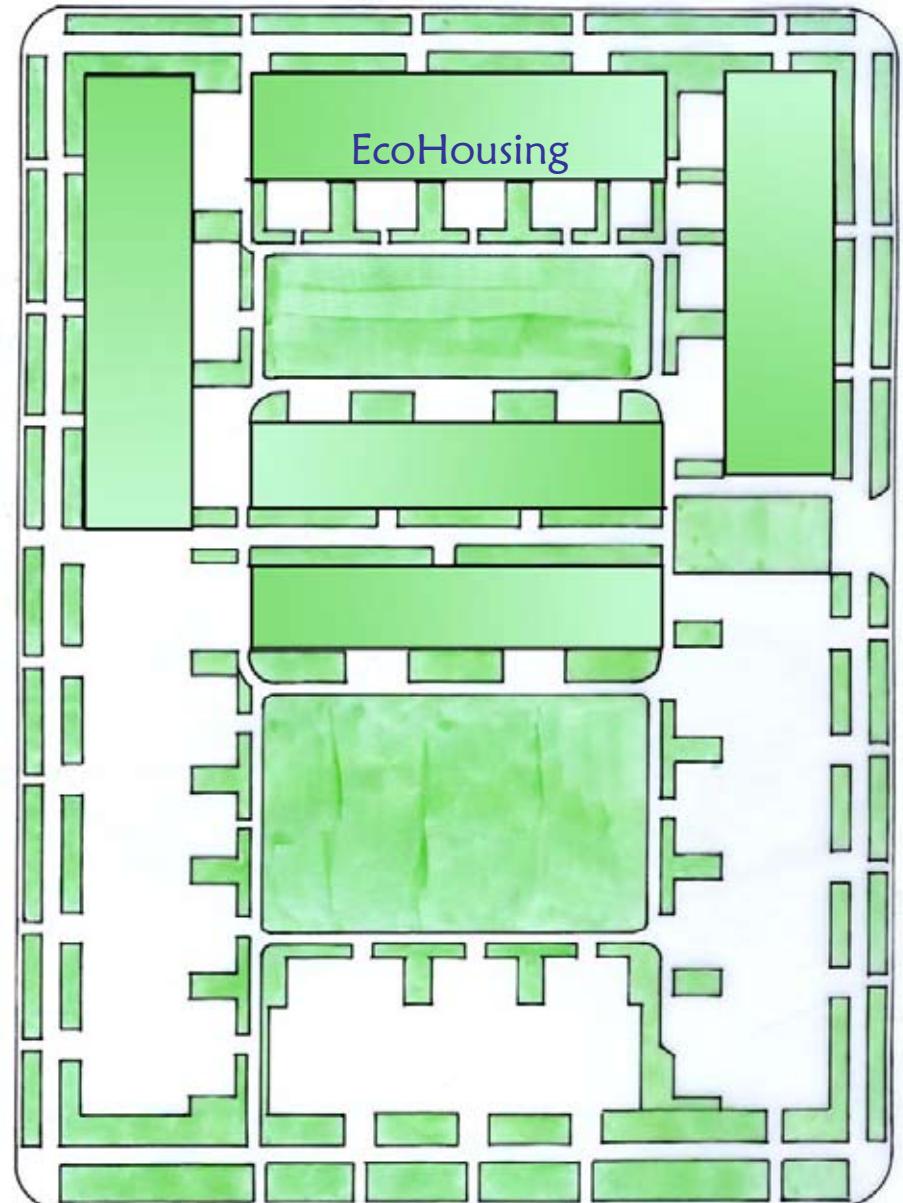
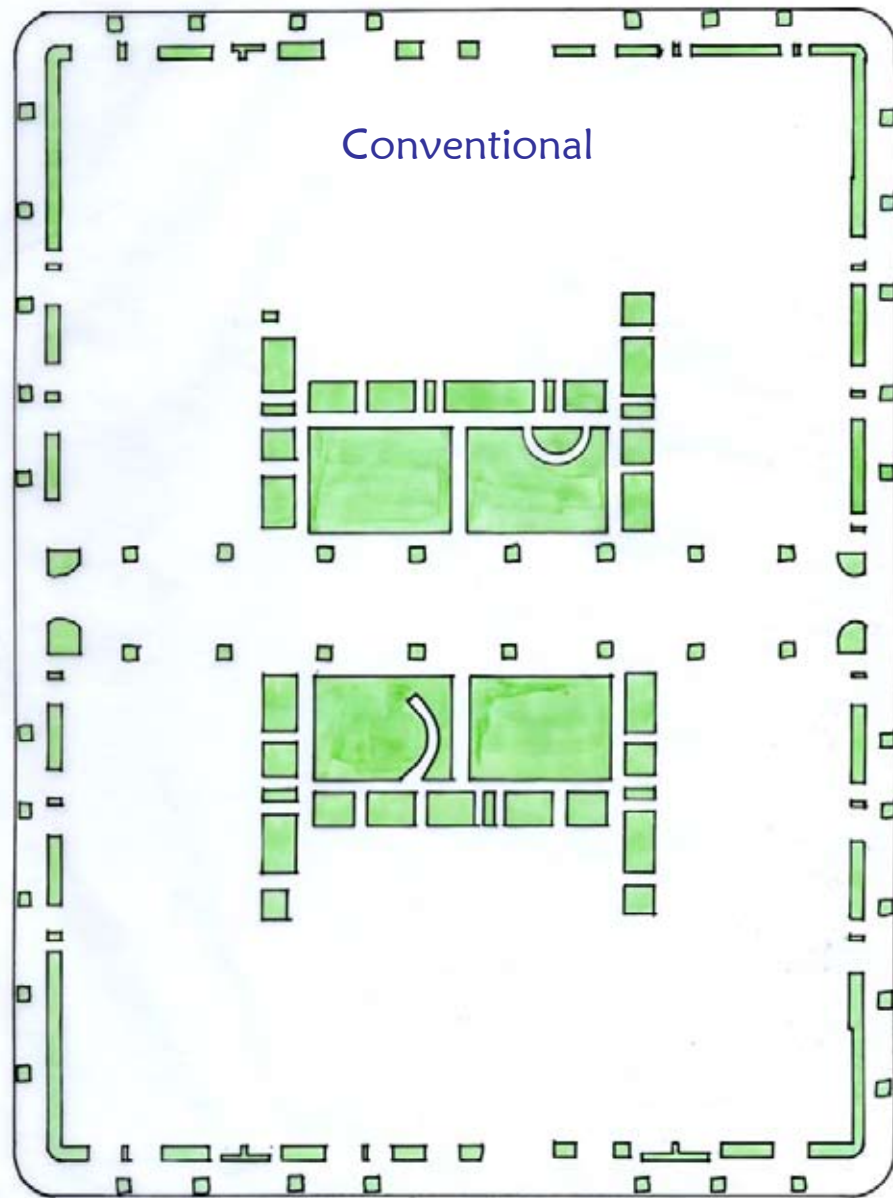
Residents enter the house at sidewalk level. Interior stairs give access to the main level of the house where the entrance is not at grade. These techniques reduce the sidewalk space needed for pedestrian circulation and maximize the planting space.

## Street Tree Planting

The street tree design includes structural soil used under the brick sidewalks to allow the tree roots growing space under the pavement. Structural soil is a mix of a specific size aggregate with soil, to allow large spaces between the aggregate for the roots to grow. Planting strips are a minimum of six feet (6') wide. A two foot (2') paved strip between the tree area and road protects trees from car doors and from people getting out of their cars.

Trees reaching a large or mature size will provide shade and other ecological services needed in the urban landscape. Temperatures under the canopy are reduced, providing increased human comfort. Trees will capture rainwater in the leaves and slow runoff as the water flows down the trunk. It is critical for urban design to include methods to improve growing conditions for trees, such as the ecohousing design has done.





The methods to maximize green space are simple and the results are significant. Residents have a highly improved living environment, with views and easy access to common outdoor green space. The increased vegetation can capture and filter water, reduce water runoff, capture air particles, and provide shading and evapotranspirative cooling. The comparison of ecohousing to the conventional housing design shows the dramatic increase of green space in the ecohousing design, including green roofs which will be covered in the next section.

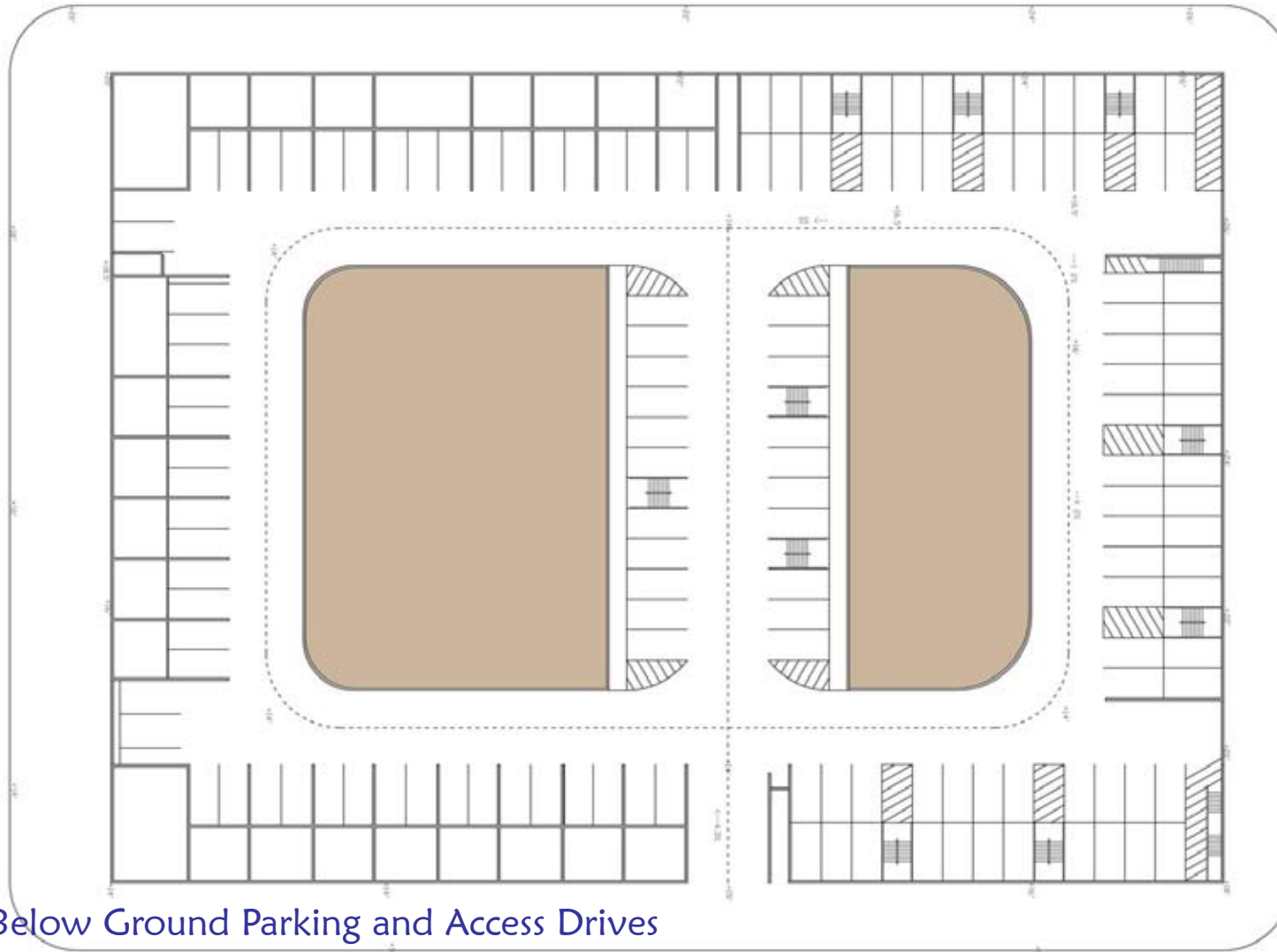
# Minimize Impervious Surface

## Below Ground Parking with Earth Well Green Roofs

A review of the conventional housing design shows that rooftops, alleys, and sidewalks take up much of the site. In a comprehensive green design, parking should be reduced since this location is in a city and easily accessible to public transportation. However, the goals of this design are to meet the requirements of the conventional design, therefore full parking capacity is included. This impact is mitigated by focusing on the resident's right to take cars off valuable ground level space.

By minimizing impervious surfaces, space can be reclaimed as green space and livable areas as shown in the previous section. These two goals are directly related. By increasing the amount of green space and soil to capture water, pervious area is created. It is important to reduce impervious surface so that water can filter into the ground and not runoff. Reducing impervious areas can also help reduce heat collection by pavement leading to cooler areas.

The strategies in Urban EcoHousing to minimize impervious surface are to create a below ground parking garage with earth wells and construct extensive green roofs on five buildings. The below ground parking and access drives allow the space above to be used, and the earth wells create a large pervious area for the courtyards. Green roofs will capture rain water in the plants and soil, and reduce the water than runs off the building roof.



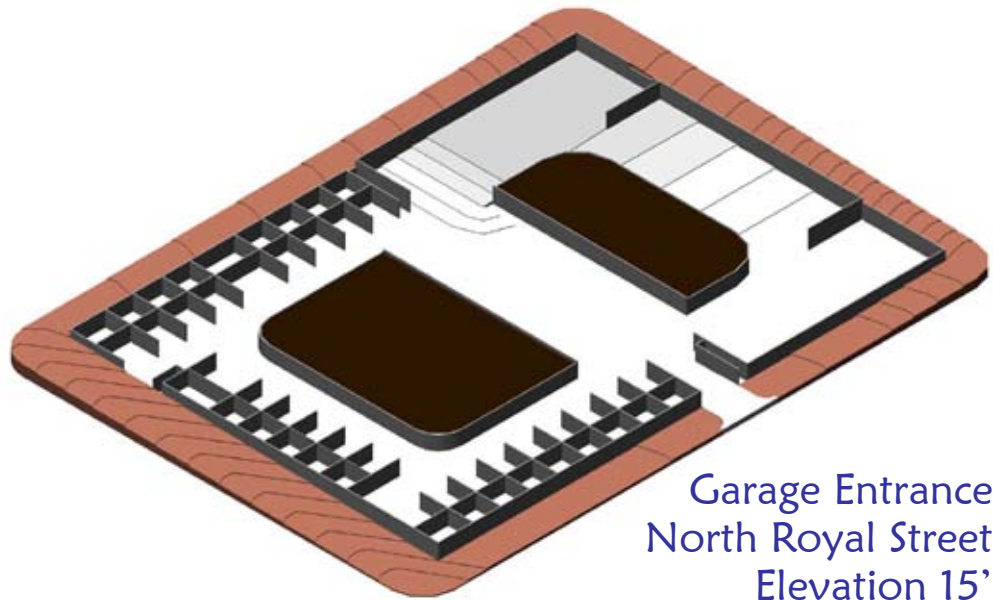
**Below Ground Parking and Access Drives**

The comparison of parking spaces shows that ecohousing meets the equivalent space requirement. Ecohousing gains street parking spaces by having three fewer curb cuts around the block than conventional housing.

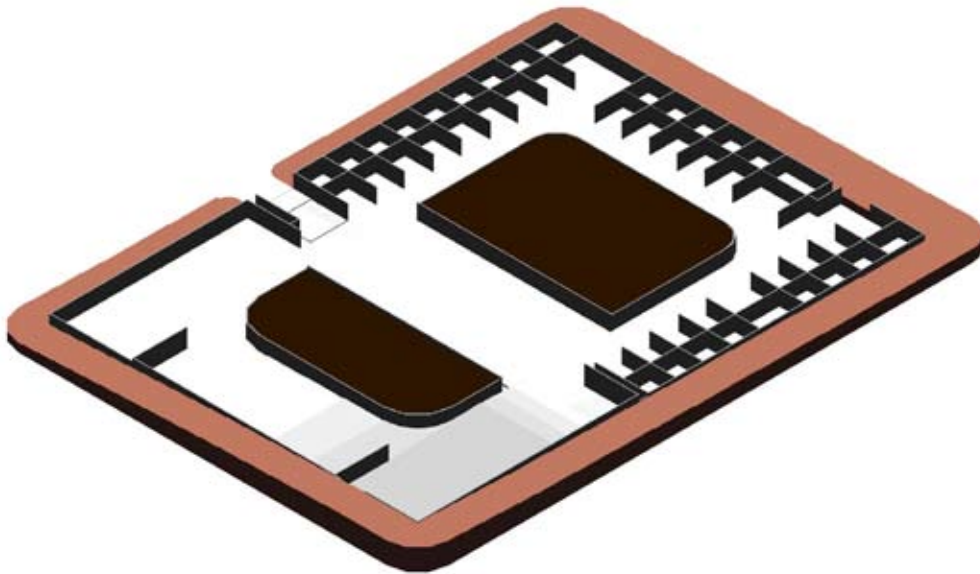
	<u>Conventional</u>	<u>EcoHousing</u>
Garage:	136 spaces	141 spaces
Alley:	10 spaces	
Street:	42 spaces	50 spaces
<b>Total:</b>	<b>188 spaces</b>	<b>191 spaces</b>

The design of the below ground garage involved several challenges, including the need for equivalent parking spaces, designing for the twelve foot (12') grade change, and the goal to use the garage rooftop as livable space.

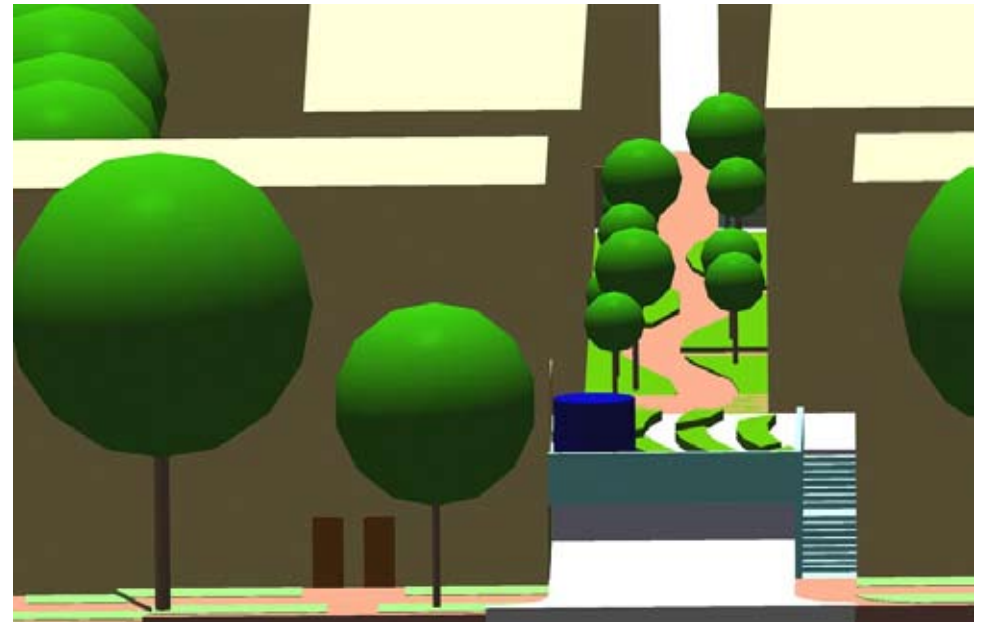
The parking spaces are allocated and sited in the same manner as the conventional housing. All parking is located below the building structure. Each townhouse has a two or three car garage occupying half of the lower level of the house. The townhouses have a half-basement living space with interior stairs to reach the main level and sidewalk entrance of the houses. Each two-story unit has two parking spaces in a common area under the building, with two spaces per parking lane. Each one-story unit has one space under the building, accessed from the center drive. There are a few extra parking spaces. Common stairwells connect the garage to the one and two story units and the exterior doors to the sidewalk.



Garage Entrance  
North Royal Street  
Elevation 15'



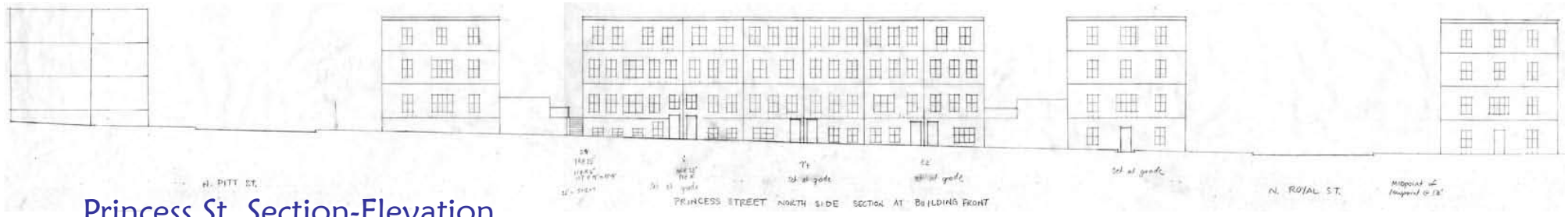
NW Corner  
Elevation 26.5'



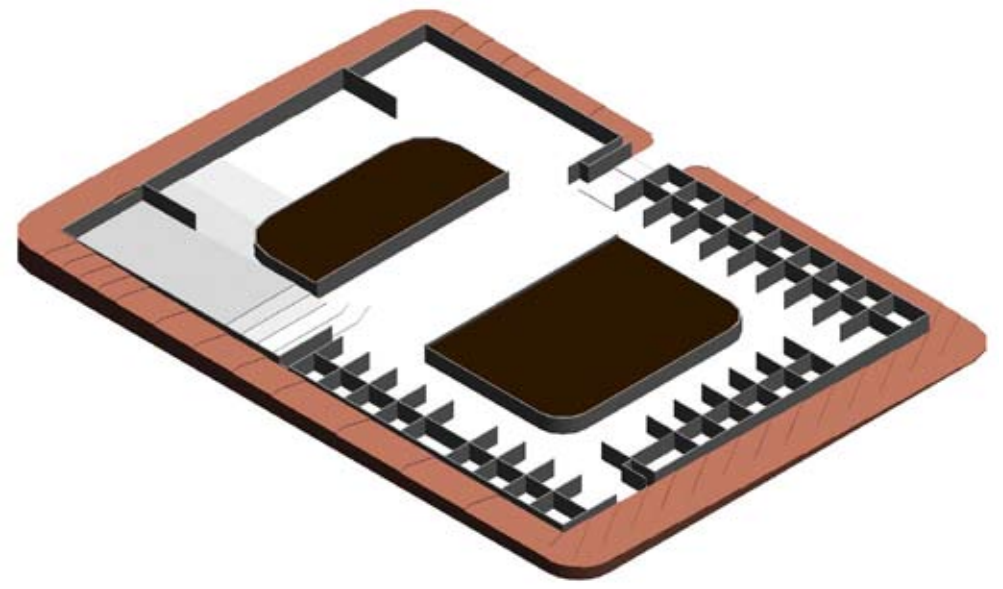
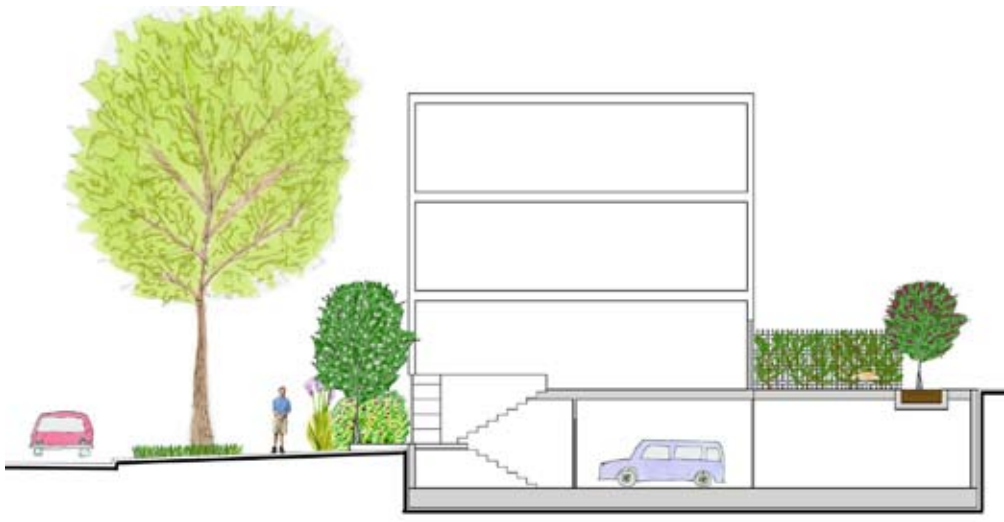
Garage Entrance

## Grade and Elevations of Garage

The grade change posed a challenge, yet also a very workable solution for establishing the grade of the garage and the main level of living space. The single garage entrance is on North Royal Street at fifteen feet (15') elevation. A small ramp takes the cars to the garage level of fourteen feet (14'). The main level of living space is twenty-four feet (24'), which is also the level of the interior courtyards. In the northwest corner, where the sidewalk grade rises to twenty-six and a half feet (26.5'), the garage level also rises to sixteen and a half feet (16.5'). The garage has a clearance level of eight feet (8') at all times.



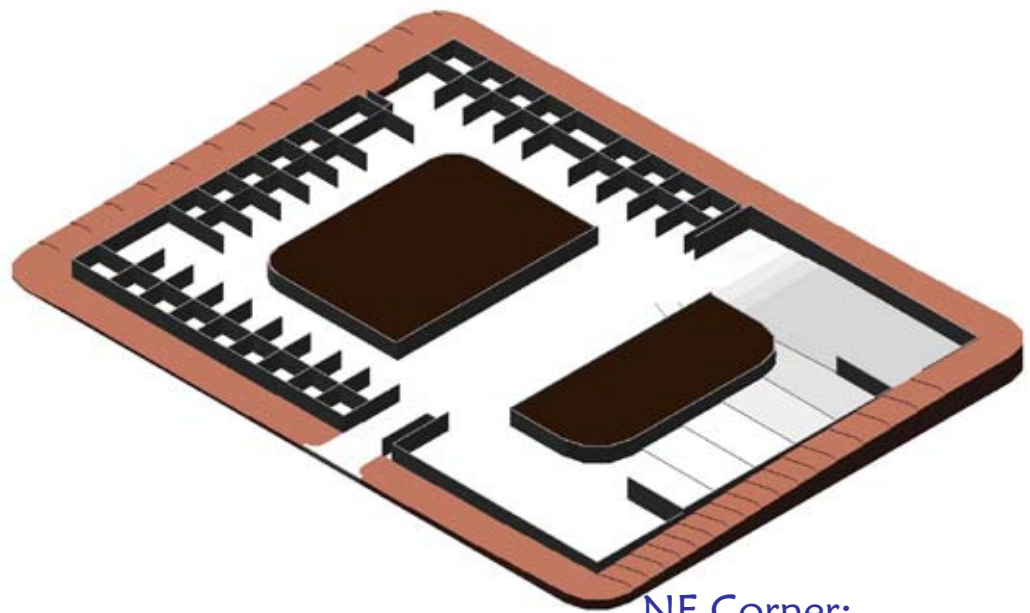
Princess St. Section-Elevation



SW Corner: N. Pitt & Princess St.

## Garage Relation to Existing Grade

The garage is partially at grade or below grade depending on street level elevation. The garages in the conventional housing design have a very similar relationship to the sidewalk grade. In ecohousing the entrance to the townhouses is at sidewalk grade level and interior stairs give access to the garage below and the living space above. The buildings with one and two story units have stairwells that can be accessed from the garage or the street to access the units. Each house and building is accessible from the garage and the street.



NE Corner:  
N. Royal & Pendleton

NE Corner

## Earth Wells

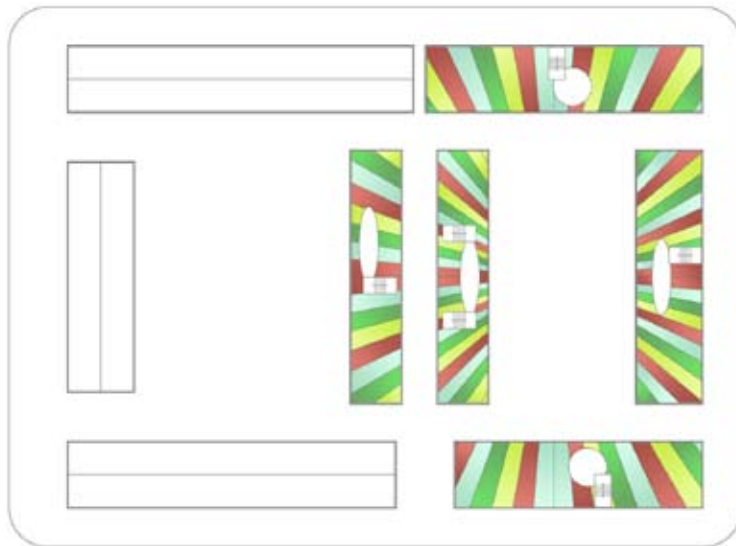
The ecohousing garage design is significantly enhanced by providing two earth wells within the garage structure. By placing the parking under the buildings around the edge of the block, and in the center of the block with the access drive, two large areas can be preserved and created. The soil that is excavated from the west side of the block for the garage can be used to create the earth wells. These large soil areas allow the courtyards to be planted with large trees and shrubs that have a large root space to grow. This strategy avoids a rooftop condition that limits and causes problems in so many courtyard plantings of this type. One earth well will be used as a bioretention area to infiltrate storm water. Drainage will be provided for both earth wells to prevent hydraulic pressure buildup.



### Extensive Green Roofs

Green roofs can have a significant impact on reducing impervious surface in the urban environment. Where space is a premium, the roof is a primary area to target for greening and making pervious surface. Extensive green roofs consist of a few inch layers of plants and soil laid on the roof structure. Water is captured in by the plants and soil and absorbed into the plant roots. A thin layer extensive green roof can absorb about half of the precipitation it receives. Weight requirements on the roof load can be minimized from fifteen to twenty pounds per square foot (15 - 20 lbs/ft<sup>2</sup>).

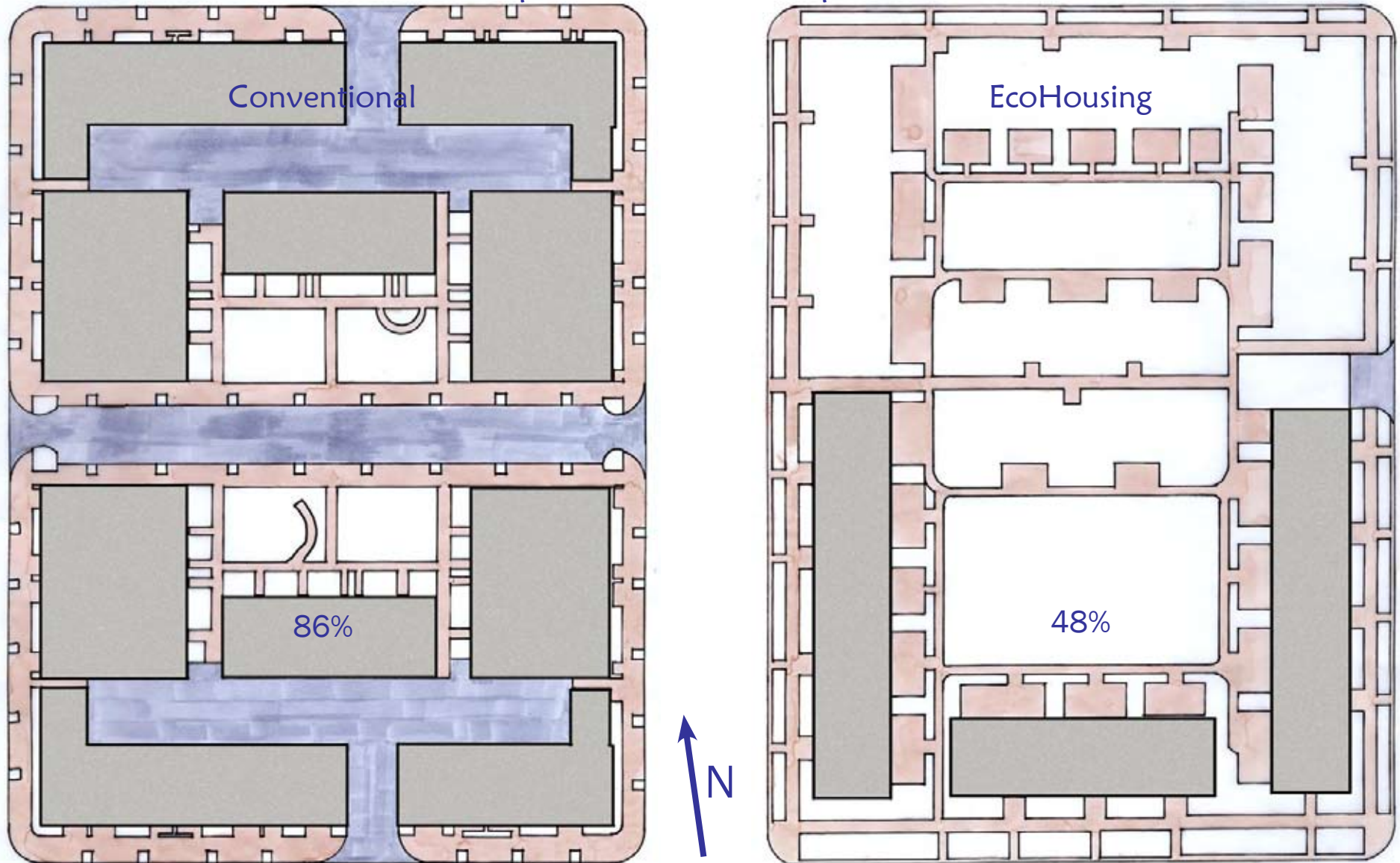
Extensive green roofs are implemented on the five ecohousing buildings with single-story and two-story units. The primary purpose of extensive green roof is to provide ecological services such as reducing water runoff, improving water quality of runoff, providing insulation, and reduce surface temperatures. The ecohousing green roofs will be accessible to residents of each building and small area for resident use is provided.



## Urban EcoHousing

### Impervious Surface Comparison

## Minimize Impervious Surface



The difference in impervious surface is shown between the conventional and ecohousing development. Dark gray areas are rooftop, medium gray are roads, rose colored areas are sidewalks, and white areas are pervious surface. The use of green roofs, below ground access drives, center earth wells, and continuous planting strips show how much impervious surface can be reduced. Impervious surface is reduced from 86% in the conventional design to 48% in the urban ecohousing design.

# Provide Natural Heating and Cooling

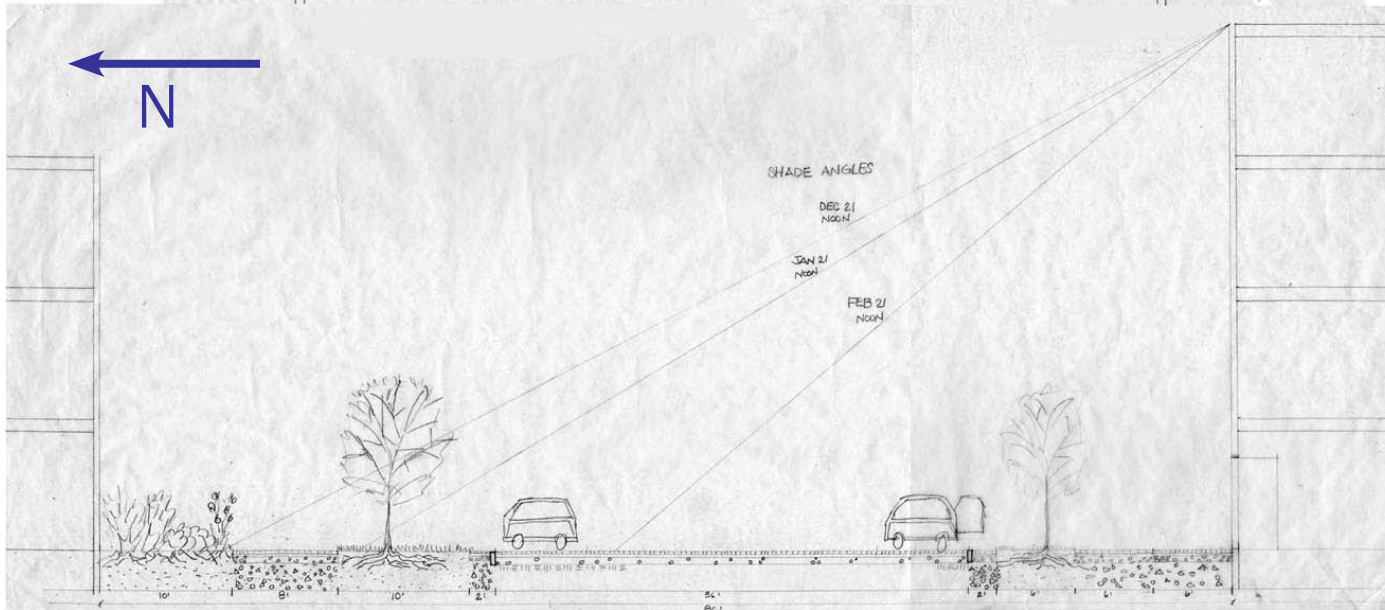
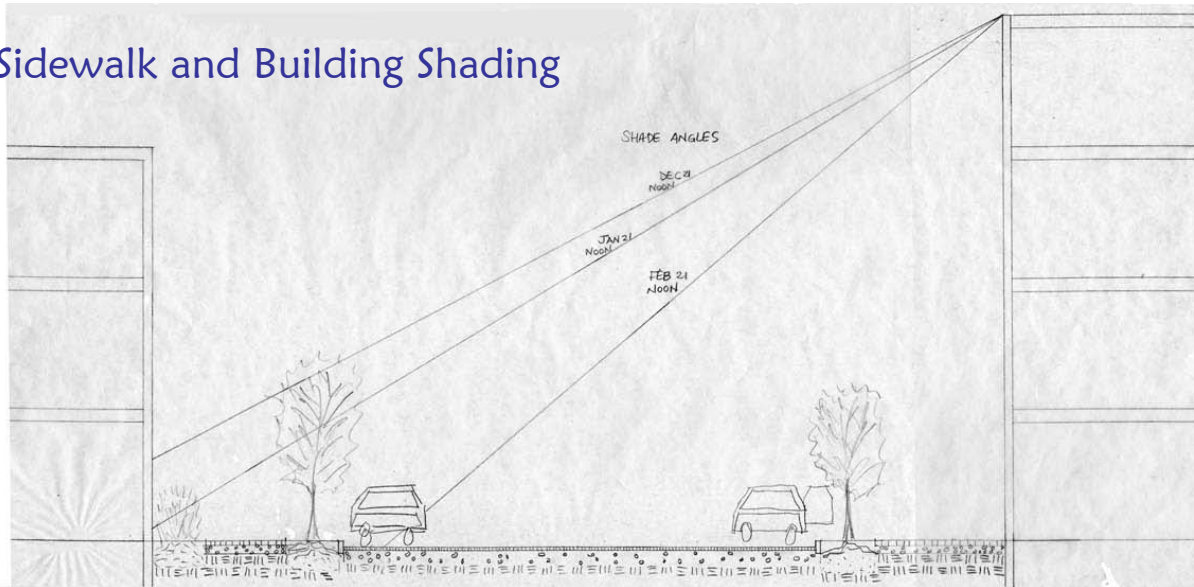
Housing units shall have:

Exposure to winter sun  
Shading from mid-day and late-day summer sun  
Natural air circulation through windows on at least two sides  
Southern wind circulation through site

The purpose of the design goal 'Provide Natural Heating and Cooling' is to design the landscape to provide ecological services for energy conservation. Alexandria experiences both hot summers and cold winters. While neither season has extreme temperatures, mechanical air conditioning is standard in new construction and retrofitted to older buildings. Winter temperatures in the twenty and thirty degrees Fahrenheit are common from December to February. Any building or landscape design that can provide natural heating and cooling will help reduce mechanical energy use.

Building placements are designed such that winter sun will reach each house, and openings will allow the winter sun into the common spaces. Street trees will be placed to provide shade to buildings and sidewalks and will be given proper root space to grow to a mature size. Trees in the interior courtyards will provide shade in the common spaces. Green walls will be used to shade buildings. Building placement and depth is designed to allow the summer southern winds into the site and for each unit to have windows on two sides.

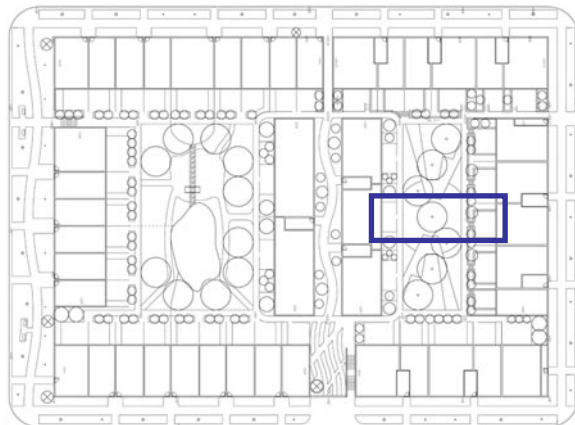
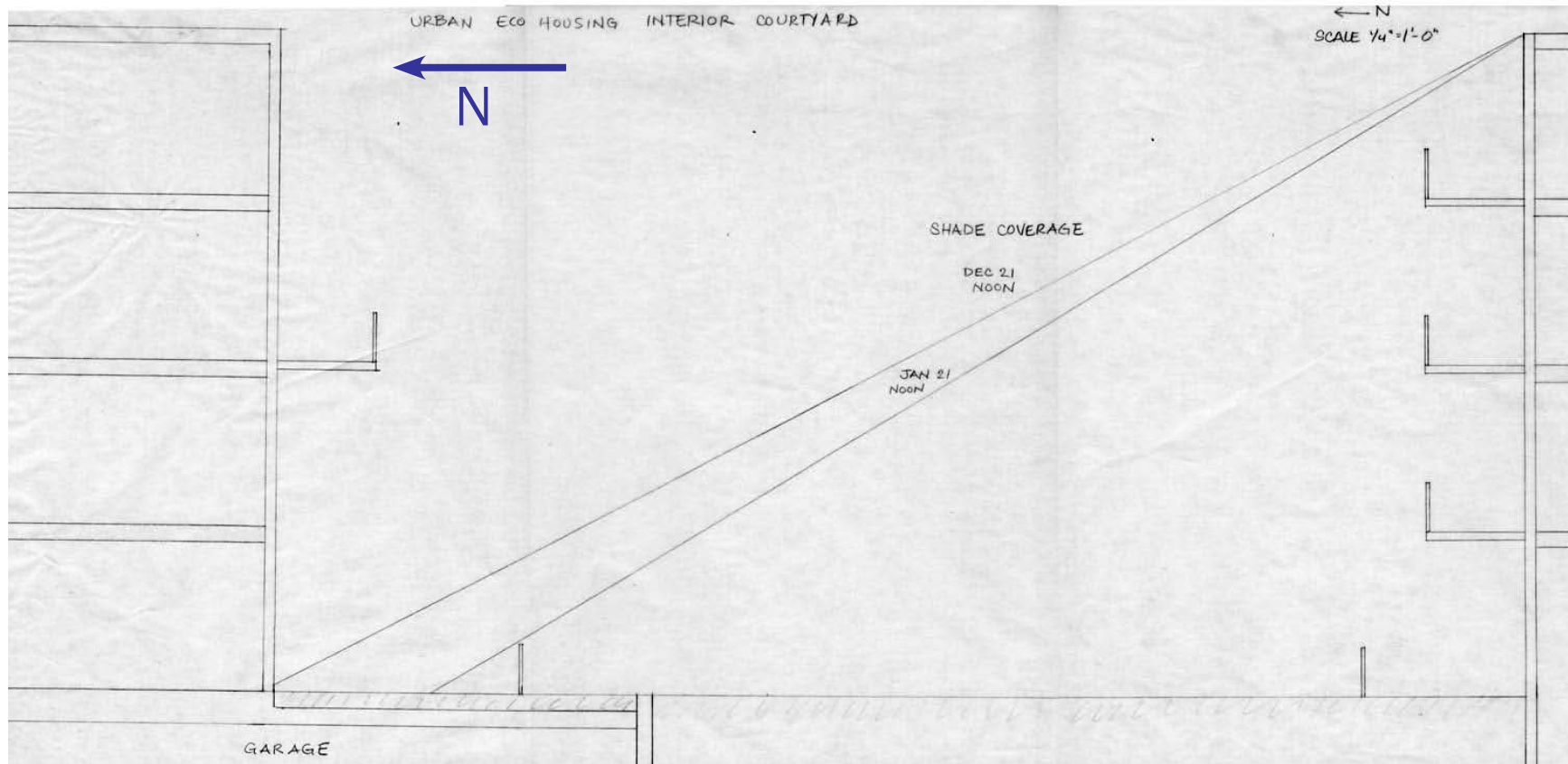
## Winter Sidewalk and Building Shading



A primary effect of building placement is how one building can shade another. The first area shown here is building placement on the south face of the block. Drawings of both the conventional and ecohousing design are shown with the sun angles for December 21, January 21, and February 21, the coldest months of the year. Areas below the sun angle line are in the shade.

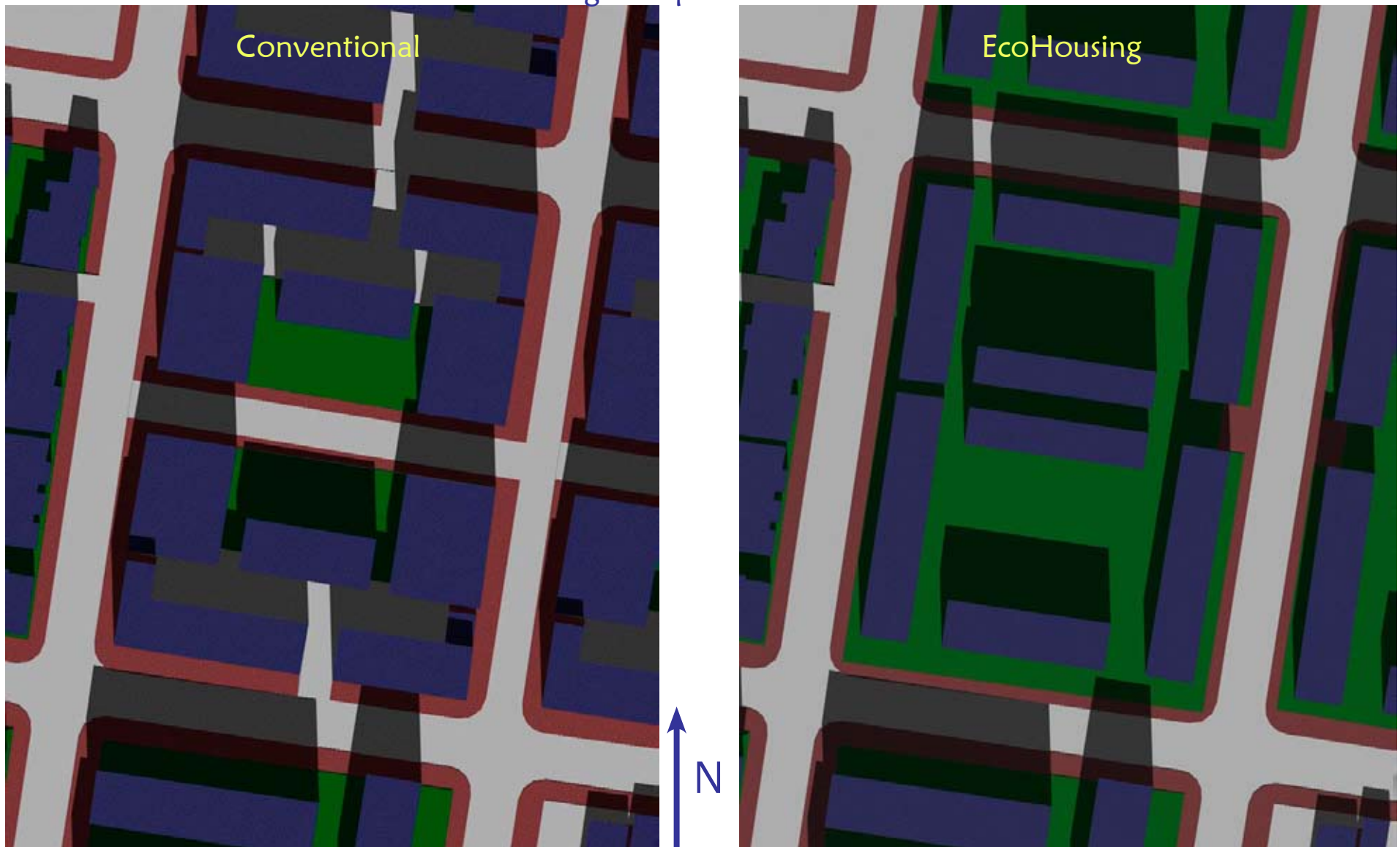
In the conventional design, the first floor of the building does not receive any sun during December. The sidewalk is shaded for one hundred days from approximately November 2 until February 9. Safety hazards are created when snow and ice cannot melt due to shady conditions.

The sun angles are used to determine the setback required so that sun will reach the first floor of ecohousing even at the lowest sun point of the year. A thirty foot (30') setback from the sidewalk allows the sun to reach the houses at all times. On a block with ecohousing on the south edge and conventional housing on the adjacent north edge, the sidewalk is shaded for seventy-five (75) days. Where ecohousing is on both blocks, the shaded sidewalk time is reduced to fifty-five (55) days.



### Interior Courtyard sizing for winter building shading

The interior courtyards are designed as one larger space and one smaller space. The size of the smaller courtyard is defined so that the sun reaches the first floor of northern building at all times of the year. The distance required between building to achieve that affect is sixty-eight feet (68'). The courtyards can vary in size, but the minimum distance is sixty-eight feet (68'), and this size is selected for the prototype block design.

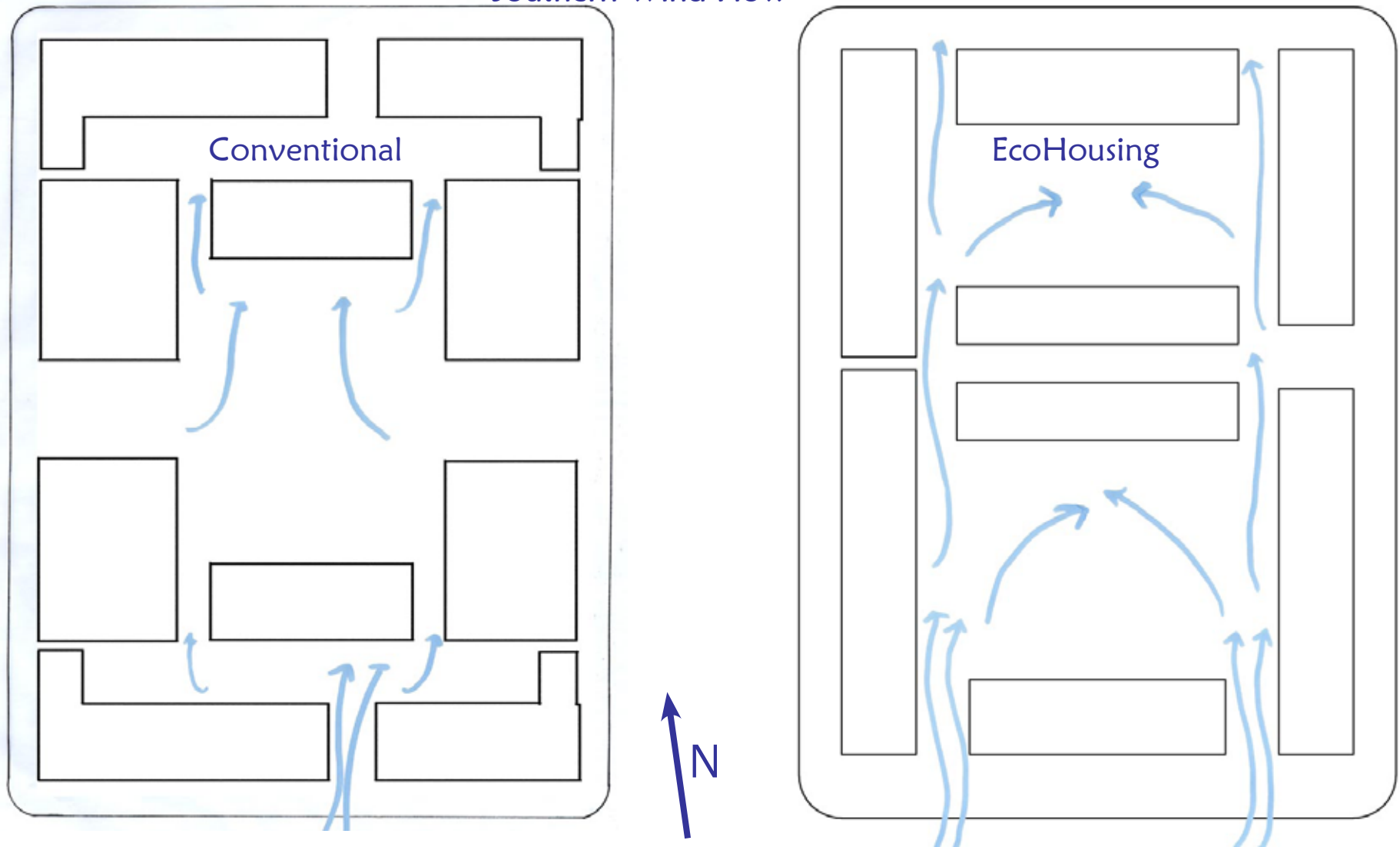


The shade diagrams for December 21 at noon illustrate the differences between the conventional and ecohousing designs. In the conventional design, the buildings each shade the one directly north of it. Buildings on the same block and on the next block north are shaded. In the ecohousing design, buildings are spaced in the north-south direction so they do not shade buildings on the same block or on the next block. Openings in ecohousing allow more sun to the interior of the site than the conventional design. Both designs cause some of the green spaces to be shaded. The ecohousing does not eliminate shading of all buildings, but it is greatly improved.

## Urban EcoHousing

Southern Wind Flow

Provide Natural Heating and Cooling

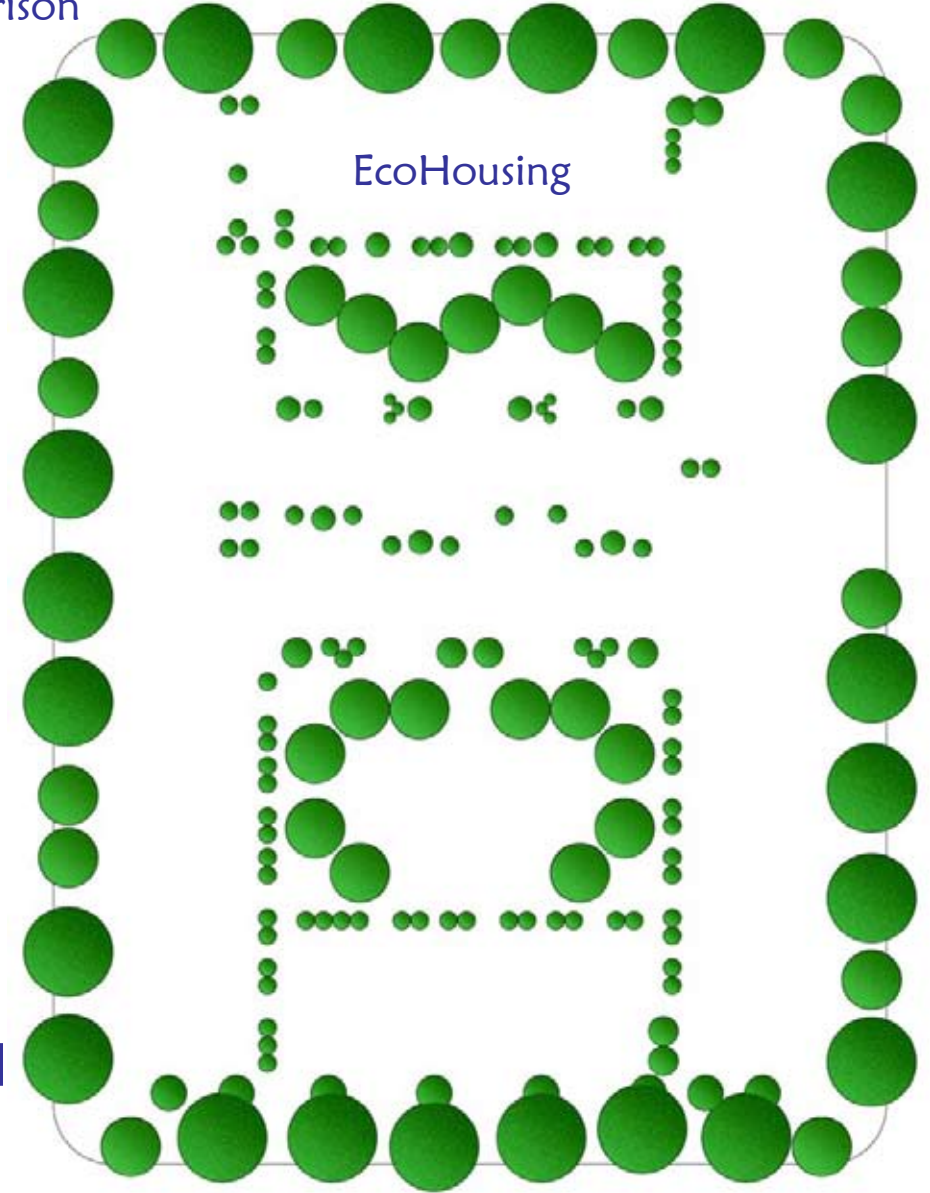
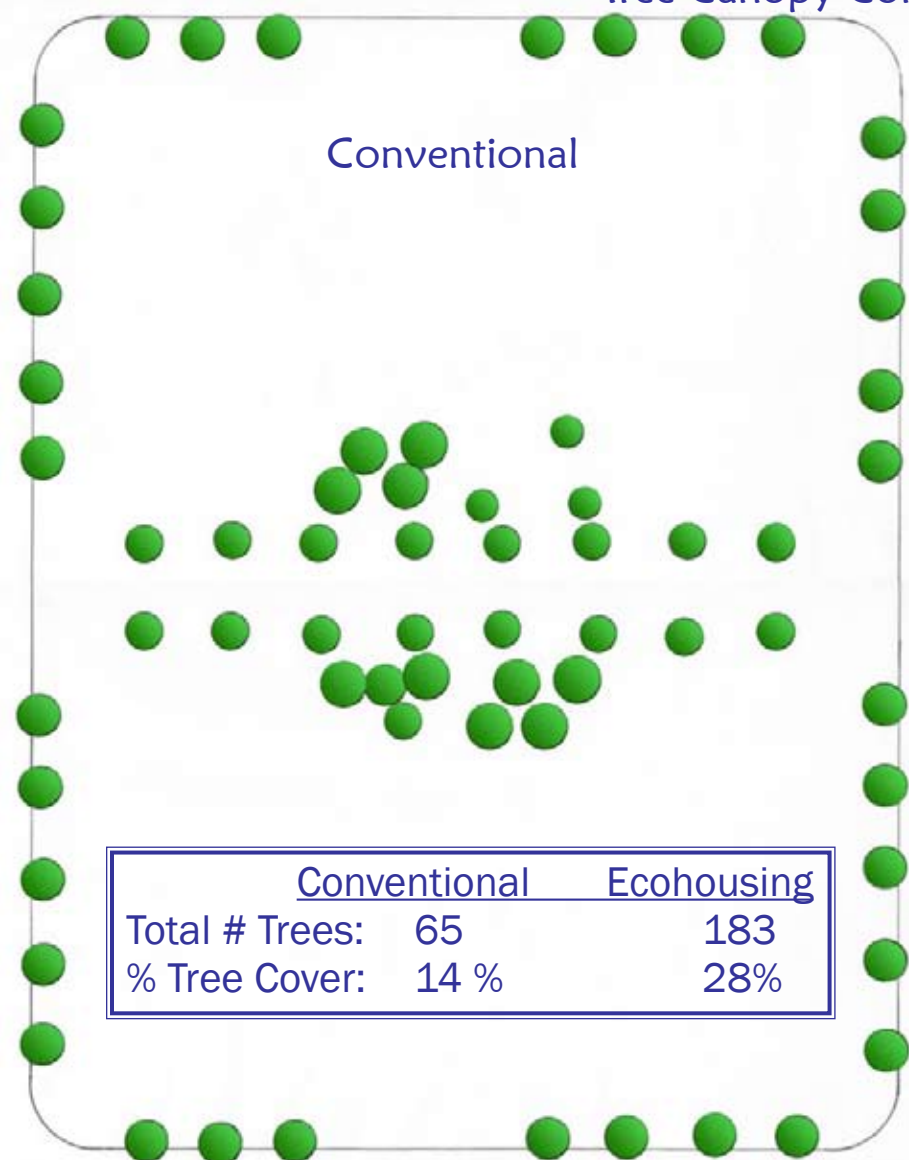


Air circulation is a very important component of natural heating and cooling. The summer wind is predominantly from the south and is needed to help cool areas during the heat of the summer. There is some debate as to how these natural wind flows actually occur in the city blocks of Alexandria. But if we look at the block as an individual entity, we can draw some conclusions. Wind cannot flow through site of conventional housing due to the buildings blocking air flow at every stage. Ecohousing is designed to have building gaps that allow the wind flow through site and into the interior courtyards. The northwestern winter wind is an air flow from which the exterior living spaces should be protected. While not illustrated on these diagrams, the buildings do provide a block to the courtyard and private patio areas.

# Urban EcoHousing

# Provide Natural Heating and Cooling

## Tree Canopy Comparison



	Conventional	Ecohousing
Total # Trees:	65	183
% Tree Cover:	14 %	28%



Trees are an important part of providing natural cooling through shade and evapotranspiration. The tree canopy comparison between the two designs shows the difference that proper growing conditions can have on the size of the canopy. Ecohousing has three times the number of trees and two times the tree canopy for the block, based on estimated mature sizes in both designs. The diagram also includes interior courtyard trees, and the trees in private patio spaces. There are no exterior private spaces that include trees in the conventional housing design.



Harkness Memorial State Park, Waterford, Connecticut



14th Street NW, Washington, D.C.



Embassy of Finland, Washington, D.C.



H Place NE, Washington, D.C.



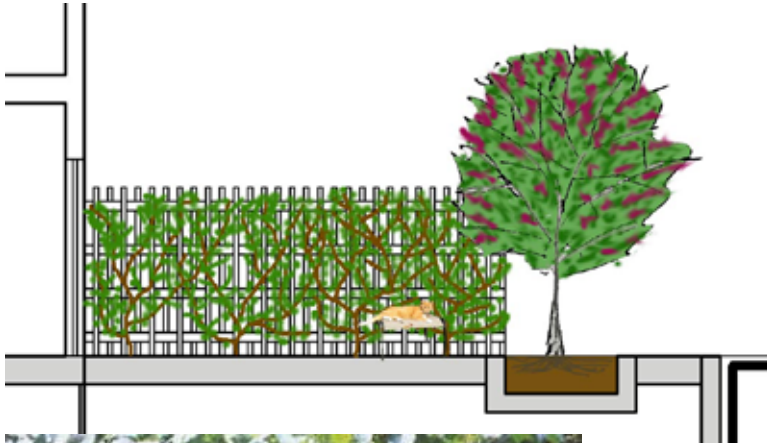
St. Gaudens National Historic Site,  
Cornish, New Hampshire

## Green Walls

Green walls have a similar effectiveness as trees, but on a vertical surface. Vines and climbing plants are grown on a trellis or built structure set away from the building by six to twelve inches (6 - 12"). Green walls can provide shade to a building in the summer and insulation in the winter. Green walls will capture stormwater and air particles in the vegetation. These images of green walls show the wide range of types and style the green walls can have.



King Street Gardens, Alexandria, Virginia



Campsis radicans



Wisteria



Parthenocissus quinquefolia



Lonicera

## Green Walls

Green walls are used in the ecohousing design in several areas. Green walls are used to separate the private patio areas. Green walls are used on the southern and western sides of buildings to provide additional shading to these critical areas. Green walls do require a soil base for the plants to grow and are not easily included in areas that are fully paved. Suitable green walls plants are shown on this page.

### Vines for Green Walls

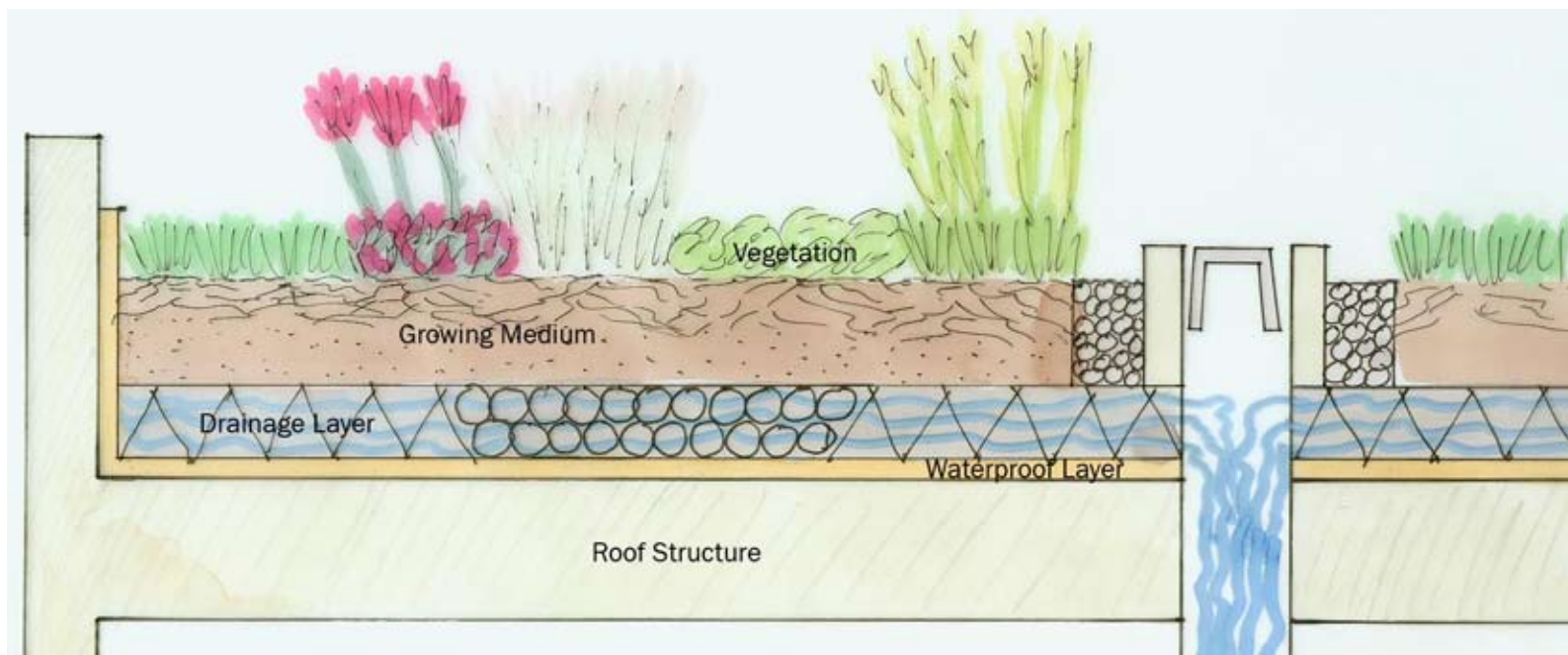
- |                                     |                    |
|-------------------------------------|--------------------|
| <i>Akebia quinata</i>               | Five leaf Akebia   |
| <i>Campsis radicans</i>             | Trumpet Vine       |
| <i>Clematis sp.</i>                 |                    |
| <i>Hydrangea anomala petiolaris</i> | Climbing Hydrangea |
| <i>Lonicera sp.</i>                 | Honeysuckle        |
| <i>Parthenocissus quinquefolia</i>  | Virginia Creeper   |
| <i>Wisteria sp.</i>                 |                    |



Hydrangea anomala petiolaris



Clematis maximowicziana



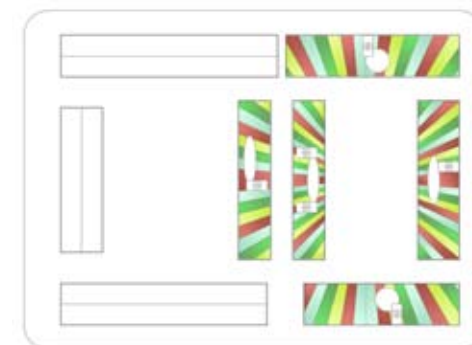
## Green Roof

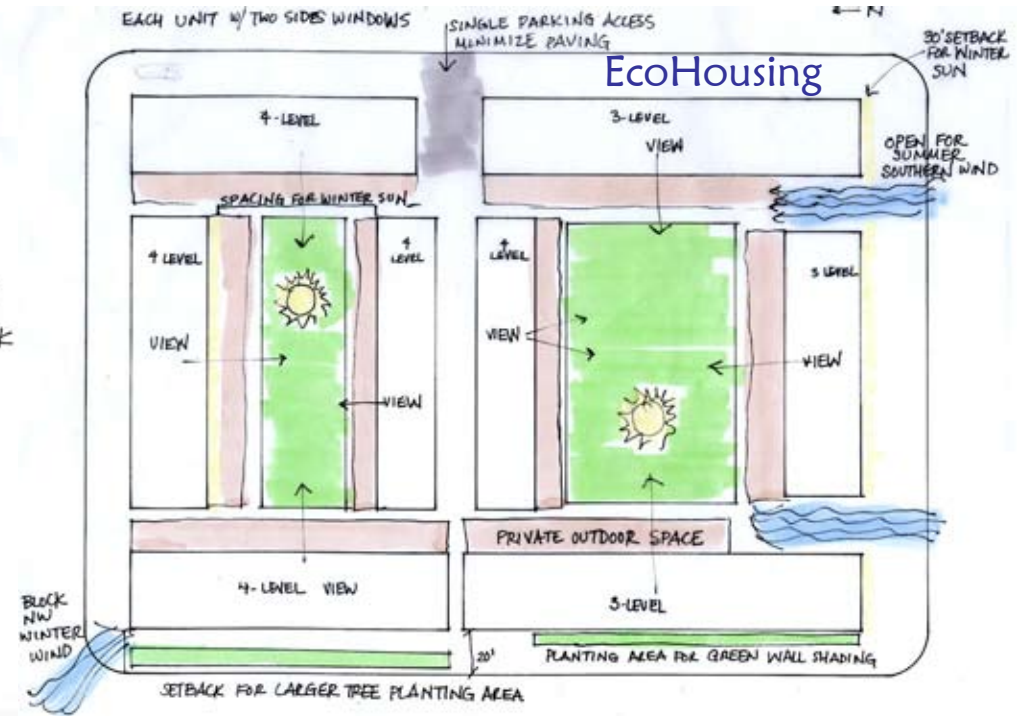
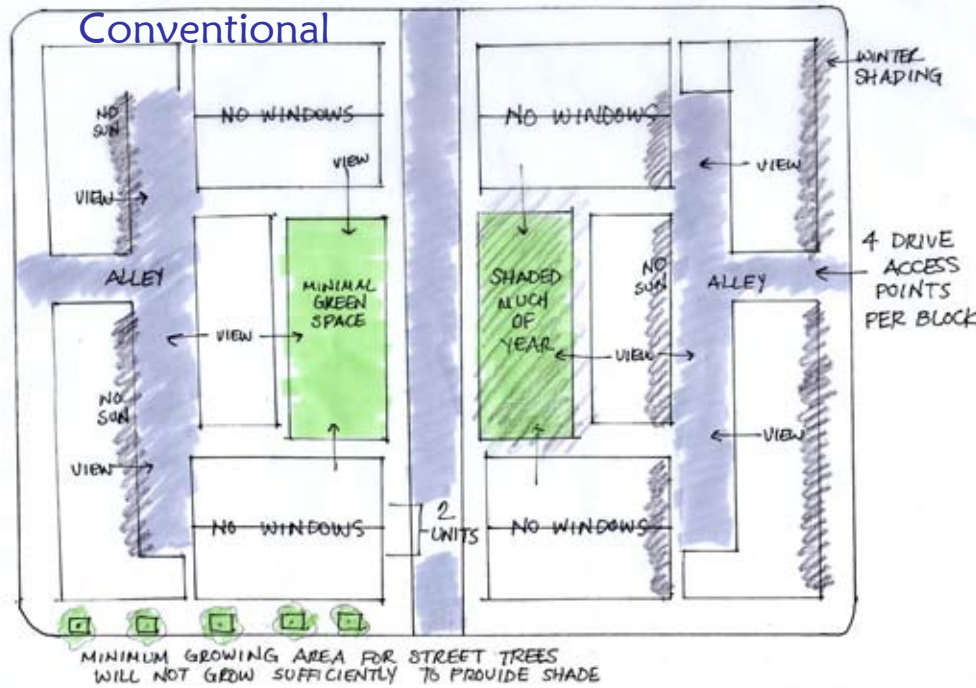
Green roofs will provide insulation to buildings through the many layers that comprise the extensive green roof. The section drawing of an extensive green roof illustrates the roof layers and construction. Green roofs can be built on different types of roof structure, such as wood or concrete. There is sometimes an insulation

layer on the roof, but it is not shown in this drawing. A layer of waterproofing, sometimes combined with a root barrier is the lowest layer of the green roof. The water proofing is a critical component to prevent water damage to the roof structure and interior of the building. Root barriers will prevent the vegetation roots from penetrating and compromising the water proofing.

The drainage layer gives additional storage space for water so that it can be absorbed by the plants and growing medium before it runs off the roof. The drainage layer can be gravel or stone. New green roof products include egg-carton like structures and plastic structures with gaps to hold the water. These new products are lightweight, reducing the overall load of the roof, and they contribute to the water holding capacity of the roof. The growing medium should be lightweight, able to absorb water, and well draining (Dunnett and Kingsbury, 72-75). It is generally a combination of organic and non organic materials such as soil, sand, clay, and expanded shale. The growing medium should give just enough nutrients and substance for the vegetation to grow. The vegetation used in extensive green roofs should be very drought tolerant and able to quickly absorb water. Low growing sedum species are most often used in green roof plantings.

The insulation effects of the green roof can keep building warmer in winter and cooler in summer. Mechanical energy use will be reduced by this insulation layer.

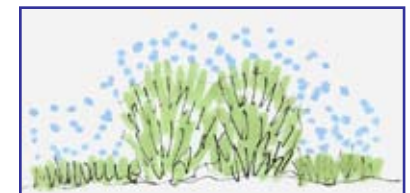




## Summary & Comparison

The landscape and buildings need to be designed to provide natural heating and cooling to the site wherever possible. Trees provide a valuable energy conservation service to the buildings around it. Temperatures will be reduced by the shade of the tree canopy and trees and vegetation will cool the surrounding air through evapotranspiration. The green roof and green walls will provide insulation to the buildings, reducing both heating and cooling energy needs. Air circulation is critically needed for cooling in the summer and healthy living at all times of the year. The ecological services the landscape provides can be quantified in cost savings to heating and cooling. Residents benefit from a more comfortable place to live, in the warmth of the winter sun, in the cooling shade of trees from the summer heat, and with a breeze blowing through their houses and outside spaces.

The conventional design does not include any of the methods for natural heating and cooling. Many buildings and areas are shaded during winter. Some units have windows on only one side, preventing natural air circulation. The configuration of the conventional buildings prevents air flow through the site. The ecohousing design has significant improvements for winter sun, summer shade, and full block air circulation.



# Control Water Quantity and Quality

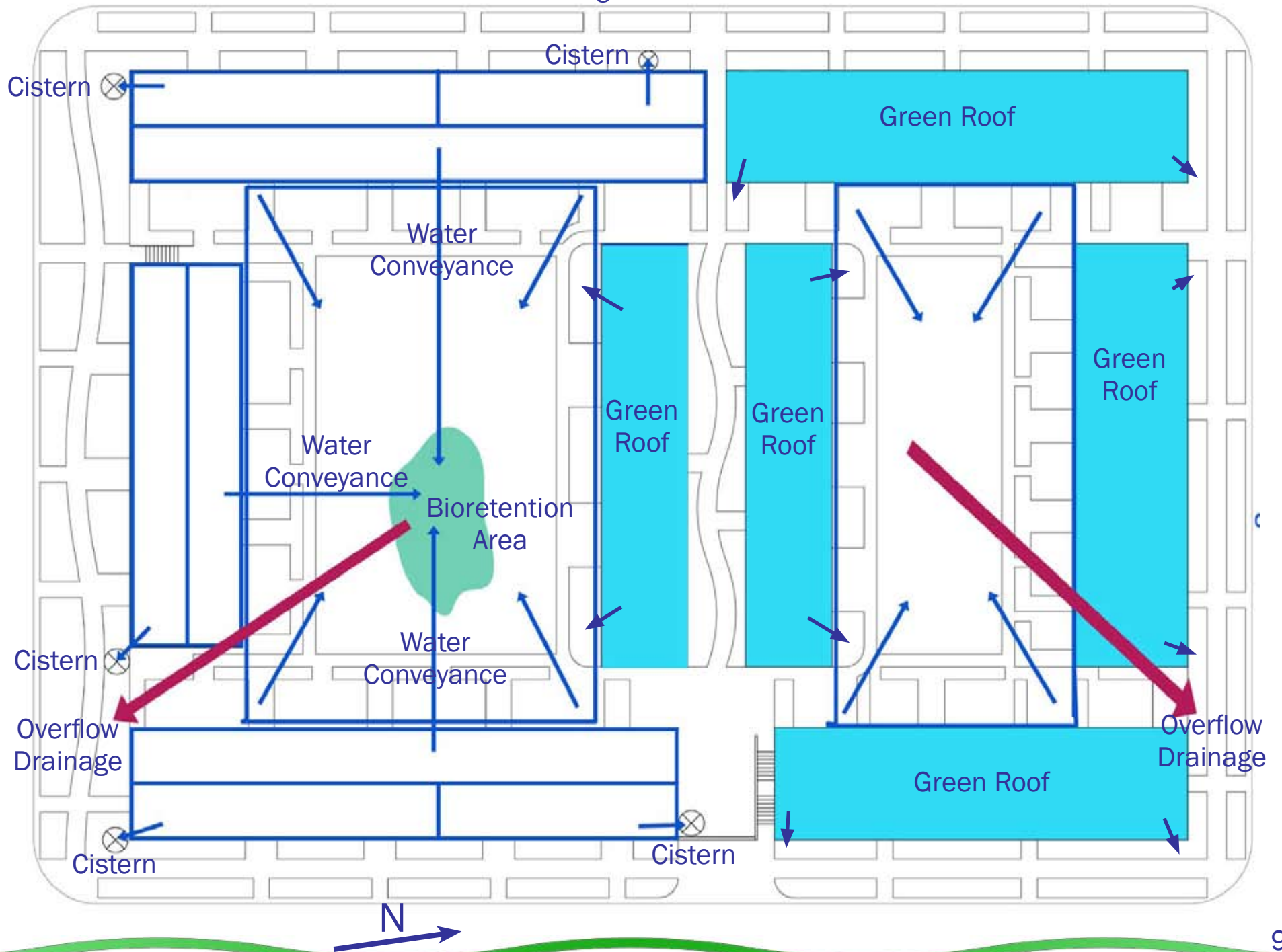
Collect and reuse  
Infiltrate on-site  
Filter before leaving site

The design goal to control water quantity and quality has a direct impact on a significant urban environmental problem. The excess water runoff from impervious surface causes scouring to streams and carries pollutants into the waterways. The companion goals to maximize green space and minimize impervious surface will reduce water runoff and the amount of water that needs to be managed.

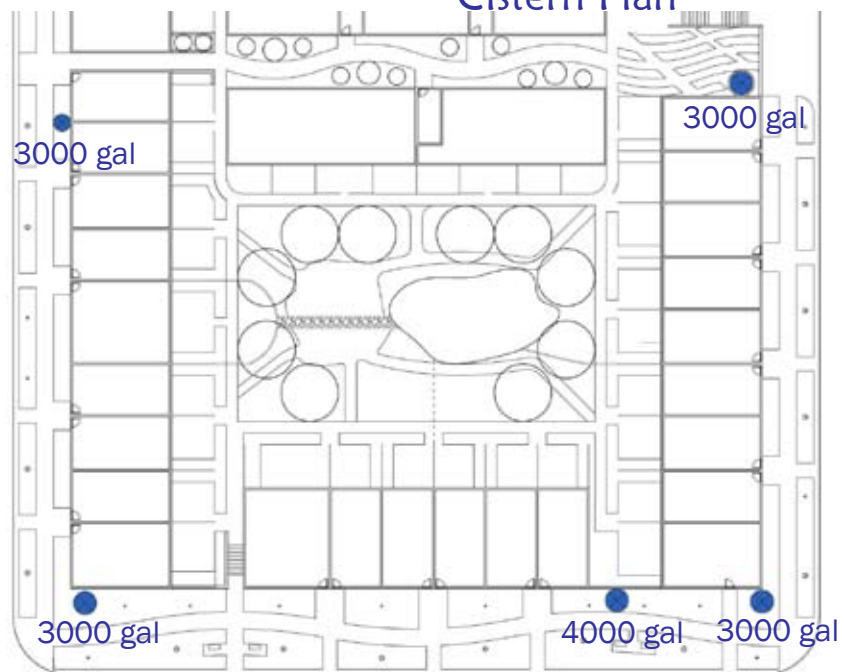
A key component of low impact development is to manage water runoff at the site. The ecohousing design manages water runoff in three ways as shown on the water flow diagram on the following page. Water is collected on site in cisterns and reused in the landscape. Water is infiltrated on site in green space, green roofs, and bioretention area. Water is filtered before leaving the site through tree canopy, shrubs, herbaceous plants, soil, bioretention, and green roofs.

These elements can improve the resident's quality of life if they are used as enhancements to the landscape. Both the bioretention area and green roofs become livable green space.

Water Flow Diagram



## Cistern Plan



Center for Neighborhood Technology  
Chicago, Illinois



Chesapeake Bay Foundation Headquarters,  
Annapolis, Maryland



Lady Bird Johnson Wildflower Center, Austin, Texas

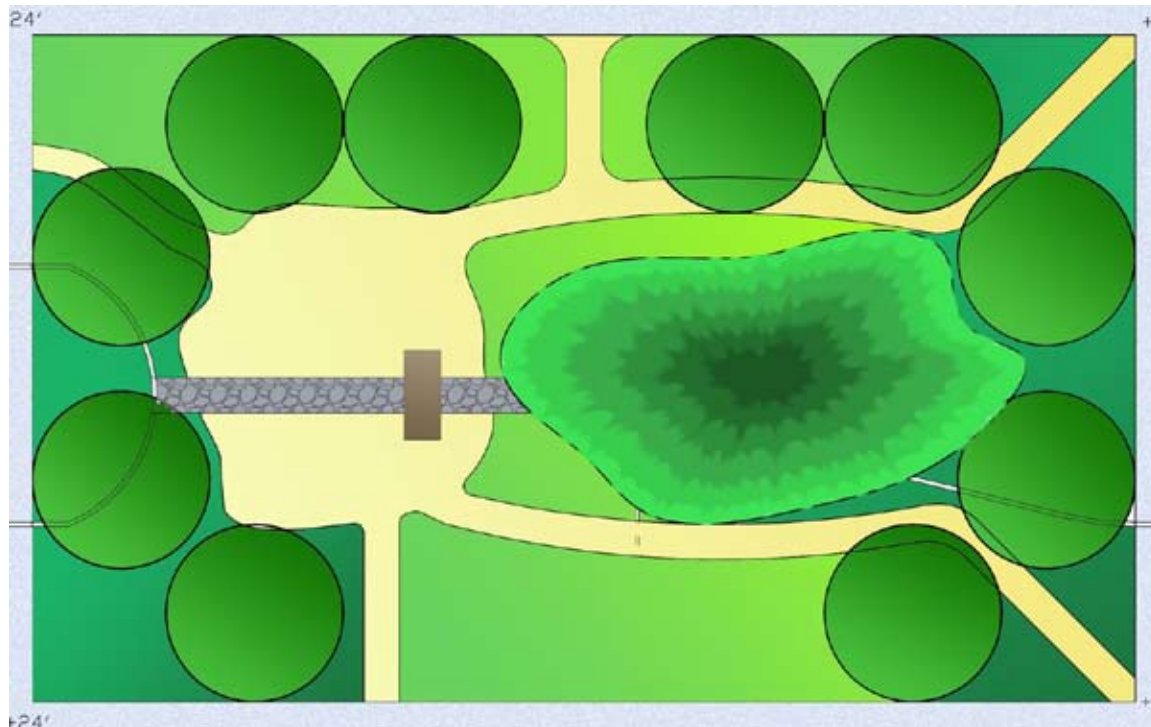
## Collect and Reuse Water

Water will be collected in cisterns and reused for landscape irrigation. The cisterns are sized to collect up to three inches of rain from the outer sides of three townhouse rooftops. The east and west townhouses each have two cisterns collecting water from the 3150 and 2990 square foot roof areas. These four tanks each have a 3000 gallon capacity and come in sizes of eight feet wide by eight feet tall (8' x 8'), or six feet wide by fourteen feet tall (6' x 14'). The southern townhouse has a 4000 gallon capacity cistern, sized eight feet wide by eleven feet tall (8' x 11'), to collect water from its 2100 square foot roof.

Cistern tanks can come in a variety of materials. The tank can be plastic or fiberglass and screened by a trellis growing vines. The tanks can be a specially designed metal, wood, or stone structure, such as seen at the Chicago Center for Neighborhood Technology, Chesapeake Bay Foundation Headquarters, and the Lady Bird Johnson Wildflower Center. The cisterns at the ecohousing site will have overflow mechanisms to handle excess water which will runoff to the sidewalk and landscape areas and eventually into the city stormwater system. The tanks will be drained and disconnected in winter to prevent freezing and icy overflow.

## Bioretention Area

One method to infiltrate water on site and filter it before leaving site is through a bioretention area, also called a rain garden. The bioretention area is located in the southern courtyard, which becomes the water experience garden. Water is collected from the interior sides of three townhouse rooftops and conveyed to the bioretention area in the center of the garden. The water from the western building is carried in an overhead conveyance channel to a surface rock channel. Water from the southern building is channeled in below surface containment. Water from the eastern building is carried in a ground surface conveyance structure.



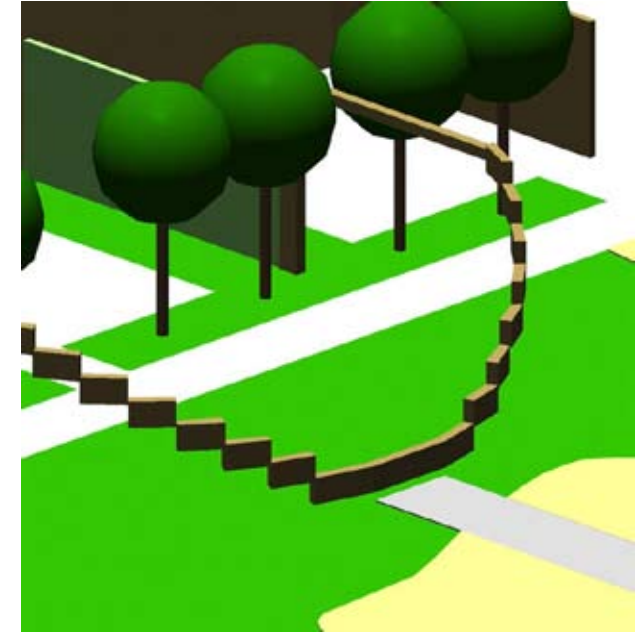
The contributing roof area for the bioretention area is 8,242 square feet. The bioretention area is designed to collect, detain, and infiltrate water from a one inch rainstorm. The size of the bioretention area is 1,370 square feet with a six inch (6") depression. A special soil mix and gravel base allows water infiltration. The bioretention area has perennials, grasses, and shrubs which tolerate wet conditions and absorb the water into their roots. An under drain system will allow excess water to be carried away and prevent ponding conditions for more than twenty-four hours. The water will drain into the southern sidewalk area and then to the city stormwater system.



Lady Bird Johnson Wildflower Center, Austin, Texas



Desert Botanical Garden; Phoenix, Arizona  
Photo: Heather Kinkade-Levario,  
Landscape Architecture Magazine



### Overhead Water Conveyance



The water experience garden includes an overhead conveyance structure to carry water from the townhouse roofs to the bioretention area. The water from the roof flows in gutters to two exit points in the center of the building. An overhead channel carries the water from the buildings approximately ten feet (10') off the ground, over the private patio areas, over the courtyard walk, and into the garden area. The water flows down chutes and into a rock channel, which carries the water to the bioretention area. Some water may be infiltrated into the rock area as it flows.

The images show water conveyance systems from the Lady Bird Johnson Wildflower Center and the Desert Botanical Garden. Water conveyance systems can be design assets for a garden and made of a variety of material, such as stone, wood, and metal. The overhead conveyance system is a participatory part of the garden and can be viewed from the upper levels of the buildings, where water flow will be active during rain events.



Yorktowne Square Condominiums, Falls Church, Virginia



Green Spring Gardens, Alexandria, Virginia



Alexandria Beatley Central Library, Alexandria, Virginia



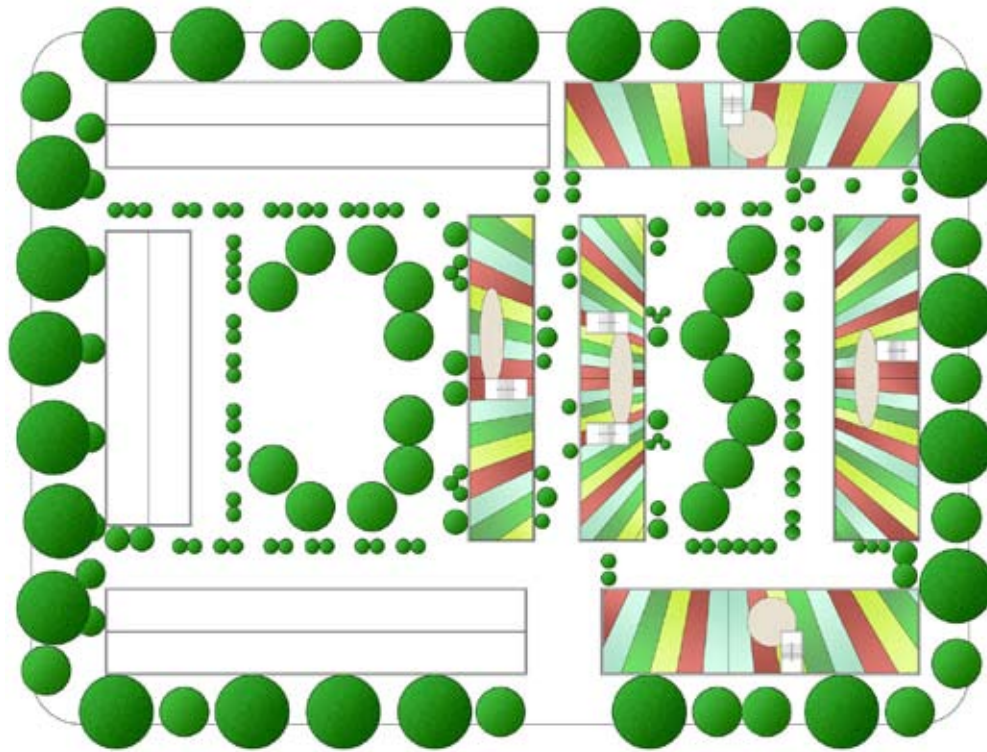
Alexandria Beatley Central Library, Alexandria, Virginia

## Surface Water Conveyance

A rock channel, also called a dry stream bed, is another component of the water conveyance system. Once water from the western building roofs is conveyed overhead and down to the ground, the water flows through the rock channel to be conveyed to the bioretention area. The water will be slowed and some infiltration will occur in the rock channel.



Water from the eastern building is carried in a ground surface conveyance structure. The surface conveyance will take water from the roof gutters, carry it through a surface drain system, and deposit it into the bioretention area. A surface conveyance can be covered with a decorative grate to reveal the water flow system, such as at the Alexandria Beatley Central Library.



## Green Roof, Tree Canopy

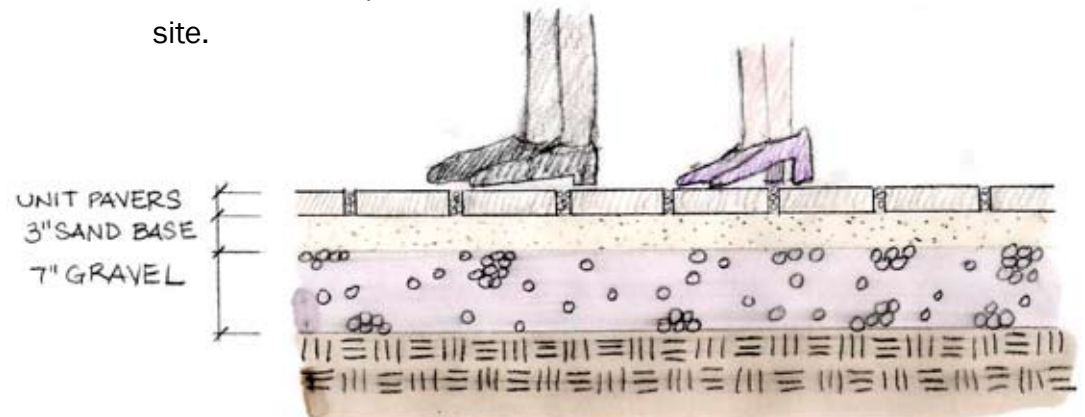
The extensive green roofs will capture about half of the rainfall depending on intensity and overall volume. The water will infiltrate into the vegetation and soil layer and be filtered before any excess runs off. The tree canopy will capture rainwater in the leaves and slow runoff as the water flows down the trunk. Particulates in the water are filtered by the leaves and stems.

## Permeable Paving

Permeable paving allows water to infiltrate into the ground, while providing a hard surface for walking and driving. Permeable paving comes in several forms, such as paving blocks, porous asphalt, and porous concrete. The most suitable application for urban ecohousing is paving blocks. Paving blocks are set on a sand and gravel base to allow water to flow and collect under the pavers as it filters to the soil. Permeable paving blocks are used in several areas of the site. Brick pavers are used for the public sidewalk and spaced to allow water to flow between pavers. The vehicle entrance drive uses concrete permeable paving blocks. Permeable paving blocks will be used for the walks in the center courtyard earth wells. The permeable paving will reduce water runoff from the paved surfaces and filter the water before it leaves the site.



Permeable concrete pavers



## Water Runoff Comparison (1 inch rainstorm)

Conventional Land Cover		% Runoff Estimated	Runoff Volume (gal)
Roof & pavement	86%	90%	51605
Green space	14%	30%	2685
Tree canopy	14 %	reduce by 30%	<u>-2784</u>
Total			51505 gallons

EcoHousing Land Cover		% Runoff Estimated	Runoff Volume (gal)
Cistern collection	15%	none	10270 (n/i)
Sidewalk pavement	12%	50%	3967
Patios & walks	21%	50%	6871
Green roof	17%	50%	5708
Green space	35%	30%	6877
Tree canopy	28%	reduce by 30%	<u>-5638</u>
Total			17785 gallons

## Summary and Comparison

In Urban Ecohousing, the storm water management system becomes a part of the livable green space, enhancing the resident's quality of life. The water collection system and bioretention area become the water experience garden and the green roofs contain a patio with a great view. The stormwater management system controls a significant amount of the water runoff from the site. The land cover, runoff estimates, and total runoff volume shown in the box text on this page give a comparison between the conventional and ecohousing developments for a one inch rainstorm.

In the conventional design, water runoff is not controlled. Storm water runoff is separated from the combined sewer flows, so the potential for overflow is slightly reduced. However, there will be significant water runoff from the conventional development's 86% impervious surface. During a one inch rainstorm, over fifty-one thousand gallons (51,505) of water will runoff the one block site.

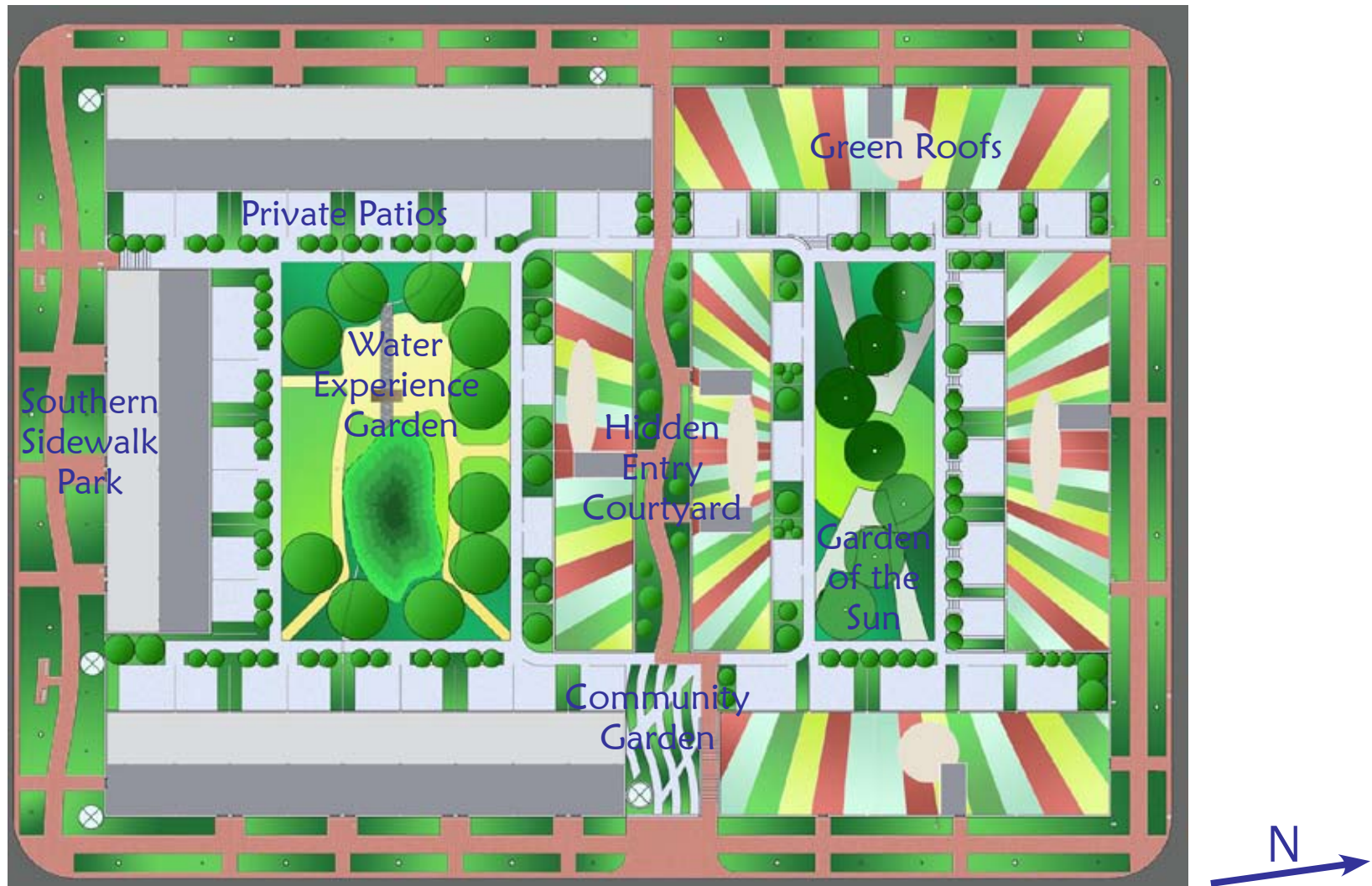
The design strategies to reduce impervious surface in ecohousing result in a 48% impervious surface rate and 52% pervious ground cover. The water runoff from impervious surfaces is controlled in several ways. Cisterns collect runoff from three roofs. The sidewalk runoff is reduced through pervious paving and directing the water runoff to sidewalk green spaces before it runs off the site. Paving on the interior of the block includes walks and patio space. Most of this paving is located above the garage structure and the water is directed to green spaces and the earth well before it leaves the site. These methods are estimated to reduce water runoff from the paved surfaces by 50%. In both ecohousing and conventional designs, the tree cover is estimated to capture 30% of the water in the tree canopy. Potential runoff from this one block site is just less than eighteen thousand gallons (17,785) of water, a two-thirds reduction from the conventional design. This design and analysis shows that increasing pervious surface and managing runoff from impervious surfaces can greatly reduce site water runoff. Peak runoff will also be greatly reduced and the time over which the water runs off the site extended.

# Create Livable Green Space

Garden of the Sun  
Water Experience Garden  
Hidden Entry Courtyard  
Community Garden  
Private Outdoor Space  
Southern Sidewalk Park  
Green Roofs

Creating green space for ecological services is important, but it is especially important at this place where people live, to create places that people can use. The final design goal, 'Create Livable Green Space', shows how the spaces in Urban EcoHousing were designed and how they can be used.

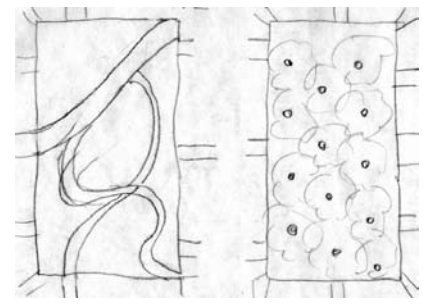
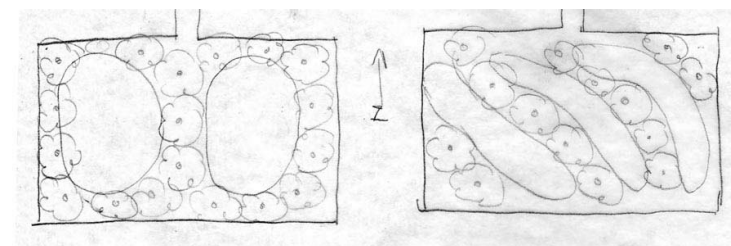
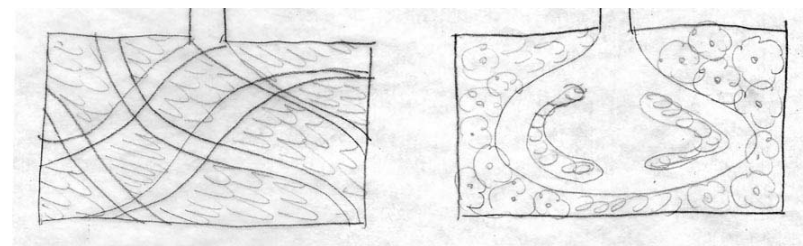
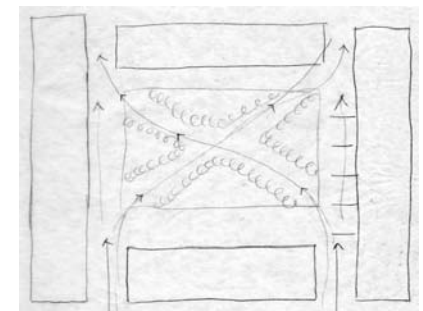
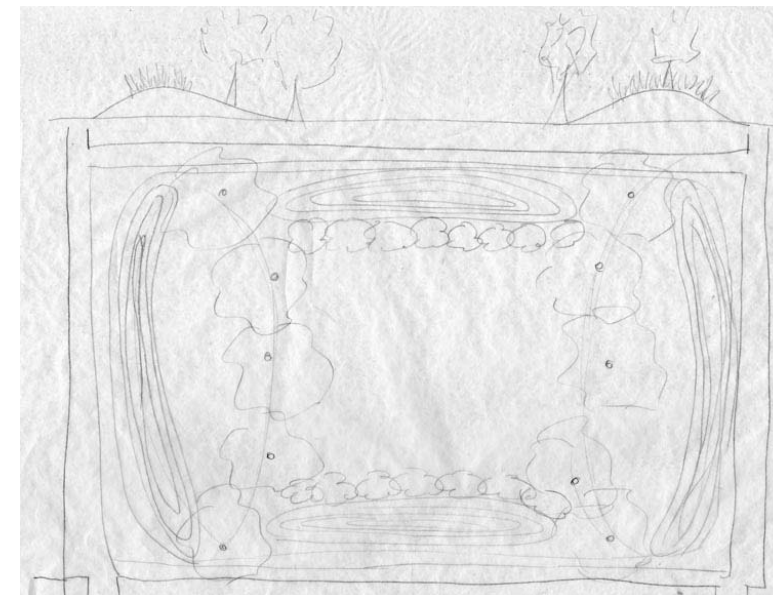
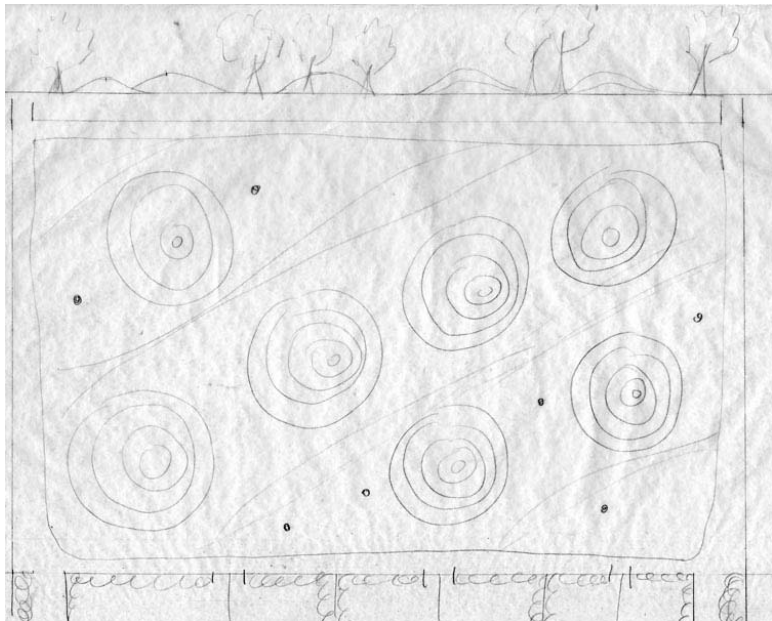
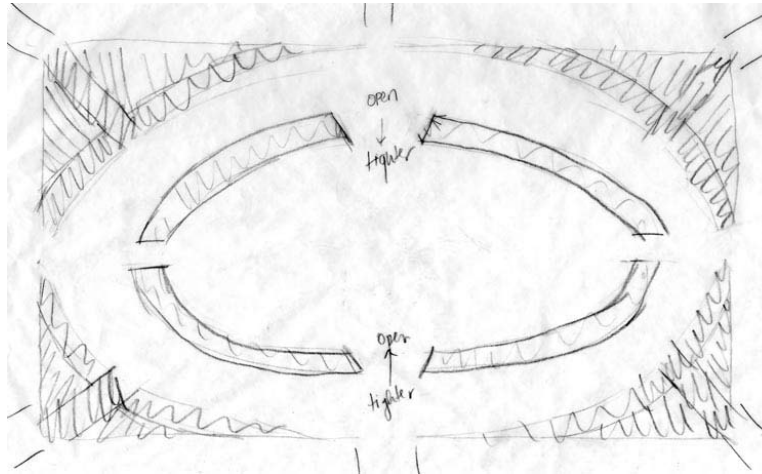
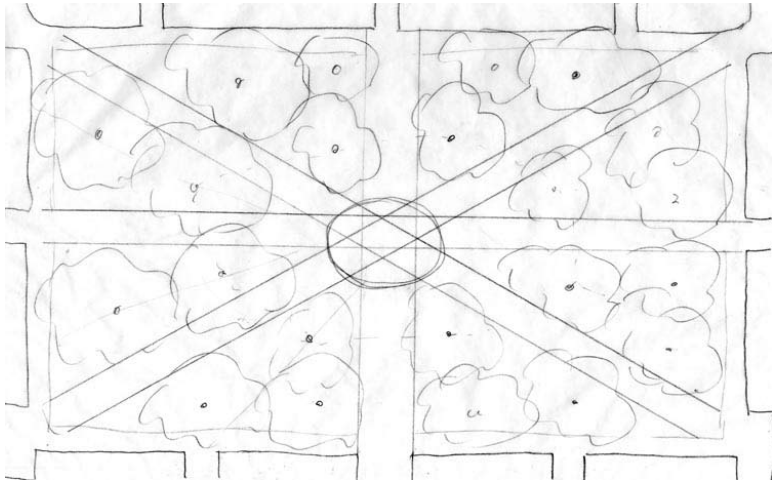
The resident's rights to have private outside space, views to common green space, common green space near the unit, a place for children to play, and cars off valuable ground level space contribute to the green space design. By focusing on the ecological services for energy conservation and air quality, the landscape will make the livable green space a more pleasant place to be.

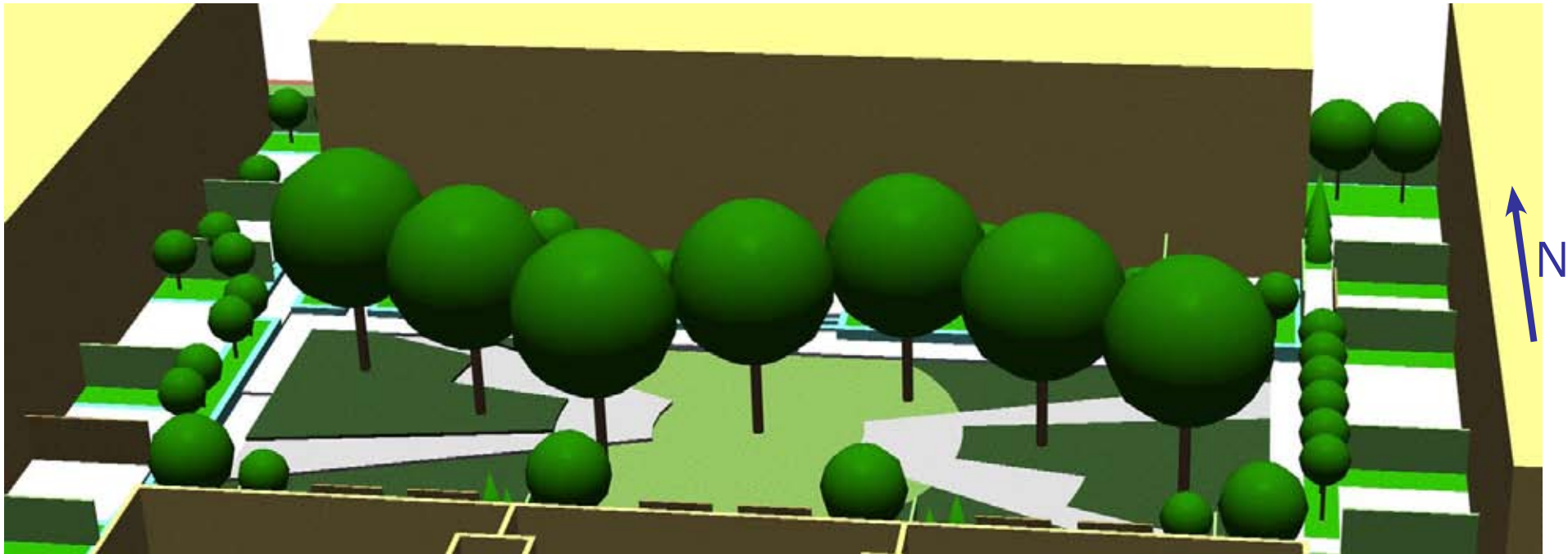


The livable green spaces are located around the block. The hierarchy of spaces defines private outdoor space, common spaces for use by the residents on the interior of the block, and public spaces on the sidewalks and entry ways. The site design is based on the rays of the sun and the flow of water and these themes are used in the courtyards, sidewalk space, and planting areas. The two courtyards created by the earth wells in the parking garage are the main common areas. These spaces contain the Water Experience Garden and the Garden of the Sun. The Community Garden is located over the parking garage. Green roofs on five of the buildings provide a space for residents high above the rest. The public entry walk to the block's interior buildings is the Hidden Entry Garden. The Southern Sidewalk Park is a public area for all to enjoy. Each space is shown in more detail on the following pages.

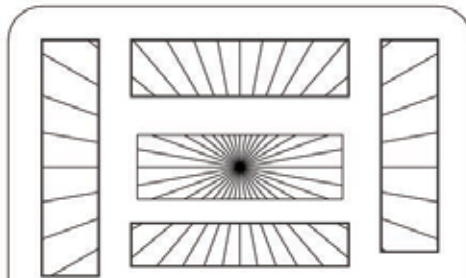
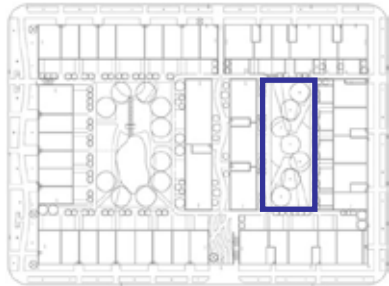
## Courtyard Design Ideas

These sketches show some of the initial design ideas for the courtyards. These designs intend to create spaces for people to gather, to relax, and to play. Land forms such as mounds and bowls are created to make natural play areas for children. The final courtyard design for the Urban EcoHousing prototype did not include these designs, but other block designs could include them.

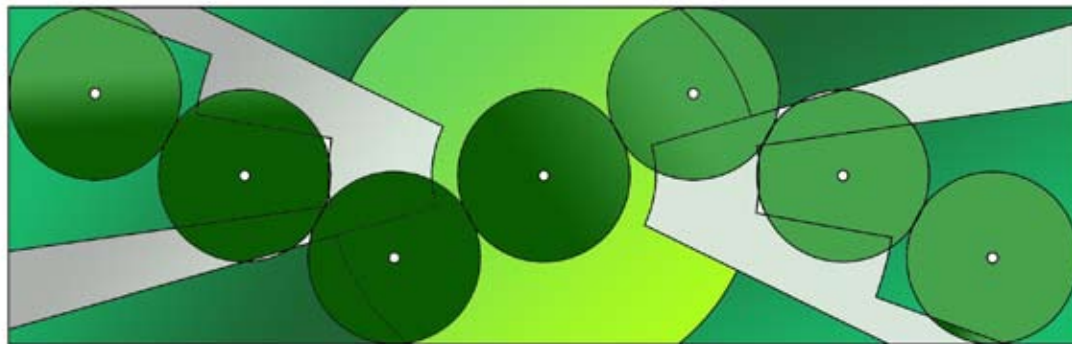




### Garden of the Sun



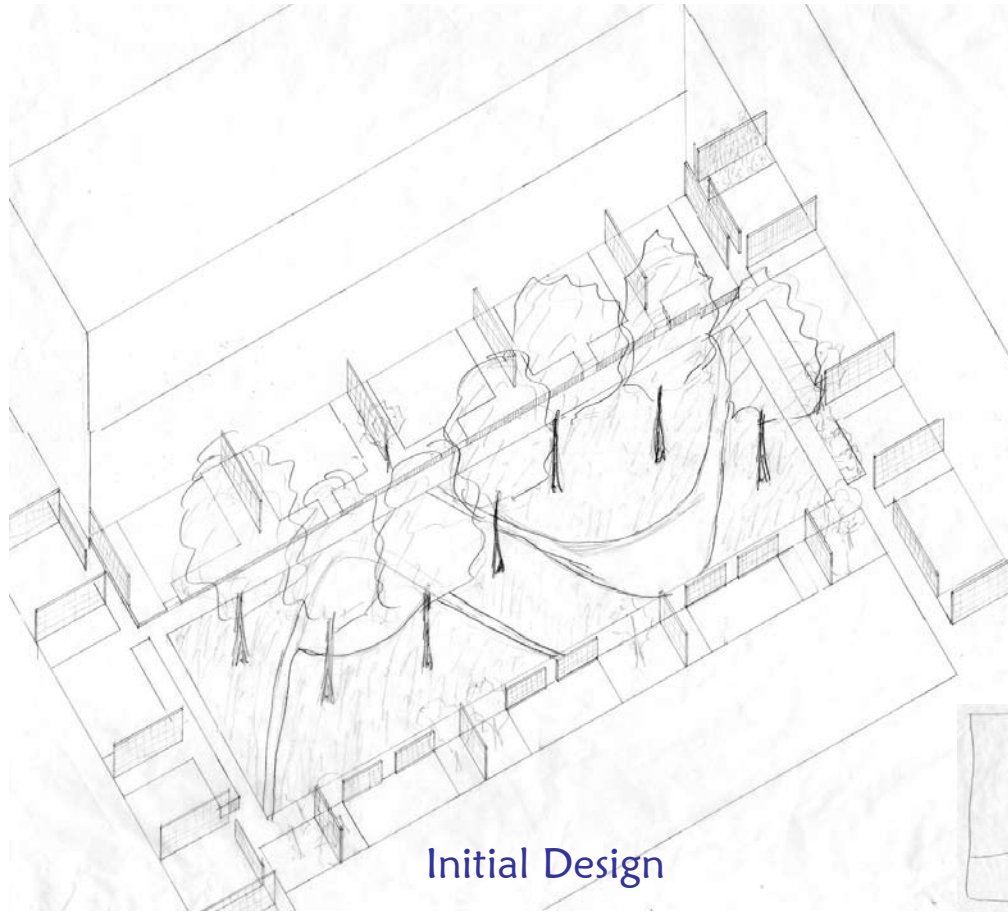
The Garden of the Sun and Shade is located in the smaller courtyard on the northern half of the block. It is surrounded by buildings with one and two-story units. The garden is intended to be a place where people can sit in the sun or the shade and have places of solitude or small places to gather. The garden has seating areas along the path and in small gathering areas. A lawn in the center of the garden acts as casual gathering and recreation area. The garden will be lushly planted with shrubs and perennials around the trees.



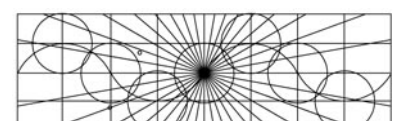
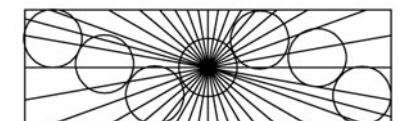
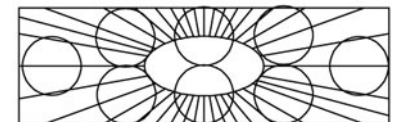
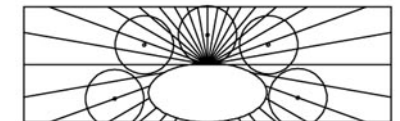
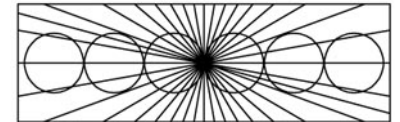
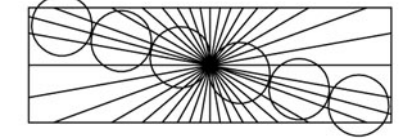
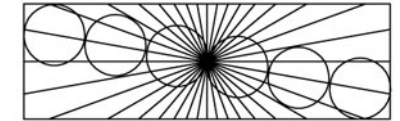
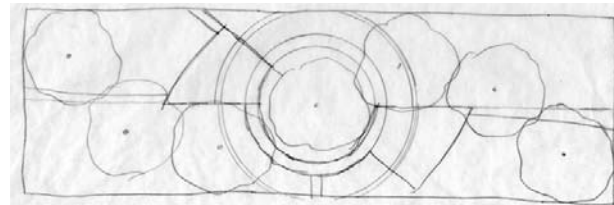
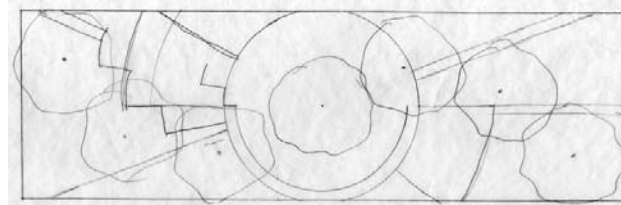
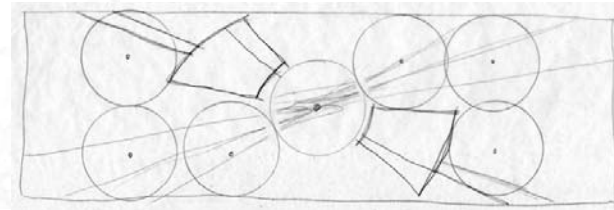
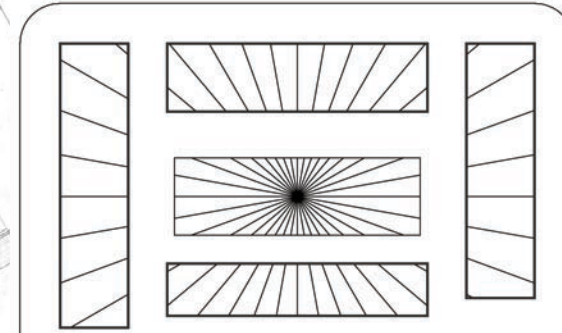
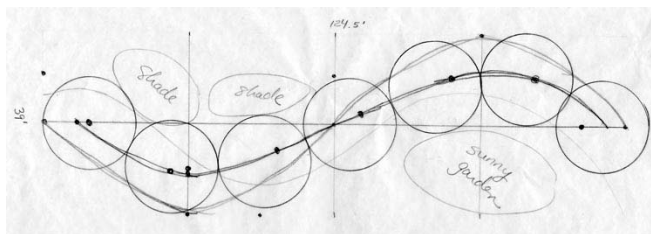
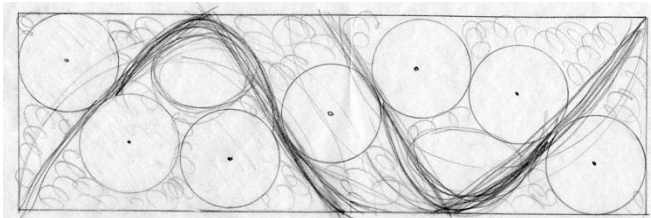
The design evolves from rays emanating from the sun at the center of the garden. The rays and circles of the sun create the plant beds, gathering areas, and paths through the garden. The rays continue to the surrounding buildings and create the design form for the green roof planting areas.

## Garden of the Sun: Design Ideas and Process

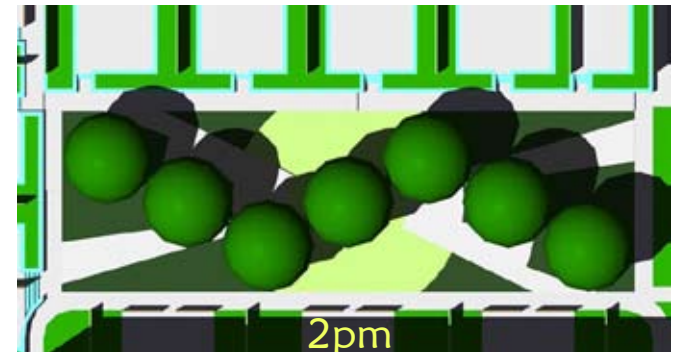
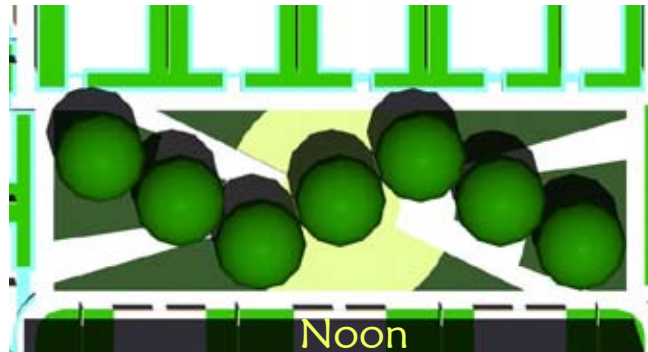
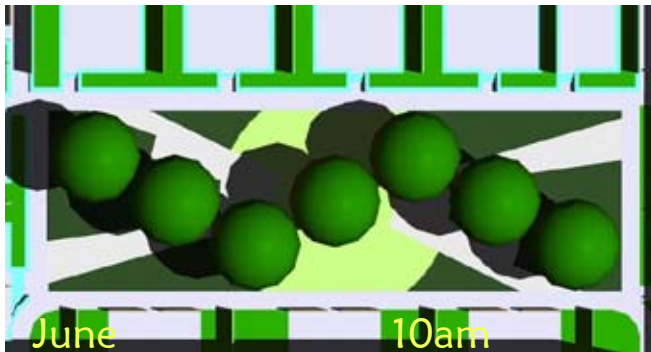
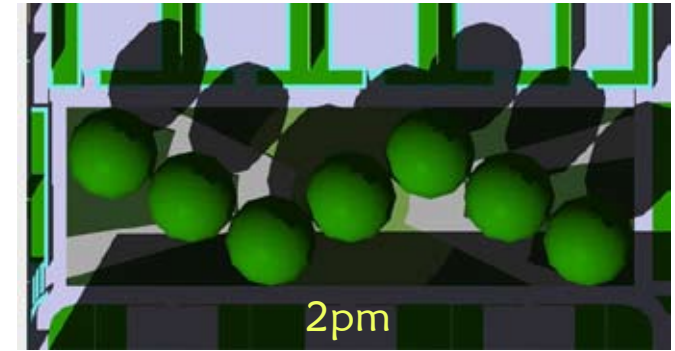
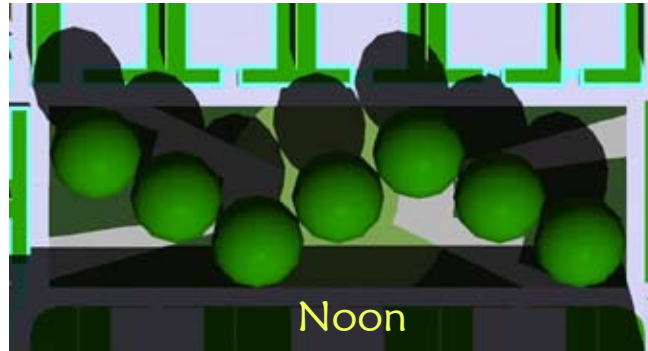
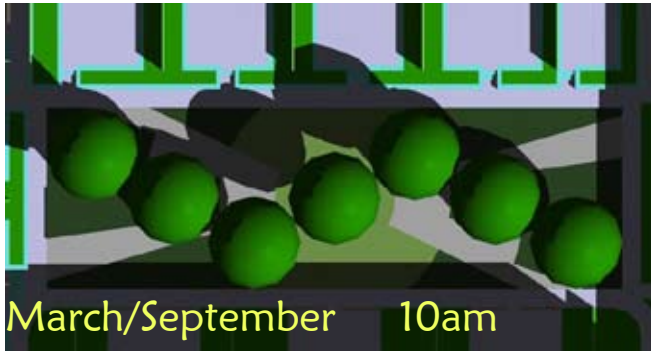
Original designs for this courtyard had flowing, circular, and wavy forms. The axonometric shows a 3d view of what this garden design may look like. As the need to connect the design of this garden to the sun evolved, ideas for the sun rays and circular shapes emerged. These design sketches and iterations show the process from initial idea to final design.



Initial Design



## Urban EcoHousing



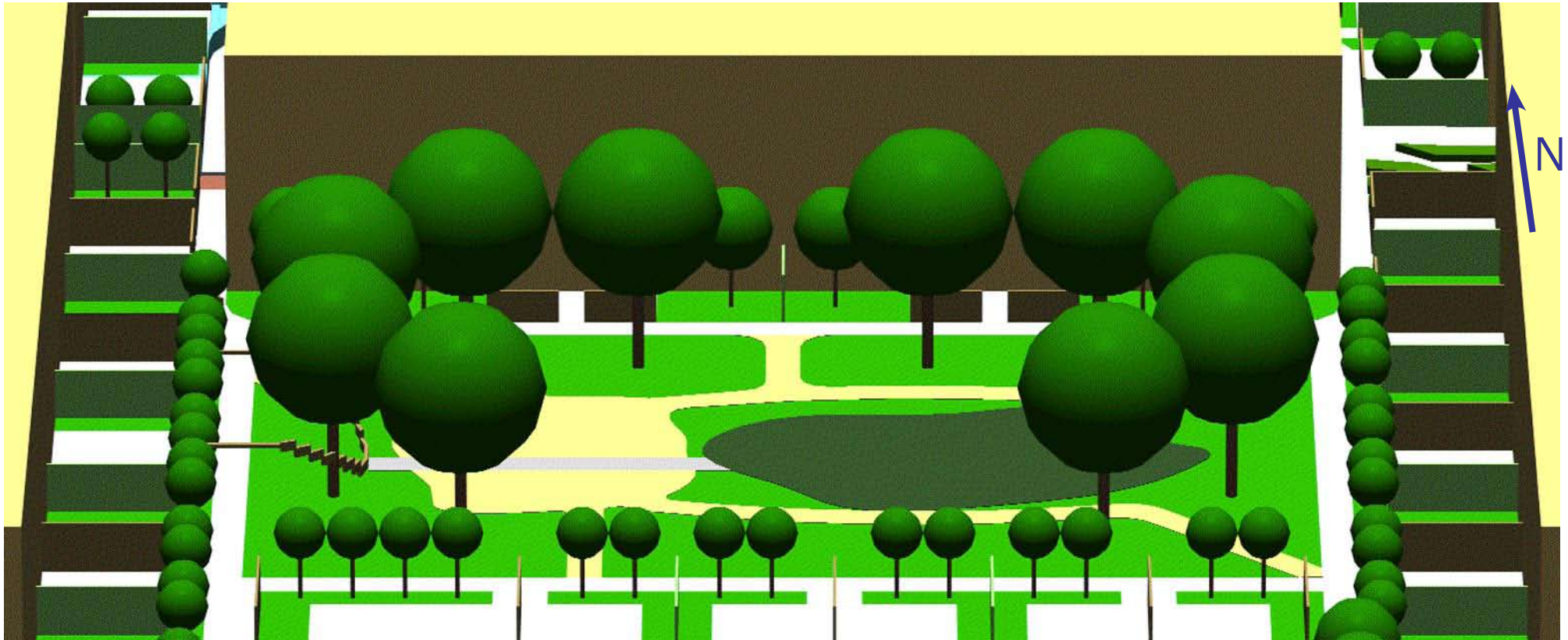
## View from Southwest



## Create Livable Green Space

### Garden of the Sun Shade Diagrams

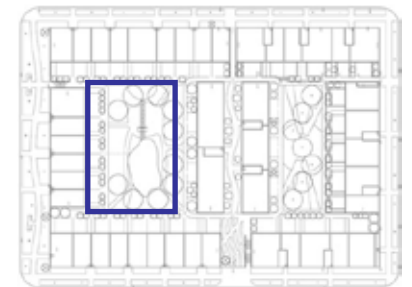
The trees in the garden of the sun are placed to create areas of sun and shade in the summer months and other times of the year. Shade diagrams from June and March/September show the areas in sun and shade. The open southern area gives some sun during all the warm weather seasons, and the trees provide shade to the seating areas in the north in all seasons.

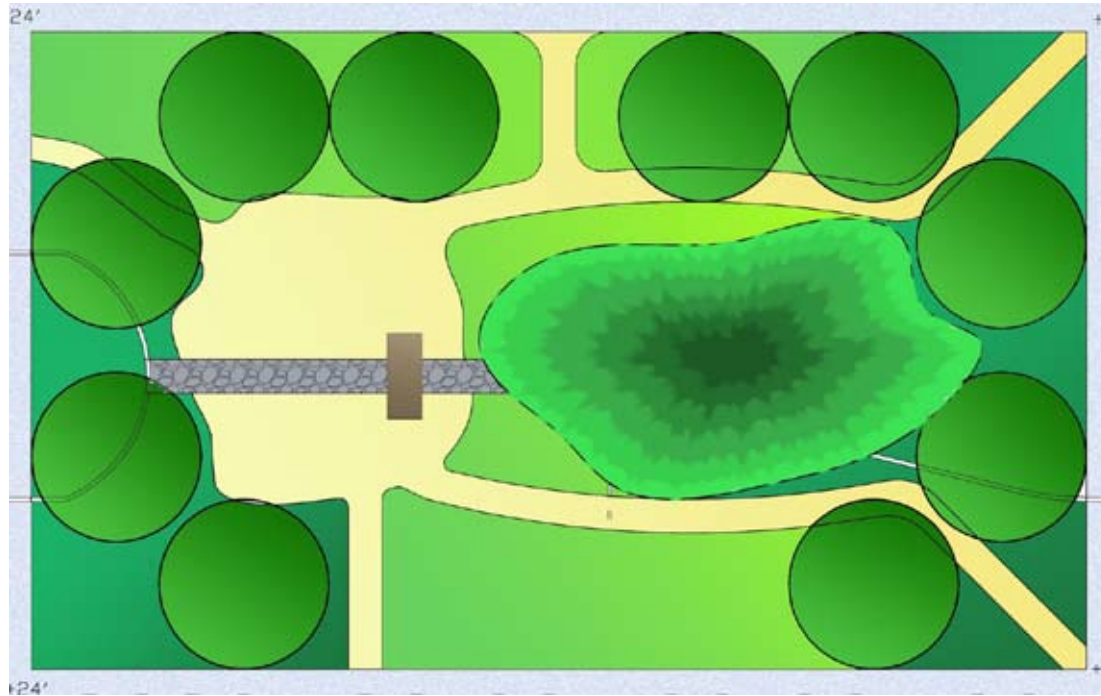


### Water Experience Garden

The Water Experience Garden is located in the larger courtyard on the southern half of block. It is surrounded by townhouses and a building with one-story units. The garden is intended to be an active and participatory area for the residents in the surrounding units. The garden reveals the flow of water and the design is reflective of a flowing and natural system.

The water experience starts with rain water falling on the roofs of the townhouse buildings. Water conveyance systems take water from the roof and carry it to a bioretention area in the center of the garden. Water is conveyed in overhead, surface, and below surface systems. The overhead conveyance system can be viewed from the second and third levels of the buildings, where water flow will be active during rain events. The transition from the overhead conveyance to the ground level rock channel can be closely viewed from within the garden.

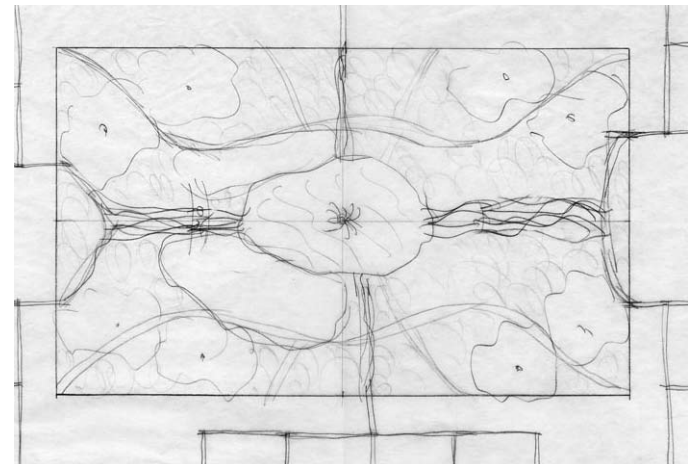
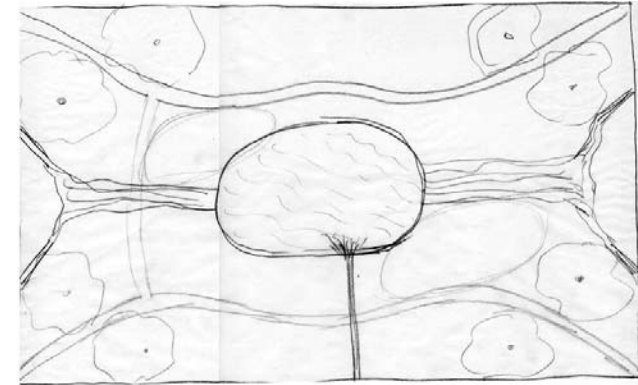
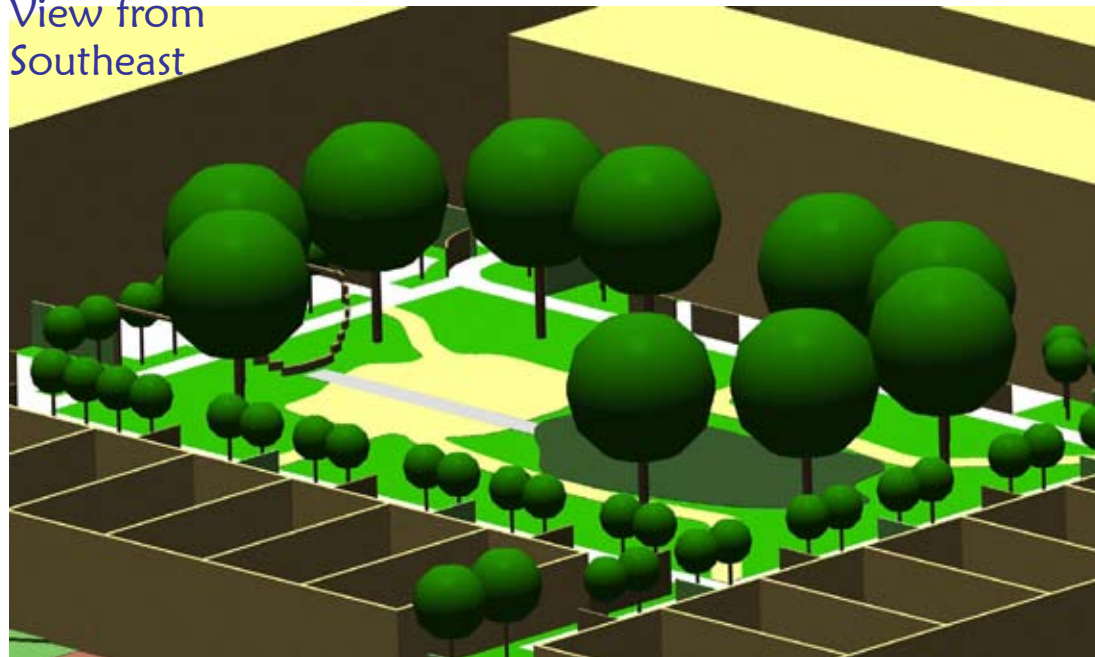


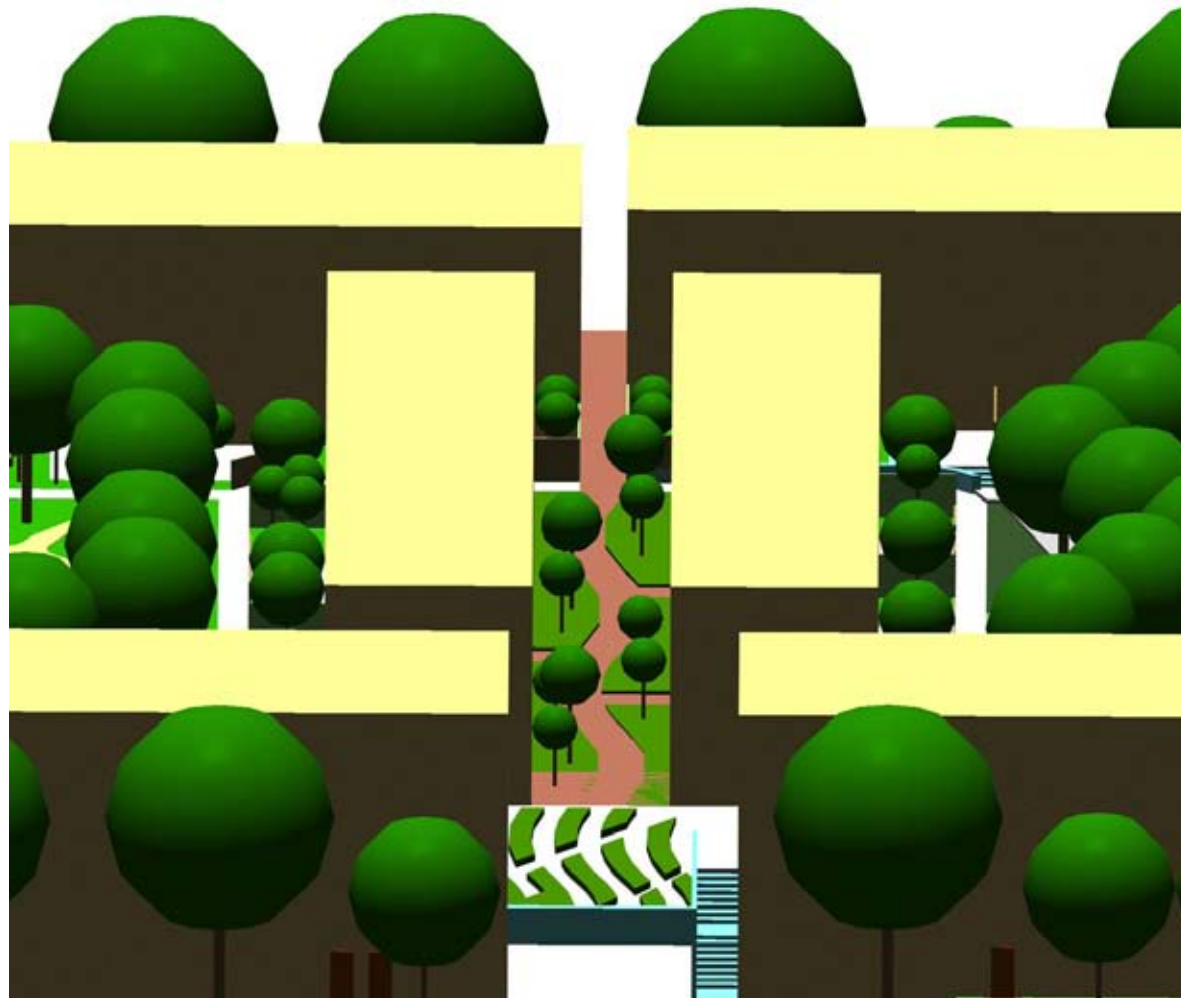
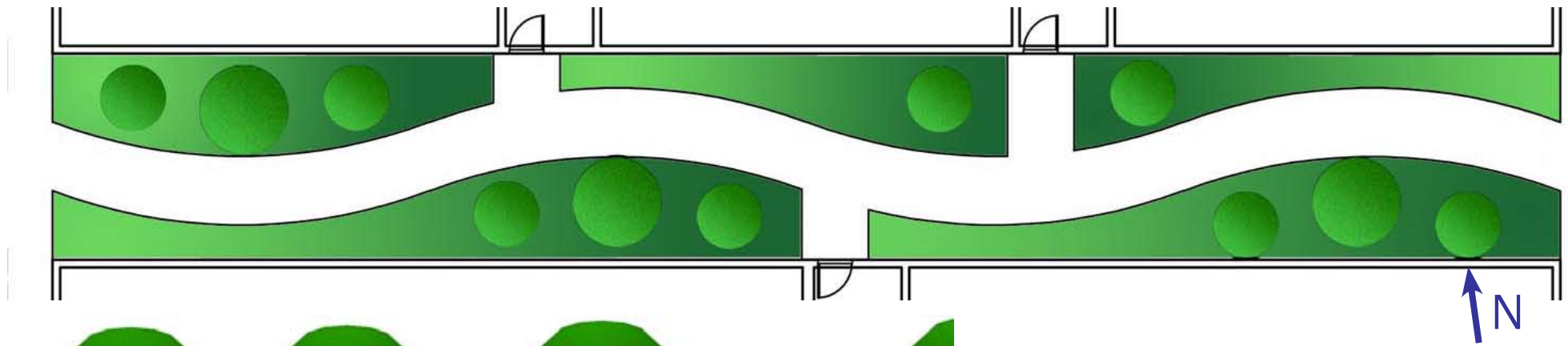


## Water Experience Garden

The garden includes two large gathering spaces (350 sq ft. and 570 sq ft.) on the western side of garden. The gathering space is divided by the rock channel, and connected by a wooden bridge over the channel. A 900 square foot lawn area allows for active recreation. Trees are placed in the garden to allow a central sunny area and to give shade on the western side of the gathering space. The outer areas of the garden are planted with shrubs and ground cover to increase the plant diversity and ecological function of the area.

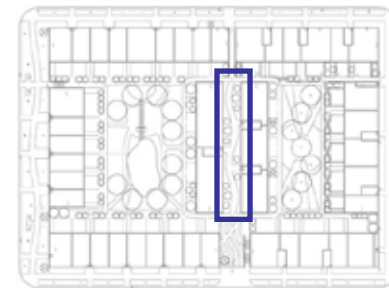
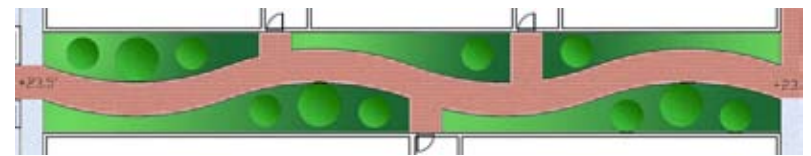
View from Southeast



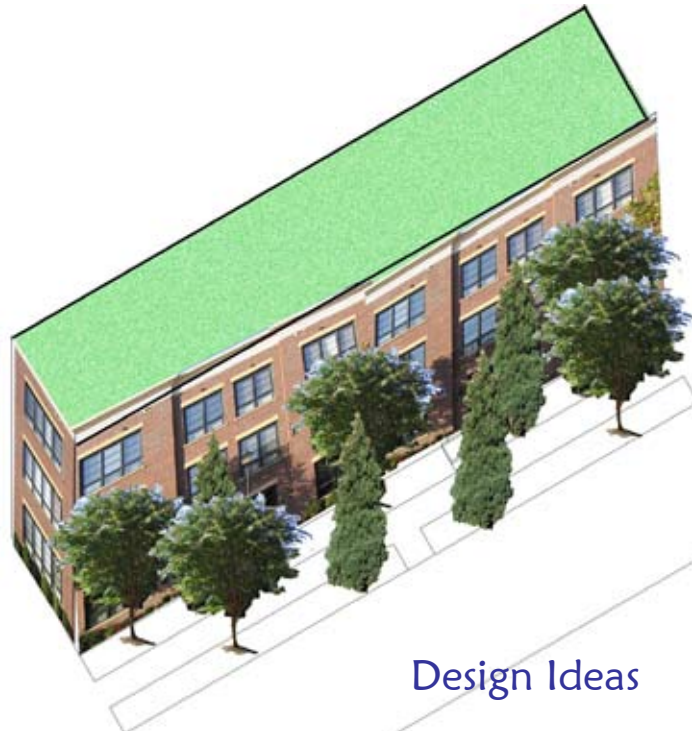
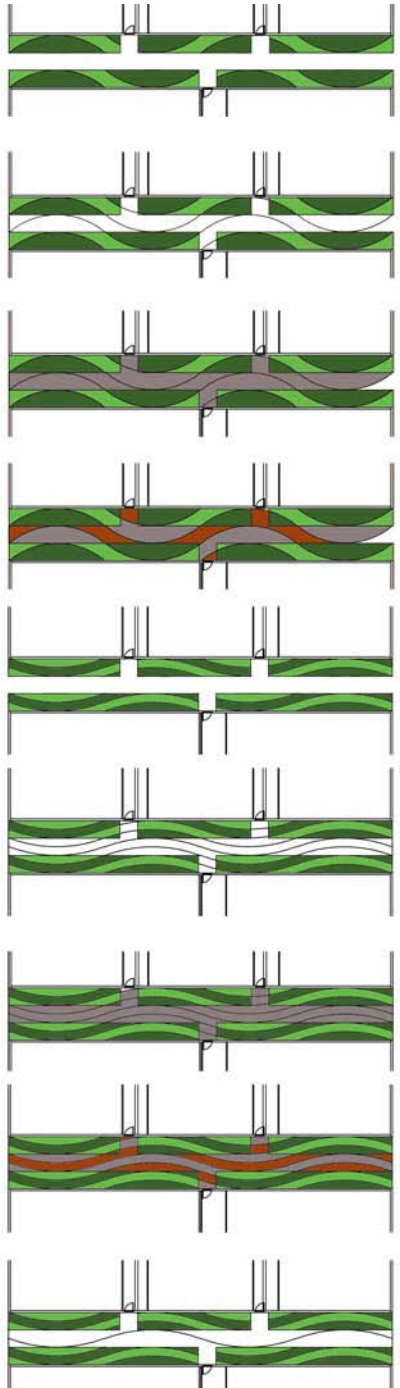


### Hidden Entry Courtyard

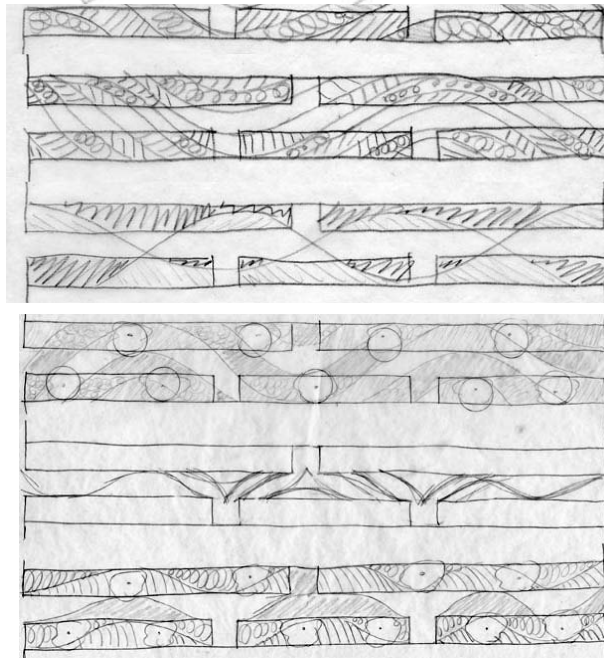
The placement of buildings on the interior of the block necessitates an entry walk to access the units. The lush entry garden is hidden but serves as the public entry way for the one-story units. The curve in planting beds and paths is inspired by the water flow that originally occupied the site.



# Urban EcoHousing



Design Ideas

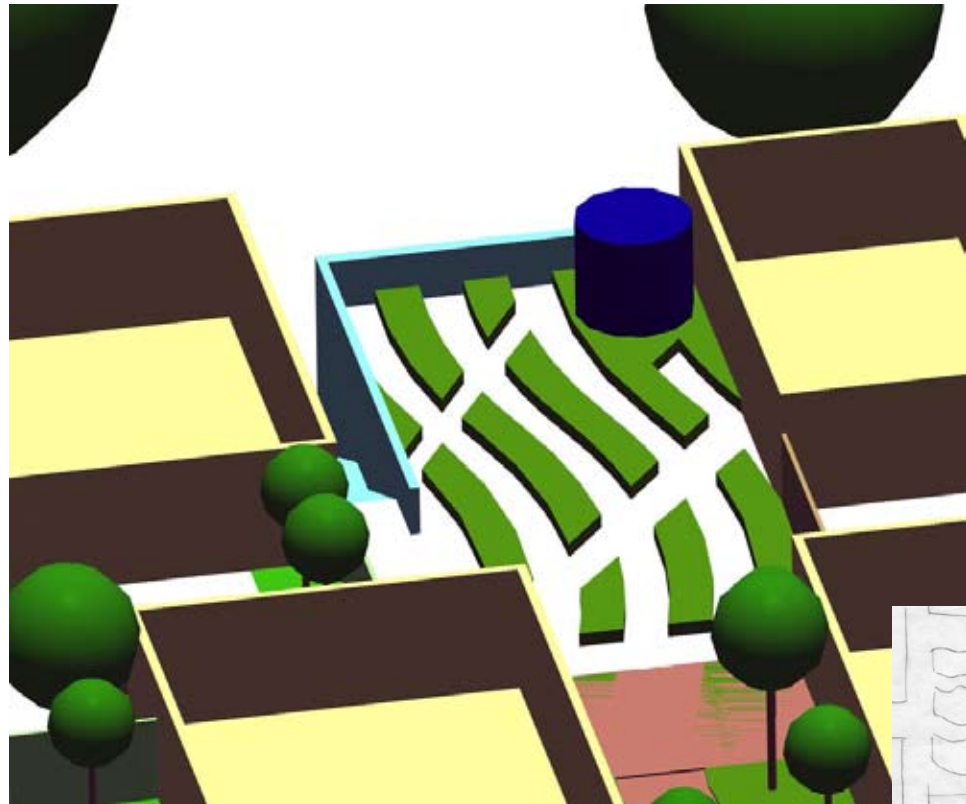
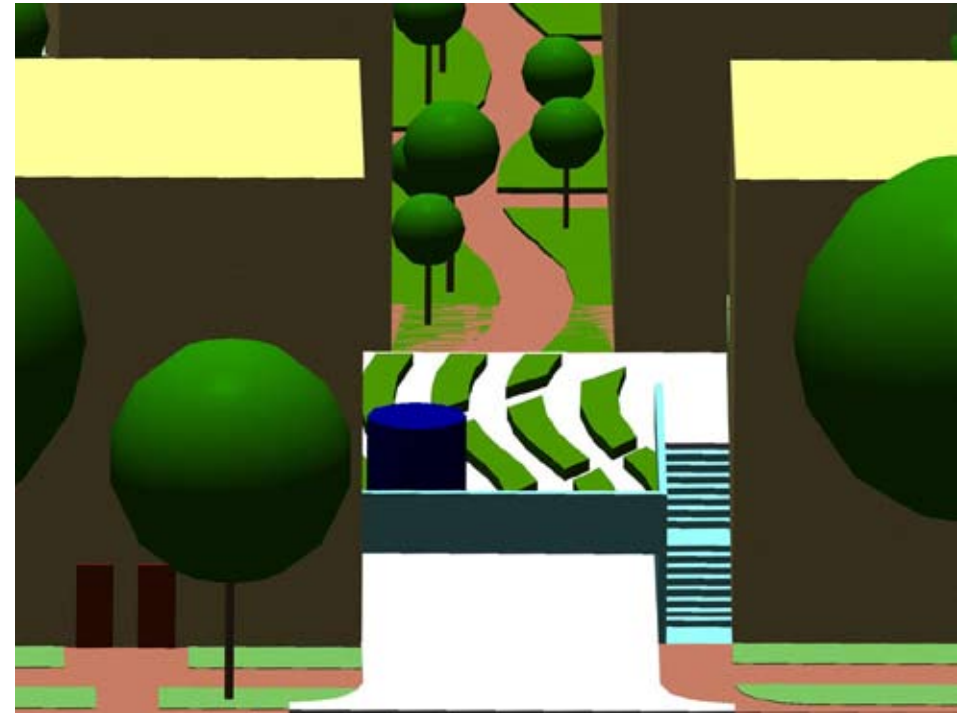
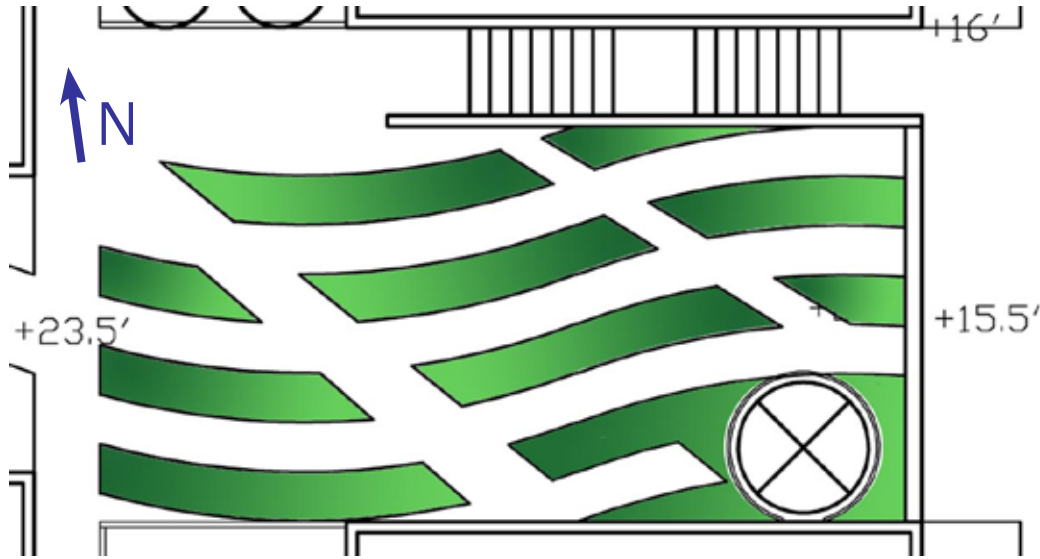


# Create Livable Green Space

## Hidden Entry Courtyard

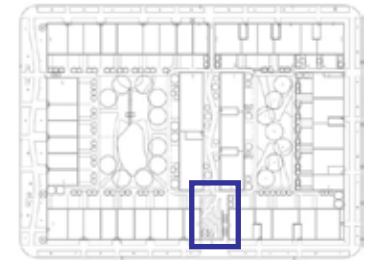
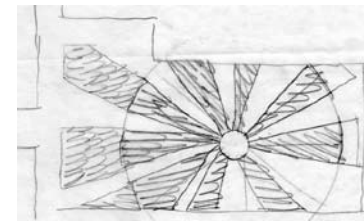
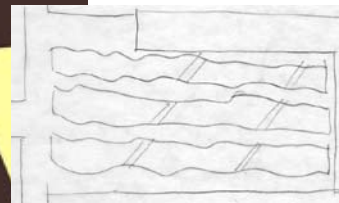
The curve of water flow inspired the designs for the Hidden Entry Courtyard. The fixed locations of the building entry required openings in the plantings and access from the walk. The first concept had rectangular planting spaces and curve variations in the planting plan and paving pattern. The design process played with ideas of plant color, paving color, and the width of planting and paving strips. Conceptual three dimensional views studied how the narrow space would look and feel when it is filled with trees.

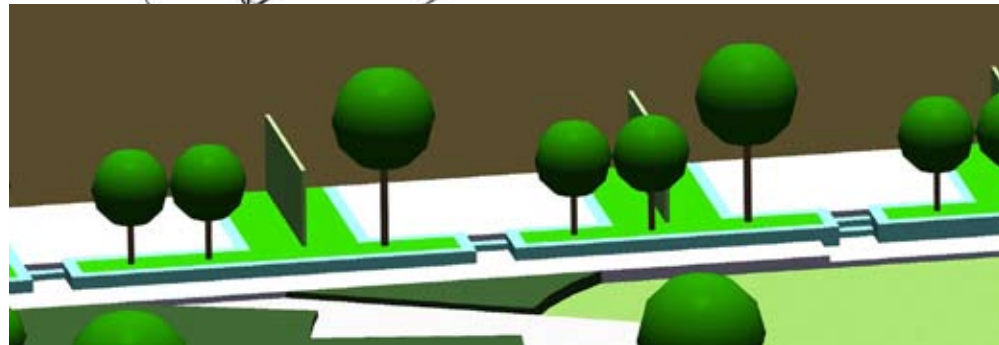




## Community Garden

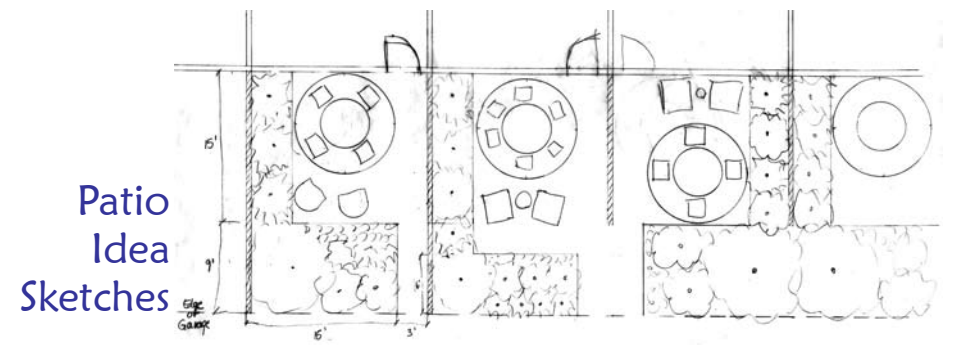
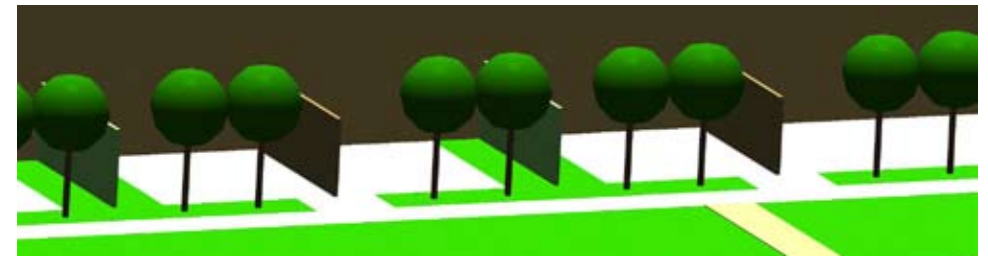
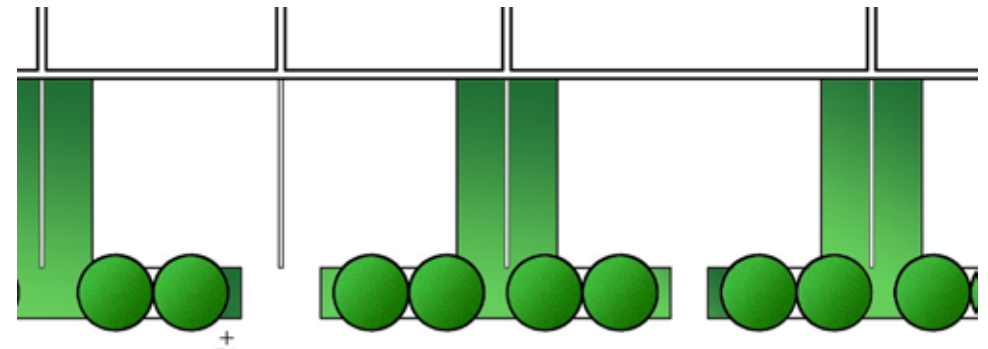
The area over the garage entrance and between the buildings is used as a community garden. Planters in raised beds give space for residents to grow flowers, herbs, and vegetables. A cistern collects water from the adjacent townhouse roofs and is used for garden irrigation. Additional weight supports may be needed in the garage construction to support the cistern. The design for the community garden continues the water flow curves from the Hidden Entry Courtyard and the rays from the Garden of the Sun.

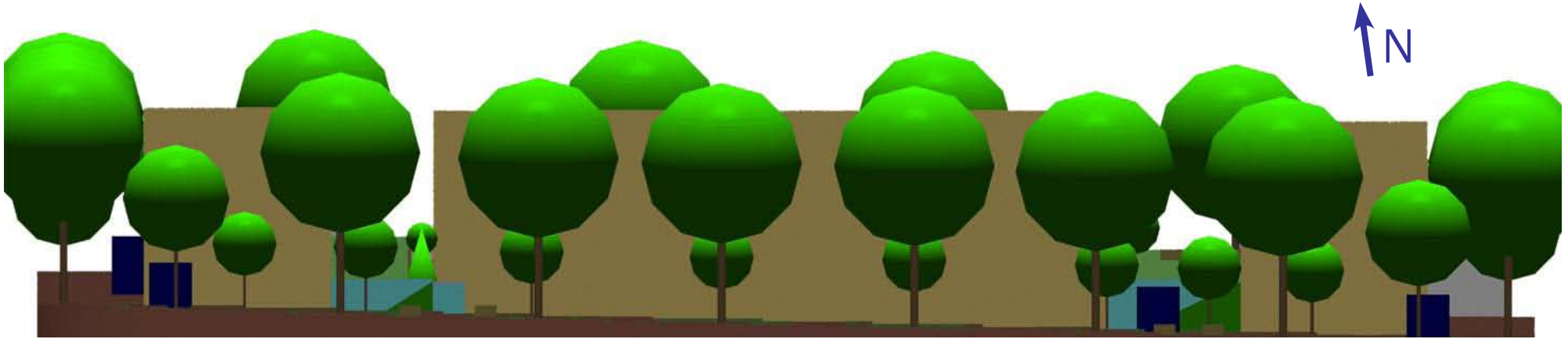
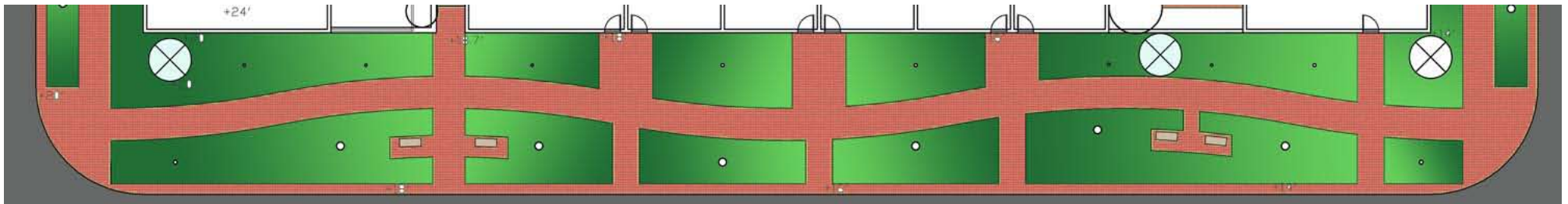




## Private Patios

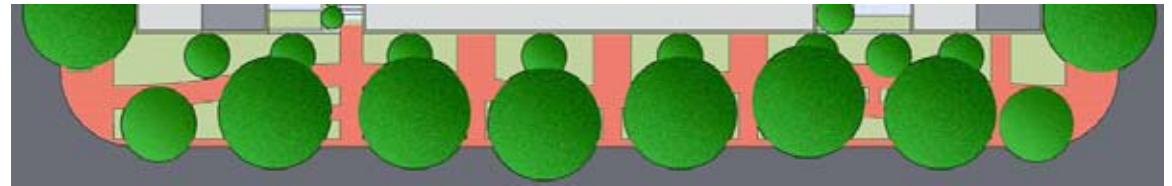
Each unit has a private outdoor space. Private outdoor spaces are important so people can be in solitude, grow plants outside, or even hang their laundry. The townhouse units and ground floor flats have a patio with garden space that leads to the common courtyards. Ground level patios are screened with green walls between the units and with trees and shrubs to the courtyards whenever space allows. Units on the second, third, or fourth floor have a balcony that overlooks the courtyards.



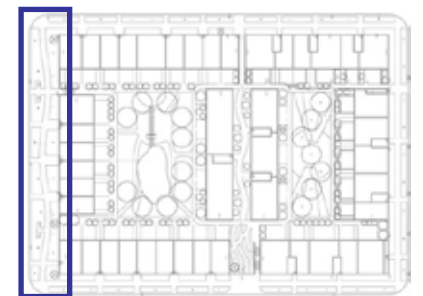


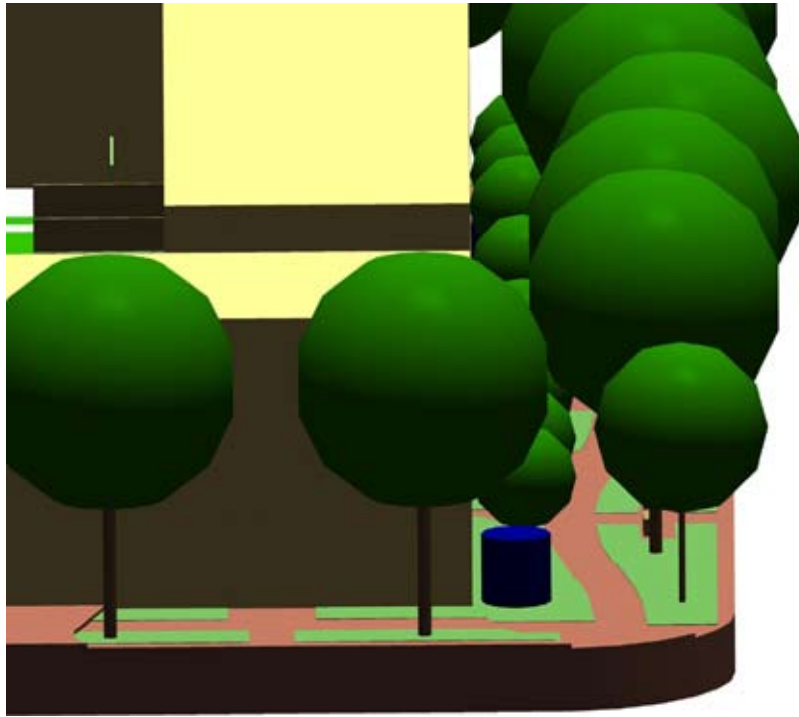
## Southern Sidewalk Park

The southern sidewalk park is created from the thirty foot (30') building setback generated by the need for sun to reach the buildings in winter. That setback also gives an opportunity to create a linear park and space on the block the public can use. The setback gives larger planting spaces for trees and the ability to create two rows of trees on the block.

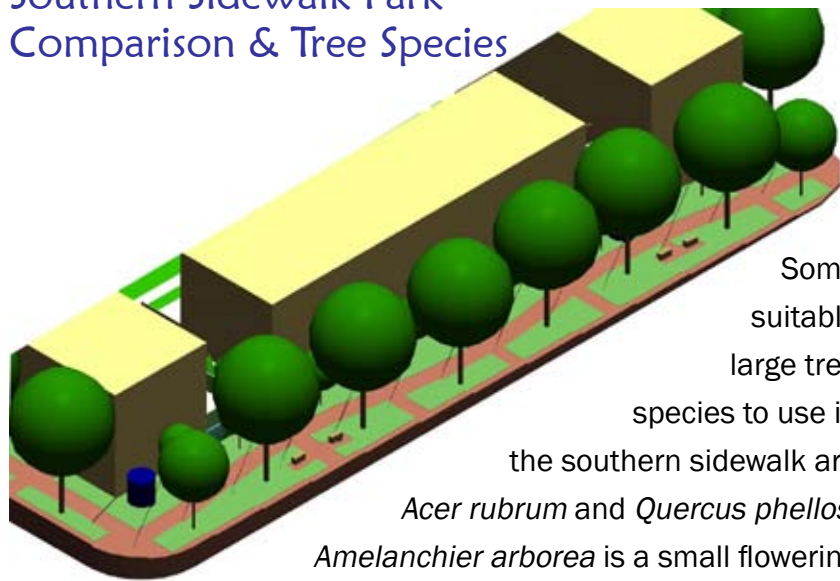


The design continues from the curves of the water flow on the interior block garden areas. There is a slight meander in the sidewalk to let people slow down and enjoy the space. Benches are provided within the trees for a place to stop and rest. The public area of the linear park is located from the sidewalk to the street and set away from the house entrances.





Southern Sidewalk Park  
Comparison & Tree Species



Some suitable large tree species to use in the southern sidewalk are *Acer rubrum* and *Quercus phellos*. *Amelanchier arborea* is a small flowering tree to use along the house borders.



Conventional Development  
Southern Sidewalk

The image of the conventional sidewalk shows the narrow tree space and dominance of the exterior stairways to the buildings. There is no opportunity for the public to experience the space or stop and take a rest.



*Acer rubrum*, Red Maple



*Amelanchier arborea*, Amelanchier

*Quercus phellos*, Willow Oaks in Alexandria



Green Roof, Center for Neighborhood Technology, Chicago, Illinois

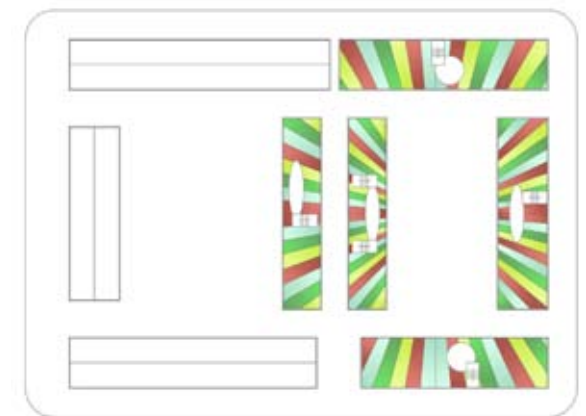


Green Roof, Yorktowne Square Condominiums, Falls Church, Virginia

## Green Roofs

The extensive green roofs are located on buildings with one and two-story units. The primary purpose of the green roofs is to increase permeable surface, control water runoff, improve water quality, and provide energy conservation. These green roofs give a secondary use as a rooftop garden space for the residents. There is a small (approximately 300 square foot) gathering area on each roof that is accessible from a stairwell in each building. Rooftop areas give spectacular views of the surrounding neighborhoods, the Potomac River, and the monuments of Washington, D.C.

The planting design is generated by the radiating sun pattern from the Garden of the Sun in the courtyard below. The pattern uses different plants, colors, and textures in the areas created by the rays. The green roof and its planting design will be visible by users of the roof and the surrounding tall buildings.



## Summary and Comparison

The ecohousing livable spaces show how the design elements of the other goals lead to the creation of interesting spaces for people to enjoy. The integration of design with urban landscape ecosystem services can achieve great results.

The conventional design includes very little livable green space. The conventional units give private outdoor space to less than half of the units. Rooftop patios are included in thirty-four of the seventy-six units and they all overlook the alley. The private outdoor space does not include any green space, but it can be added through container plantings. The alleys and garage access in the conventional design occupy most of the space where livable space could be.

Two courtyards are located on the conventional block interior, co-located to the center street. The courtyards include seating and play areas, with a few trees. These two courtyards are 3300 square feet each, compared with the two ecohousing courtyards, at 4800 and 9200 square feet.

Just thirty-four of the seventy-six conventional units have views of the courtyard and the remaining view the street and the alley. All of the ecohousing units have views to the interior courtyards.



Conventional Design Interior Courtyard



Conventional Design Interior Courtyard



Conventional Design Paved Alley and Garages



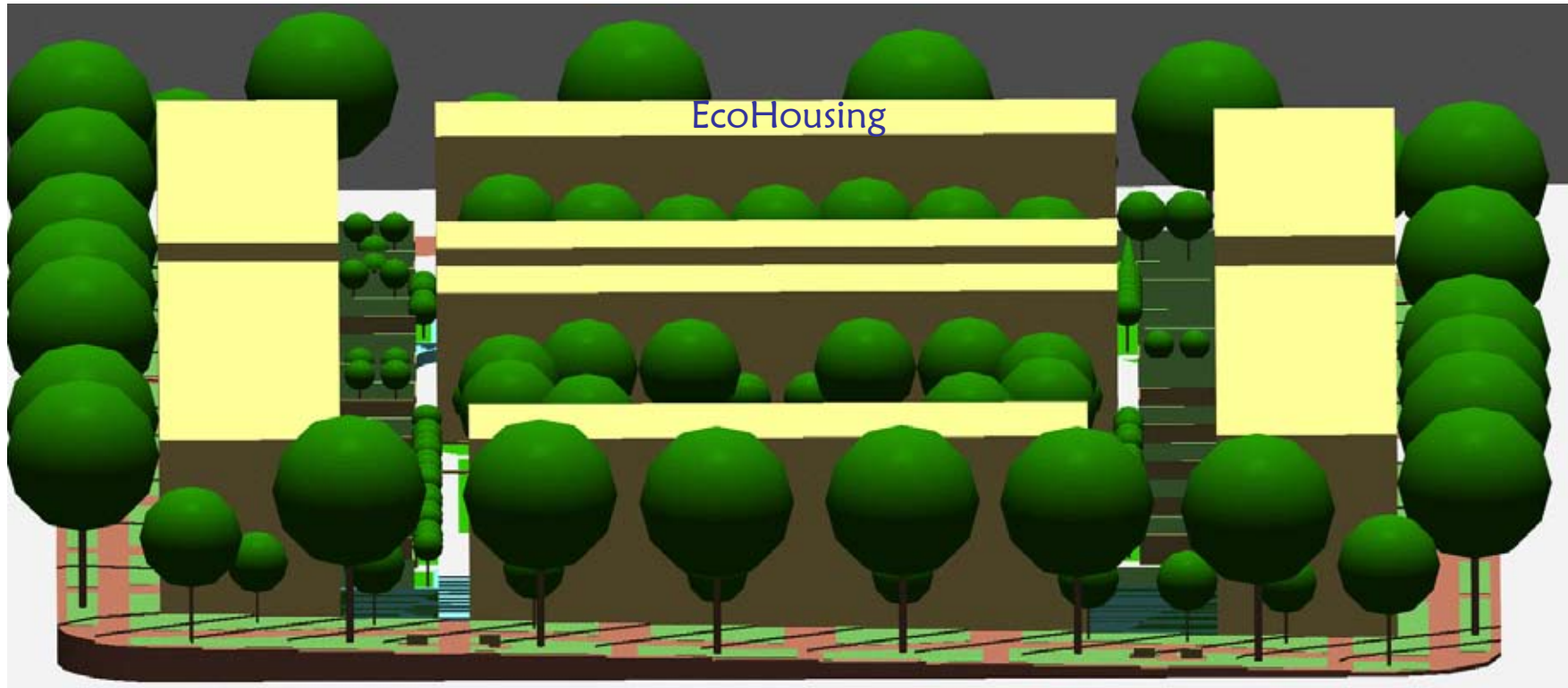
Conventional Design Alley through Interior Courtyard

# Conclusions

Green Infrastructure:  
The Landscape of Urban EcoHousing



The image of the Alexandria neighborhood overlaid with the Urban EcoHousing prototype shows how this site design might look compared to the blocks around it. The green roofs and interior green space stand out compared to other blocks. The prototype design is conceptually implemented over all four blocks of the site. In reality, changes would be made to the other block designs to make each space unique. Changes may be made to how the common space is allocated and designed. Many design variations are possible for the interior courtyard and streetscape plans.



SW

Princess Street

SE



Conventional

The photo collage of the conventional design and the three dimensional rendering of the ecohousing give a sense of the differences of the two designs. The conventional design has one opening on Princess Street to access the interior alley. The view from the street is to garage entrances and the rear of other houses. The ecohousing design allows more openness to the block and provides views to green space and the active life of residents. The increased setback on this southern sidewalk will also give a park like feel and larger trees to shade the area



SE

North Royal Street

NE



Conventional

The buildings on North Royal Street have a similar configuration in the two designs. A single opening at the middle of the block gives auto access to the alley. In the conventional design, a paved alley leads to the center of the block. In the ecohousing design, the entrance leads to the below ground garage, and views above show green space and the active community garden.



The Oronoco Street comparison between the conventional and ecohousing designs shows a similar condition to Princess Street. The single opening in the conventional is a view to the alley and the two openings in ecohousing give views to the courtyards. Differences are also seen in how the units are accessed from the sidewalk. In the conventional design, stairs are used to access the first floor of units. In ecohousing, the entrances are at the sidewalk grade, thus allowing green space instead of paving.

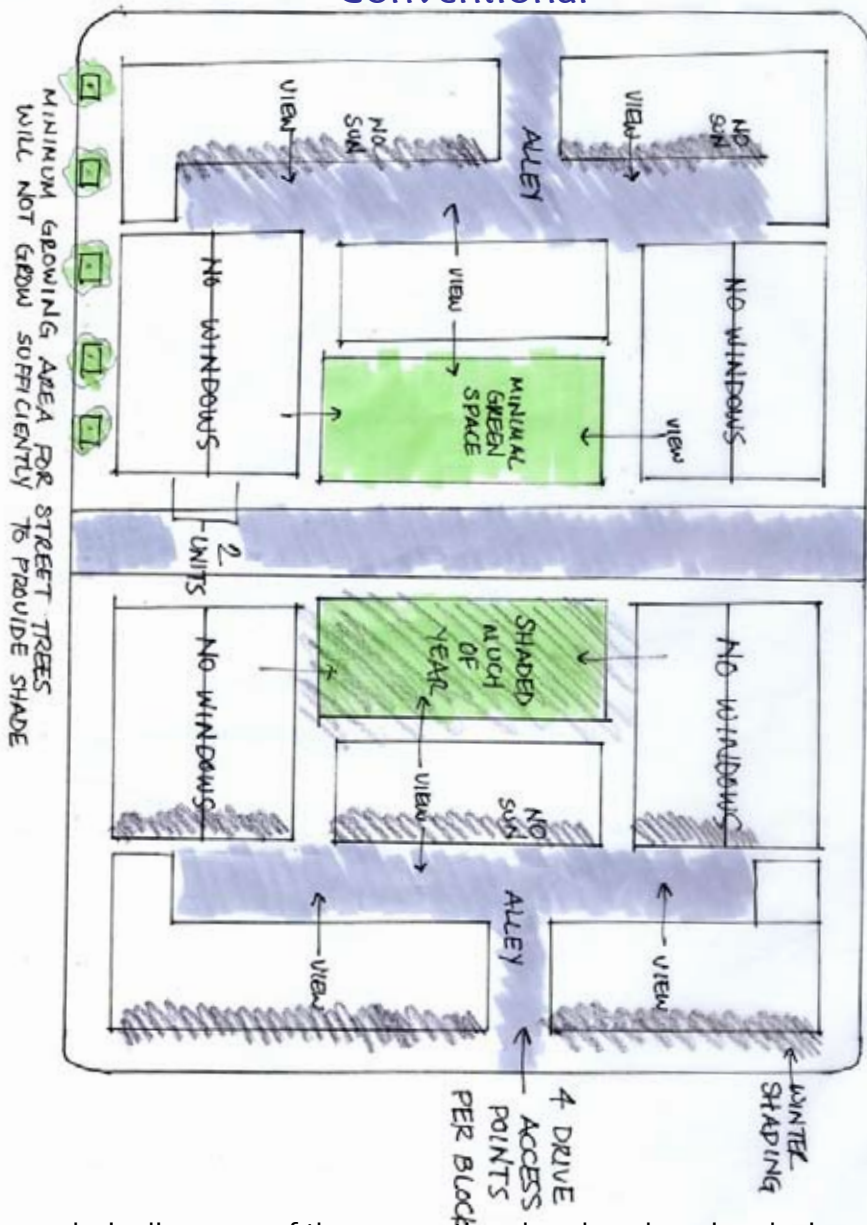


Conventional

The Pitt Street collage and renderings show similar building configuration with the conventional and ecohousing design. The conventional design has a single opening to the alley and central courtyards. The ecohousing design has the smallest opening of all blocks on Pitt Street. Larger setbacks on the north and south streets, Princess and Oronoco, are shown to give larger growing spaces.

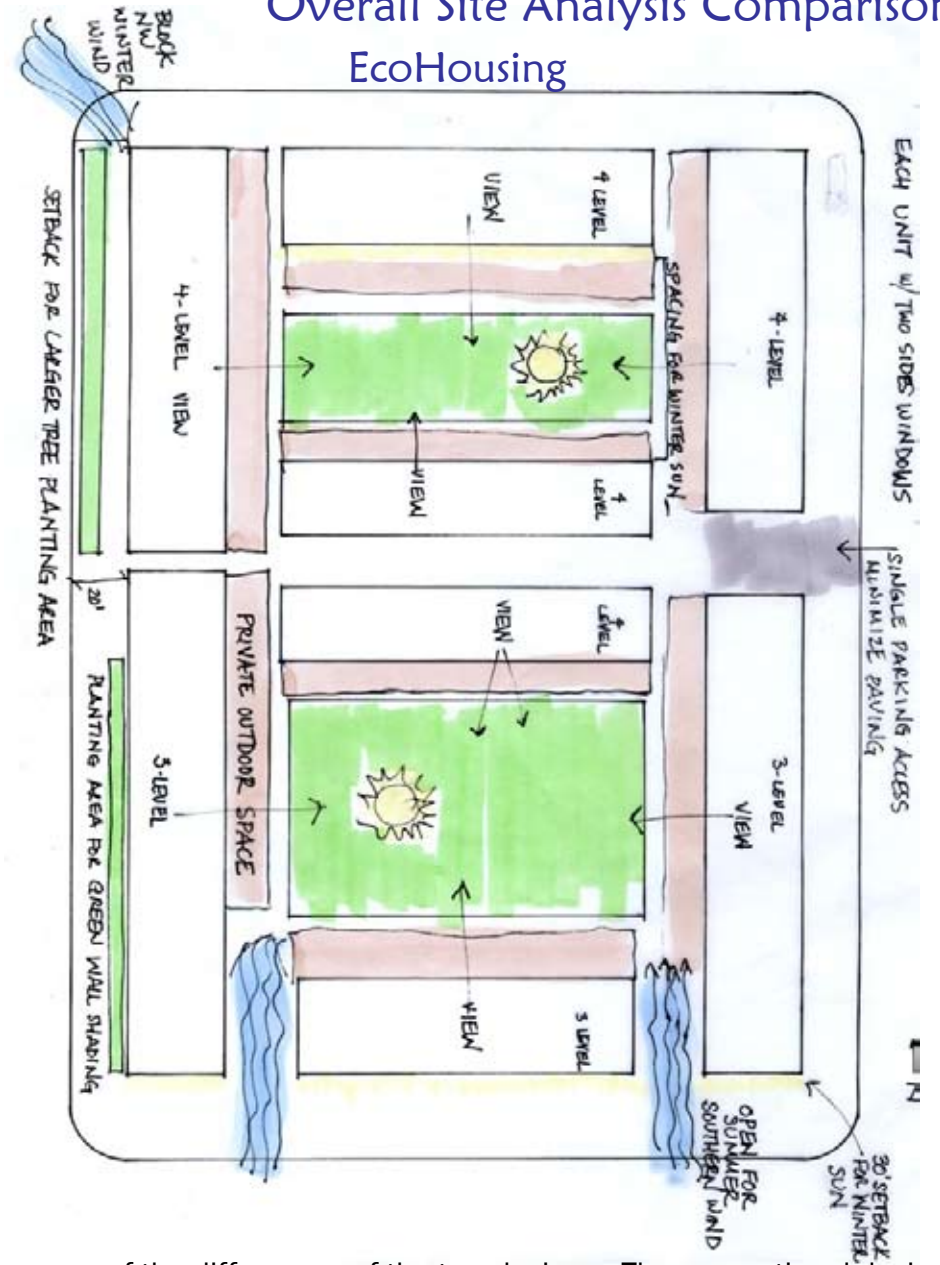
# Conclusions

## Conventional



# Overall Site Analysis Comparison

## EcoHousing



The analysis diagrams of the conventional and ecohousing designs summarize some of the differences of the two designs. The conventional design has significantly more impervious surface with three alleys, minimal green space areas, and views from most units to the alleys. The ecohousing design shows increased green space and tree growing areas, minimized impervious surface with one parking access drive, and views to the green space. The ecohousing allows better air circulation and solar access to the buildings and open space.

# Conclusions

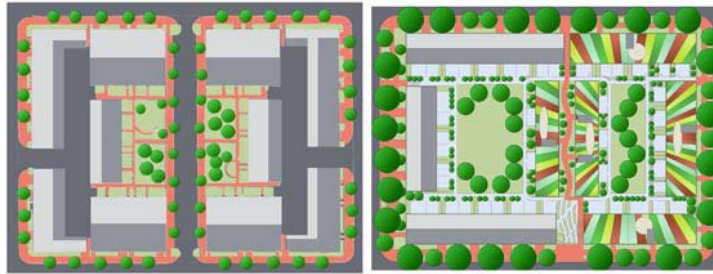
Comparisons

Conventional

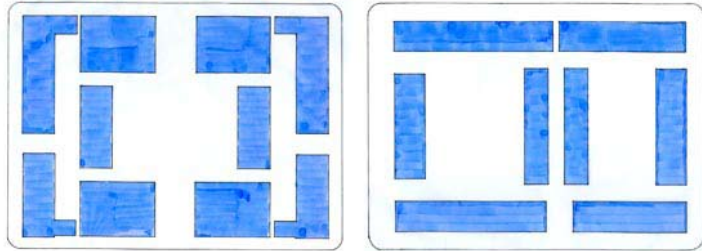
EcoHousing



1" = 30'

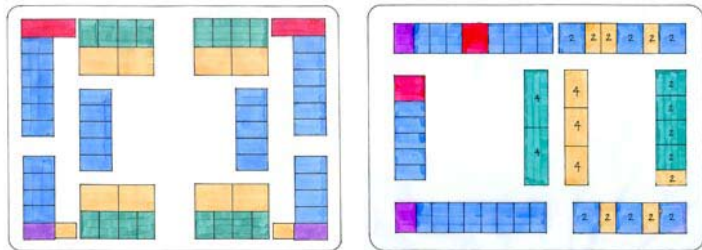


Building Footprint

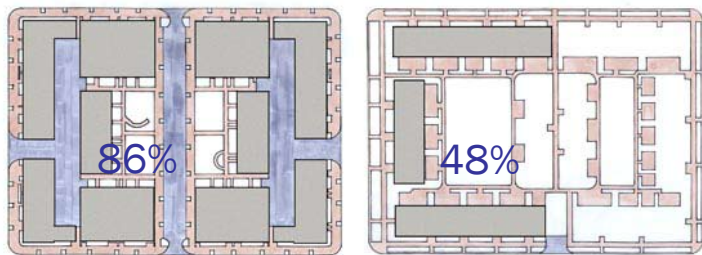


Housing Units

SQUARE FEET KEY: ■ 3500 ■ 2700  
■ 2100-2200 ■ 1800-2000 ■ 1200-1400



Impervious Surface



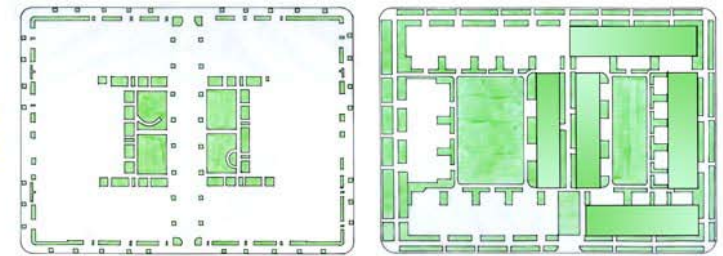
# Comparison Diagrams

Comparisons

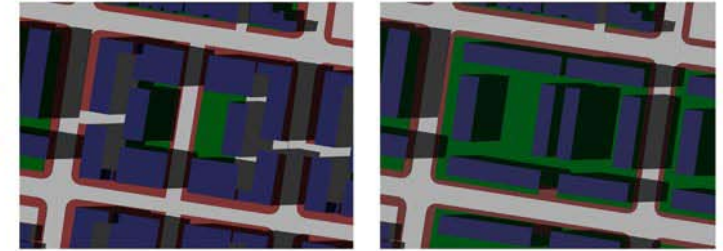
Conventional

EcoHousing

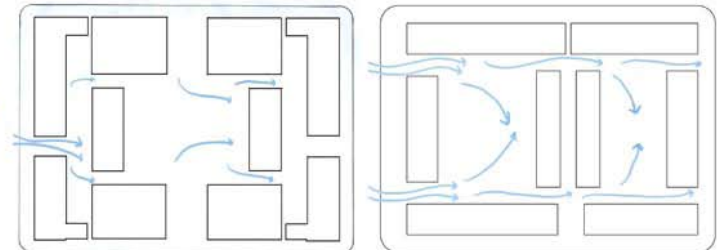
Green Space



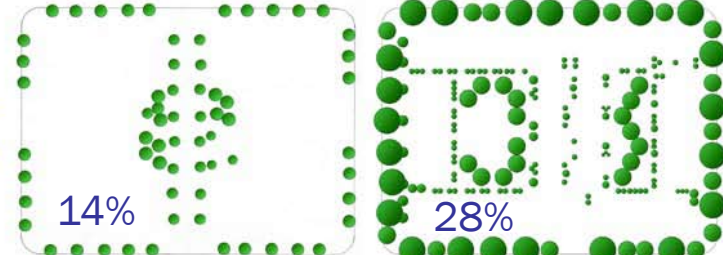
Winter Shading



Southern Wind Flow

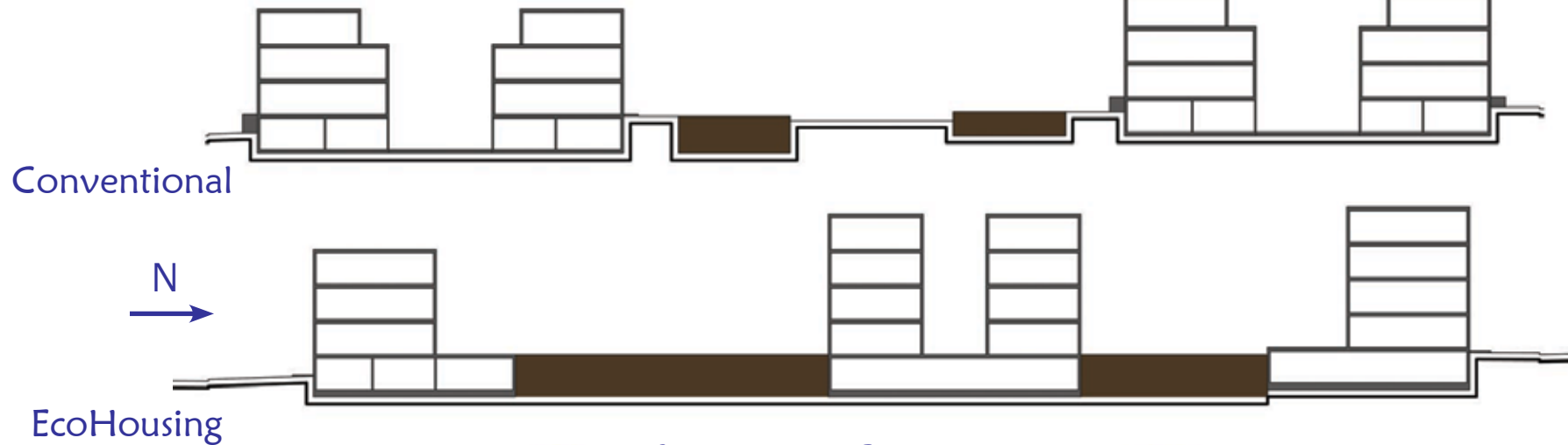


Tree Canopy

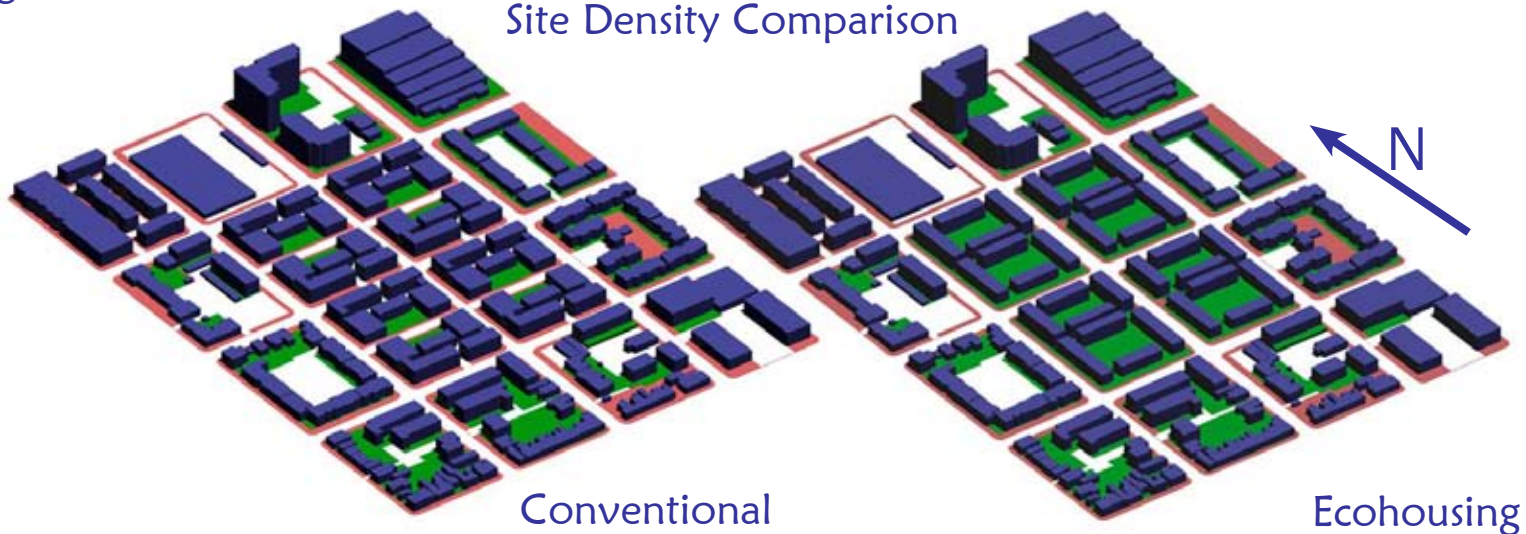


The comparison diagrams described and illustrated in the previous sections are shown to summarize the comparison study between the conventional and ecohousing designs. The ecohousing design reduces the building footprint and achieves equivalent floor space and unit requirements. Ecohousing reduces impervious surface and increases green space through a below surface garage, surface courtyard spaces, and green roofs. Ecohousing provides improved winter solar access and summer wind flow to the block. Tree design methods and increased planting spaces give a larger and more robust tree canopy.

North-South Section Comparison



Site Density Comparison



Water Runoff (one inch rainstorm)

51,000 gallons

17,000 gallons

The section and 3d density comparisons show the reduced footprint of the ecohousing. The below ground parking and earth wells significantly increase the amount of pervious surface. Water runoff for a one inch rainstorm is reduced by two-thirds in the ecohousing design.

## Conclusions

Designing an environmental landscape in an urban area is not hard to do. The ideas and methods presented in this project are not all new ideas either. However, I question why these practices are not used more widely. The landscape can be designed to achieve the same building density and parking requirements, and create great outdoor public and private spaces. The landscape designed for green infrastructure can perform urban ecological services for the people at the site and the larger city. People need sun, shade, air circulation, and access to outdoor space. Cities need management of water quantity, water quality, air quality, and energy use.

To push the green infrastructure design, the details of materials, soils, and vegetation should be further explored. Materials can be used to provide heating, light absorption, light reflection, and water permeability. Materials can be produced from recycled and renewable resources to be more beneficial for the environment. The structure of the existing urban soil should be thoroughly studied and determined how it can be improved and what soil will be used in planting beds and earth wells. Plant selection should be based on soils and sun exposure. The landscape should be planted with native plants and plants suitable for urban dry and container conditions.

The usual impediments to a green infrastructure design are knowledge and cost. As more design implementations are used, and more people educated about the practices, green infrastructure design will become more widespread. To determine the cost benefit, future costs, present costs, costs to the landowner, and costs to the city must be accounted for. Many cost savings will be seen in the future and to the larger city. This may not give the current owner incentive to invest more in the present. Cities must give land owners part of the benefits they receive. With more research that directly links ecological services to costs, at both the small and large scale, the incentives may become more apparent and the benefits shared from city to resident.

Landscape architects, allied design professionals, and landscape researchers must continue to push for green infrastructure methods and implementation. Landscape architects should use the research quantification and benefit data to promote the urban landscape. The landscape serves an important aesthetic role in our communities, but it serves just as important a role for ecological services. It is with many small scale implementations that larger scale benefits will be seen.

Design the urban landscape as the green infrastructure providing ecological services to sustain people in the built environment.

After all...It's not rocket science.

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### Maps

*Plat of land where on stands the town of Alexandria*. Map. 1748

*A Plan of Alexandria, new Belhaven, with List of Promoters*. Map. 1749.

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*Copy of the Original Plot of the Town of Alexandria*. Map. 179?

*Plan of Alexandria (showing end of Alexandria canal)*. Map. 185?

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**All photos and images are by author, except where noted.**

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 Team Lead, Astrodynamical Analysts, 1999 - 2000  
 Project Lead, Astrodynamical Analysts, 1996 - 1999  
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 Second Place, Group Submission, National Low Impact Development Student Competition, 2004  
 Landscape Architecture Service Award, Virginia Tech Washington-Alexandria Architecture Center, 2003, 2004  
 Sigma Alpha Lamda, Landscape Architecture Honor Society, 2003  
 Lockheed Martin Technical Leadership Development Program, 2000 – 2002  
 Customer Appreciation for Successful System Delivery, 1999  
 Lockheed Martin Technical Operations Special Recognition Award, 1999  
 Lockheed Martin Management and Data Systems Presidents Award, 1996, 1997  
 NASA Recognition for support to Hubble Space Telescope service mission, 1993

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