1-1-2011

Sustainable Site System

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Sustainable Site System

by

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A Design Thesis Project

presented to Ryerson University

in partial fulfillment of the

requirements for the degree of

Master of Architecture

In the Program of

Architecture

Toronto, Ontario, Canada, 2011

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Sustainable Site System

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Abstract

This thesis discusses a method of analysing the input of interventions in a building's site design, all of which affect the heat island effect, bio-diversity and hydrology of urban areas. Existing standards from Toronto, Vancouver and Berlin have been researched and analysed. This paper presents an evolution of a method called *biotope area factor* used in Berlin, Germany. A synthesis of the approach of all three systems was considered and distilled into the key points which were then incorporated into the proposed method. In addition to the impact of an individual building, it also includes the impact from the adjacent street area. The final components of this thesis are the application of the method developed to an urban area in the city of Toronto and results showing the impacts on architectural design from site rating systems.

Acknowledgments

Professor Hitesh Doshi has been my thesis supervisor during the development of this thesis. Professor Doshi`s assistance has been critical throughout the entire development of this thesis, his timely comments has been instrumental in raising the standard and enriching the concepts which have been developed. Professor Doshi also provided a perspective to this thesis which was unique and wouldn`t have been provided from any other supervisor.

Lastly, I would like to thank all of those who have provided me with comments through my interim reviews and in casual conversations. While an inconspicuous random conversation may not lead to changing the thesis direction or content, it was instrumental on providing reassurances that the work which has been researched is important and on track.

Jorden Lefler

Dedication

I would like dedicate my thesis to my wife Serah Lefler who`s continuous support and encouragement kept my spirits high throughout this time. Without this strong support and encouragement I don`t think I would have produced as developed and complete thesis within the time I have taken.

Table of Contents

List of Tables

List of Figures

1.0 Introduction

The urban environment has been developed with density as the primary goal and ecology a secondary goal. The urban design in high density areas has also disturbed the pre-existing solar and wind patterns. Any development will disturb the pre-existing natural processes, but development has grown to such an extent that it is permanently altering the natural environment. This has led to a decrease in bio-diversity, and created an artificial water cycle which allows a higher volume of pollutants and higher-temperature water to run into rivers and lakes. A negative effect on our own development is seen through the effects of the Urban Heat Island Effect (UHI) that current city planning and construction styles have. This development requires more energy to maintain the climate within buildings. Resolving the issues of UHI modified hydrology and reduced bio-diversity would greatly aid the natural and built environments.

The development of a system which can address these issues simply and allow for the flexibility of design is required. Existing city guidelines and regulations are not stringent enough from the ecological point of view and are too restrictive in allowing for new and innovative way to respond to the problems at hand.

There are three processes to the research methodology for this thesis. The first is a literature review, the second is synthesis process of the literature into a responsive system, and the third is a theoretical application of the developed system.

Within urban areas there is a decrease in permeable surfaces which allow water to naturally run off and infiltrate the ground. This effect has led to more phosphates, nitrates and suspended solids in streams and lakes; as a result these water areas are now polluted.

Tall buildings also deflect the natural wind patterns which can help cool the city. City planning of roads did not take this into account when they were first designed. This planning has led to reduced natural ventilation of urban areas. As a result more energy is required to cool buildings in the summer and additional heat is created by chilling towers on buildings.

Cities like Toronto, Vancouver and Berlin have incorporated aggressive standards to help mitigate the above mentioned problems. The existing guidelines of these cities will be investigated. Toronto's and Vancouver's standards are prescriptive and restrictive and allow designers little creativity when addressing urban issues. Conversely, Berlin has adopted a standard called Biotope Area Factor which is performance in nature and allows the designer to respond appropriately to each project with a unique solution.

To synthesize the research will be the second step. A system will be created which will take all of the key issues which have been identified by the literature review. This system will be tested for its responsiveness to various climatic conditions. The understanding of the systems impacts and responses to different climates will be summarized. The creation and testing of a system called the Sustainable Site System, which will quantify the negative impacts of a region and produce a rating system which is based on the use of materials and systems. This system will compare the climatic issues from four different regions of Canada, then apply the system to a series of buildings and analyse the impact that the system has on site design.

The final part of the thesis will be to perform a theoretical application of the system created. This application will evaluate the impacts on the architectural form and site. These observations will be summarized and categorized into different areas.

2.0 Literature Review

The literature review portion will research papers and books on three primary topics:

1. UHI - the effect of a temperature bubble above a city which is warmer than the surrounding area, this effect limits the transmission of natural winds and increases the levels of pollution in the city.

2. Bio-Diversity - within the urban and suburban areas. This definition includes both fauna and flora. The principles which are to be reviewed are the rates of growth or decline, as well as the types of wildlife found.

3. Hydrology - is the study of water in its various states and locations in a given region. Emphasis will be given to research which demonstrates how the hydrological cycle has been disturbed.

"With rapid urbanization, there has been a tremendous growth in population and buildings in cities. The high concentration of hard surfaces has triggered many environmental issues; The UHI effect for example, is a phenomenon where air temperatures in densely built cities are higher than those in suburban rural areas." (Chen & Nyuk-Hien, 2010).

2.1 Urban Heat Island Effect

The city's production of heat is of primary concern. This heat is produced by two sources; the first is the solar radiation which is absorbed by surfaces and reradiated again; the second is the heat produced by buildings as a result of using electronics and air conditioning. The resultant is called "Urban Heat Island Effect", additionally it is not only the result of additional heat but also the absence of water for evaporation, and of winds which ventilate the city.

The solar gains by the city are a result of the materials which are exposed to the solar radiation. The Met Office is an organization which tracks the meteorological processes in the United Kingdom has identified that the surface material properties in regards to; reflection from buildings, the absorption of heat during the day on hard surfaces by concrete, tarmac, and brick, and reflection of solar radiation by glass all have a part in the heat gain in the local climate(Smith, 2010).

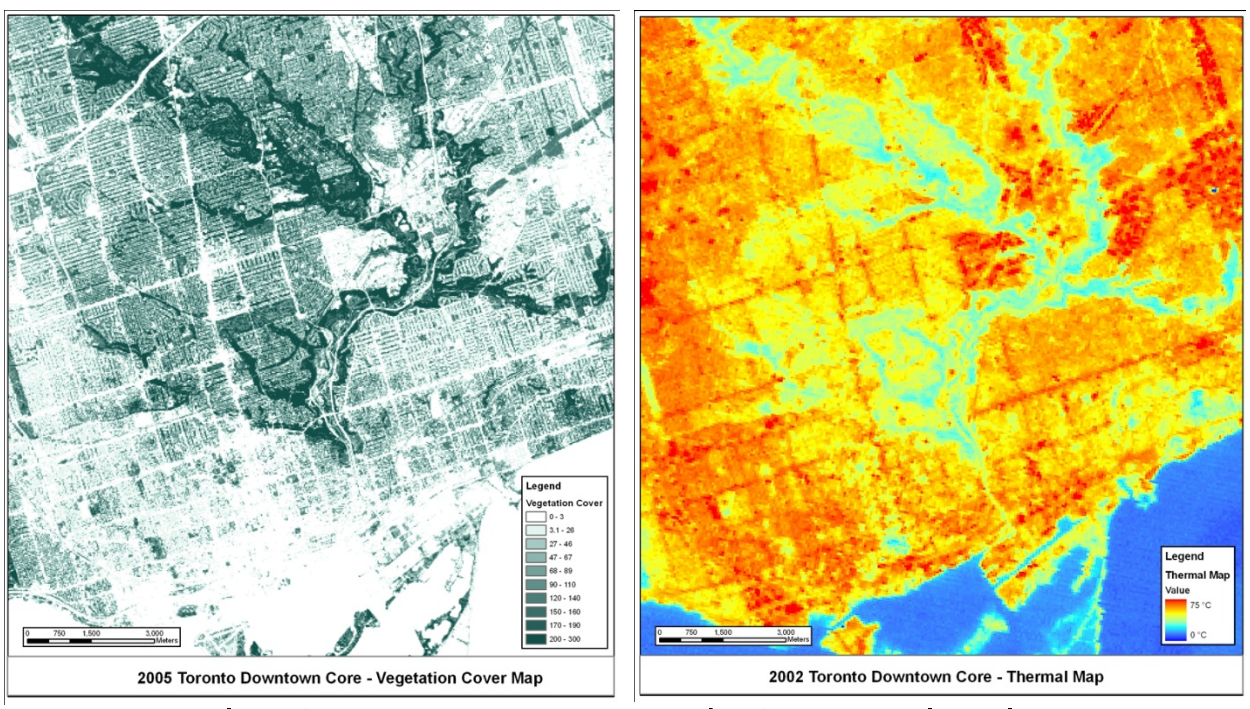


Figure 2-1 - Toronto Downtown Vegetation Coverage & Thermal Map

Source: (Maloley, 2011)

The UHI effect can be seen using the surface temperature of Toronto on June 29, 2007. Maloley (2011) has demonstrated the existing surface temperatures in an urban setting. Through his research he has developed a direct correlation between the vegetated areas and non-vegetated areas. The ground cover vegetated areas show a significantly lower temperature, at times this difference of surface temperature can be up to 50^{o}C (Figure 2-1). He demonstrated the density of vegetation also has an effect on the surface temperature. Maloley has created one of these maps for the downtown Toronto. His mapping is meant to aid cities in applying localized policies to vulnerable areas.

The Met Office has also identifired that the absence of strong winds and the absence of water would also add to the Urban Heat Island Effect (Smith, 2010).

There has been increased attention to how the built environment is amplifying the ambient temperature. In London, England the 'heat island effect' has added up to 6°C to the temperature of the core compared to the countryside (Figure 2-2). (Smith, 2010)

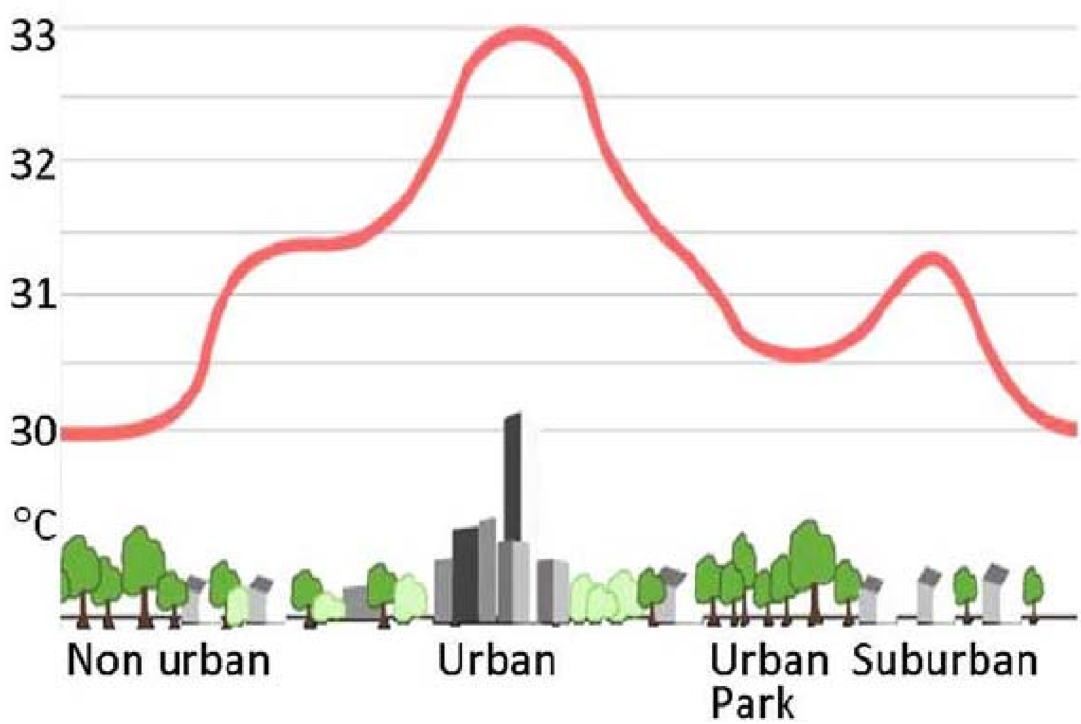


Figure 2-2 - Schematic View of the Urban Heat Island Effect

Source:(Forkes, 2010)

2.2 Hydrological Processes

A major issue which increases the Heat Island effect is the lack or reduction in the ambient air moisture. Hydrological cycle in city's have been altered to such an extent that it is having many negative effects on the ecology. A city produces pollution which causes damage to existing ecological processes. Typically this damage is caused by pollution which is transmitted through water systems (stream and lakes). These pollutants are often a by-product of human excrements, fertilizers or technology (manufacturing or vehicles).

“Urbanization is strongly influencing hydrological processes, often causing a reduction of groundwater recharge and severe flooding. There is an urgent need to approach urban water management in a more sustainable way." (J.Dams. O. Batelaan & J. Nossent, 2009).

The rate of which rainwater escapes the urban areas is a point of concern. This rapid movement of water does not allow it an opportunity to be evaporated in to the air and cool the ambient temperature. As a result flash flooding is more likely to occur downstream of any urban areas.

Dams points out that the issue of flooding had been occurring prior to human development, but the rate of which rainwater is getting to problem areas have been accelerating, thus leading to a higher risk of flooding (Figure 2-3).

Smith points out that “(t)he flash flood problem has been exacerbated by extensive developments requiring large areas of hard surface with runoff consequences. In new developments, like supermarkets"(Smith, 2010),

The issue now becomes how to manage this development in order to improve this problem. Some suggest that the city must make it "mandatory for hard surfaces other than roads to be porous. This should also apply to the paving over of domestic gardens to create parking in areas where on-street parking is becoming more difficult and/or expensive."(Smith, 2010)

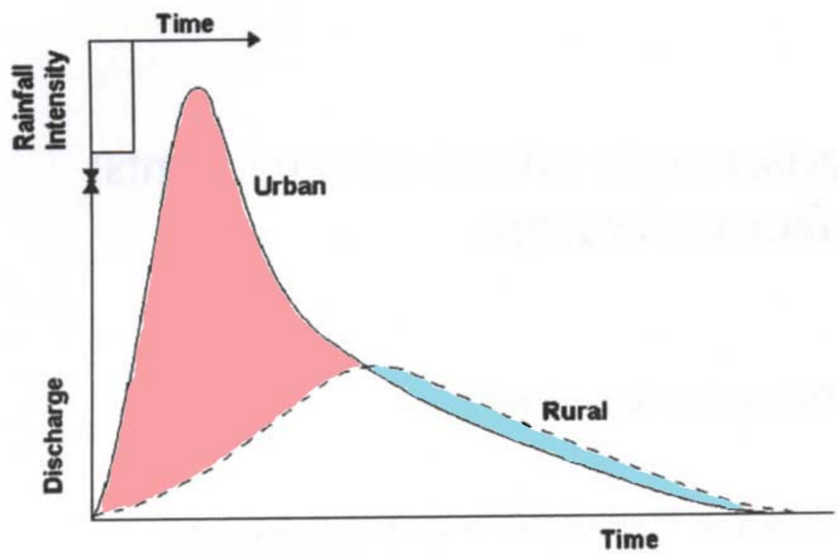


Figure 2-3 - Rainwater Runoff Rates in Urban and Rural Areas

Source: (Feyen, Shannon, & Neville, 2009) colour added by Jorden Lefler

Hydrological processes may remain altered within the city limits but the effect from the city itself needs to be minimized if not eliminated. This means that the rapid drainage of rainwater to streams and rivers needs to be slowed down. The amount of water which reaches the rivers and lakes needs to be reduced and the extra water needs to have an opportunity to be absorbed into the ground, once it is absorbed the water may still make its way to the rivers and lakes but it will take significantly longer. This response would also help in reducing the risks of flash flooding in low lying areas by streams and rivers.

Pollution in the water has also become more prevalent in since urbanization. The water quality of the great lakes basin is represented by the water quality index. This index shows the pollutants found and quantity of marine life. According to Figure 2-4 the water in Lake Superior and Huron is of good quality, while Lake Erie and Ontario are either degraded or highly degraded (Government of Canada, 2010).

“A new paradigm is emerging from the successes and failures of efforts to control pollution that offers the promise of adequate amounts of clean water for all beneficial uses. Urban waterways are the historic core of our cities’ economies and have the potential to be rich sources of biological"(Baker & Breszonik, 2007)

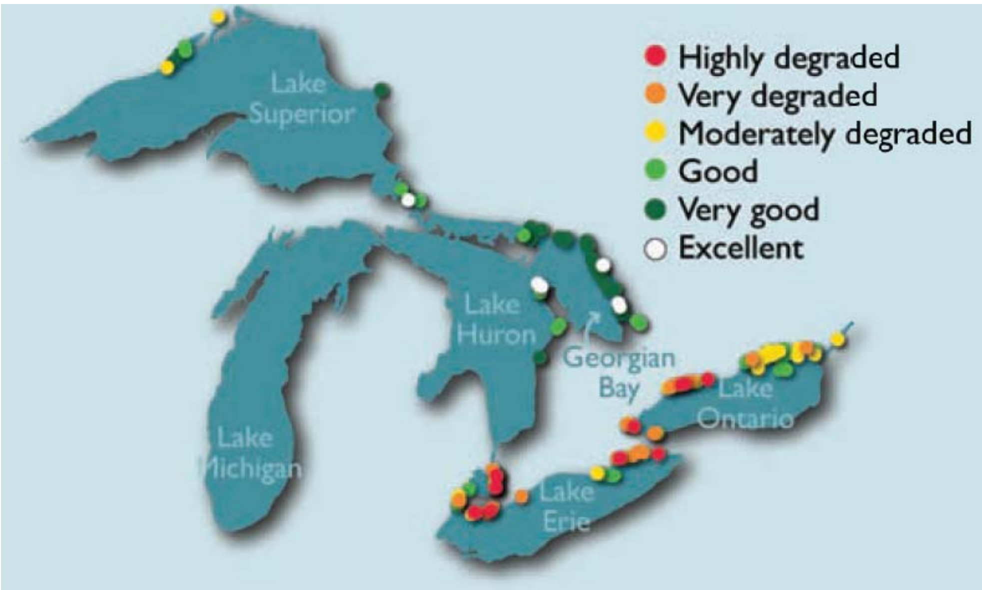


Figure 2-4 - Water Quality Index for the Great Lakes

Source: (Government of Canada, 2010)

Wetlands are an important component of the water cycle, it provides time for water to recharge the groundwater and holds additional rainfall which prevents flooding, and it filters sediments and pollutants and stabilizes shorelines. (Government of Canada, 2010)

The water quality degradation is a result removing the natural water flow patterns which would provide a natural means of filtering the water. The accelerated runoff rate there is little opportunity for the water to be cleansed.

2.3 Bio-Diversity

Bio-diversity is the variation of form of life within a given ecosystem or region. Once a bio-diversity has been lost it becomes difficult and requires a long time to create a new one. The ecosystem is very complex and interdependent on all the components which make it up. There are two issues which arise with bio-diversity, the first is the location and the second is its quality.

The Canadian Biodiversity: Ecosystems status and trends 2010 released by the Canadian Government; Southern Ontario has lost 72% of its wetlands which existed prior to European settlement (Figure 2-5). This loss of wetlands is a result of the demand by humans to use the land for their benefit. These lands have been converted to cities, transportation infrastructure or agriculture. Wetlands are one of the most productive ecosystems in the world; it supports a disproportionally high number of species. "Wetlands near large urban centres are particularly at risk and have suffered severe losses. It has been estimated that less than 0.2% of Canada's wetlands fall within 40 km of urban centres, and that 80 to 98% of wetlands in or adjacent to major urban centres have been lost." (Government of Canada, 2010)

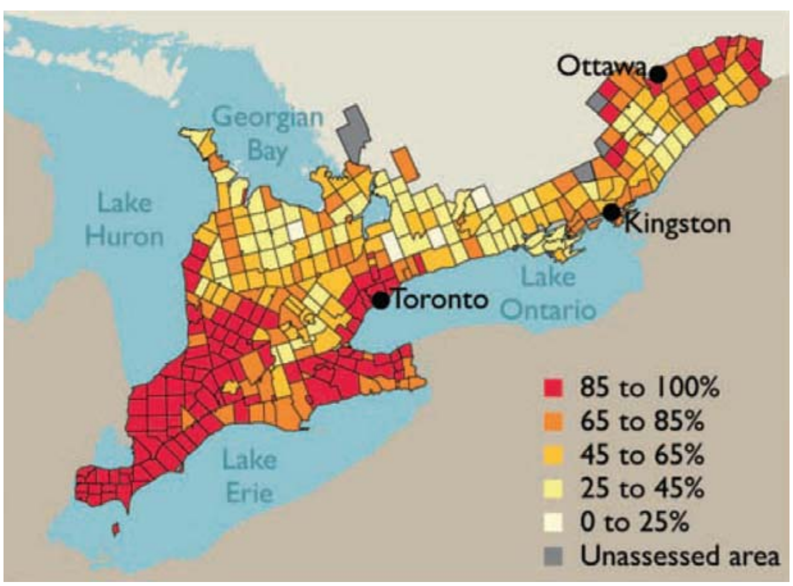


Figure 2-5 - Wetland Loss in Southern Ontario from 1800 to 2002

Source: (Government of Canada, 2010)

The loss of natural habitates, such as wetlands, is a result of the growth and expansion of the cities humans live in. It is important that consideration of these losses be incorperated into the future design of developed ares.

Pollution in the ecosystem is a problem which needs to be addressed at the source. Ecosystems can filter some pollutants it is not able to handle the high quantities which are currently entering them. Baker states that “...attempts to control pollution originating from diffuse, non-point sources were added to the growing complex of structural water management infrastructure. …also called the “end-of-pipe control."(Baker & Breszonik, 2007)

There is an opportunity to use an ecological method of treating wastewater. This idea solves two issues which all inhabited area has: the loss of ecosystems and the processing of human waste. Beneke introduces three methods of arranging the infiltration sites for different scales of development. The first scenario looks at a local site for filtering the wastewater. This approach would be able to handle approximately 70 inhabitants (Figure 2-6 Figure 2-7). This process introduces either many small sites or a single connected site for filtering the water. This intern introduces ecosystems which would do the work of filtering the wastewater. (Beneke, 2009)

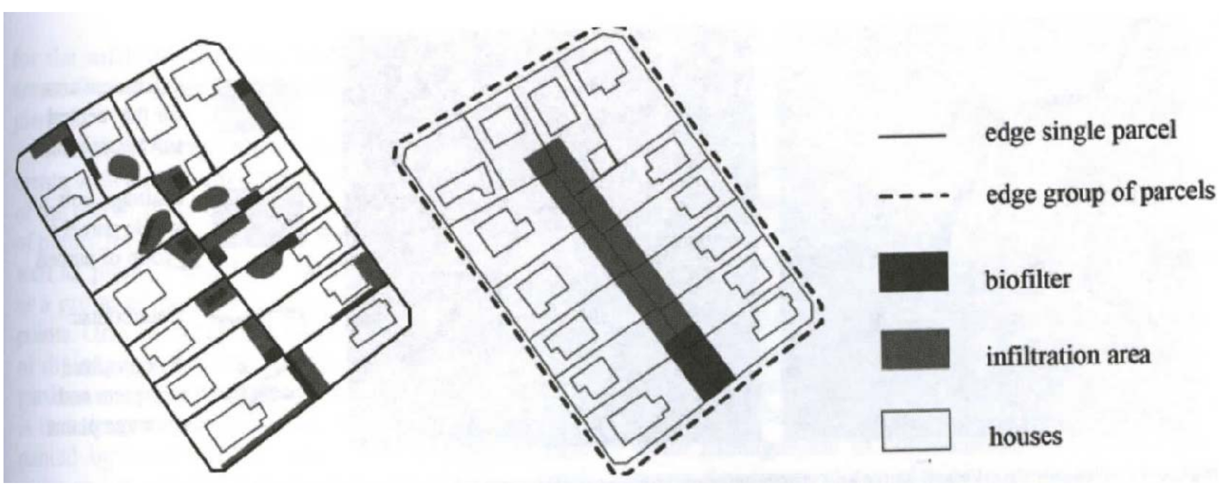


Figure 2-6 - Decentralized and Grouped Water Management Strategies

Source: (Beneke, 2009)

The second scenario is to introduce a larger single site to manage a large area (Figure 2-7). This system would be much larger and more complex then the independent systems in the first scenario. This can result in a healthier ecosystem of more wildlife inhabitants. This system could handle approximately 6800 inhabitants.

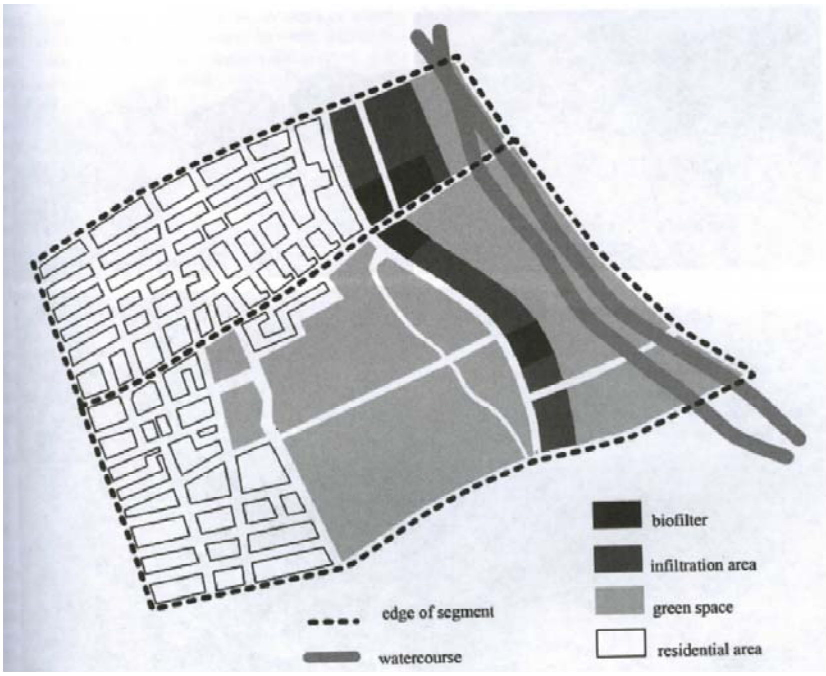


Figure 2-7 - Decentralized based on Urban Landscape Segments

Source: (Beneke, 2009)

While developing ecological strategies within a city there are environmental boundaries which are created as a result of the urban design. According to (Ng, Edward; Sterling, VA, 2010) the modern city planning uses a hierarchical system to planning. The designers use three levels of streets which are primary distributors, secondary distributors and local distributors. These districts which are bound by primary roads then divided the area into several environmental zones (Figure 2-8).

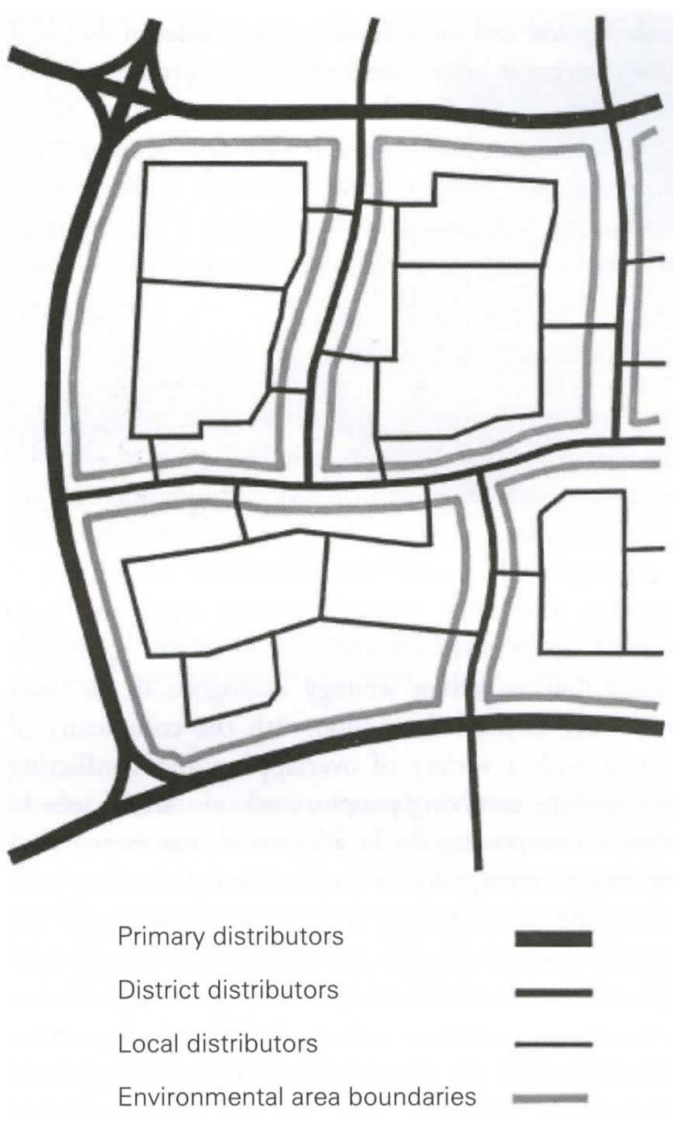


Figure 2-8 - The Hierachey or Streets

Source: (Ng, Edward; Sterling, VA, 2010)

2.4 Urban Ventilation

Natural winds provide many positive benefits to urban areas, such as, reducing the ambient air temperature, introduction of clean air, it allows for migration of seedlings and provides an opportunity for natural ventilation in buildings.

“In many high-density cities in subtropical and tropical regions, such as Singapore, Hong Kong, Tokyo, and so on, the hot summer can cause thermal stress, which is unhealthy to inhabitants. Buildings add to the problem as they increase the thermal capacity and, thus, add to the UHI intensity, reduce trans-evaporation, and increase roughness, slowing down incoming wind.”(Ng, Designing for Urban Ventilation, 2010)

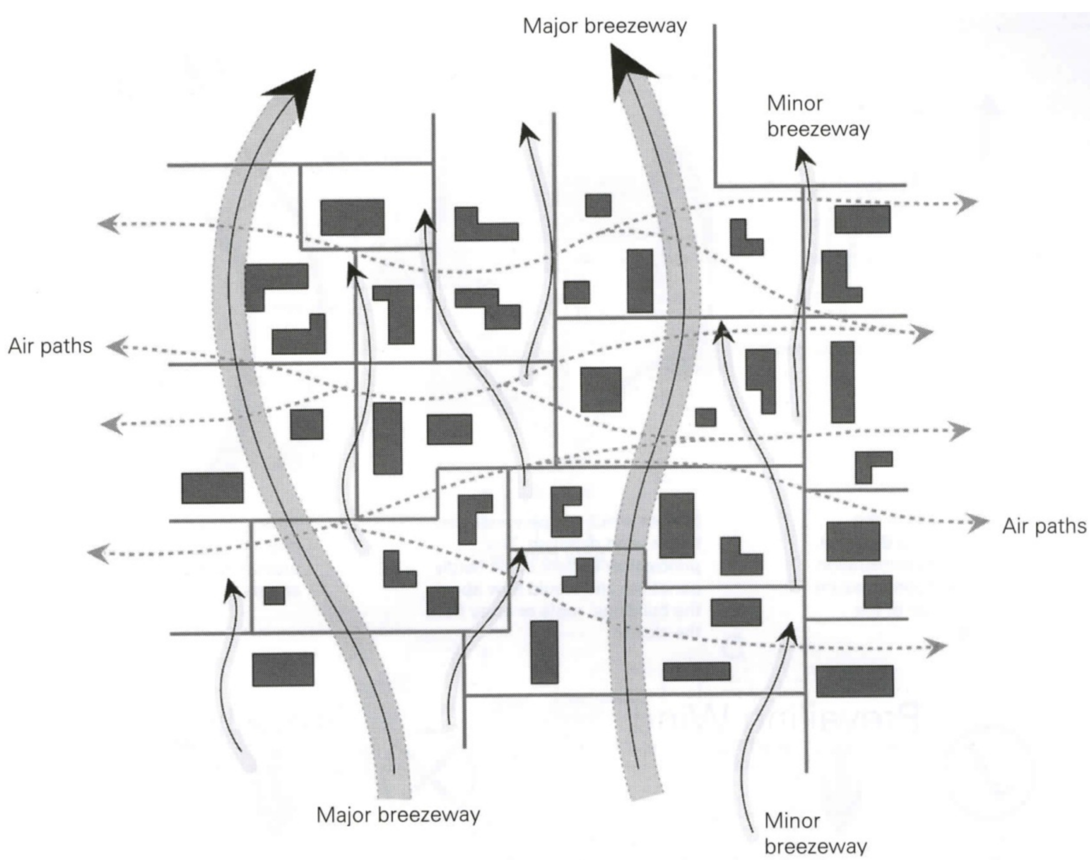


Figure 2-9 - Breezeways and air paths when planning a city are better for city air ventilation

Source: (Ng, Designing for Urban Ventilation, 2010)

While some of the issues impacting the natural breezeways may be from the buildings themselves, it is the responsibility of the city to restrict density and heights of certain buildings accordingly. The breezeways are an important component of restoring the natural temperature and seedlings migration paths.

According to Gissen, early passive environments in tall buildings were utilized due to a lack of means and technology to do so. “In the late nineteenth century – before electrical heating, cooling, and illumination – architects used a combination of devices and “passive” techniques [which worked without electricity or mechanical equipment] to illuminate and ventilate the interior spaces of high-rise and long-span buildings.”(Gissen, 2003)

This considers city planning and suggests using the wind to naturally cool and clean the cities air. It also looks at the micro effects of wind within various configurations of building heights and orientations.

This paper proposes design guidelines:

- Breezeway / air path
- Orientation of streets
- Linkage of open spaces
- Non-building area
- Waterfront sites
- Scale of podium
- Building heights
- Building Disposition

The density of the urban environment should consider the relationships between social and environmental sustainability. The “Building density has an intricate relationship with urban morphology; it plays an important role in the shaping of urban form. For instance, different combinations of plot ratio and site coverage will manifest into a variety of different built forms.”(Ng, Edward; Sterling, VA, 2010)

2.5 Summary

Cities are introducing policies which address: UHI, Hydrology, Bio-Diversity and Urban Ventilation. The cities are attempting to compensate and correct these issues which arise from high density development. Each of these issues are not independent from each other, there is some cross-over of principles and problems.

3.0 Site Practices Case Studies

This thesis reviewed the existing site practices of Toronto and Vancouver, Canada and Berlin, Germany. These three cities have been chosen because they have different approaches and methods to controlling site designs, as well as they are all within 9 degrees latitude. The local climates are a little different which provides an opportunity to investigate the validity of each cities practices to each other.

Toronto has developed a regulatory system call Toronto Green Development Standards. This system has three classification and the requirements between them are very similar.

Vancouver has developed Water Wise which is a guideline system. They do not require any site planning by law and instead offer suggestions to the designers on the programming of the site.

Berlin has developed a system called Biotope Area Factor. This system is law and every project constructed must meet is requirements. This system is points based and leave the method of achieving the required points up to the designer.

3.1 Biotope Area Factor - Berlin, Germany

The City of Berlin has a long history of implementing green construction policies. One of the first policies was their green roof legislation which was implemented in the 1970's. The green roof legislation was only limited to the roof of a building and did not affect the rest of the site. The Biotope Area Factor policy also began in the 1970's. The Biotope Area Factor policy was developed for the design of the un-built areas of a site. It was also concerned with the hydrology of the site and the rainwater runoff. The current Biotope Area Factor legislation is an amalgamation of the green roof policy and Biotope Area Factor. This new policy provides a simpler way of achieving a site rating without restricting the designers with individual elements, rather the policy provides different methods and allows the designer to choose what to include.

3.1.1 Biotope Area Factor

The Biotope Area Factor (BAF) is derived from a mathematical equation using various coefficients for different site materials. Each surface area is assigned a score, when all of the scores are averaged a rating for the site is provided. The ratings that may be achieved were developed based on the properties of the various surfaces (Table 1).

A sealed surface receives a score of 0.0 because it doesn't allow for any water to penetrate and infiltrate into the soil below, this in turn does not provide an opportunity for water to evaporate and cool the ambient air temperature. This type of material does not mitigate the effects of the heat island. At the opposite end of the spectrum a vegetation area connected to soil below receives a credit of 1.0. This is the highest score which can be achieved. This is the best scenario for water infiltration, ambient air temperature and ecology.

Other types of surfaces are then broken down to how efficient they are for water infiltration, air infiltration, ambient air temperature, and ecology. A site would take the different surface types as an area and multiply them by the appropriate credit score and add them together. To provide an average score for the site the total sum would then be divided by the total area of the site.

The credits which are given for each material have no scientific definition; it was derived based on a comparison relative to other materials. The systems design demonstrates a clear hierarchy of materials based on these qualities for; hydrology, bio-diversity and heat gain.

Table 1 - Biotope Area Factor By-Law Credits

Type	Credit score
Sealed surface	0.0
Partially sealed surface	0.3
Semi-open area	0.5
Vegetation surface without connection to soil below (soil under 80 cm)	0.5
Vegetation surface without connection to soil below (soil over about 80 cm)	0.7
Vegetation area connected to soil below	1.0
Rainwater infiltration per sm or roof area	0.2
Vertical green of windowless walls and walls up to 10m in height	0.5
Green roof	0.7

Source: (German Senate Department for Urban Development, Biotope Area Factor By-Law, 1994)

3.1.2 Site Rating

Site rating is calculated based on the cumulative score achieved for the entire property divided by the total area of the property. This provides an average score for the entire property (Equation 1).

Equation 1 - Biotope Area Factor Site Calculation

$$BAF = \frac{(\ldots\ m^2 \text{ type a} \bullet \text{credit factor a}) + (\ldots\ m^2 \text{ type b} \bullet \text{credit factor b}) + \ldots}{\ldots \text{ total } m^2 \text{ land}}$$

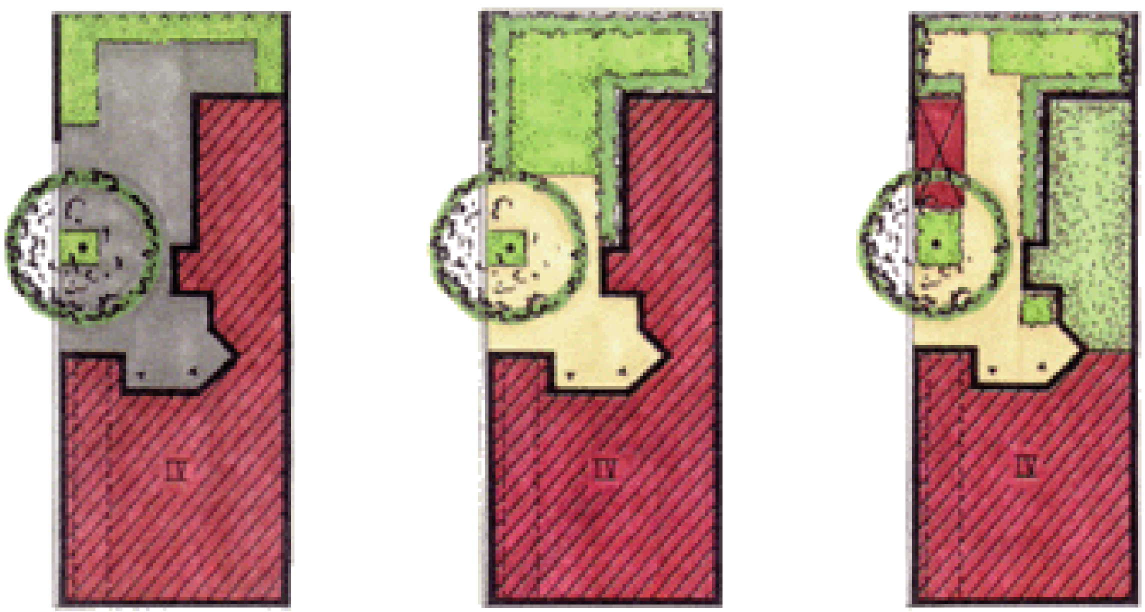
Source: (German Senate Department for Urban Development, BAF - Biotope Area Factor, 2010)

This system requires that each property achieve a certain rating. The manner of how to achieve the rating is at the discretion of the designer. Allowing for the most flexibility in design and therefore each design may be unique and appropriate for the site.

3.1.3 Site Examples

This is an example of a small property BAF calculation:

Each plot of land can be designed in various ways. In principle, measures that lead to an expansion of the area of vegetation on the ground are given priority. Only then should additional possibilities, such as the replacement of asphalt and concrete with other surfaces, be utilized. The following example uses a site area of 479m^2 and a development ratio of 0.59.



Existing Site	Option 1	Option 2
BAF = 0.06	**BAF = 0.3**	**BAF = 0.3**
Sealed Surface= 140 m^2 Semi-Open Surface = 59 m^2 Vegetation Connected = 1 m^2	Vegetation = 15m^2 Semi- Sealed Surface = 25.5m^2	Concrete surface = 21m^2 Vegetation Connected = 79m^2 Semi- Sealed Surface = 100m^2 Green walls = 10m^2 Green roofs = 41m^2

Figure 3-1 - Examples of Biotope Area Factor Ratings

Source: (German Senate Department for Urban Development, BAF - Biotope Area Factor, 2010)

This demonstrates how it is possible to achieve the same rating on the same site in multiple ways. This system encourages uniqueness in the design; as a result it is able to respond to different design constraints.

3.1.4 Zoning Standards Study

The previous study demonstrates that there are different ways to achieve the same beneficial site design that the city is attempting to achieve. This system leads to unique designs which can be appropriately responsive to various sites. The integration of multiple green site design standards together into a single standard simplifies the intent of the legislation, which is to mitigate the heat island effect, increase bio-diversity within the city, and restore ground water and evaporation.

The BAF has been applied to various parts of Berlin. The figure below is an example of an existing area and the proposed BAF zoning. Demonstrating how the BAF will have a positive effect on the communities' hydrological and environmental atmosphere. Within the zoning there are special exceptions made for the schools. The BAF also does not include the street design in its calculation (Figure 3-2).

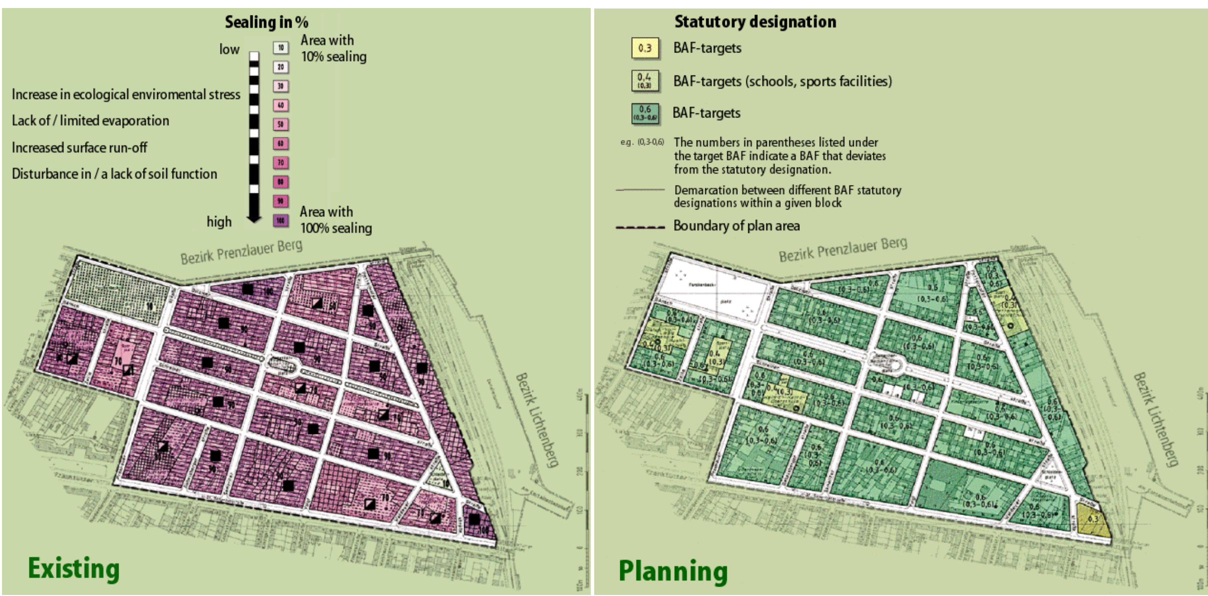


Figure 3-2 - Zoning study of BAF targets

Source: (German Senate Department for Urban Development, BAF - Biotope Area Factor, 2010)

Currently the city of Berlin has set BAF targets for different occupancies in lieu of creating a zoning map for the entire city. This approach is similar to the green roof standards which have been set in the past. The highest standards are for Residential, Public Facilities, and Nursery Schools and Day Care Centres. The lower standards are for Commercial, Office, Schools, and Technical Infrastructure. This form of regulation makes it simple for the city to oversee the future developments in the city with minimal regional planning.

Table 2 - Biotope Area Factor Targets

BAF Targets for		
Alterations / Extensions of construction sites **Creation of additional residential space or increase in the degree of coverage (DC)**		**New structures**
DC	BAF	
Residential units **(Residential use only and mixed use with no commercial use of open space)**		
up to 0.37 **0.38 to 0.49** **over 0.50**	0.60 0.45 0.30	0.60
Commercial use **(Commercial use only and mixed use with commercial use of open space)**		
	0.30	0.30
Typical use in key areas **(Commercial enterprises and central business facilities Administrative and general use)**		
	0.30	0.30
Public facilities **(for cultural or social purposes)**		
up to 0.37 **0.38 to 0.49** **over 0.50**	0.60 0.45 0.30	0.60
Schools **(General-education schools, Vocational centres, Education Complexes, Outdoor Sports facilities)**		
	0.30	0.30
Nursery Schools and Day Care Centres		
up to 0.37 **0.38 to 0.49** **over 0.50**	0.60 0.45 0.30	0.60
Technical Infrastructure		
	0.30	0.30

Source: (German Senate Department for Urban Development, BAF - Biotope Area Factor, 2010)

3.1.5 Summary

The Biotope Area Factor standard which Berlin has developed is very simple in its ideas and execution. They allow the most amount of freedom for the designer to resolve the uniqueness of each project in an appropriate manor. The interesting thing about the BAF is that it's only control over the design happens with the material properties and objective ratios that a type of project must achieve.

This system does not account for the solar properties of a site. For example, an area of asphalt in the sun and shade receives the same points while asphalt in the shade doesn`t add to the heat effect on the environment as much as asphalt in direct sunlight. Another example: areas of vegetation which are in the sun and shade receive the same points but vegetation in the shade would not have the same effect on the environment as vegetation in the sun. The BAF does not encourage one type of vegetation over another. The planting of trees would provide a better benefit then planting shrubs or grass. Trees can hold more water on their leaves from the first 15 minutes of a rain event then grass or shrubs, this benefit should be accounted for in this system.

3.2 Toronto Green Development Standards - Toronto, Canada

In July of 2006, Toronto commissioned a report titled "*Making a Sustainable City Happen: The Toronto Green Development Standard*". This report suggested many standards both voluntary and mandatory for all new developments. If a project completed all of the voluntary requirements, it would receive a 20% rebate off their development charge.

"*Making a Sustainable City Happen: The Toronto Green Development Standard*, proposes the adoption of enhanced targets for site and building design that address matters of sustainability. It proposes an integrated set of targets, principles, and practices to guide the development of City-owned facilities and to encourage green development amongst the private sector." (City of Toronto, Making a Sustainable City Happen The Toronto Green Development Standard 2006, 2006)

Points Included:

This report effectively argued why we needed a green standard in the city. Environmental Pressures, Air Quality and Climate Change, Energy Use, Water Quality and Efficiency, Solid Waste, Urban Forest Health, Quality of Wildlife Habitat, Light Pollution, Economic and Social Health. There is an additional concern Toronto projected population growth to 3 million residents by 2031.

Making a Sustainable City Happen: The Toronto Green Development Standard has led to the development of "The Toronto Green Development Standard" which was implemented on January 29th of 2010. This Standard has taken into account all of the recommendations of the report 3 years earlier and incorporated additional green standards like the Toronto Green Roof By-law.

The development standard covers:

- Air Quality
- Greenhouse Gas Emissions / Energy Efficiency
- Water Quality, Quantity and Efficiency
- Ecology
- Solid Waste
- Below are summaries of the five sections and how they relate to the topic of sustainable site designs.

3.2.1 Air Quality

Within the Air Quality section of the development standard there are five topics: Automobile Infrastructure, Cycling Infrastructure, Pedestrian Infrastructure, and Urban Heat Island Reduction: At Grade, and, Urban Heat Island Reduction: Roof. The urban heat island reduction at grade and roof does pertain to the research (Table 24 - Toronto Green Roof By-law requirements

Gross Floor Area (Size of Building)	Coverage of Available Roof Space (Size of Green Roof)
2,000 - 4,999 m^2	20%
5,000-9,999 m^2	30%
10,000-14,999 m^2	40%
15,000-19,999 m^2	50%
20,000 m^2 or greater	60%

Source:

Table 25).

The Air Quality section of the Toronto's Green Development Standard sets out to decrease the ambient air temperature in a couple of ways. The first is to increase the potential for water to evaporate while simultaneously using the heat energy. The second is to prevent the sun from reaching materials which are prone to absorbing the solar energy and radiating it, thus reducing conditions which warm the environment. These methods seek to mitigate the UHI effects.

They propose to address the UHI problem by two methods. Firstly, they propose to alter the types of materials which are used for hardscape on a site. The preferred materials would be high-albedo, open grid pavement, and green walls. Secondly, environmentally to shade areas which are hardscaped from 50 to 75% depending on the materials used.

The preferred method of shading would be trees at least 5 years old, also manmade structures or appropriate site planning is also an acceptable means of shading.

Table 24 - Toronto Green Roof By-law requirements sets a specific percentage of a roof area which requires being green. This legislation was adopted prior to the Toronto Green Development Standard. The biggest problem with this by-law is that if a roof is sloped enough then there is no requirements for a green roof, thus if the site allows for such a design it is easy to avoid adding a green roof. This would result in more surface area which is exposed to heat gain and makes local climate unnecessarily warmer.

3.2.2 Water Quality, Quantity and Efficiency

Within the Water Quality, Quantity and Efficiency section of the development standard there are four topics and there are two principles to this research. The first principle pertains to do with rainwater. The goal of this principle is to minimize the amount of water which leaves a site and ends up in the storm drain and storm sewer systems. The other goal is to increase the amount of water which is infiltrated into the ground which in turn minimizes pollutants which end up in streams and lakes. The second principle has to do with minimizing potable water usage in the upkeep of landscaping. This is intended to reduce the demand for potable water and increase the use of rainwater for landscaping (Table 26).

3.2.3 Ecology

Within the Ecology section there are three topics: Urban Forest: Tree Protection, Urban Forest: Encourage Tree Growth, Natural Heritage: Site, Soil Quality and Planting Conditions (Table 27).

Under the Ecology section there are three main principles. The first principle prioritizes the protection and growth of trees. The Development Standards outlines the protection of existing trees within certain areas of the city or if the tree has achieved a certain girth to the trunk. This section also outlines the amount of trees which must be planted on a property. The second principle, aims to protect native plants from invasive non-native plants. This protection is a positive point for the existing ecosystem of the city. There is special emphasis on areas near ravines and other naturalized locations. The third principle defines planting medium; the concern being to have a healthy and nutritious soil for plants to maximize their growth potential.

3.2.4 Summary

The Toronto Green Development Standard covers many areas of environmental concern. All of the points which were covered do have some concern when there is additional growth to the city. The additional stress of new development and demand for resources like water and energy have been foreseen and accounted for by this policy. There is however some important policies which can be achieved through additional design consideration and minimal construction costs.

The Toronto Green Development Standard is very restrictive in resolving design problems. The development standards require certain items and it is not lenient to alternative designs. While the Development Standard does provide alternative options for certain requirements, it still demands certain design criteria which cannot be decided by the designer. In some instances if the designer doesn't allow for certain items such as a flat roof, then there is no requirement to ad a green roof. Another example is the amount of connected vegetation, if a designer expands the basement beyond the ground floor perimeter this would reduce the requirements for trees on a site. These workarounds are legal and may at times cost less then what would have been required by the standard, thus clients would prefer these options at the detriment to the local ecology. This standard has three different variations for different types of projects which can lead to complications that can be avoided if the system were to be simplified.

3.3 Water Wise - Vancouver, Canada

Vancouver introduced "Water Wise Landscape Guidelines" in July 2009. The water wise landscape guideline is the only enforceable by-law which addresses site designs with regards to layout, plant selection and materials. The primary subject users for this guideline are people who are undertaking development and have a landscape component. The goals of this legislation are to control the design of landscapes in order to "preserve water quality and availability; create healthy ecological environments; increase quantity of plant life or "biomass"; reduce the Urban Heat Island Effect; reduce greenhouse gas emissions, and mechanical and energy inputs related to maintenance; reduce maintenance efforts; reduce strain on local infrastructure; reduce environmental impacts by recycling and reusing materials and resources; and reduce costs."(City of Vancouver, 2009)

Water wise is intended to be an integrated design approach which can have a positive effect on the design of the project. Water wise is also intended to make landscapes take advantage of the given attributes of a site (Figure 3-3).

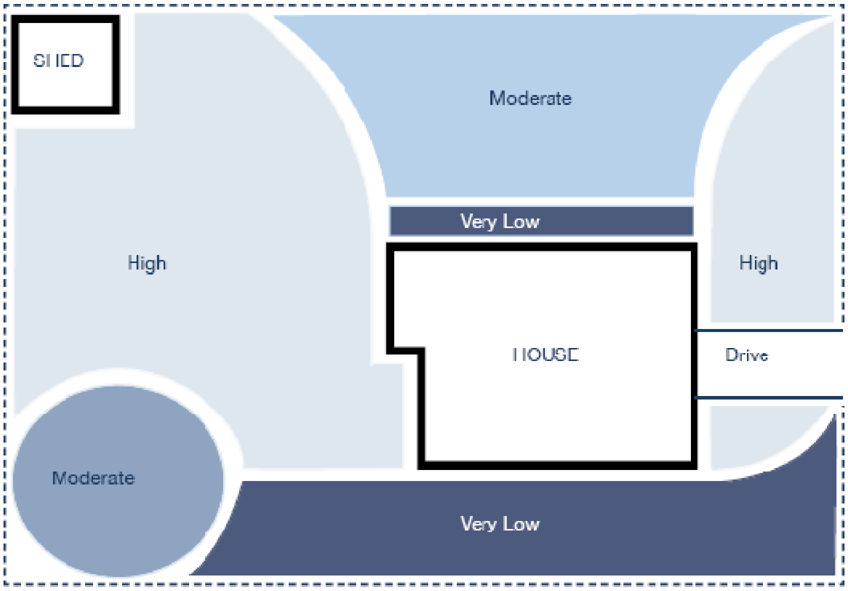


Figure 3-3 - Site planting considerations

Source: (City of Vancouver, 2009)

3.3.1 Water Wise Strategies

There are 8 strategies which are mandated by this legislation:

- Site planning,
- Materials,
- Techniques,
- Design Considerations,
- Plants,
- Shrubs, Vines, Ornamental grasses and Perennials,
- Lawns,
- Lawns Alternatives

These 8 categories each represent an aspect of concern for the City of Vancouver. These categories provide suggestions to maximize the health and sustainability of the site design, it also mandates a required maintenance regiment which must be followed for some plant types.

Water Wise strategies are designed to assist in making smart and positive site design and vegetation choices. Water Wise suggests a stratification approach to planting (Figure 3-4). This stratification provides multiple layers of surfaces which can allow for the initial rainfall to stay and not be drained off the site or immediately absorbed into the ground.

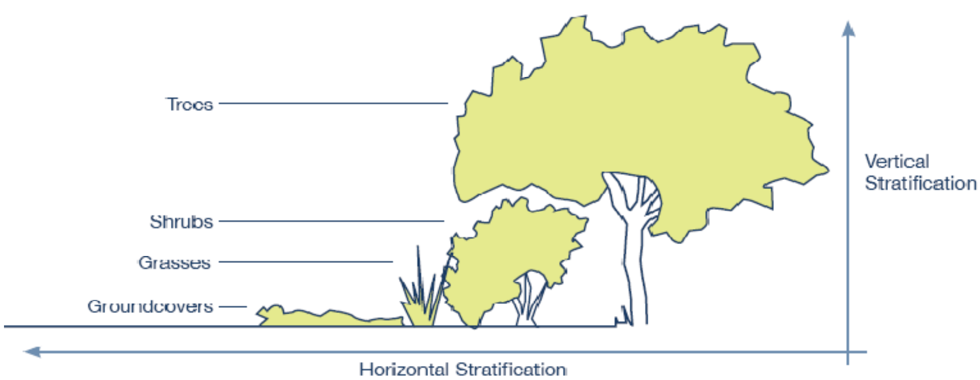


Figure 3-4 - Plant stratification

Source: (City of Vancouver, 2009)

Water Wise encourages multiple planting choices on a single site; this is meant to increase the bio-diversity in the city. Water Wise suggests not using just a lawn but using local native plants which are more hardy and able to handle the local weather better.

Water Wise suggests the use of green facades and living walls which are a great opportunity to add to the bio-diversity. Rain gardens also provide local locations for the immediate rain water to flow to during a rain event. Rain gardens also provide opportunities for the water to infiltrate the ground. Rain gardens can be planned adjacent to large areas of non-permeable surfaces (Figure 3-5).

Source: (City of Vancouver, 2009)

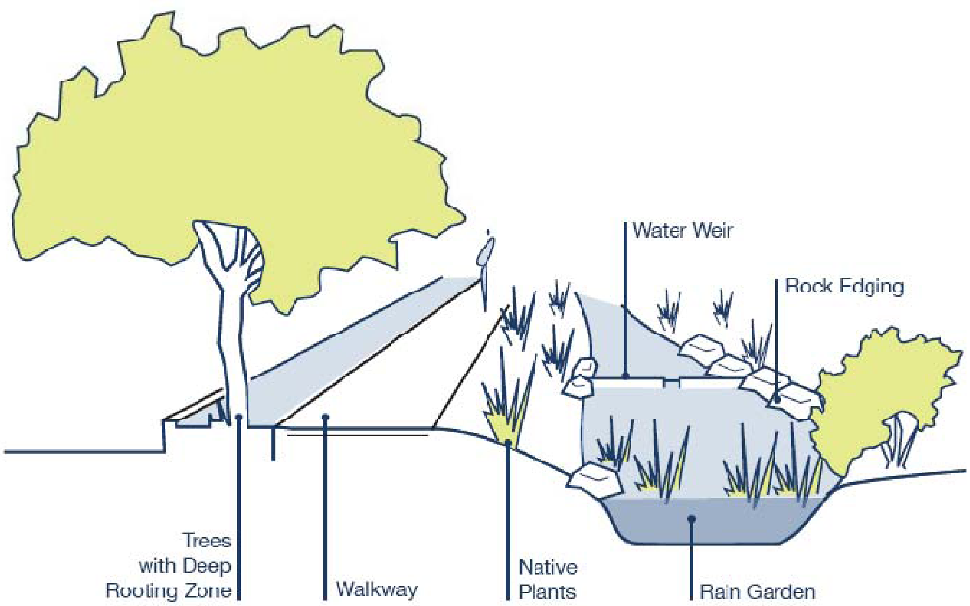


Figure 3-5 - Rain Garden design guidelines

The city of Vancouver has other initiatives which attempt to increase the density of the city by utilizing laneways. These initiatives are positive growth options because they don't require additional infrastructure like roads which can have a detrimental effect. Ecodensity proposes new houses to be built in a location of existing garages, this leads to a minimal impact of permeable ground surfaces. Many new houses are designed conscious of the ecological processes and in some instances improve the local ecology.

3.3.2 Summary

The city of Vancouver has a very complete set of guideline which must be followed; however guidelines are not very stringent for the designer. Water wise system does allow for flexibility within the design. This system places the responsibility of any vegetation on the owner's radar and makes them maintain what they plant. This is a positive consideration because whatever plants are planted will be given a healthy start.

There are few required goals; instead the system has responsive objectives that must be met after the design has been completed. This provides the designer many opportunities to circumvent the standard. As a result the ecological benefits which could be achieved are reduced.

3.4 Summary of Site Practices Case Studies

The three systems in this case study have different approaches to the creation of policies. The three areas which are compared below are: design flexibility, amount of requirements, consideration of materials (inert and biological), and simplicity.

Materials:

Biotope Area Factor, **Berlin;**

Good - the choice of materials are completely up to the designer, the designer must meet the minimum rating for the site. This rating may be difficult to achieve in some instances and would require additional cost to achieve.

Toronto Green Development Standard, **Toronto;**

Good - there are few material restrictions in this system. There is some consideration for finishes on materials for the protection of animals. Additional requirements require the use of certain types of vegetation, but the specific species and location is flexible.

Water Wise, **Vancouver;**

Great - There are few requirements for materials which designers must consider. Water Wise is a tool for designers to use to understand the impacts and benefits of using certain materials.

Amount of requirements:

Biotope Area Factor, **Berlin;**

Fair - there are few requirements, this is both positive and negative. It is simple to understand and follow, but this does not set enough specific goals which could be used to help the environment.

Toronto Green Development Standard, **Toronto;**

Fair - there are too many requirements, this system could not be completely remembered and each project would have to begin with a new checklist to ensure that you have covered all of the required points.

Water Wise, **Vancouver;**

Great - the guideline is length and has a lot of useful information. This system educates the designers throughout the process. There are very few requirement in terms of design, but there are a lot of responsive requirements once things have been designed.

<u>Design Flexibility:</u>

Biotope Area Factor, **Berlin;**

Great - the choice of material, layout, and choice of features allow for the greatest amount of flexibility for the designer.

Toronto Green Development Standard, **Toronto;**

Poor - all of the requirements have few choices if any at all. In some instances there may be requirements which may be a detriment to the overall design.

Water Wise, **Vancouver;**

Good - There are few requirements for designers to consider. Once there has been a design completed there are many requirements for maintenance programs and other things which must be done.

<u>Simplicity of System:</u>

Biotope Area Factor, **Berlin;**

Great - the BAF can be explained with 2 pages. The principle to apply the scoring method is easy to understand and doesn't require additional instruction

Toronto Green Development Standard, **Toronto;**

Fair - this system is extensive and has hundreds of points which must be followed. While each requirement is simple to understand and apply, the quantity of requirements is daunting and time consuming.

Water Wise, **Vancouver;**

Fair - this system is easy to follow and understand, but the length and depth of information is overwhelming. This system is a guideline and as such it should be used as a reference guide.

Berlin's system is the best in terms of flexibility in the design. Toronto's system is the best in terms of requirements to help maintain and heal the ecological systems. Vancouver's guideline is not a policy with requirements in site design; it is a guideline and information tool for designers to use.

The best components and approaches will be incorporated into the Sustainable Site Systems, while minimizing the negative aspects of these systems.

4.0 Development of the Sustainable Site System

There are two different design considerations to follow: the first is the creation of a rating system which responds to various local climates. The second is the application of the developed rating system on a given area and what ratings are achieved through various contemporary design styles. For the purpose of the development of the Sustainable Site System weighting of numeric values and distribution of materials and properties is developed as a tool to investigate the architectural design possibilities. The values which are produced are approximate and should be studied in comparison to other values which have been developed within this paper.

4.1 Sustainable Site System

The Sustainable Site System will be similar in nature to the Berlin's BAF system. The proposed system will be used by both professionals and laymen people. The system will use local climate data to modify the ratings and requirements for different regions. As a result the development of a Sustainable Site System must:

- be simple to understand
- be simple to execute
- cover all types of projects
- applicable to various regions
- not be restrictive to the designers
- allow ingenuity in design
- mitigate the effects of the Heat Island Effect
- encourage Bio-Diversity in plants and animal life
- allow water to resume it`s natural cycle with minimal disturbance by development
- provide a benefit to developers with incentives to achieve better standards then the minimum
- provide a healthier environment for everyone

This system will derive its scores based on a series of input variables which I have chosen in three different categories: Hydrology, Bio-Diversity, and Heat Island effect. These three categories are based on my initial research into the leading problems faced in urban areas. Based on these three categories a series of input variables will allow for the system to output different scores for various materials considered. This adaptability will allow this system to be applied to various regions.

There are 8 recognized site materials which influence exterior site design. This applies to all areas which are outside of the building envelope (including sloped surfaces greater then 1sm in area).

4.2 Inputs

The inputs for the Sustainable Site System have been chosen based on three categories: hydrology, bio-diversity, and heat. The three categories have been identified as the leading issues facing urban development. It is also noted that these inputs are not the only acceptable inputs for this system but they have been chosen to create a framework for which this discourse may begin. It is also noted that there are many other issues facing the development of urban regions throughout the world, remembering again that these three have been chosen with regards to the research provided.

Distribution of the points will be derived from an equal distribution of all the points from the input variables. Higher priority is not provided to one section over another; due to the fact that there is no statistical information available to determine that one input is more affected over another. This approach leave room for further consideration in the future. For this reason a simple equal division is used (Figure 4-1).

4.2.1 Hydrology

Hydrology input parameters have four important variables which have been chosen, not to say that these could be the only parameters possible. Additional variables may be added or removed in future. The current variables provide a data point along the hydrological cycle.

Ground water level

Ground water level addresses the level of water in various conditions surrounding a city. These conditions may be underground aquifers, well levels and local ponds or lakes. It is understood that these levels vary greatly from year to year based on the level of precipitation received in that given year. The water level can also change based on human intervention such as consumption, storing and redirecting natural flow of the water. Two leading causes for decreasing water levelling in aquifers is increased consumption and decreased ground absorption capabilities. This variable is determined by a 5 year average of the water level compared to the previous 5 year average. This will lead to a determination that the water level is; decreasing, remaining consistent or increasing. These three outcomes will determine the score for this variable.

Moisture Index

Moisture index is based on the humidity index which reflects the surplus of water and an aridity index which reflects a deficiency of water. The moisture index demonstrates the amount of water in the air and ground on an annual average. This is used for the purpose of understanding the need to either increase or decrease the amount of moisture within the area. Development of a city does not affect the amount of rain it may receive, but it does affect what happens to the precipitation after it falls. The moisture index indicates whether the precipitation is retained in the area or if it is being dissipating out of the local climate. The moisture index has four different considerations: less than 0.5, between 0.5 to 1.0, between 1.0 to 1.5 and above 1.5. Where the moisture index is for a given area will determine the score for this variable.

10 Year 15 Minute Rain Event

The 10 year 15 minute rain event is used by building codes to determine the amount of rain which can fall in 15 minutes in order to size stormwater drainage systems. This is used in the sustainable site system to determine whether the area is prone to flash flooding. A site designed to retain and manage this rain appropriately can help mitigate the effects of flash flooding. Current city planning with regards to roads and drainage systems compounds the issues of flash floods by draining rainwater into streams and rivers faster than the natural systems can handle. There are four different considerations: less than 5mm of rain, between 5mm to 10mm, between 10mm to

20mm and above 20mm. Rain events under 10mm do not pose as a high risk to flash floods, while above 10mm of rain do pose as a risk. The higher the amount of rain the higher the risk of flash floods

50 Year Daily Rain Event

The 50 year daily rain event is used in building codes to determine the amount of rain which may fall over a single day in order to properly size cisterns and reservoirs. This is used in the sustainable site system to understand the requirements for ground absorption of water. A site design can be used to maximize the absorption capacity in response to the amount of rain which may fall. There are four different considerations: less than 50mm of rain, between 50mm to 100mm, between 100mm to 150mm and above 150mm.

4.2.2 Bio-Diversity

Bio-diversity is very important to all life in an ecosystem. When a single life form has been removed from an ecosystem it often has a detrimental effect on all other life forms. Many times the ecosystem can adapt to losing a single life form, but when many life forms are removed it leads to a collapse of the ecosystem. It is imperative that bio-diversity is maintained to increase the strength of the ecosystem. In developed areas ecosystems are often completely destroyed in order to support the lifestyle which humans want. It is possible to maintain portions of the existing ecosystem within the developed area. It is understood that humans and wildlife do not live in a symbiotic relationship however it remains possible that the built environment may support wildlife. Predatory animals such as bear, wolves, coyotes and foxes are dangerous to humans and their pets, so it is accepted that these animals will not be accommodated for. Large animals such as deer, moose, elk, and others require a large areas in order to survive and this is not possible within developed cities. Animals such as birds, fish, insects and small mammals can be accommodated for within the city but their populations must be monitored and maintained.

Water Pollution

Pollutants in water such as phosphates and toxins have detrimental effects on wildlife. Pollution can kill and alter the reproductive rates of animals. While the majority of pollution is monitored by laws, there is still pollution which is produced by humans through our use of vehicles and road maintenance. These pollution levels are determined by the quantity of suspended solids in water. It is possible to reduce these pollutants which are drained directly into rivers and lakes by redirecting the water to be absorbed into the ground and then allowing the natural water flow to filter the water prior to it arriving at rivers and lakes. There are three considerations for water pollutant levels: less than 20mg/l, between 20mg/l to 45mg/l and greater than 45mg/l.

Fauna Bio-Diversity

Fauna bio-diversity is concerned with the quantity of different species within a given city. This diversity allows for a strong ecology and aids in the development of fauna growth. Along with the quantity of different species, reaching the critical mass of the wildlife is also important. There are three considerations for the fauna bio-diversity: rising, remaining constant or decreasing.

Flora Bio-Diversity

Flora bio-diversity is concerned with the quantity of different species within a given city. This diversity allows for a strong ecology and supports the quantity of flora within the city. Flora is important to urban area as it provides change to both climatic and hydrological benefits as well. There are three considerations for the flora bio-diversity: rising, remaining constant or decreasing.

Plant Density

Plant density is concerned with the total quantity of vegetation within a given city. The amount of plants within the city supports the hydrological system. Plants provide an opportunity for water to evaporate into the air; this in effect cools the air temperature through the laws of thermodynamics. Vegetation also provides a surface area for rain to land on and not touch the ground and nit begin it transportation to large bodies of water. Plant density has three considerations: rising, remaining constant or decreasing.

4.2.3 Heat Island

The addition of extra heat in any environment is detrimental to all of the natural processes. Warmer water can lead to increased algae growth and death to some animals. An increase of heat in the ground can lead to thawing of permafrost in northern climates; an increase of heat in ambient air temperature can lead to an increase in smog and other pollutants. Modern buildings use air conditioning to cool the interior climate, while it cools the interior additional energy is used and heat is produced which is then expelled into the local climate, which in turn requires that buildings be cooled even more. It is important to keep heat within in the city controlled as to avoid a heat bubble over it and preventing the natural winds to filter through and cool the city. Heat can be reduced and prevented in a few of ways; firstly, reduction of dark surfaces which absorb and re-radiate solar energy. Secondly, an increase in ambient moisture can absorb heat energy when water is transformed from its liquid state into its gaseous state. Thirdly, shading surfaces which don't have evapo-transpiration properties will decrease the heat gain. Lastly, increasing evapo-transpiration can be achieved by increasing plant density thus increasing the moisture in the air and shading of the ground.

Temperature difference is calculated based on average temperatures of locations 20km to the East, South, West and North of the subject city. If there is a body of water in any of the directions from the subject city, which is larger than 20km, then that direction is disregarded and the average is created using the other directions only. The heat island effect has four different levels: no difference, between 0.5 to 1.5^{o}C warmer, between 1.5 to 3.0^{o}C warmer and over 3.0^{o}C warmer.

Summary of Inputs

These inputs are only a selected few and may be expanded upon at a later date. Weighting of these inputs may also be adjusted according to scientific data if it were available. This scientific information would have to prove that a certain input is responsible for a determinable percentage of that category. For the purpose of an architectural thesis an even distribution of weighting is acceptable and understood that the designs are only a demonstration of the output variables; should the output variables be changed the designs themselves would be modified accordingly.

Table 3 - Inputs of Sustainable Site System

Parameters	Points	Variables
Ground Water level	-1.0	Rising
	0.0	Remaining Constant
	1.0	Decreasing
Moister Index	-1.0	< 0.5
	0.0	0.5 to 1.0
	1.0	1.0 to 1.5
	2.0	> 1.5
10 yr. 15 minute Rain Event	-1.0	<5mm
	0.0	5mm to 10mm
	1.0	10.1mm to 20mm
	2.0	>20.1mm
50 yr Daily Rain Event	-1.0	< 50mm
	0.0	50.1mm to 100mm
	1.0	100.1mm to 150mm
	2.0	> 150.1mm
Water Pollutants (Total Suspended Solids)	-1.0	< 20 mg/l
	0.0	20 mg/l to 45 mg/l
	1.0	> 45 mg/l
Fauna Bio-Diversity	-1.0	Rising
	0.0	Remaining Constant
	1.0	Decreasing
Flora Bio-Diversity	-1.0	Rising
	0.0	Remaining Constant
	1.0	Decreasing
Plant density	-1.0	Rising
	0.0	Remaining Constant
	1.0	Decreasing
Heat Island Effect	-1.0	no difference
	0.0	0.5 to 1.5 ^{o}C
	1.0	1.5 to 3.0 ^{o}C
	2.0	3.0 ^{o}C or more

4.3 Synthesis of Inputs

After inputs are determined, the next step is to synthesize the data into equal distribution between the three subject areas: hydrology, bio-diversity and heat. This is a necessary step which will lead to the creation of the final material scores. This means that in some regions certain inputs may not carry any importance at all while more emphasis may be placed on only a few inputs. This process will allow for the system to be adjusted according to various regions and produce different output scoring systems which will respond accordingly (Figure 4-1).

4.3.1 Hydrology

Hydrology has two distinct paths which water can take after it becomes a liquid; first it can evaporate into the air where it will be turned back into a liquid at a later time, or it remains a liquid and moves along the grounds tributary paths where it will eventually join a larger body of water. The inputs into the hydrology section are: ground water level, moisture index, 10 year 15 minute rain event and 50 year daily rain event. All of the aforementioned inputs can be distilled into two outputs: evaporation and ground water absorption.

Evaporation

Evaporation of water can be achieved through many different methods. For example, pools of water can directly evaporate into the ambient air, or plants can evaporate water through a process called evapo-transpiration. Whenever evaporation is able to occur, it should be considered a benefit in regions which require additional moisture in the air.

Ground Water Absorption

Ground water absorption is achieved when water is absorbed into the ground. While there are other methods of absorbing water for example in potted planters or fountains, this water does not participate in the hydrological cycle within the ground. For the purpose of this system water must be able to be absorbed directly into the ground itself and not stored on site. For these reasons water should participate in the natural patterns which originally existed and be rewarded appropriately.

4.3.2 Bio-Diversity

Bio-diversity may increase and decrease at various times during the ecological cycle. However in the context for this research, it is important that the bio-diversity be respondent to local natural cycles. To introduce a species which is alien to a region can have detrimental effects to the natural processes. For these reasons bio-diversity can be distilled into two paths; native vegetation and non-native vegetation.

Native Vegetation

Native vegetation is vegetation which can survive in the local climate without any human interventions such as; irrigation, trimming, pesticides and seasonal protection. Also the vegetation must be a part of the natural food supply to the area, such that it has a purpose and use for the fauna. For these reasons the use of native vegetation should receive the most benefit and points.

Non-Native Vegetation

Non-native vegetation is vegetation which cannot survive in the local climate without any human interventions such as; irrigation, trimming, pesticides and seasonal protection. Also this vegetation may be considered poisonous or hazardous to the local fauna. For the above reasons non-native vegetation should be discounted in its score in comparison to native vegetation.

4.3.3 Heat

Heat is becoming an issue in urban centers due to the extra energy required to cool buildings. Heat is created by two sources; solar radiation and manmade heat. Solar radiation impacts the local climate in two ways; first its the direct radiation felt from the sun itself, the second is through secondary radiation from surfaces which absorb solar radiation and then re-radiates it. Manmade heat comes from various sources such as the transmission and use of electrical energy, and through manufacturing processes. For the Sustainable Site System manmade heat sources are not considered, only solar heat energy is considered. There are two methods of quantifying and controlling solar heat; the first is through sunlight and shading of surfaces, the second is through the tonal colour of materials used.

Sunlight and Shade

Solar heat gain which materials can re-radiate varies based on the individual materials capacity to retain heat. If a material doesn't have enough thermal mass to store heat energy then it will re-radiate less than a material which has a greater capacity to store heat energy. This means that materials which have greater ability to re-radiate heat should be shaded. Materials which do not re-radiate heat as much such as vegetation should be placed in the sunlight's path. In order to maximize the growth potential of the vegetation a higher rating will be provided to vegetation placed in direct sunlight.

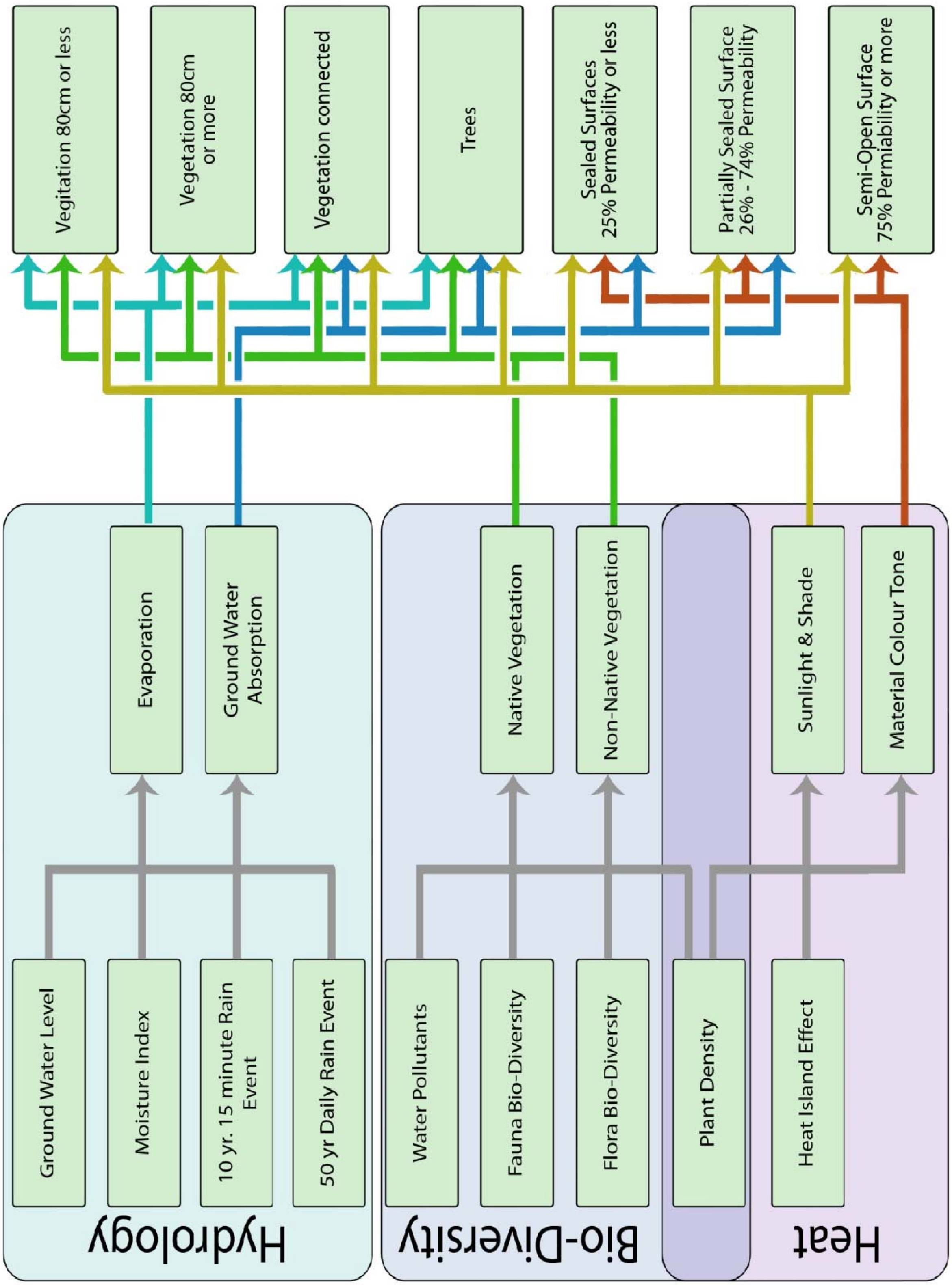
Material Colour Tone

Colour tones of surfaces have a direct correlation to its ability to absorb solar radiation. The darker the tone the hotter the surface and thus re-radiate more heat into the air. The lighter the tone the less the surface may get hot and thus it re-radiates less heat into the air. The use of lighter materials should be encouraged when it is exposed to the sunlight while darker tones should be avoided in areas where excess heat is an issue.

4.3.4 Summary of Synthesis of Inputs

It is an important step to distil the input variables into an understandable format for further development. The choice of these three primary categories relate to this thesis' initial research which presented these three issues. Further division of these three categories into two sub categories each is in response to climatic impact methods which exist within each. This further division also allows for more responsive material effects in each category which will be further defined in section Materials.

Figure 4-1 - Sustainable Site System Flow Chart



4.4 Materials

The final stage in creating the sustainable site system is to provide a useable chart with scores for the various materials used. Until this phase this system has been processing the input variables and then synthesizing them into useable data points which will be used to develop final scores. The material phase is going to apply the synthesized data into final scores. As different input data is used the material scores will change accordingly.

This system only accepts 8 categories of materials. The definition of each material is defined by using the principles of material properties. When choosing which is the appropriate material score to be used it should be referenced to the basic properties it exhibits.

1. Vegetation with 80 cm or less of planting medium - any soil area which supports plant growth and has 80cm or less of growth medium. This definition accounts for low moisture carrying capacity of the soil due to its depth. This planting depth also reduces the ability for plants to develop complex and extensive root systems. This system may also require additional irrigation in times of drought (Figure 4-2). Additionally ponds may also be included in this section as long as the pond supports life.

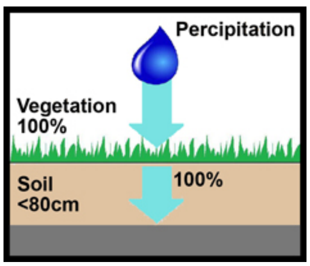


Figure 4-2 - Examples of Vegetation with 80cm or less of planting medium

Source: (Villagelynx, 2011)

2. Vegetation with 80 cm or more of planting medium - any soil area which supports plant growth and has 80cm or more of growth medium. This definition accounts for the higher moisture carrying capacity of the soil due to its depth. This planting depth also increases the ability for vegetation to develop complex and extensive root systems (Figure 4-3).

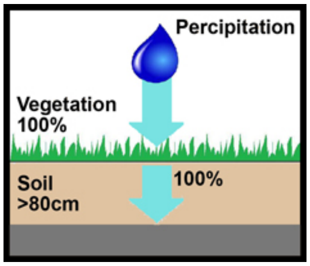


Figure 4-3 - Examples of Vegetation with 80cm or more of planting medium

Source: (Villagelynx, 2011)

3. Vegetation Connected - any soil area which supports vegetation growth and has uninterrupted connection to the ground below. The area must be a minimum of 1 square meter. The vegetation may be of any density and species. Any paths which may intrude on the vegetated areas must be calculated separately. This material must have 100% permeability to the ground underneath. There must not be any protective barriers which prevent the roots from growth into the ground (Figure 4-4).

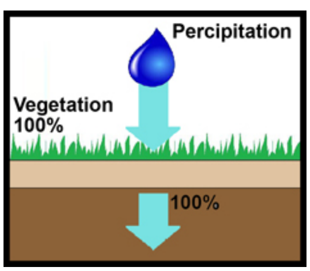
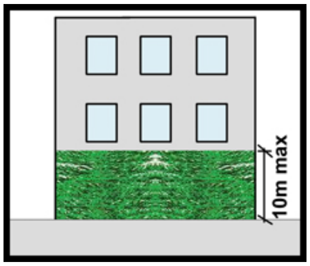


Figure 4-4 - Examples of Connected Vegetation

Source: (Villagelynx, 2011)

4. Vertical Greenery - any vertical surfaces which allow for plant growth, requiring a

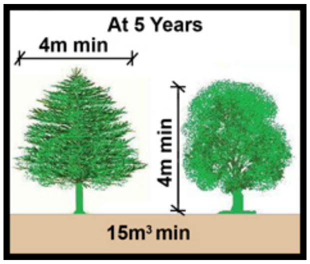


minimum of 3m high up to a maximum of 10m high. Any plant material higher then 10m off the ground plane is not applicable. This 10m height restriction is based on the bio-regeneration of subsequent bio-life. The area calculated is restricted to the area for the planting medium and not to the area which the plant will eventually grow into. This restricts the use of vines and other climbing plants which grow up a wall or lattice structure (Figure 4-5).

Figure 4-5 - Examples of Vertical Greenery Systems

Source: (Villagelynx, 2011)

5. Trees - this credit is received per tree which is planted in at least $15m^3$ of soil and

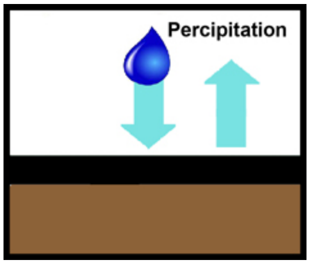


reaches a height of at least 4m in 5 years. The diameter of the widest branch span must be at least 4m. This height and diameter of the tree is to achieve a stratification of five times the leaves. This stratification is to provide a surface area for rainwater to sit as well as to provide area for evapo-transpiration to occur. There is no distinction between coniferous or deciduous trees; all trees are acceptable as long as they meet the above criteria (Figure 4-6).

Figure 4-6 - Examples of Trees

Source: (Villagelynx, 2011)

6. Sealed Surface - are surfaces which do not allow any penetration of water, air, plant



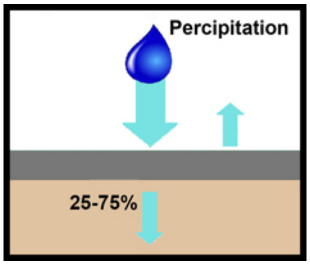
vegetation, and are typically waterproof. The acceptable permeability of this material must be less than 25% water which falls on it, for example if 1 Litre water is placed on this surface it must not absorb more than 250 ml in a 24 hour time frame (Figure 4-7). Water fountain which do not contain any life is also included.

Figure 4-7 - Examples of Sealed Surfaces

Source: (Villagelynx, 2011)

Examples of sealed surfaces are: concrete, asphalt, terrazzo (or other stone), paving (bound by joint resin, or have a sealed structural support), waterproof plastics and roof areas which are not covered by any other material.

7. Partially Sealed Surfaces - are surfaces which do not allow any plant vegetation to



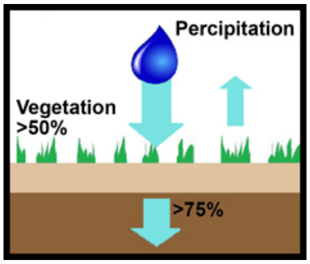
grow, but do allow air and water to seep directly to the connected ground underneath. The acceptable permeability of this material must be more than 25% but less than 75% of water which falls on it, for example if 1 Litre water is placed on this surface it must absorb more than 250 ml and less than 750 ml in a 24 hour time frame.

Figure 4-8 - Examples of Partially Sealed Surfaces

Source: (Villagelynx, 2011)

Examples of partially sealed surfaces may include small paving stones, concrete composite blocks, heavily compressed soil, sand, and gravel. Note that this material must be directly placed on the ground plane and have direct contact to the ground underneath, if there is a sealed surface underneath this material is does not qualify under this class of material (Figure 4-8).

8. Semi-open Surface - are surfaces which have a high amount of jointing with areas



for vegetation like grass to grow. The vegetation must account for at least 50% of the area. This percentage of vegetation must be applicable to any randomly selected 1 square meter of area. The acceptable permeability of this material must be more than 75%. This means that the material must absorb more than 75% of water which falls on it, for example if 1 Litre water is placed on this surface it must absorb more than 750 ml in a 24 hour time frame.

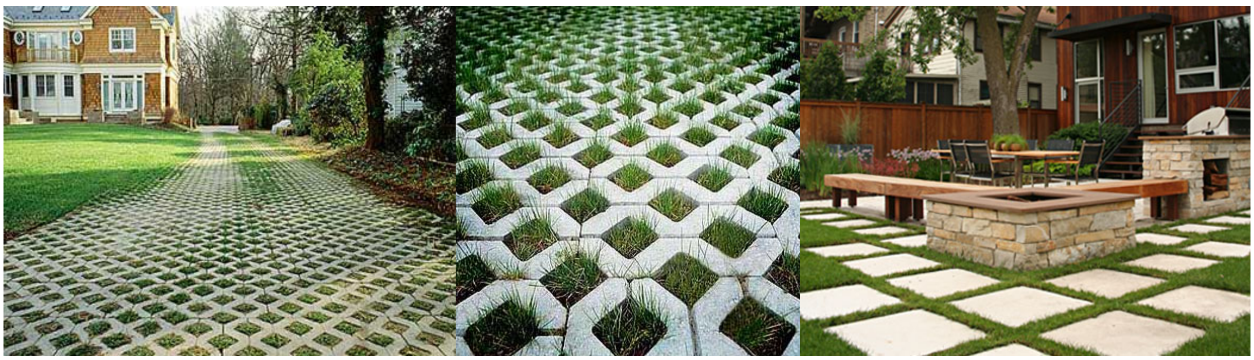


Figure 4-9 - Examples of Semi-Open Surfaces

Source: (Villagelynx, 2011)

Suggested areas for semi-open surfaces include fire escapes, and low traffic access points as the vegetation would be vulnerable to high traffic. There are many products and systems which achieve the parameters described above. Creative use of small pavers within a field of vegetation would also satisfy this material parameter (Figure 4-9).

4.5 Material Properties

In addition to the above material categories there are three sub material property categories which apply; direct sunlight vs. shade, native planting vs. non-native planting, and low vs. high maintenance levels. These additional material parameters provide the final level of site design impacts on the material. This last step provides a higher resolution on understanding the impact of a given design in a region.

Direct Sunlight vs. Shade

The impact of direct sunlight on various surfaces are different when it comes to re-radiating heat It is understood that asphalt in sun radiates more heat energy than asphalt in shade; the same principle applies to vegetation, as plants grow faster and are healthier when they receive direct sunlight vs. only daylight. This reasoning leads to the individual materials receiving a penalty for instances when direct sunlight or shade has a negative effect on the material. Thus all vegetation which is in shade will be penalised according to the rating system. All other surfaces will also be penalised when they are in direct sunlight according to the rating system.

For this system the definition of direct sunlight is: unobstructed sunlight which hits a surface either horizontal or vertical at 1pm on June 21st (Summer Solstice). Only permanent structures shadows are considered. Any non-fixed structures shadows are not considered for calculations. Any vegetation shadows also does not count, for the reason that the vegetation may grow and alter its shading location and capacity over time.

Material Tone

Sealed surfaces require additional consideration due to the solar gains which are greater when the material is darker. For this reason there are three tonal distinctions which are made. Any colour pigmentation is removed from this consideration; instead the colour is to be considered unsaturated such that it only contain white, grey and black (monochrome). The three tonal categories are; 0 to 25%, 26 to 74%, and 75 to 100% (Figure 4-10 & Figure 4-11).

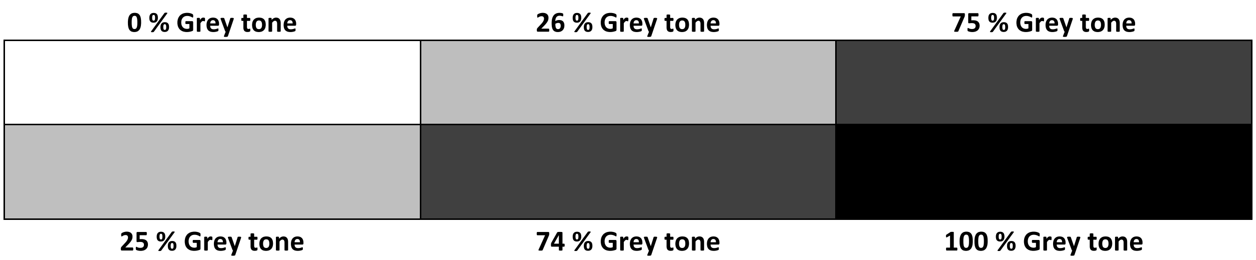


Figure 4-10 - Grey Tone Examples

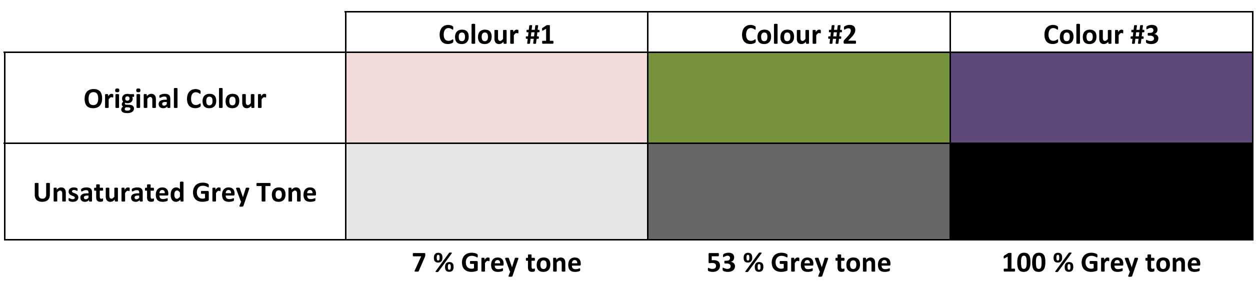


Figure 4-11 - Examples of Denaturised Colours

Native vs. Non-Native Vegetation

There are two reasons why there should be different ratings for native and non-native vegetation. Native vegetation if not treated with a pesticide has an active role in the local food chain. While local fauna are not familiar with non-native plants they may not use them as a source of food. In some instances the non-native vegetation may also be poisonous to local fauna. Non-native plants are sometimes invasive and can overtake local ecology. For these reasons alone non-native plants should not be allowed, but it is accepted that these plants tend to be for ornamental purposes and must allow some leniency. The second reason why there is a penalty for non-native vegetation has to do with the energy required to maintain these species in some climates, for example, in a northern climate winter kills certain plants and it must be replanted the following spring, or in a dry climate the vegetation requires constant watering.

For this system the definition of native vegetation is if the plant in question can be found in a natural habitat within 500 km of the project site. All other plants not found within this radius will be considered a non-native vegetation species.

Low vs. High Maintenance

The final additional parameter is placed on the materials that have to do with vegetation. The level of maintenance required for different types of vegetation should be considered due to the use of energy which is consumed. The higher the maintenance levels the more fuel, water, and fertilizer is used. Higher consumption of these resources has a detrimental effect on the local climate. The use of fuel or other sources of energy increases the ambient heat and releases additional pollutants into the air. When the use of water is diverted for irrigation it is removed from a larger body of water, weather it is a river, lake or aquifer. This removal of water decreases to total amount of water which would accumulate there had it been left alone. Throughout the process of irrigation there are some benefits to the ambient air temperature as well as increased vegetation growth rates. These positives and negatives would be demonstrated in the output ratings according to the various input parameters. By introducing a penalty for these reasons it encourages designers to respond more conservatively in the choices for vegetation types.

For this system the definition of high maintenance includes any of the following criteria;

1. Requires trimming or cutting more than once a month
2. Requires any irrigation
3. Requires any pesticides
4. Requires any fertilizers

Examples of high maintenance are; cut grass, manicured gardens, farmland and maintained planters.

4.6 Material Score Calculation

Each material's score is determined by either adding or subtracting the material parameters which apply or does not apply. Below is the maximum input chart which synthesizes the input parameters into specific material variables. This chart indicates how the individual materials achieve their rating.

Table 4 - Score Rating Synthesis Chart

Input Parameters		**Synthesis of input**	**Max**	**Material Properties**	
Hydrology	7.0	**Ground Water**	3.5	<25% Permeability	**0.00**
		Choose one		26% - 74% Permeability	**1.75**
				>75% Permeability	**3.50**
		Evaporation	3.5	Evapo-Transpiration	**3.50**
Bio-Diversity	4.0	**Native Vegetation**	4.0	Low Maintenance	**4.00**
		Choose one		High Maintenance	**2.00**
		Non-Native Vegetation	2.0	Low Maintenance	**2.00**
				High Maintenance	**1.00**
Heat Island	3.0	**Material Colour Tone**	1.5	<25% Gray tone	**1.50**
		Choose one		26% - 74% Gray tone	**0.75**
				>75% Gray tone	**0.00**
		Shade	1.5	In Sunlight	**1.50**
		Choose one		In Shade	**1.50**
Total Input Points	**14.0**				

Each material score is determined by adding or subtracting the Synthesis of Input rating weather it applies or does not apply. The total points for material are then divided by the total input points to provide the individual materials unit score.

Example #1 *Native Low Maintenance Vegetation Connected in Sunlight*

Table 5 - Native Low Maintenance Vegetation Connected in Sunlight Material Properties

Material Properties		Native Low Maintenance Vegetation Connected in Sunlight
Applicable Properties (add)		Total input points = 3.5+3.5+4.0+1.5+1.5-0 = **14.0** Total material points = **14.0** **Therefore material score is 14.0/14.0 = 1.0**
>75% Permeability	**3.50**	
Evapo-Transporation	**3.50**	
Native Low Maintenance	**4.00**	
<25% Gray tone	**1.50**	
In Sunlight	**1.50**	
Non Applicable Properties (subtract)		
None		
Total Material Points	**14.0**	

Example #2 Sealed Surface 25 - 75% Permeability - 26% - 74% Gray tone In Shade

Table 6 - Sealed Surface 26 - 74% Permeability - 26% - 74% Gray tone in Shade Material Properties

Material Properties		*Sealed Surface 26 - 74% Permeability - 26% - 74% Gray tone In Shade*
Applicable Properties (add)		Total input points =1.75+0.75+1.5-3.5-4.0 = **-3.5** Total material points = **8.0** **Therefore material score is -3.5/14.0 = -0.25**
26- 74% Permeability	**1.75**	
26% - 74% Gray tone	**0.75**	
In Shade	**1.50**	
Non Applicable Properties (subtract)		
Evapo-Transporation	**3.50**	
Native Low Maintenance	**4.0**	
Total Points	**-3.5**	

This process is repeated for all of the materials in order to determine material scores. The final output is represented by a table which looks similar to Table 7.

The final guideline has a total 8 different material types with a total of 52 individual material ratings. This may seem like a lot but the final chart is simple to understand and apply materials. Each of the sub sections are clearly defined and described. The application of all the various materials provides many opportunities for designers to choose appropriate materials and achieve the required score for their project.

4.7 Universal Base Score

The purpose of creating a universal base score is to assess the output variables of the system with a maximum input in all the parameters. This provides an opportunity to understand what the base system rating is prior to applying it to various regions and climates.

For the creation of a base chart it is assumed that all of the input parameters have been maxed out, this is to achieve equality in the numbers based on materials and not climatic data. The base chart (Table 7) represents the score received for each square meter of various materials (Table 4). As a result all vegetative materials have a positive rating and all hard surfaces have a negative rating.

Table 7 - Sustainable Site System Base Chart

				Native Vegetation				Non-Native Vegetation			
				Maintenance				Maintenance			
				Low		High		Low		High	
Material		Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade
Vegetation 80cm or less				**0.75**	**0.54**	**0.61**	**0.39**	**0.61**	**0.39**	**0.54**	**0.32**
Vegetation 80cm or more				**0.88**	**0.66**	**0.73**	**0.52**	**0.73**	**0.52**	**0.66**	**0.45**
Vegetation connected				**1.00**	**0.79**	**0.86**	**0.64**	**0.86**	**0.64**	**0.79**	**0.57**
Vertical Vegetation				**0.75**	**0.54**	**0.61**	**0.39**	**0.61**	**0.39**	**0.54**	**0.32**
Tree		**25.00**	**19.64**								
Sealed Surface	<25% Gray tone	**-0.54**	**-0.32**								
<25% Permeability	26% - 74% Gray tone	**-0.59**	**-0.38**								
	>75% Gray tone	**-0.64**	**-0.43**								
Partially Sealed Surface	<25% Gray tone	**-0.41**	**-0.20**								
26% - 74% Permeability	26% - 74% Gray tone	**-0.46**	**-0.25**								
	>75% Gray tone	**-0.52**	**-0.30**								
Semi-open Surface	<25% Gray tone	**-0.07**	**-0.29**								
>75% Permeability	26% - 74% Gray tone	**-0.13**	**-0.34**								
	>75% Gray tone	**-0.18**	**-0.39**								

4.7.1 Observations of Universal Base Score

Under review of all of the base numbers there are a couple of unexpected anomalies. Overall the numbers which have been provided do demonstrate a hierarchical pattern which responds to the various inputs.

Under review of the base numbers in the system it is seen that a positive score is given to all of the vegetated parameters while all the other surface materials have negative values.

It is observed that there is an inverse in scores provided between partially sealed surfaces and semi-open surfaces. Each material maintains its own hierarchy from darker to lighter tones. When these materials are in sunlight the Semi-open Surface receives higher scores then the Partially Sealed Surfaces. There is a reversal of scores when shade is introduced, and the Partially Sealed Surfaces receive higher scores then the Semi-open Surfaces. This is occurring due to the vegetation component of the Semi-open Surface and when it is in shade it receives a penalty. This penalty is sufficient to decrease the score and makes the Partially Sealed Surfaces score higher. The marginal difference between the two in shade is significantly less than when the materials are compared in sunlight.

There are no anomalies within vegetative materials. The best scoring material is the Connected Native Low Maintenance Vegetation in the Sun. This was expected due to this material being the most natural. The worst scoring material is Sealed Surface - >75% Grey tone in Sun. This was also expected due to the negative properties which it has on the hydrological process, restriction of bio-life, and radiating properties.

4.7.2 Base Site Rating

In order to understand what the Base Site Rating is, the Site Standards System will assume that all materials have 10 square meters of area and 1 tree in sun and shade. This will provide a baseline which can be used to compare various output charts. The Site Standards System will also determine the final score by averaging the total score by the total area of the site, not the total area inputted as some surfaces may be duplicated along the height of the building, trees and vertical vegetations don't represent any ground area.

There is no minimum or maximum which a site can achieve due to the ability to duplicate surfaces with cantilevers. But a single plane undisturbed natural site without trees would receive a rating of **positive 1.0** and a worse developed single plane rating would be **negative 0.64** according to the Base Site Rating.

The Base Site Rating is **0.40** (Table 7). This number represents an average off all system inputs and will be used as a comparison when different input variables are introduced.

The Ideal scenario is to achieve a rating of 1.00 which would represent a natural undisturbed site without any trees. If it were a natural site with 1 tree every 25m^2 then the rating would be 2.00. To achieve this rating within an urban site would require a lot of cantilevers resulting in duplicated surfaces, a reduction in road widths (may not be possible) and the addition of many trees. These additional expenses may not be possible and may also be too expensive to construct.

Determining Project Objectives

The determination of the required site rating will be similar to the Berlin's BAF. In the BAF there is a difference in the required rating based on new and renovation projects. The BAF also distinguishes different goals for different types of project, this differentiation of project types will not be accommodated, due to the fact that the different type of project has no additional benefits to the local ecological systems. Site ratings for a project will depend on whether the project is new or existing. Existing sites may not be able to meet as high standards as new projects. Each goal will be a proportional response to the local climate and the individual rating system. The minimum site rating should be equal to the base rating of the system in that climatic region. This minimum will also apply to renovation projects. Using the Base System Rating for a renovation project it will have to achieve a 0.40. For new projects the objective rating will be determined by multiplying the base rating by 150%. Using the Base System Rating for a new project it will have to achieve a 0.40 x 150% = 0.60. It would be acceptable to round the expected rating to simpler numbers to making the goals easier to understand (Table 9).

Table 8 - Rating Objectives Examples

Location	Base Rating	Renovation Projects	New Projects
Example 1	0.30	0.30	0.45
Example 2	0.40	0.40	0.60
Example 3	0.50	0.50	0.75
Example 4	0.55	0.55	0.83
Example 5	0.60	0.60	0.90

4.8 Site & Surfaces

Site definition with regards to Sustainable Site System is the property ownership area plus sidewalks and roads at a perpendicular line to the property line to the midpoint of the adjacent road.

To determine the site rating, sum all of the points received in the total area then divide the total by the site area under consideration. This is meant to provide a site rating, which accounts for all duplicated surfaces created along vertical axis of the project.

The purpose of adding the public area to the privately owned area is to account for the effects which are incurred on the public property. This will lead to higher requirements for the development. It is the intent of this system that the city would want to make public property better and be more accountable to natural systems. This position will lead to a common goal by both the city and the developer to make the street area more ecologically friendly, in turn this will lead to synergy between the two parties and adjust the planning of the public spaces. It is understood that the city does have a limited budget to handle the construction of the streets and sidewalks, however if the developer were to take on these expenses so that they may move forward with their project, these costs would not impact the city's budget.

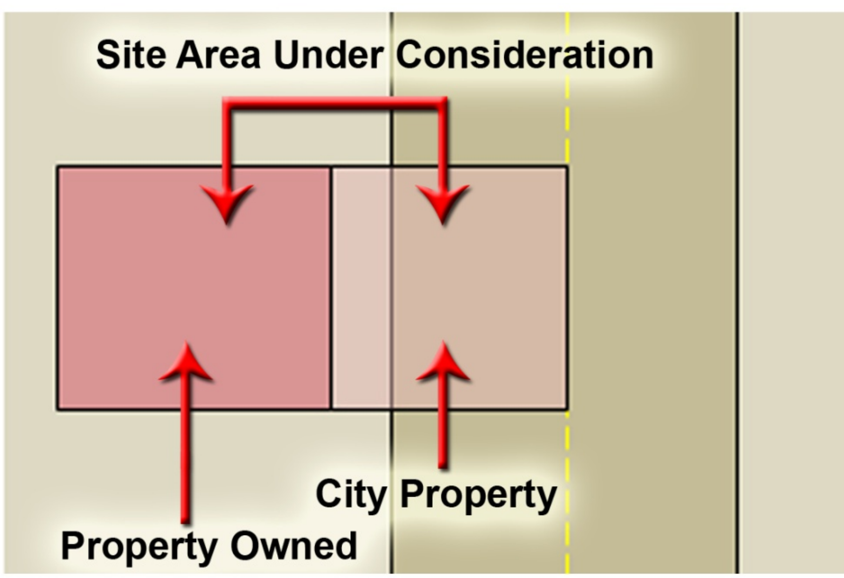


Figure 4-12 - Site Area under consideration

Sometimes certain surfaces may not be eligible for points. The first criteria have to do with the amount of enclosure around a surface. A surface will be omitted from the scoring if its surface perimeter is enclosed by more than 60% and has a protective barrier above which matches the surface under consideration (Figure 4-13), all enclosures may not allow the transmission of rain or solar energy through it to the surface. The second surface area which is omitted is any surface with a solid roof drawn back by a 45 degree angle inboard from the roof. The area which is inside of this parameter is also omitted from the scoring (Figure 4-14).

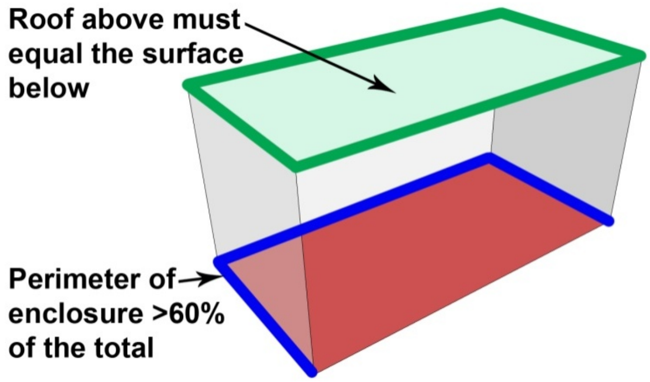


Figure 4-13 - Enclosure Parameters Diagram

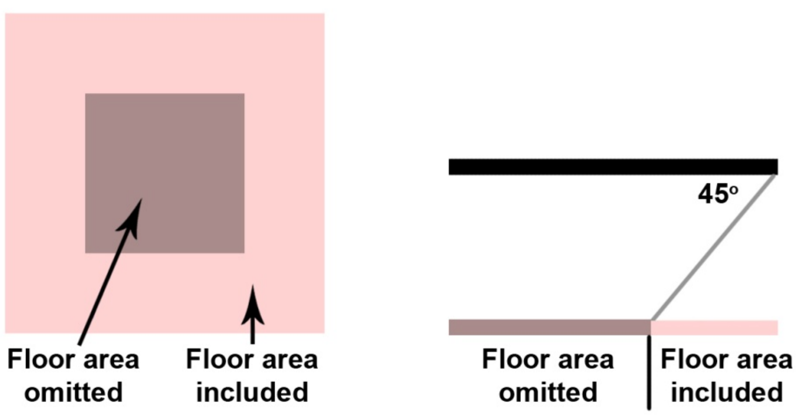


Figure 4-14 - Covered Floor Area

4.9 Climate Application Study

The four sites (Figure 4-15) considered for the application study have different: climatic statistics, population density, and scale of development, coastal conditions, geographic latitudes and macro environmental conditions. This makes them each unique and thus will be able to demonstrate how material scores will change.

Figure 4-15 - Sites Chosen for Study

Refer to Table 31 - Climatic Statistic for a comparison of the climatic data for the four selected cities and their total points. From this data, individual material score charts will be created.

4.9.1 System Climate Application Study

The base ratings for the 5 different cities demonstrate the renovation and new construction objectives (Table 9).

Table 9 - Design Rating Objectives

Location	Renovation Projects	New Projects
Base Scenario	0.40	0.60
Uranium City, Saskatchewan	0.58	0.87
Toronto, Ontario	0.41	0.61
Vancouver, British Columbia	0.40	0.60
Halifax, Nova Scotia	0.35	0.52
Biotope Are Factor (Berlin)	0.30	0.60

According to these numbers Uranium City should have the highest rating while Halifax should have the lowest. There should be some variation of the differences according to the different designs. The base rating has a difference of 40% between the highest and lowest scores, demonstrating that the rating system is very responsive to the various climates.

The addition of the Biotope Area Factor rating is used as a comparison to the current similar system. This will also demonstrate how various designs would not be credited for potentially positive design.

A series of building designs is needed in order to understand the implications of the various inputs. These designs abstractions of the principles of design intent for each have been accentuated in order to exaggerate the effect on the output rating.

All designs have a development density between 7,500 m^2 and 9,000 m^2. The site area for all designs is 4015m^2. The height of all designs will vary as the shadowing effect will be one that is investigated. The site coverage, quantity of trees, maximizing green roofs and shadows are all principles which will be investigated.

Design #1

Design #1 encompasses 43% of the ground plane site area. The total green roof accounts for 55% of the site area. There are two large planters on the east and west sides of the building which accounts for 8% of the site area. The design also features a step back on the top floor of the podium in order to allow for sunlight to reach more of the sidewalk area. The building also utilizes a large cantilever which allows for duplication of the roof area where additional green roof vegetation may be placed. This building also has 1000m^2 of green walls along the south side of the building. There are a total of 10 trees planted on the site. The sidewalk is constructed using interlocking pavers.

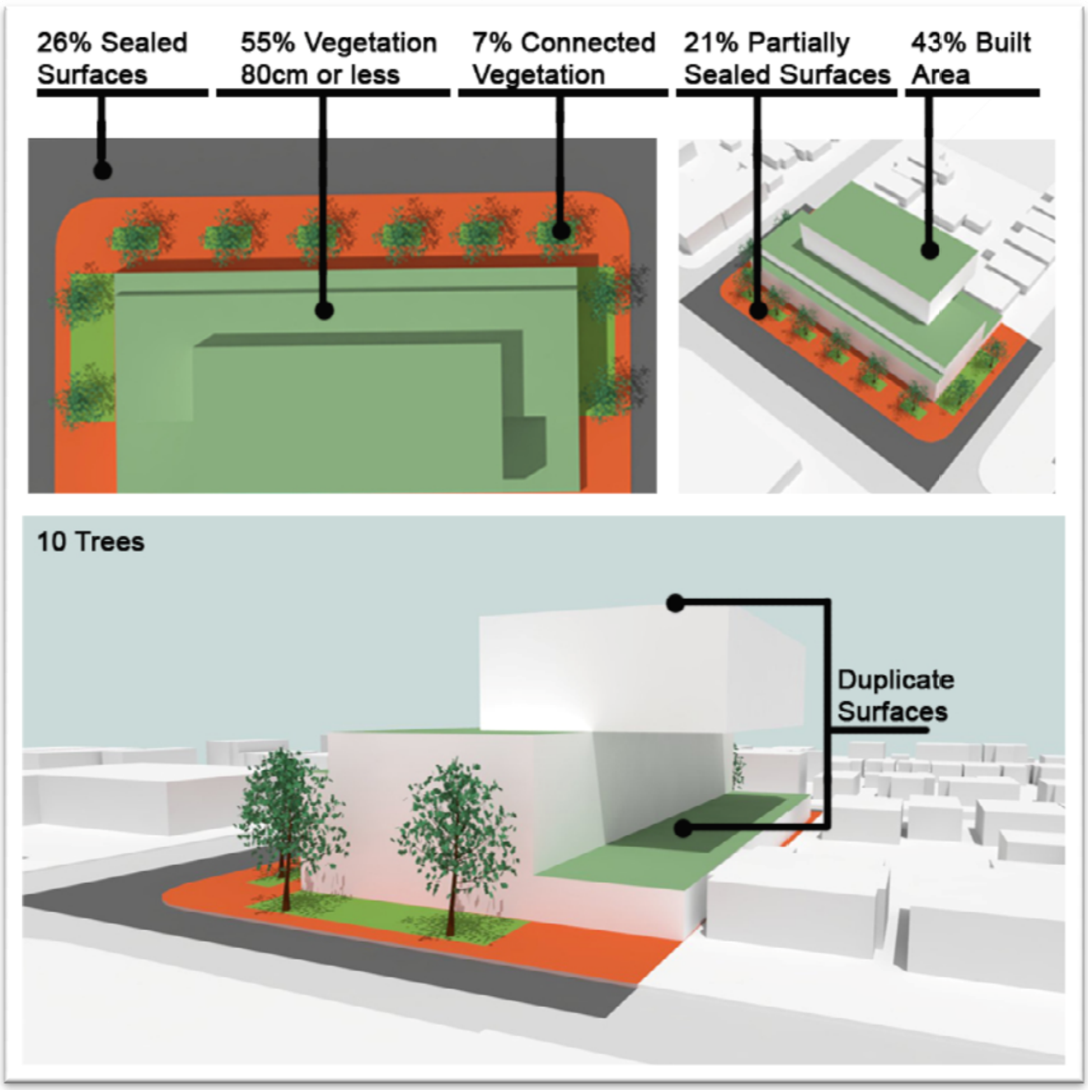


Figure 4-16 - Design #1 Plan and Perspectives

Table 10 - Sustainable Site System Rating for Design #1

Location	Design Rating	New Projects Rating	Rating Deficiency
Base Scenario	0.43	0.60	-0.17
Uranium City, Saskatchewan	0.43	0.87	-0.44
Toronto, Ontario	0.44	0.61	-0.17
Vancouver, British Columbia	0.43	0.60	-0.17
Halifax, Nova Scotia	0.42	0.52	-0.20
Biotope Area Factor (Berlin)	0.65	0.60	0.05

This design has a difference of no more than 5% between all of the various cities. Toronto performed the best and Halifax and Uranium City performing the worst. This design does not meet the required design objective of the different cities; additional features would have to be added to increase the rating. The difference between the cities is quite small thus leading to the conclusion that this design method could be considered transferable to all climates except Uranium City.

This design would meet the minimum requirements for the BAF. The additional points required for Uranium city is a result of the contexts minimal issues which exist and a development such as this would have a greater impact on the local ecological systems.

Design #2

Design #2 encompasses 38% of the ground plane site area. The total green roof accounts for 38% of the site area. There are two large planters on the east and west sides of the building as well as a courtyard to the south of the building, this connected vegetation accounts for 17% of the site area. This building also has 960m^2 of green walls along the south side of the building. There are a total of 12 trees planted on the site. The sidewalk is constructed using interlocking pavers. The design introduces a taller portion of the building along the sidewalk side to cast additional shadows on the sidewalk.

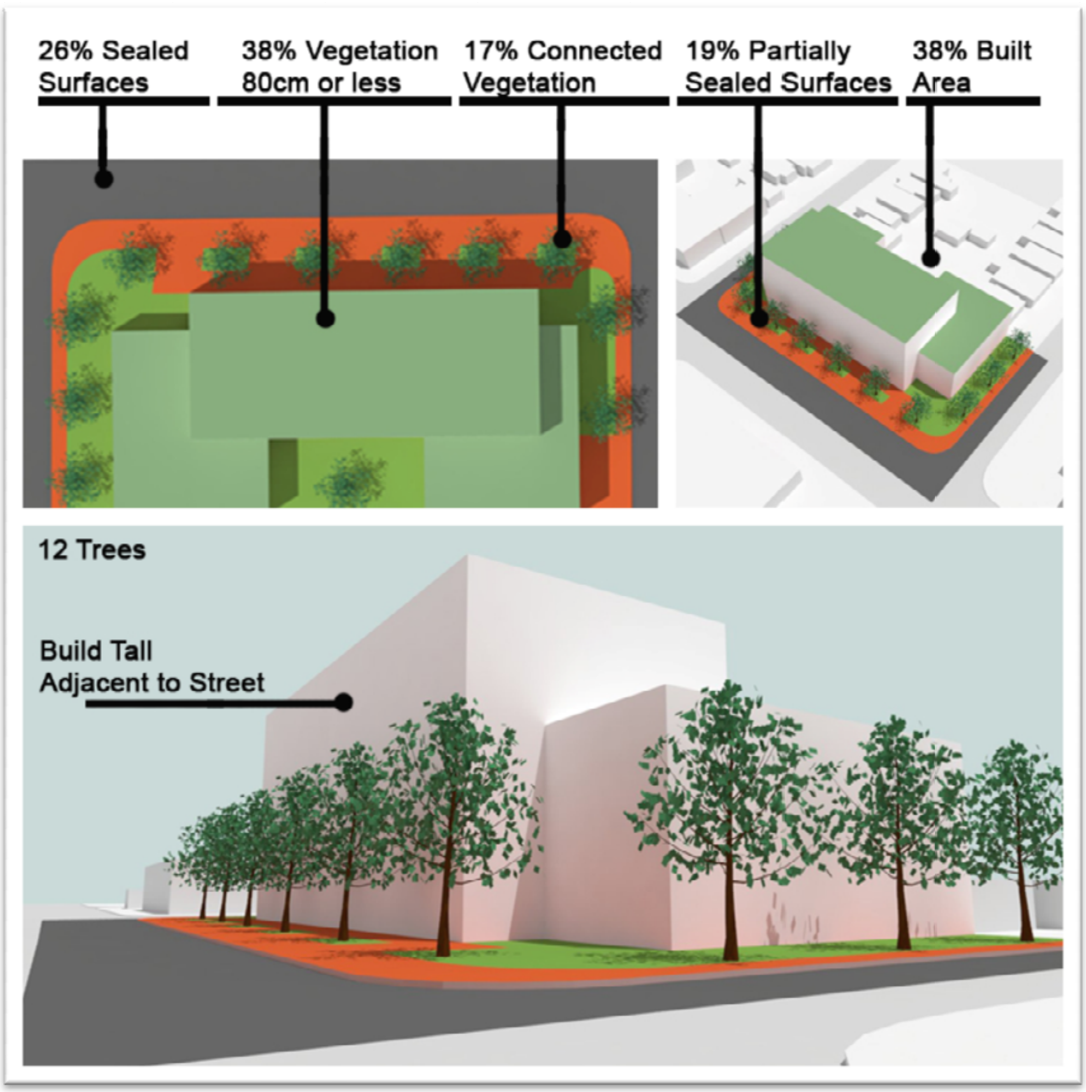


Figure 4-17 - Design #2 Plan and Perspectives

Table 11 - Sustainable Site System Rating for Design #2

Location	Design Rating	New Projects Rating	Rating Deficiency
Base Scenario	0.45	0.60	-0.15
Uranium City, Saskatchewan	0.43	0.87	-0.44
Toronto, Ontario	0.46	0.61	-0.15
Vancouver, British Columbia	0.44	0.60	-0.16
Halifax, Nova Scotia	0.43	0.52	-0.19
Biotope Area Factor (Berlin)	0.62	0.60	0.02

This design has a difference of no more than 7% between all of the various cities. Toronto performed the best and Halifax performed the worst. This design does not meet the required design objective of the different cities; additional features would have to be added to increase the rating. The difference is larger than design #1. This design does not meet the required design objective of the different cities; additional features would have to be added to increase the rating. This means that in climates like Toronto or Vancouver the act of shading of the sidewalks is more beneficial than in the remaining climates. Also reduction in the green roof area has had little impact on the ratings.

This design would meet the minimum requirements for the BAF. The additional points required for Uranium city is a result of the contexts minimal issues which exist and a development such as this would have a greater impact on the local ecological systems.

Design #3

Design #3 encompasses 34% of the ground plane site area, the second lowest of all the examples. The total green roof accounts for 34% of the site area, the second highest of all the examples. There is a small planter on the east side of the building as well as a large planting area on the west that wraps along the south side of the building, this connected vegetation accounts for 23% of the site area. This building also has 1000m^2 of green walls along the south side of the building. There are a total of 15 trees planted on the site. The sidewalk is constructed using interlocking pavers. The building introduces a tall tower to cast shadows on the street while minimizing the shadows on the sidewalk.

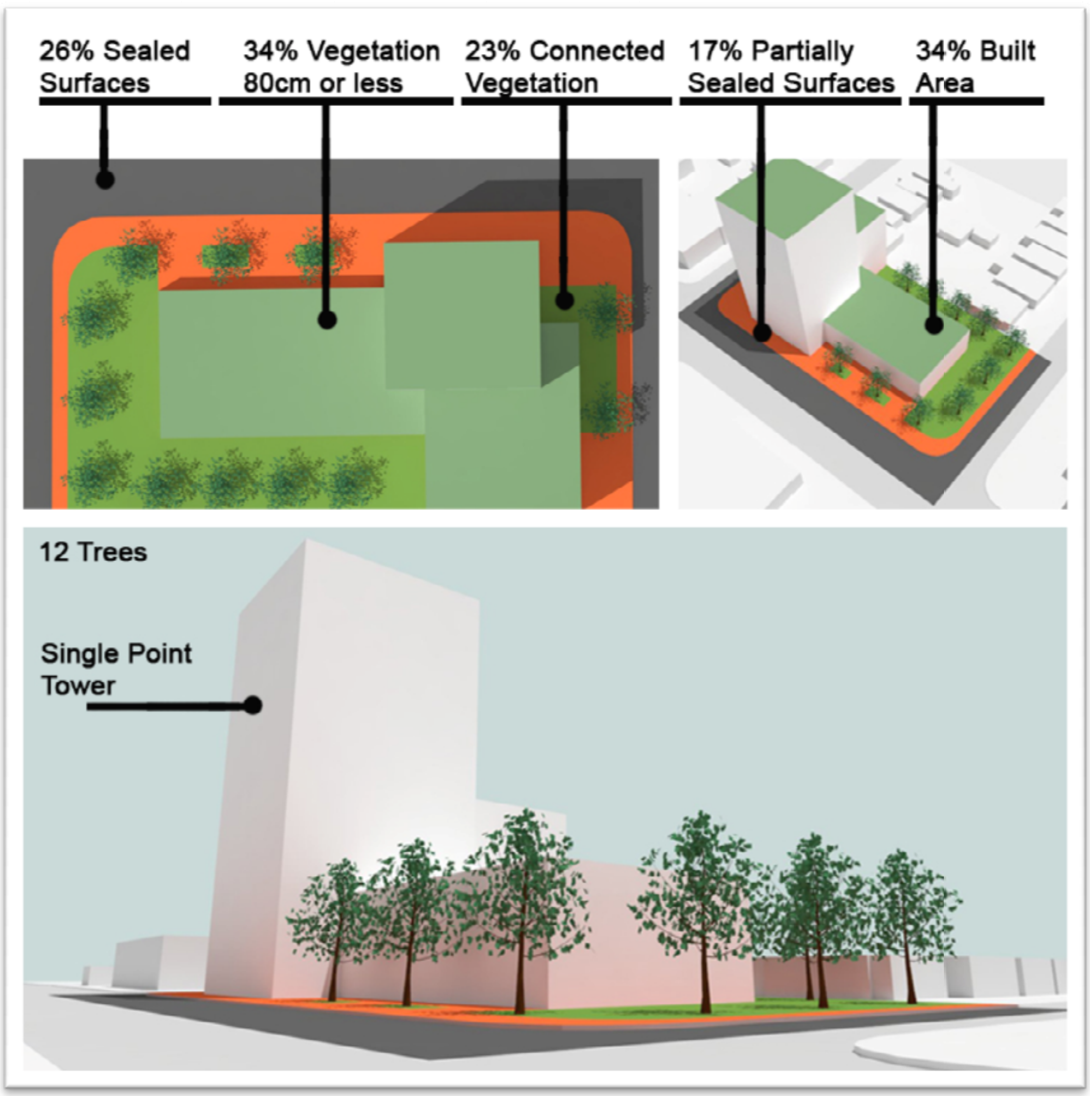


Figure 4-18 - Design #3 Plan and Perspectives

Table 12 - Sustainable Site System Rating for Design #3

Location	Design Rating	New Projects Rating	Rating Deficiency
Base Scenario	0.52	0.60	-0.08
Uranium City, Saskatchewan	0.50	0.87	-0.37
Toronto, Ontario	0.52	0.61	-0.08
Vancouver, British Columbia	0.51	0.60	-0.09
Halifax, Nova Scotia	0.49	0.52	-0.03
Biotope Area Factor (Berlin)	0.65	0.60	0.05

This design has a difference of no more than 6% between all various cities. Toronto performed the best and Halifax performed the worst. This design does not meet the required design objective of the different cities; additional features would have to be added to increase the rating. The rating is very close for Halifax and this would suggest that this design response would almost be acceptable. The reduction in the green roof area and the addition of more ground plane connected vegetation had a positive impact on the rating; this increase was approximately 11% while only increasing the connected vegetation by 6% of the site area.

This design would meet the minimum requirements for the BAF. The additional points required for Uranium city is a result of the contexts minimal issues which exist and a development such as this would have a greater impact on the local ecological systems.

Design #4

Design #4 encompasses 29% of the ground plane site area, the second lowest of all the examples. The total green roof accounts for 30% of the site area which is the second highest of all the examples. There is a large planting area on the along south side of the site and wraps up the west side of the building, this connected vegetation accounts for 29% of the site area. This building also has 1000m^2 of green walls along the south side of the building. There are a total of 16 trees planted on the site. The sidewalk is constructed using interlocking pavers. The building introduces two tall towers to cast shadows onto the street.

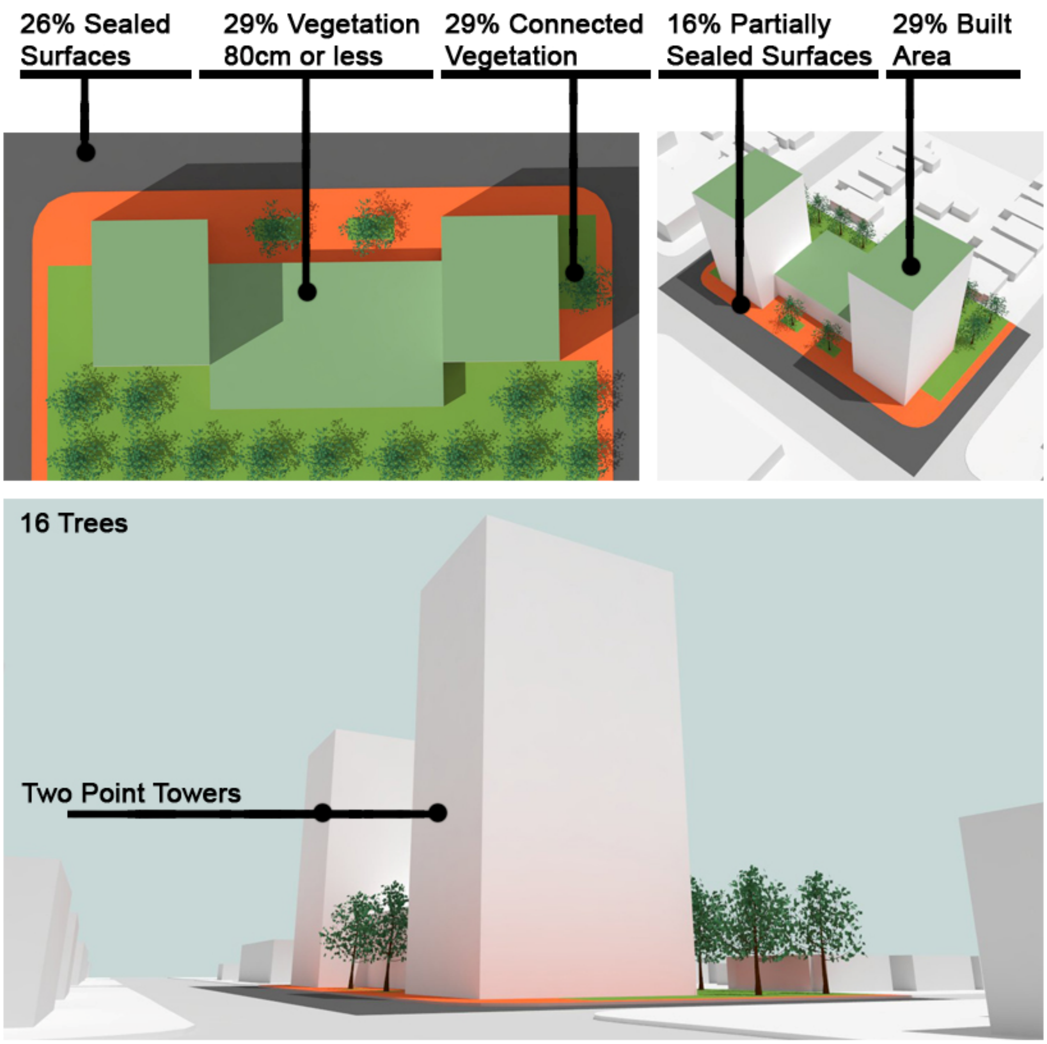


Figure 4-19 - Design #4 Plan and Perspectives

Table 13 - Sustainable Site System Rating for Design #4

Location	Design Rating	New Projects Rating	Rating Deficiency
Base Scenario	0.55	0.60	-0.05
Uranium City, Saskatchewan	0.54	0.87	-0.33
Toronto, Ontario	0.56	0.61	-0.05
Vancouver, British Columbia	0.54	0.60	-0.06
Halifax, Nova Scotia	0.52	0.52	0.0
Biotope Area Factor (Berlin)	0.67	0.60	0.07

This design has a difference of no more than 7% between all of the various cities. Toronto performed the best and Halifax performed the worst. This example improves upon the score received for a single point tower by 7% while increasing the ground plane connected vegetation by 6%. This design does meet the objective of Halifax but does not meet the required design objective of the other cities; additional features would have to be added to increase the rating. This demonstrates that the increase in the score was due to the increase of the connected vegetation.

This design would meet the exceed requirements for the BAF. The additional points required for Uranium city is a result of the contexts minimal issues which exist and a development such as this would have a greater impact on the local ecological systems.

Design #5

Design #5 encompasses 35% of the ground plane site area, the second lowest of all the examples. The total green roof accounts for 51% of the site area the second highest of all examples. There are two large planting areas on the along the south side of the building, this connected vegetation accounts for 23% of the site area. This building also has 1000m^2 of green walls along the south side of the building. There are a total of 6 trees planted on site; this is due to the reduced ground area for vegetation. The sidewalk is constructed using interlocking pavers. This building design uses a single large cantilever which reaches over the sidewalk and casts a shadow onto the street. This design also increases the green roof potential.

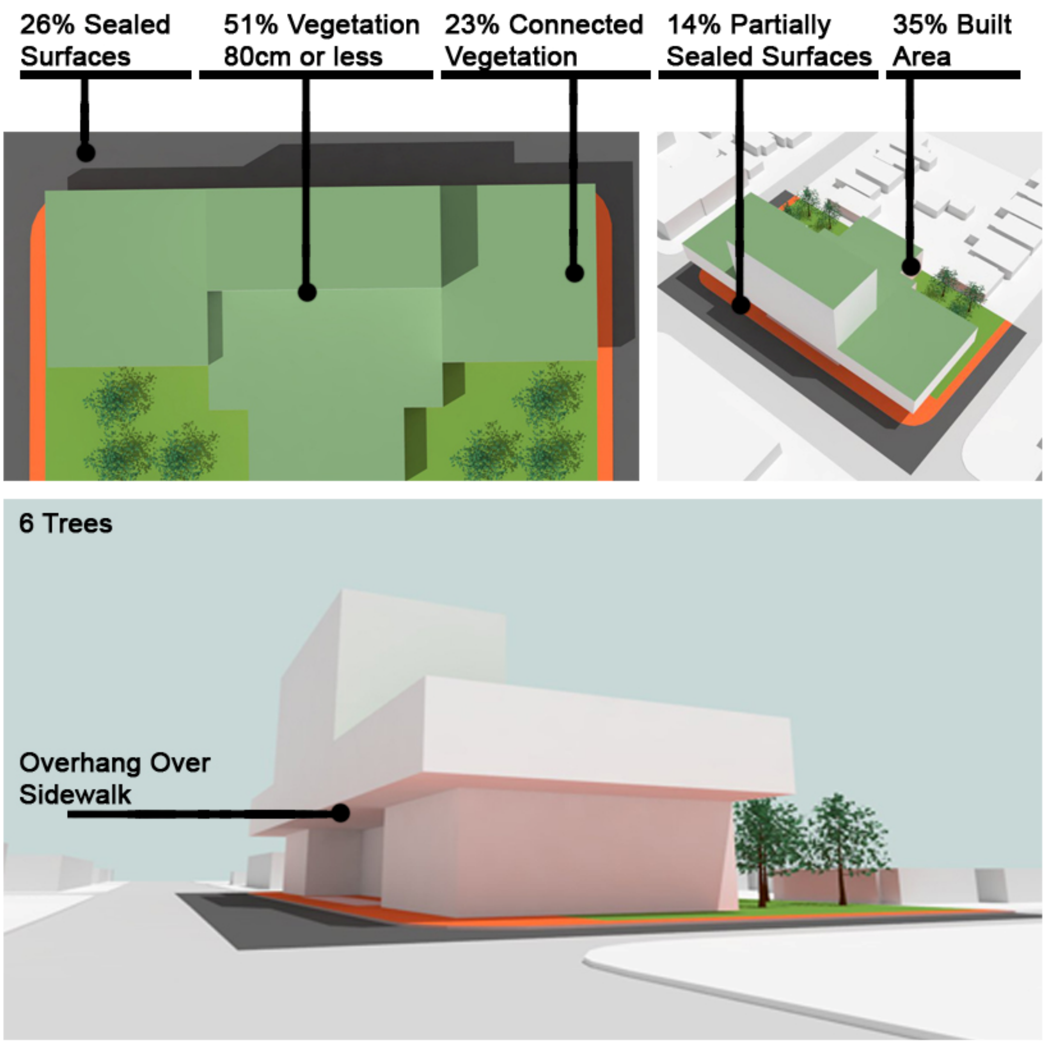


Figure 4-20 - Design #5 Plan and Perspectives

Table 14 - Sustainable Site System Rating for Design #5

Location	Design Rating	New Projects Rating	Rating Deficiency
Base Scenario	0.68	0.60	0.08
Uranium City, Saskatchewan	0.55	0.87	-0.32
Toronto, Ontario	0.69	0.61	0.08
Vancouver, British Columbia	0.68	0.60	0.08
Halifax, Nova Scotia	0.66	0.52	0.14
Biotope Area Factor (Berlin)	0.77	0.60	0.17

This design has a difference of 20% between all of the various cities. This design does meet the objective of all the cities except Uranium City. Some of the overhang features could reduce a little bit to save money and reduce the rating. This example demonstrates an increase in score when there is an increase in the green roof area by introducing a cantilever and casting a shadow on the road which is the most negative scoring points. This design response does not provide as much of a benefit to Uranium City though. The reason for such a smaller increase in score for Uranium City is due to the scores for sealed surfaces being the same in sunlight or shade, thus the additional effort to cast a shadow has no effect on this region.

This design would meet the minimum requirements for the BAF. Halifax's deficiency rating is very close to the BAF rating. The increase of a large overhang which shades the sealed surfaces raises all of the ratings for the Sustainable Site System.

Design #6

Design #6 encompasses 31% of the ground plane site area, the second lowest of all the examples. The total green roof accounts for 38% of the site area, the second highest of all the examples. There are two large planting areas on the along the south side of the building as well as two smaller planters underneath the bridge, this connected vegetation accounts for 23% of the site area. This building also has 1000m^2 of green walls along the south side of the building. There are a total of 20 trees planted on the site. The sidewalk is constructed using interlocking pavers. This building design uses a single large bridge to join the east and west towers. The bridge is constructed adjacent to the sidewalk to maximize the shading potential. Through the use of the bridge there is addition space on the ground plane which can be used for vegetation and trees.

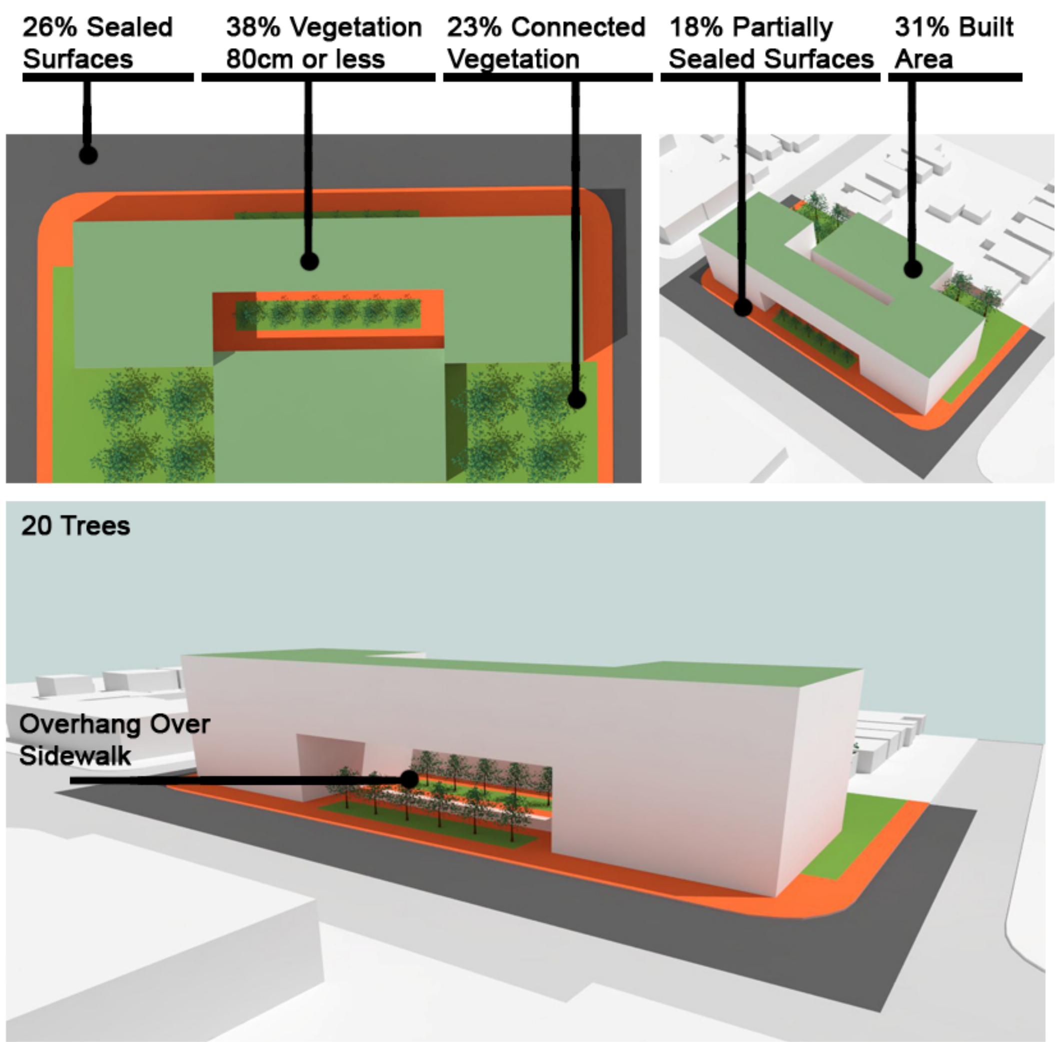


Figure 4-21 - Design #6 Plan and Perspectives

Table 15 - Sustainable Site System Rating for Design #6

Location	Design Rating	New Projects Rating	Rating Deficiency
Base Scenario	0.65	0.60	0.05
Uranium City, Saskatchewan	0.57	0.87	-0.30
Toronto, Ontario	0.66	0.61	0.05
Vancouver, British Columbia	0.64	0.60	0.04
Halifax, Nova Scotia	0.63	0.52	0.11
Biotope Area Factor (Berlin)	0.67	0.60	0.07

This design has a difference of 14% between all of the various cities. This design does meet objective of all the cities except Uranium City. Features could be reduced save money and reduce the rating. Toronto performed the best and Uranium City performed the worst. This example has a reduced score compared to design #5, this is due to the reduction in green roof area as well as the building is not tall enough to cast a shadow onto the street, for these reasons the scores for Toronto, Vancouver, and Halifax have decreased. The score for Uranium City has increased as a result of an increase in the ground floor vegetation.

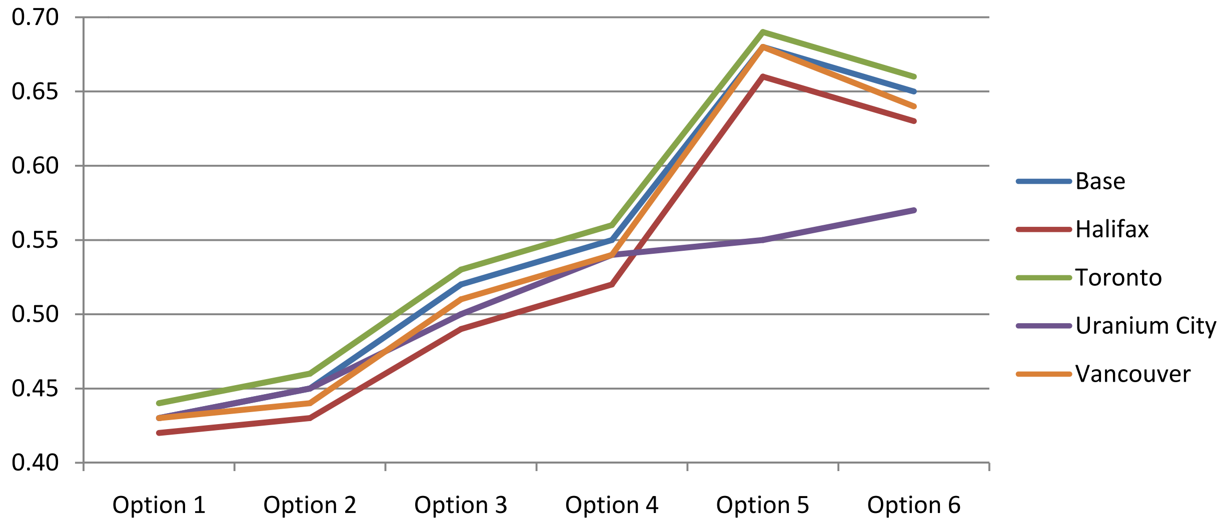
This design would meet the minimum requirements for the BAF. Halifax's deficiency rating is higher than the BAF rating. The increase of a large overhang and building higher along the property line on the north which shades the sealed surfaces raises all of the ratings for the Sustainable Site System.

Summary of Climate Application Study

The impact of the various climates has led to a couple of conclusions. First, the impact of shading asphalt is only effective in regions which have problems with the Heat Island effect. Second, the addition of connected vegetation is important to any site in any climate. Sometimes extreme designs will achieve a similar rating as a well-planned generic design. This system does not require that all buildings become super-buildings; rather, the financial costs can be controlled while the designer can take into consideration local issues.

The rates achieved in the various regions are different (Table 16), which demonstrates that the system is responsive to different climates. The scale of the differences also change which demonstrates that the system responds in relation to the input data. The order of the cities performances for the different designs also changes, this demonstrates that the different input importance in the different regions.

Table 16 - Summary of Application Ratings



Berlin's Biotope Area Factor does not account material properties as finely as the Sustainable Site System. The Sustainable Site System considers additional properties such as: sun/shade, material tone, native/non-native vegetation, and maintenance levels. This additional layer or filtering the materials makes the Sustainable Site System more stringent and requires additional design considerations.

5.0 Application of the Sustainable Site System

5.1 Public Street Study

Public area will be considered separately in order to understand the implications of the rating of different street designs. These designs may only be applicable to some locations. There are two studies which will be done.

5.1.1 Primary Streets

The site dimension under consideration is the city's right-of-way which is 100 meters long and 26 meters wide.

Existing Main Streets- Rating -0.37

The existing main street has the worst rating among all of the examples provided. This rating is due to the lack of vegetation. This main street is seen throughout the high density areas of many cities. It is often difficult to incorporate connected vegetation when there are services which are directly under the road and sidewalk.

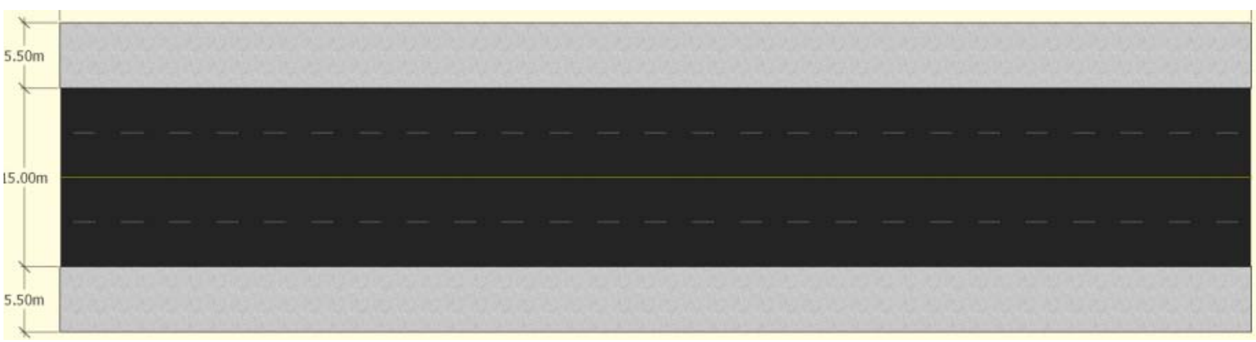


Figure 5-1 - Primary Street - Existing Main Street Example

Properties

- 5.5m wide sidewalks on the North and South sides of the street
- 15m wide road with two driving lanes in each direction

Option 1 – Rating -0.27

Option 1 moves the street so that it is asymmetrical to the sidewalks to the south and north. This idea makes the sidewalk wide enough on the north such that it can incorporate large planters, but these planters cannot be continuous due to the pedestrian access for exiting vehicles. A similar project recently completed by the Bloor Yorkville BIA in Toronto (Figure 5-4 & Figure 5-3).

Figure 5-2 - Primary Street - Option 1

Properties

- 7m wide sidewalk on the North with large planters with low maintenance native plants and trees
- 4m wide sidewalk on the South side of the street
- 15m wide road with two driving lanes in each direction

Precedents

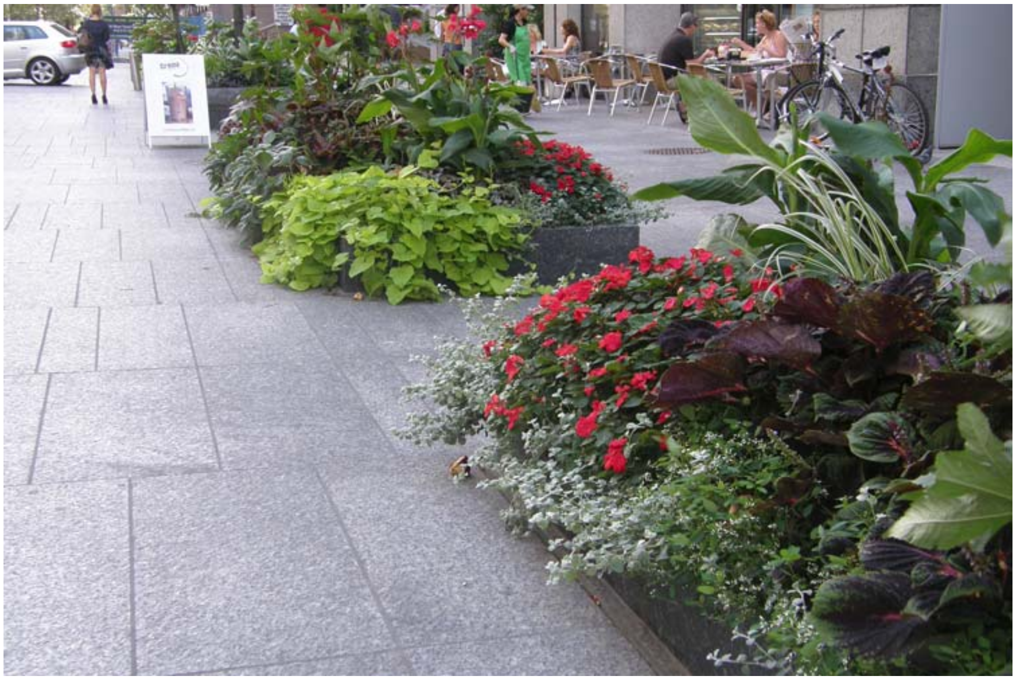


Figure 5-3 - Bloor Street Renovation Image #1, Toronto

Source: (BIA, 2011)

Figure 5-4 - Bloor Street Renovation Image #2, Toronto

Source: (BIA, 2011)

Option 2 - Rating -0.02

Option 2 introduces a 5m wide center island with trees. In order to introduce a large center island the sidewalks on each side of the street must get smaller. In some instances of existing development this option may not be possible. Some sidewalks require more than 3 meters due to the quantity of pedestrian. This option is similar to the design of the green island on the median on University Avenue in Toronto (Figure 5-9).

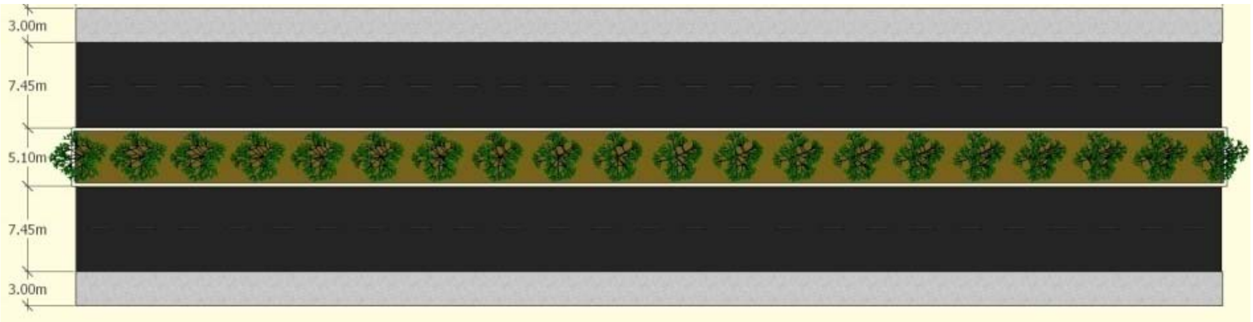


Figure 5-5 - Primary Street - Option 2

Properties

- 3m wide sidewalks on the North and South sides of the street
- 5m wide center island with trees and low maintenance native planting
- 7.5m wide road with two driving lanes on each side of the center island

Precedents

Figure 5-6 - University Avenue, Toronto

Source:(Villagelynx, 2011)

Option 3 - Rating -0.11

Option 3 uses the same principles as option 2. This option integrates a bike path in a portion of the center island. The introduction of a bike lane adds to a higher density of traffic.

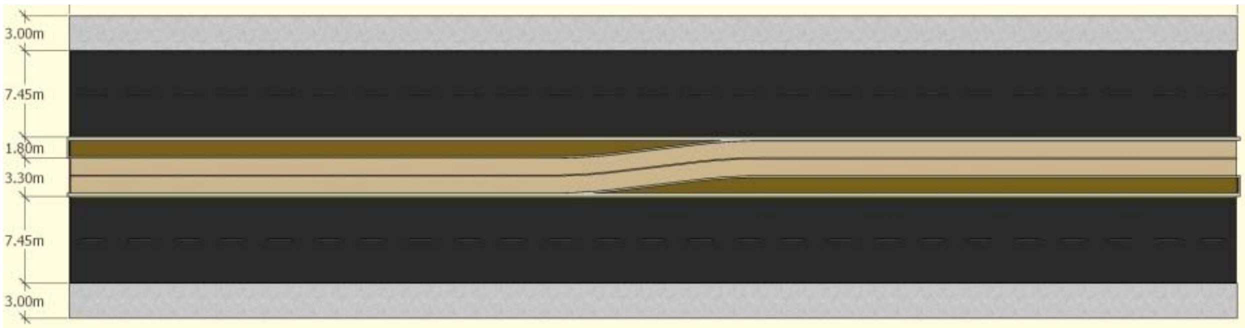


Figure 5-7 - Primary Street - Option 3

Properties

- 3m wide sidewalks on the North and South sides of the street
- 5m wide center island with 3m two-way bike lane and 2m continuous planter with low maintenance native planting
- 7.5m wide road with two driving lanes on each side of the center island

Precedents

Figure 5-8 - Various Bike Lane Designs

Source:(Villagelynx, 2011)

5.1.2 Tertiary Streets

The site dimension under consideration is 100 meters long with the cities right-of-way at 20 meters wide. Below is a graph demonstrating the rating which each of the tertiary street designs have achieved.

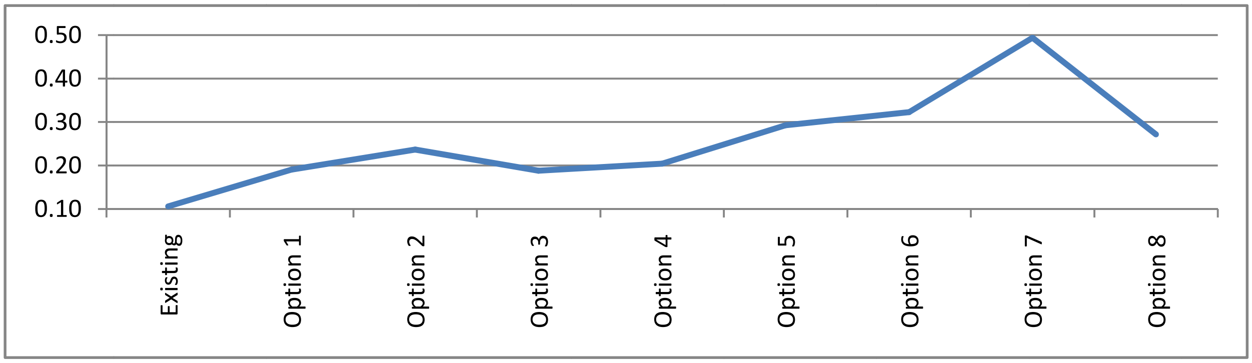


Figure 5-9 - Tertiary Street Rating

Existing Street - Rating 0.11

The existing tertiary street for this study has two driving lanes and a single parking lane. There is a tree planted every 10 meters on both sides of the street.

Figure 5-10 - Tertiary Street - Existing Tertiary Street Example

Properties

- 1.8m wide sidewalks on the North and South sides of the street
- Trees and maintained grass is used for the vegetated area
- 8.3m wide road with one driving lane in both directions and one parking lane

Option 1 - Rating 0.19

Option 1 reduces the street to a one-way street with a single parking lane. This reduction is a realistic proposal which can be introduced with the cities regular maintenance program.

Figure 5-11 - Tertiary Street - Option 1

Properties

- 1.8m wide sidewalks on the North and South sides of the street
- Trees and maintained grass is used for the vegetated area
- 5.8m wide road with one driving lane in one direction and one parking lane

Option 2 - Rating 0.24

Option 2 is the same as option 1 with one exception. There is a reduction of 50% in parking and an addition of additional green space. This change increases the rating by 21% compared to option 1.

Figure 5-12 - Tertiary Street - Option 2

Properties

- 1.8m wide sidewalks on the North and South sides of the street
- Trees and maintained grass is used for the vegetated area
- 5.8m wide road with one driving lane in one direction and one parking lane with planters at points

Option 3 - Rating 0.19

Option 2 is the same as the existing site one exception. There is a reduction of 50% in parking and an addition of additional green space. This change increases the rating by 42% compared to the existing site.

Figure 5-13 - Tertiary Street - Option 3

Properties

- 1.8m wide sidewalks on the North and South sides of the street
- Trees and maintained grass is used for the vegetated area
- 8.5m wide road with one driving lane in both directions and one parking lane with planters at points

Option 4 - Rating 0.20

Option 4 removes all parking and leaves both lanes of driving. This rating is 45% higher than the existing option by the removal of the parking.

Figure 5-14 - Tertiary Street - Option 4

Properties

- 1.8m wide sidewalks on the North and South sides of the street
- Trees and maintained grass is used for the vegetated area
- 5.6m wide road with one driving lane in both directions

Option 5 - Rating 0.29

Option 5 further reduces the streets profile by making it only one lane in one direction. This study doesn't allow for any parking at all. Option 5 has a rating that is 31% higher than option 4 due to the further reduction of the street.

Figure 5-15 - Tertiary Street - Option 5

Properties

- 1.8m wide sidewalks on the North and South sides of the street
- Trees and maintained grass is used for the vegetated area
- 3m wide road with one driving lane in one direction

Option 6 - Rating 0.32

Option 6 terminates the street at the half way point allowing access only from the secondary street. This reduced the amount of asphalt. This provides an opportunity to plant an additional 6 trees. Willow Walk in Compton, California has a central parking with walkways to the townhomes (Figure 5-17).

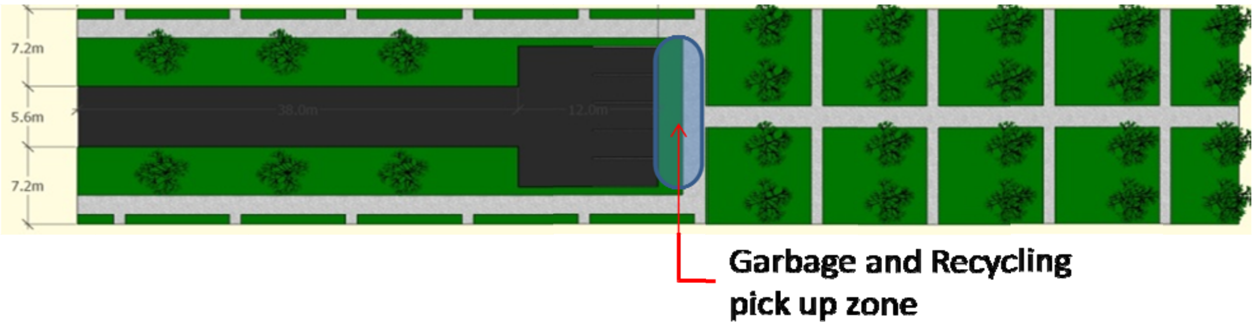


Figure 5-16 - Tertiary Street - Option 6

Properties

- 1.8m wide sidewalks on the North and South sides of the street and a single center sidewalk when there is no street
- Trees and maintained grass are used for the vegetated area
- 5.6m wide road with one driving lane in both directions which ends in a dead-end with parking

Precedents


Figure 5-17 - Willow Walk Town homes in Compton, CA

Source:(NHS, 2011)

Option 7 - Rating 0.49

Option 7 removes the street completely and allows for parking off of the secondary street only. This proposal adds an additional 8 trees to the existing study site. The additional green space which has been created could be used for additional programming such as community gardens, playground, Dog Park, and any other community initiatives. This option has the best rating with 0.47 (Figure 5-19).

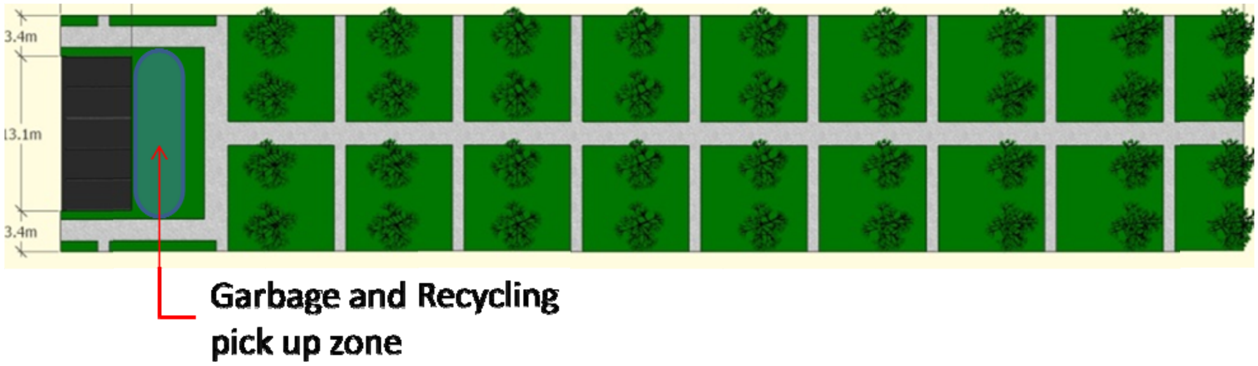


Figure 5-18 - Tertiary Street - Option 7

Properties

- 1.8m wide sidewalk in the center
- Trees and maintained grass is used for the vegetated area
- Parking spaces would be placed adjacent to Secondary Streets

Precedents

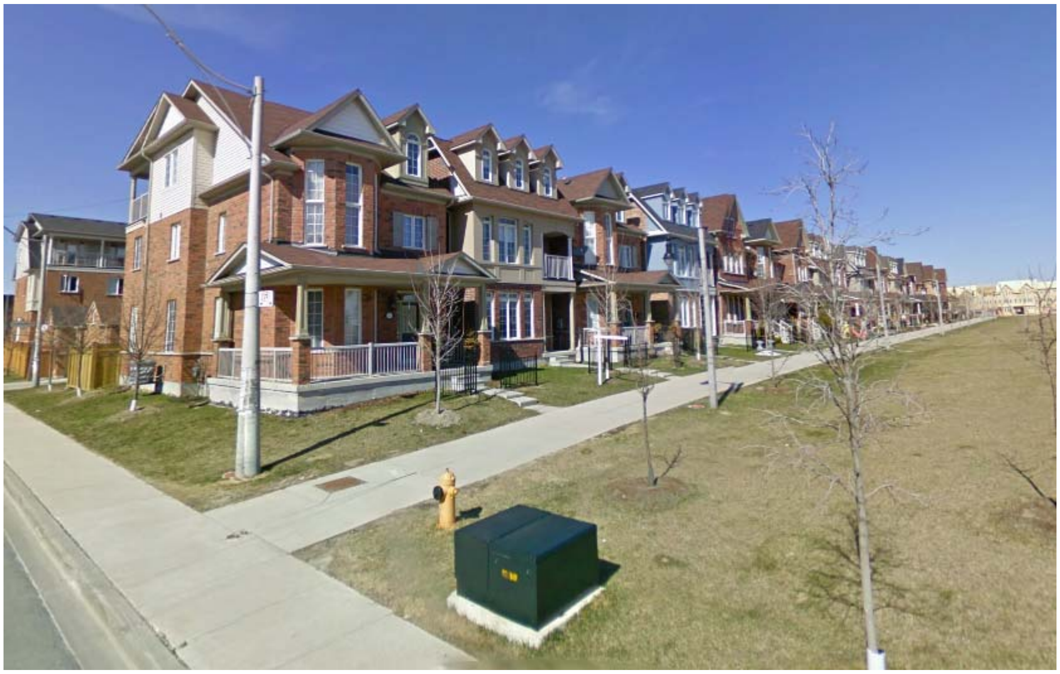


Figure 5-19 - New Houses Constructed without a street

Option 8 - Rating 0.27

Option 8 provides an extreme scenario if there were additional funds available and if there was a requirement for a street. This scenario places a roof above the road to shade the roadway. The additional roof area also provided additional space for vegetation. This proposal also maintains the 20 trees which the existing site has. The additional roof area has the potential to become a breading area for some animals. This benefit is not quantified within this system. The roof area can also be used as an amenity for the local community,

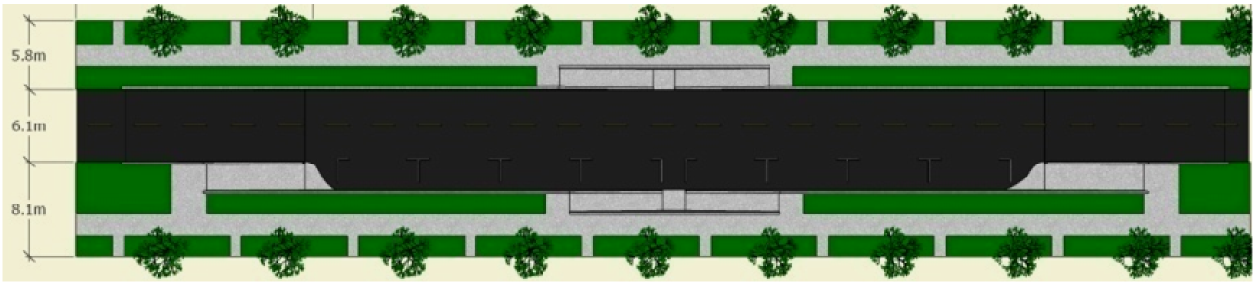


Figure 5-22 - Tertiary Street - Option 8 - Street Level

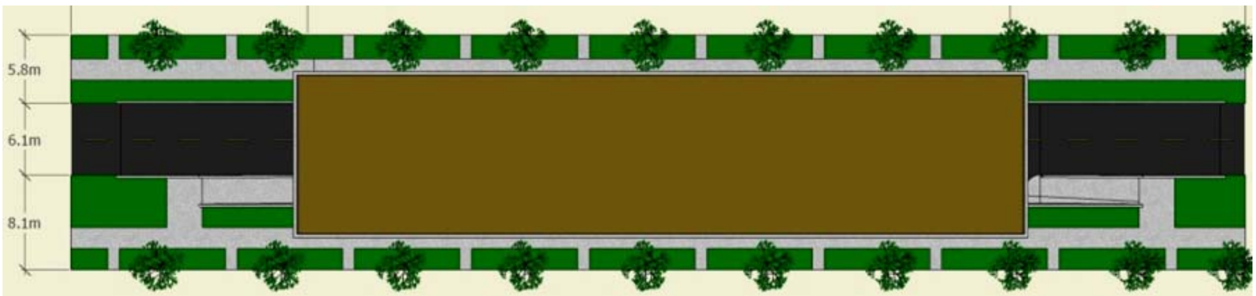


Figure 5-21 - Tertiary Street - Option 8 - Roof Plan

Figure 5-20 - Tertiary Streets - Option 8 - Section Perspective

Properties

- 1.8m wide sidewalks on the North and South sides of the street
- A depression of the street and an addition of a roofed area to shade parts of the ground plane
- Trees and maintained grass is used for the vegetated area on the ground plane and low maintenance native plants and trees on the elevated plane
- 8.3m wide road with one driving lane in both directions and one parking lane

5.1.3 Summary

The primary street options which achieve a higher rating reduce the size of the sidewalks. This compromise may be acceptable if the projects adjacent to the street were to be redeveloped and the new buildings can be set back further, allowing for a wider sidewalk. The best ratting also maximizes the planting area including trees. An option which has not been addressed by this thesis would be the changing of the material tones. Making the asphalt a lighter tone would also increase the scoring. The important fact is that the existing street design without vegetation is the simplest item to change and it is not difficult to add planters to the existing sidewalks.

The tertiary street option showed that by reducing parking or removing a driving lane can have a significant impact on raising the score. Also by terminating the street half way or removing it completely has the best impact for the score, but these streets must not have a high volume of traffic, pedestrian or vehicular. In addition each household would have to take their garbage bins to a common pickup point instead of leaving them in front of their own homes; this would benefit the garbage pickup services which would save travel time to each house individually. The introduction of a roof over the roadway does provide some benefit to the rating while maintaining a high level of traffic. There are also benefits for the breeding of small animals which is not picked up by this rating system.

The impact of the street rating appears to have a large variation from negating 0.37 to positive 0.49. This represents the hurdle which the building design must compensate for in order to achieve the rating which is required. The rating for primary streets is much lower than the tertiary street ratings; this lower score will require more design ingenuity than tertiary streets. It is more likely that the buildings which are adjacent to primary streets will be larger and have more opportunity to increase their score. The buildings off of the tertiary streets are assumed to be low-rise residential development; these developments will have more connected vegetation as a result, and their rating will not require many additional design considerations.

6.0 Architectural Impact

The impact of the Sustainable Site System on architecture must be understood. While there was an early study done to understand the large gestures of architectural form and massing the specific designs of a building must also be investigated and understood. This study will look at the impact on existing developments and their ratings as well as proposals for new developments using some of the most progressive architectural forms which claim to be ecologically sensitive.

6.1.1 Architectural Design Study

The Crossroads of the Danforth BIA has been selected for the area of research due to the City of Toronto's recent Avenue Study (Figure 5-23). This location is in the East end of Toronto. The City of Toronto has established that this area is set for a complete redevelopment along Danforth Avenue from Victoria Park Avenue in the West to Warden Avenue in the East. This means that the majority of the existing two storey buildings will be demolished and rebuilt with taller buildings varying from 6-12 stories. The following research has been completed using the Toronto rating system which was developed.

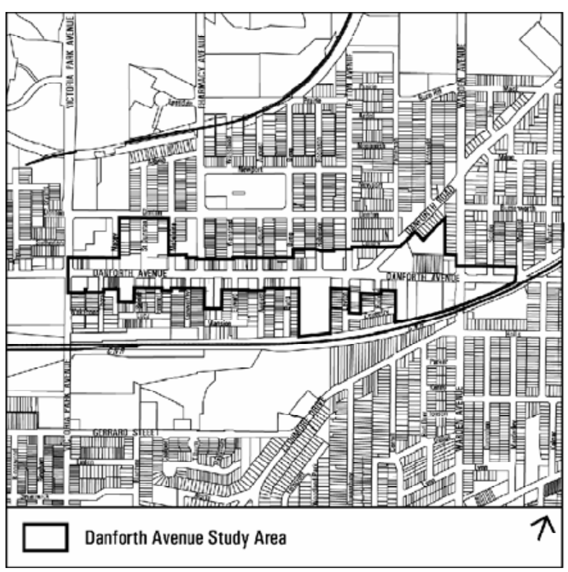


Figure 5-23 - Danforth Avenue Study Area

Source:(City of Toronto, Danforth Avenue Study – Victoria Park Avenue to Medford Avenue – Official Plan, Zoning – Final Report, 2007)

An area in the south west corner of the Danforth Avenue Study has been chosen for study due to the high area of parking, two playgrounds, existing single family dwellings, and a vehicular storage area which can be reclaimed. Immediately to the south of the study area are the C.N.R. tracks and to the north is Danforth Avenue.

Figure 5-24 - Study Area

The study area has been subdivided into seven sub areas. Studies of high density towers, existing low density residential, new low density residential, park and re-naturalized areas will be applied to different blocks.

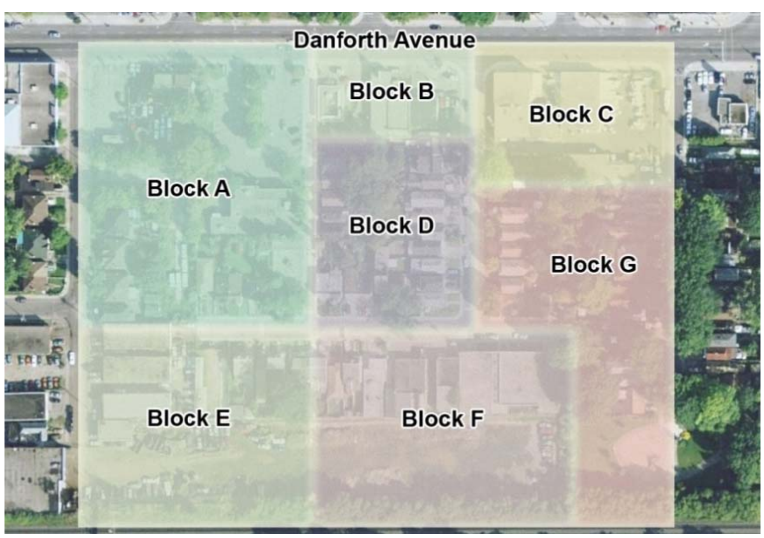


Figure 5-25 - Study Area Key Plan

Block A

Block A is the largest of all the study blocks with 13,460m^2. Currently this block houses approximately 40 people in 14 houses. There are four businesses which are also on the property, an LCBO, two used car salesmen lots and one long term vehicle storage lot. All of the business area have paved or gravel areas for vehicles use. These sealed surfaces are what provide the negative rating for this site.

The existing Sustainable Site System rating is **-0.20**

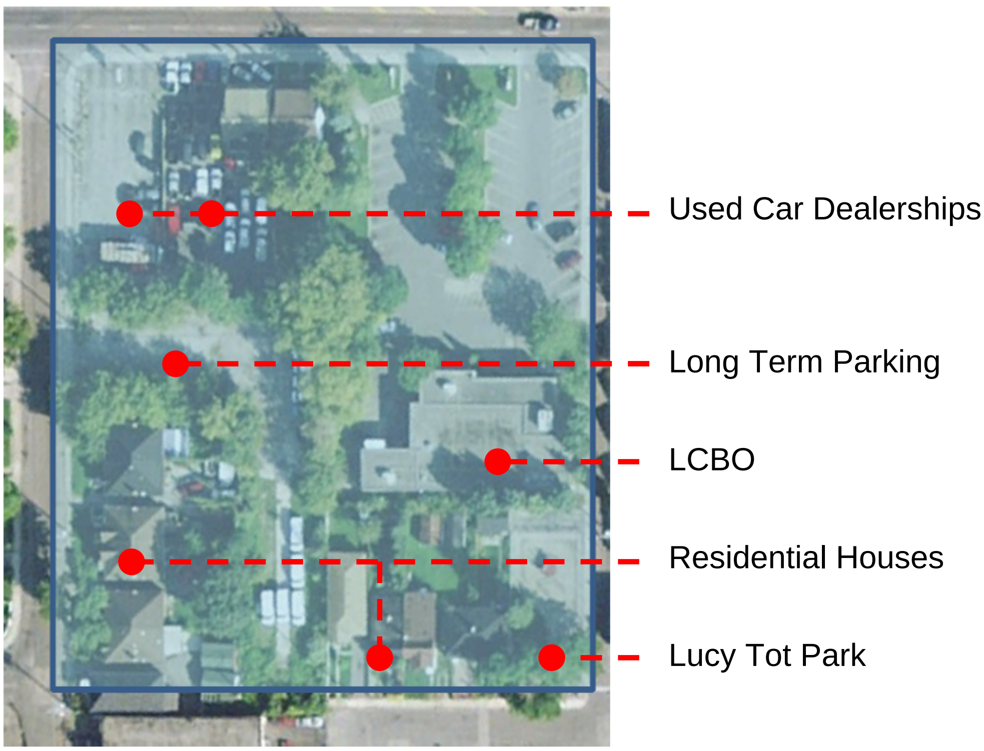


Figure 5-26 - Existing Block A Plan

Existing Site Statistics

Vegetation Connected	- 2900 m^2
Trees	- 44 Trees
Sealed Surfaces – under 25%	- 834 m^2
Sealed Surfaces – 25% - 75%	- 2188 m^2
Sealed Surfaces – over 75%	- 5701 m^2
Partially Sealed Surfaces – 25% - 75%	- 2067 m^2
Semi-open Surfaces – under 25%	- 7 m^2

Block A Precedent

Block A has taken its design inspiration from some of the newest condominium developments in Toronto. While these designs are basic in their form, it will be a good judge of the system to see what additional design parameters would be needed to achieve the required rating.

Figure 5-28 - Verve Condo - 2009 Completion

Figure 5-27 - Quartz Condo - 2011 Completion

Figure 5-29 - The Station Condo - 2011 Completion

Source: (URT, 2011)

Block A Design

Block A proposal has a single point tower with 26 storeys of resident and a 3 storey podium with walk-up town homes. There is also another 3 storey walk-up town homes adjacent to the tower. There is a 5 storey residential building adjacent to Danforth Avenue at the north side of the site. There are 328 residential units for a potential 820 tenants; there is also 1,500 m^2 of retail space fronting on Danforth Avenue. The existing single family homes along Lucy Avenue were retained but the dead end portion of Lucy Avenue was eliminated and an area of natural vegetation was placed, the existing Lucy Avenue tot park provides the area with sufficient amenity space for children to play. Danforth Avenue will also have a median planter dividing the east and west traffic. All of the proposed buildings will have a natural green roof, while the backyards to the existing houses and some of the new town homes while have high maintenance grass. There is

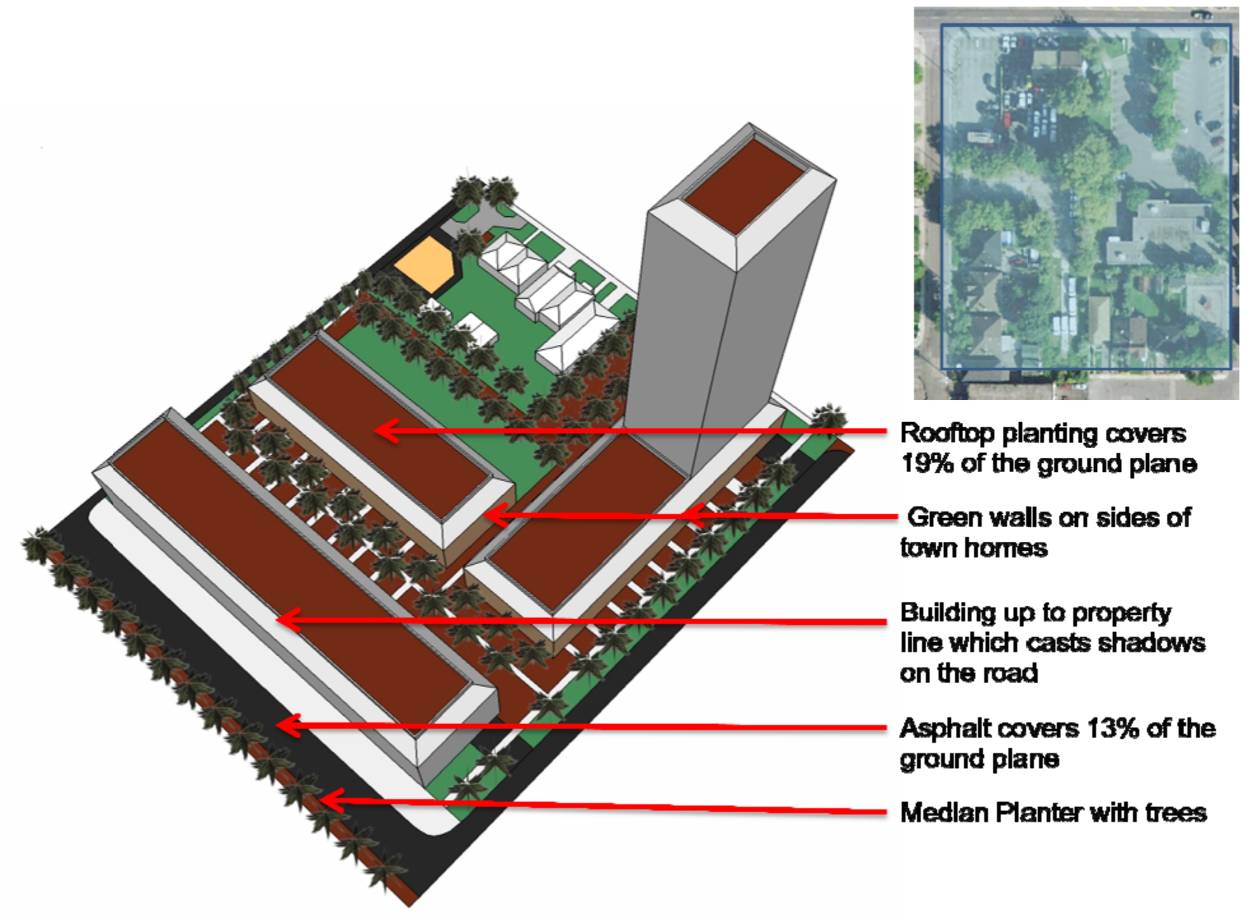


Figure 5-30 - Proposed Block A

an area to the east of the tower which will have a naturalized planting with trees to

Table 17 - Block A Material Statistics Comparison

Material	Existing	Proposed	Difference
Vegetation 80mm or less	0 m^2	3534 m^2	+ 3534 m^2
Vegetation Connected	2900 m^2	4861 m^2	+ 1961 m^2
Vertical Vegetation	0 m^2	3000 m^2	+ 3000 m^2
Trees	44 Trees	79 Trees	+ 35 Trees
Sealed Surfaces – under 25% tone	834 m^2	3008 m^2	+ 2174 m^2
Sealed Surfaces – 25% - 75% tone	2188 m^2	556 m^2	- 1632 m^2
Sealed Surfaces – over 75% tone	5701 m^2	1744 m^2	- 3957 m^2
Partially Sealed Surfaces – 25% - 75% tone	2067 m^2	116 m^2	- 1951 m^2
Semi-open Surfaces – under 25% tone	7 m^2	0 m^2	- 7 m^2
Rating	**-0.20**	**+0.60**	**+ 0.80**

provide an area for birds and squirrels to use.

Block A utilizes the reduction of sealed surfaces which existed from the parking area and replaces it with more connected vegetation. There is an increase in building footprints which reduces the potential for the connected vegetation; there is an introduction of green roofs on top of all the proposed buildings. The placement of the tower at the south side of the site does not help with the rating due to the fact that it casts shadows onto vegetated areas and not on sealed surfaces. Block A did not achieve the required site rating by the building and site designs alone there is a need for 3000m2 of vertical vegetation which provided an additional 0.16 points to the total rating.

Block A design is successful in achieving the needed rating while also meeting the density which the City of Toronto has set out for this site.

Block B

Block B is the smallest of all the study blocks at only 4500m^2. It has two automotive repair shops and a car rental business. This block is completely covered in asphalt and buildings. This small block has a large percentage of roadways on it and will test how a site may react to such a negative rating.

The existing Sustainable Site System rating is **-0.40**

Figure 5-31 - Existing Block B Plan

Existing Site Statistics

Sealed Surfaces – under 25% tone	- 196 m^2
Sealed Surfaces – 25% - 75% tone	- 786 m^2
Sealed Surfaces – over 75% tone	- 2061 m^2

Block B Precedents

The views of buildings wrapped in trees and flowers are one that relates back to the individual user of the building. Instead of introducing a monolithic for which determines the image of the building these designs allow for the user to use their balconies to define the architecture and image.


Figure 5-33 - Buenos Aires (2007)


Figure 5-32 - Esplanade Ave. New Orleans (2010)


Figure 5-34 - Cuajimalpa Tower, Mexico (2009)

Source: (Villagelynx, 2011)

Block B Design

Block B is 9 storeys tall and will house approximately 200 people. The existing single storey buildings along with their parking areas will be completely removed. The ground floor area will be devoted to retail, access to underground parking and building services. The goal of this design is to use vegetation on the balconies to shade the building and to provide an ever-changing dynamic to the building's exterior.

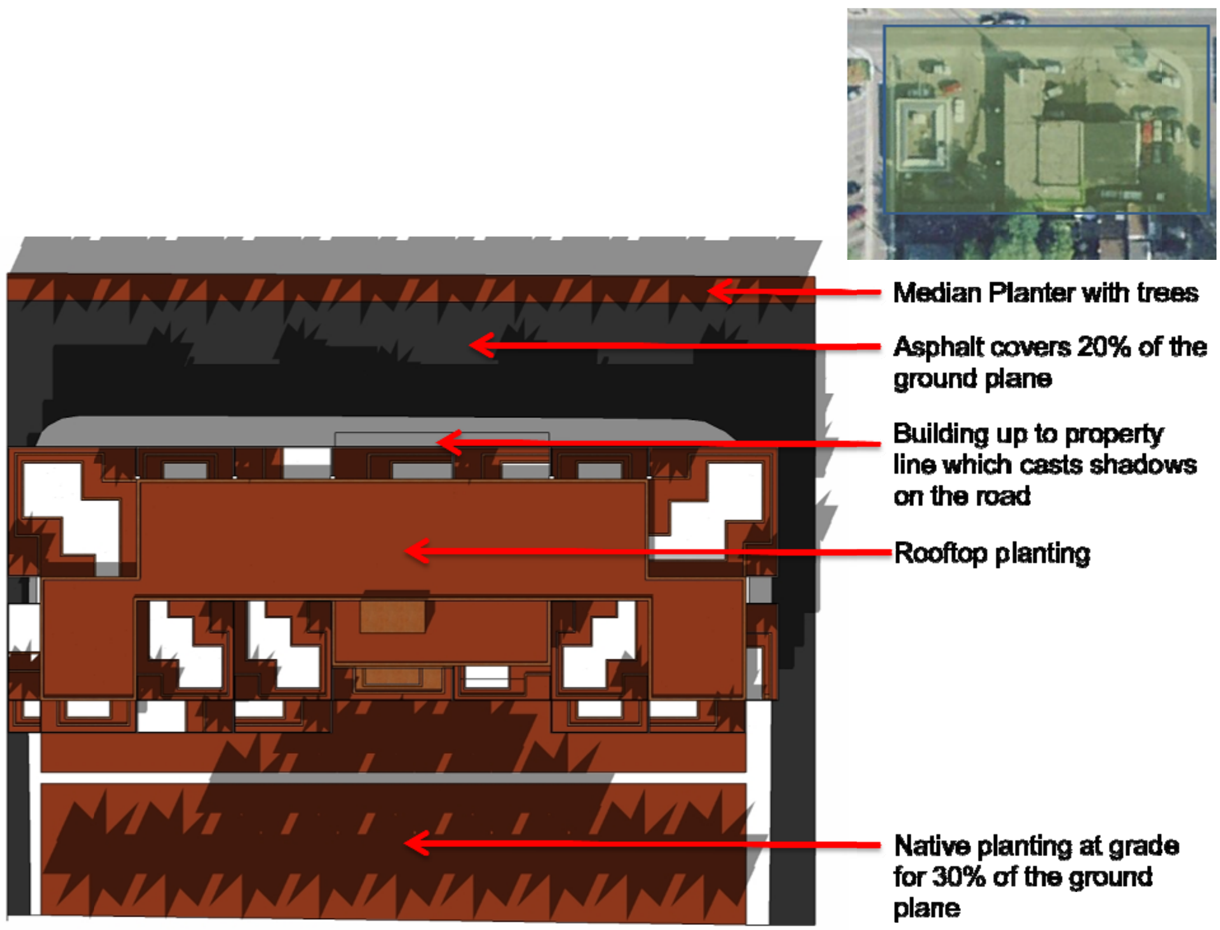


Figure 5-35 - Block B - Proposed Site Plan

Figure 5-36 - Rendering of Block B from Danforth Avenue

Figure 5-37 - Rendering of Block B - Balconies

Balconies

There are four variations of balconies on Block B. The design of these balconies is to provide the residents with an opportunity to have their own garden adjacent to their unit. These balconies are not attached to every unit. There are three different sizes to the balconies. The first is one which is the largest would be placed on top of a roof area and would serve the resident adjacent to it. The units which would have this balcony would be larger. This balcony design has two tree planters as well as additional shallower planters for other vegetation. The second balcony design would be used on corner units and would wrap the corner of the building. This balcony has two tree planters as well as shallower planters for additional vegetation. The third and fourth balconies are for any other unit which does not have access to a roof area or a corner. The third balcony has a single tree planter as well as a shallower planter for additional vegetation. The fourth balcony has a deep and shallow planter, but the amount of soil in the deep planter is not sufficient for a tree to survive. The deeper planters can be used to plant shrubs or other bushes which the individual owner would choose.

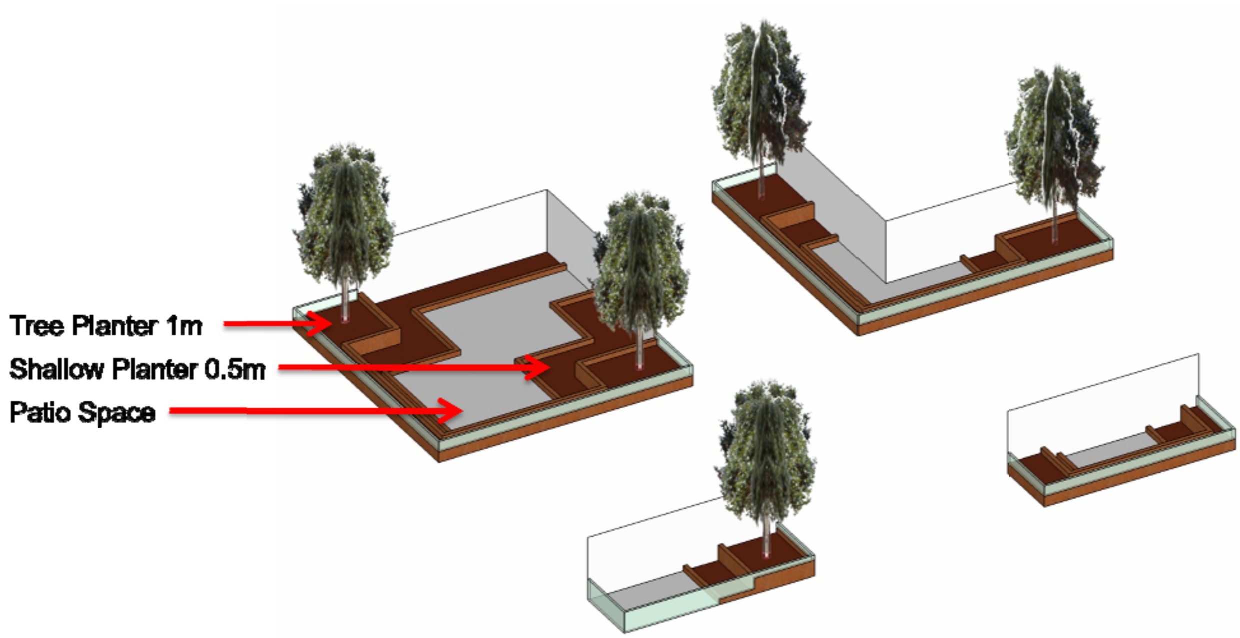


Figure 5-38 - Block B - Balcony Designs

Table 18 - Block B Material Statistics Comparison

Material	Existing	Proposed	Difference
Vegetation 80mm or less	0 m^2	1134 m^2	+ 1134 m^2
Vegetation 80mm or more	0 m^2	479 m^2	+ 479 m^2
Vegetation Connected	0 m^2	1616 m^2	+ 1616 m^2
Trees	0 Trees	50 Trees	+ 50 Trees
Sealed Surfaces – under 25% tone	196 m^2	1399 m^2	+ 1203 m^2
Sealed Surfaces – 25% - 75% tone	786 m^2	0 m^2	- 786 m^2
Sealed Surfaces – over 75% tone	2061 m^2	908 m^2	- 1153 m^2
Rating	**-0.40**	**+0.67**	**+ 1.07**

Block B uses just over 1000m2 of the ground floor area for the building. The left over space is then used for a native vegetation garden with trees on the south side of the building. This native vegetation accounts for 30% of the ground plane. Block B also introduces the same median planter on Danforth Avenue as seen in Block A. The building utilizes it tall northern facade to cast a shadow onto the road in order to reduce the negative points received. Block B also introduces larger balconies with deep planters which can be used for small trees and other vegetation. This additional area plus the green roof adds 0.26 to the overall rating for the site. This addition is instrumental in achieving the high rating for the project.

Block C

Block C is a moderate size which would be most applicable to a single large development. The site is 6160m^2 in area and has 50 meters site depth for construction. There is a single roofing supply company which owns and operates on the site. They have joined 2 buildings with a single addition. The entire site has asphalt in order to make it easier for trucks to move on the site.

The existing Sustainable Site System rating is **-0.39**

Figure 5-39 - Existing Block C Plan

Existing Site Statistics

Vegetation Connected	- 167 m^2
Sealed Surfaces – under 25% tone	- 458 m^2
Sealed Surfaces – 25% - 75% tone	- 1230 m^2
Sealed Surfaces – over 75% tone	- 2741 m^2

Block C Precedents

VM Bjerget by BIG Architects uses a stepped system for the residential units. This stepping allows the unit above it to use the roof of the unit below it as a garden and patio. This project has a sense of suburban mentality but in a tower design. The site which Block C is on is much smaller then this site and will have to make the outdoor space smaller.

Figure 5-40 - VM Bjerget, Copenhagen - View of Balcony

Figure 5-42 - VM Bjerget, Copenhagen - View of Balconies from below

Figure 5-41 - VM Bjerget, Copenhagen - View from Transit Station

Source: (BIG, 2011)

Block C Design

Block C is 12 storeys tall and will house approximately 250 people. The existing single storey buildings along with their paved storage areas will be completely removed. The ground floor area will be devoted to retail, access to underground parking and building services. The goal of this design is to maximize the amount of balcony space per unit, as well as to maximize the potential for trees on the balconies.

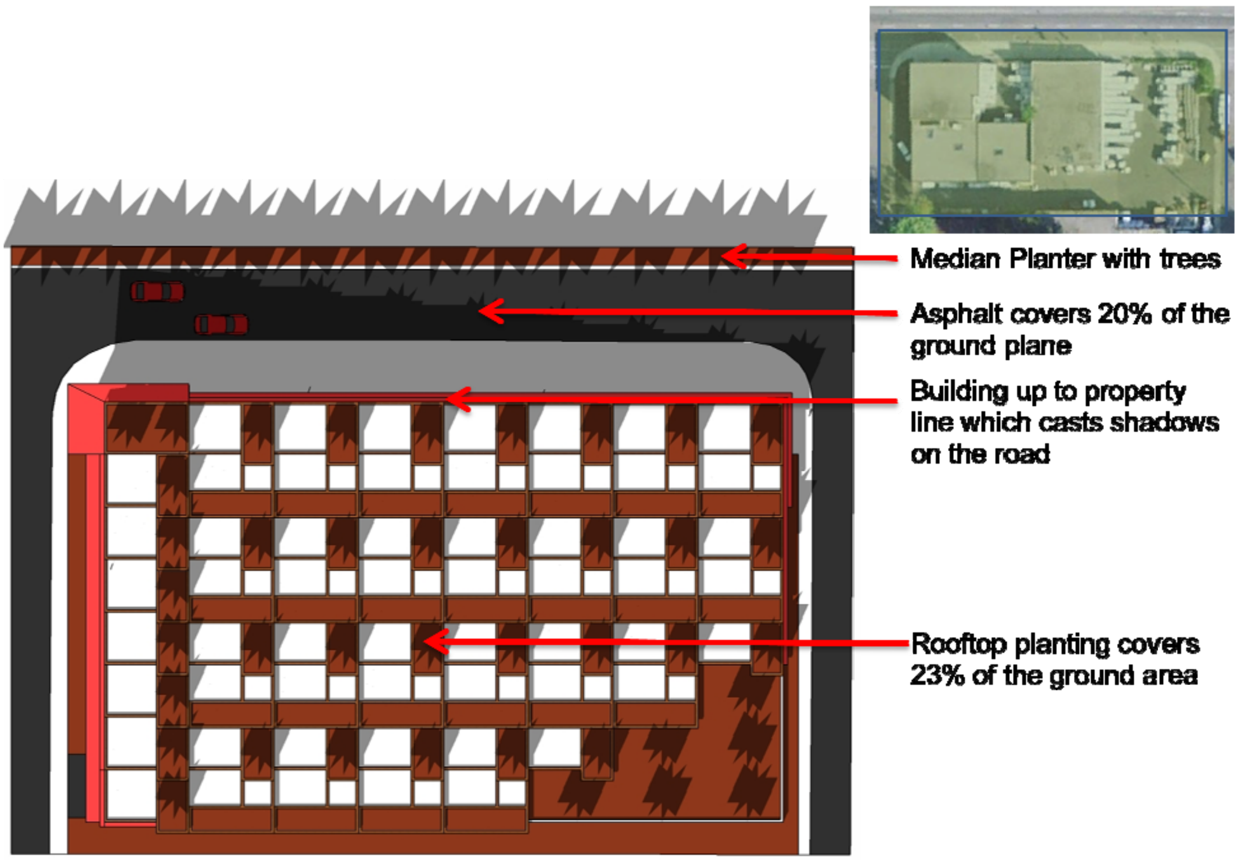


Figure 5-43 - Block C - Proposed Site Plan

Figure 5-44 - Rendering of Block C from Danforth Avenue

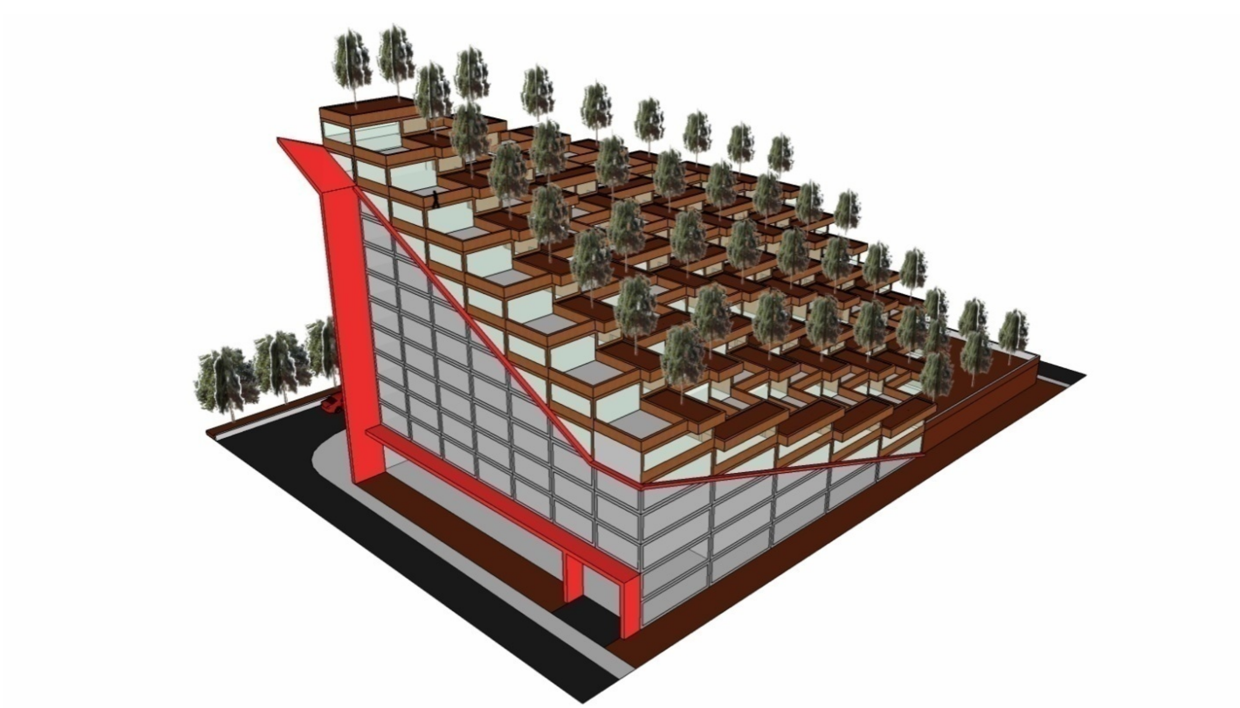


Figure 5-45 - Rendering of Block C - Balconies

Balconies

The balcony design allows for up to two units to use a balcony pod. Each pod has a large planter. In the preliminary design phase every other planter was used for a tree. As the rating for the site does not meet the requirement additional trees would have to be planted in the other planters as well. This increase in trees will add 0.15 to the overall rating. The planters have a small overhang which helps shade some of the sealed surface of the balcony below. If the sealed surfaces were to be replaced with a type of grass then the rating would increase by an additional 0.10, but for this design we will assume a concrete finish.

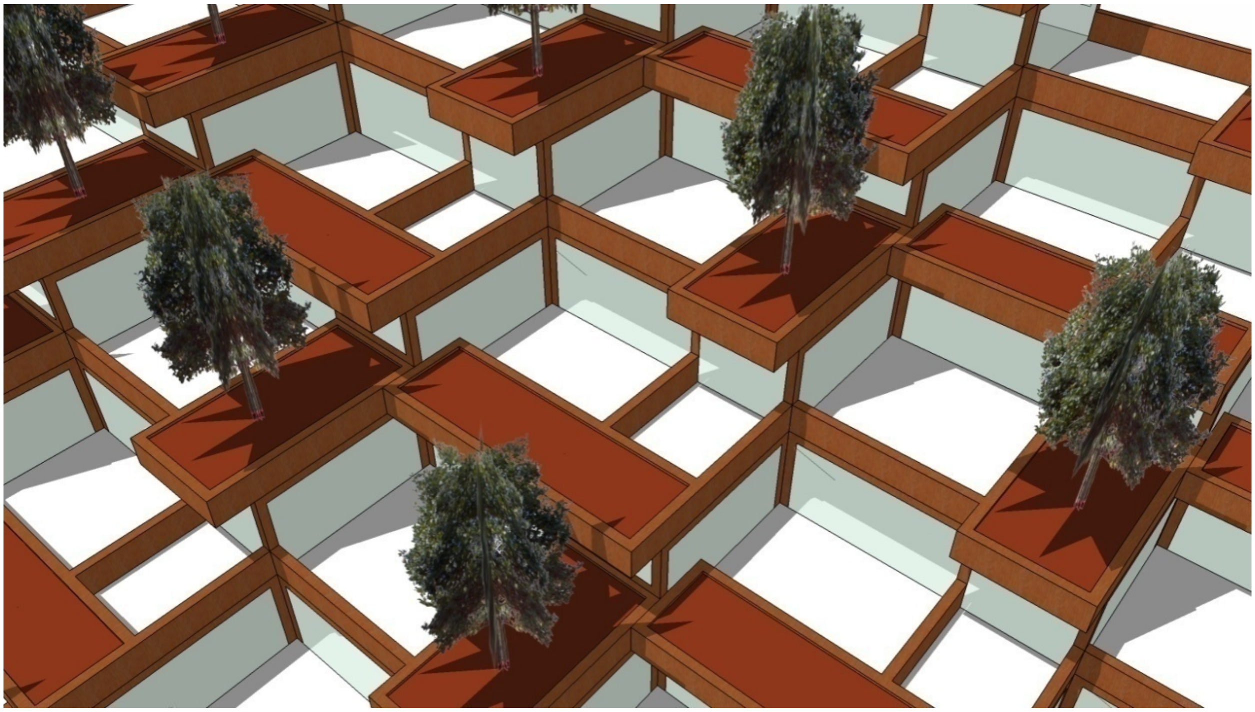


Figure 5-46 - Block C - Balcony Designs

Table 19 - Block C Material Statistics Comparison

Material	Existing	Proposed	Difference
Vegetation 80mm or more	0 m^2	1393 m^2	+ 1393 m^2
Vegetation Connected	167 m^2	711 m^2	+ 544 m^2
Vertical Vegetation	0 m^2	1085 m^2	+ 1086 m^2
Trees	0 Trees	90 Trees	+ 90 Trees
Sealed Surfaces – under 25% tone	458 m^2	1763 m^2	+ 1305 m^2
Sealed Surfaces – 25% - 75% tone	1230 m^2	0 m^2	- 1230 m^2
Sealed Surfaces – over 75% tone	2741 m^2	1243 m^2	- 1498 m^2
Rating	**-0.39**	**+0.58**	**+ 0.97**

Block C uses the entire buildable area and achieves a rating of 0.58, which is just below the City of Toronto's rating requirement. In order to achieve this rating there was a lot of gestures which would be very expensive to implement. The first is 1,085 m^2 of green walls along the first two storeys of the south and east sides of the building. The second is the amount of planters and trees required to boost the rating. This expense could have been avoided if there was more area on the ground plane for connected vegetation. The shading effect from the building did help a little in reducing the effect from the road. The balconies design also duplicated some area with the overhang of the planters above the balcony below. This overhang also shaded some of the concrete surfaces which would be used by the tenants.

Block D

Block D is the first of the single family dwellings. It is also the smallest of the areas to be considered for single family dwelling. This area houses 23 houses and about 60 people. This proposal will look at how to modify the existing area to achieve the required rating of 0.40 for a renovation.

The existing Sustainable Site System rating is **+0.10**

Figure 5-47 - Existing Block D Plan

Table 20 - Block D Material Statistics Comparison

Material	Existing	Proposed	Difference
Vegetation 80mm or less	0 m²	862 m²	+ 862 m²
Vegetation Connected	2310 m²	2310 m²	+ 0 m²
Trees	4 Trees	23 Trees	+ 19 Trees
Sealed Surfaces – under 25% tone	1848 m²	684 m²	- 1164 m²
Sealed Surfaces – over 75% tone	1085 m²	815 m²	- 270 m²
Partially Sealed Surfaces – under 25% tone	52 m²	360 m²	+ 360 m²
Rating	**+0.10**	**+0.43**	**+ 0.32**

Block D will introduce green roofs on some of the houses; while the roofs are sloped the green roofs will have to be extensive in design. The removal of asphalt for parking spaces will raise the rating, and crushed gravel will be used instead. Since most of the parking spaces are in direct sunlight, the use of semi-open surfaces instead would not raise the total rating due to the small area which it has. The change of the concrete sidewalk to interlocking pavers also has no effect on the overall rating, again due to the small amount of area involved.

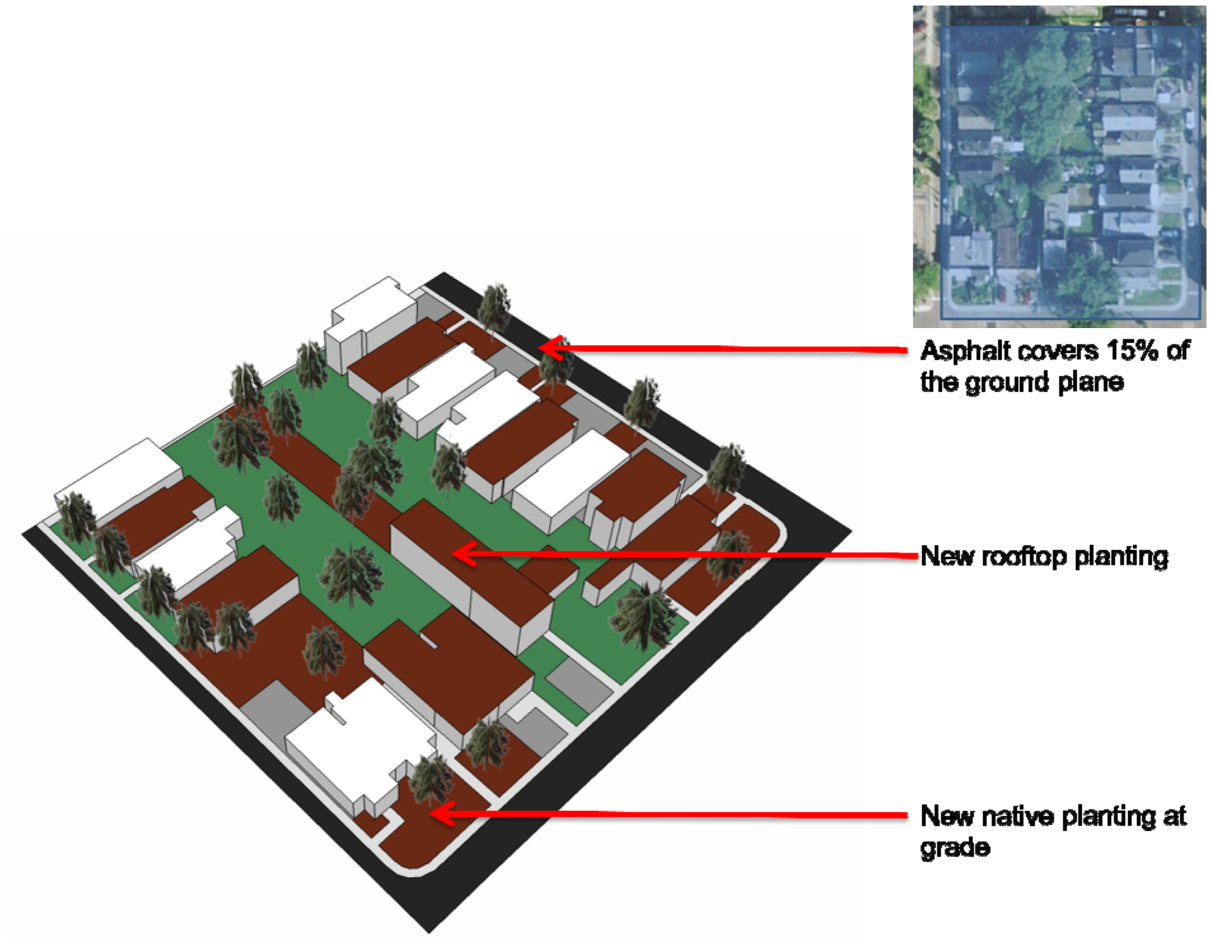


Figure 5-48 - Block D - Proposed Site Plan

Block E

Block E has 4 existing auto repair shops and 6 residential houses. The largest business on this block is an automotive junk yard which processes damaged vehicles for parts and scrap metal. This storage of vehicles requires a large amount of area and is not friendly to the ecological processes. For this study the area next to the railway which is at the south part of the site will be reclaimed to a natural habitat for indigenous animals. The businesses themselves will be demolished and new town homes will be built. The removal of two dead-end streets Lucy Avenue and Thora Avenue will be replaced by natural vegetation and trees.

The existing Sustainable Site System rating is **-0.30**

Figure 5-49 - Existing Block E Plan

Existing Site Statistics

Vegetation Connected	- 908 m^2
Trees	- 7 Trees
Sealed Surfaces – under 25%	- 199 m^2
Sealed Surfaces – 25% to 75%	- 1729 m^2
Sealed Surfaces – over 75%	- 2546 m^2
Partially Sealed Surfaces – under 25%	- 3319 m^2
Semi-open Surfaces – under 25%	- 2542 m^2

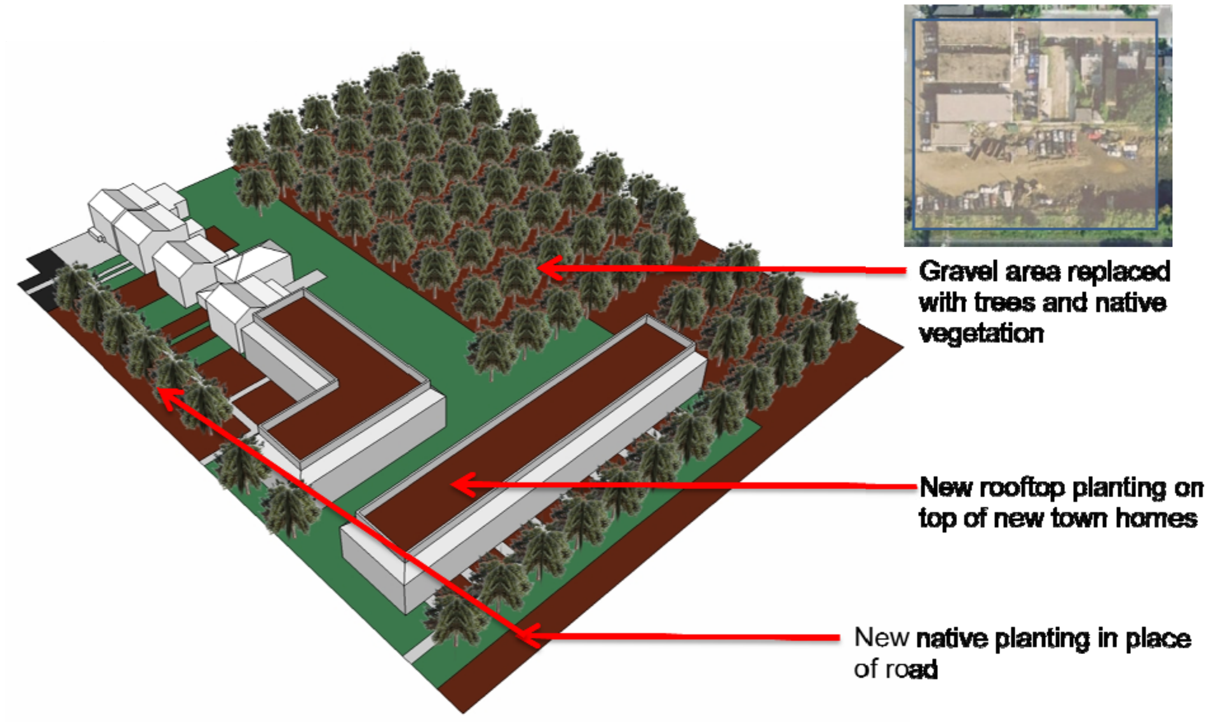


Figure 5-50 - Block E - Proposed Site Plan

The removal of unnecessary and underused streets can be a common response to raise the rating of an area. The city can do this while it undergoes regularly its scheduled maintenance program.

The added benefits include a safer area for children to play, a cooler microclimate, stronger bio-life, protection from winter winds and a more intimate environment. The addition of some parking spots can offset the removal of street parking. In the end it is possible for these units to become more desirable.

Figure 5-51 - Existing and Proposed Site Plan for the Removal of a Dead-end Street

Table 21 - Block E Material Statistics Comparison

Material	Existing	Proposed	Difference
Vegetation 80mm or less	0 m^2	803 m^2	+ 803 m^2
Vegetation Connected	908 m^2	8035 m^2	+ 7127 m^2
Trees	7 Trees	77 Trees	+ 70 Trees
Sealed Surfaces – under 25% tone	199 m^2	1392 m^2	+ 1193 m^2
Sealed Surfaces – 25% to 75% tone	1729 m^2	0 m^2	- 1729 m^2
Sealed Surfaces – over 75% tone	2546 m^2	96 m^2	- 2546 m^2
Partially Sealed Surfaces – 25% to 75% tone	3319 m^2	52 m^2	- 3267 m^2
Semi-open Surfaces – under 25% tone	2542 m^2	0 m^2	- 2542 m^2
Rating	**-0.30**	**+0.86**	**+ 1.08**

Block E has added 70 new trees and over 7000m^2 of connected vegetation. Block E has also removed over 7000 m^2 of sealed surfaces which would have drained rainwater directly into the storm sewer and to Lake Ontario. This change if applied as a city policy would be able to divert a lot of water and reduce the wear and tear on the storm water systems. With these moves, Block E has achieved a rating of 0.86 which is an improvement of 1.08 over the existing site.

Block F

Block F has 3 residential houses and two warehouses. For this study the area next to the railway which is at the south part of the site will be reclaimed to a natural habitat for indigenous animals, a total of 53 trees will be added to the site. The dead-end on Lucy Avenue will be removed like Block E and natural vegetation and trees will be planted. The flat roofs above the two warehouses and the last residential building will also receive a green roof. This proposal will look at how to modify the existing area to achieve the required rating of 0.40 for a renovation.

The existing Sustainable Site System rating is **-0.03**

Figure 5-52 - Existing Block F Plan

Table 22 - Block F Material Statistics Comparison

Material	Existing	Proposed	Difference
Vegetation 80mm or less	0 m²	2192 m²	+ 2192 m²
Vegetation Connected	1791 m²	5977 m²	+ 4186 m²
Trees	10 Trees	63 Trees	+ 53 Trees
Sealed Surfaces – under 25% tone	194 m²	200 m²	+ 6 m²
Sealed Surfaces – 25% to 75% tone	2486 m²	294 m²	- 2192 m²
Sealed Surfaces – over 75% tone	937 m²	358 m²	- 579 m²
Semi-open Surfaces – under 25% tone	3364 m²	0 m²	- 3267 m²
Semi-open Surfaces – 25% to 75% tone	36 m²	390 m²	- 354 m²
Rating	**-0.03**	**+0.90**	**+ 0.93**

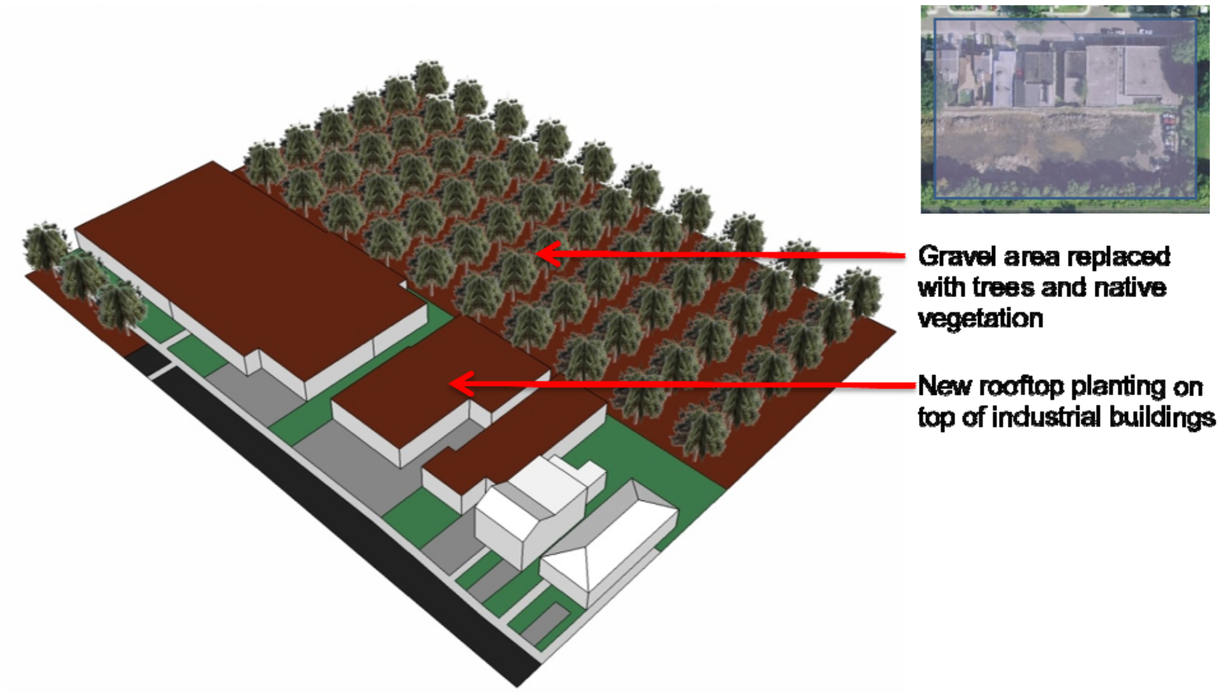


Figure 5-53 - Block F - Proposed Site Plan

Block G

Block G has 23 residential houses with approximately 65 people. There are only three items which will be introduced for this block. First, the grass in the park will be removed and natural vegetation will be used instead, secondly the addition of 15 trees in the park and along the streets, lastly the portion of Lucy Avenue which ends in a dead-end will be removed and replaced with natural vegetation. All of these items are realistic and not expensive or intrusive to the homeowners.

The existing Sustainable Site System rating is **+0.26**

Figure 5-54 - Existing Block G Plan

Table 23 - Block G Material Statistics Comparison

Material	Existing	Proposed	Difference
Vegetation Connected	5366 m²	5493 m²	+ 127 m²
Trees	30 Trees	45 Trees	+ 15 Trees
Sealed Surfaces – under 25% tone	834 m²	0 m²	- 834 m²
Sealed Surfaces – 25% to 75% tone	2191 m²	2191 m²	+ 0 m²
Sealed Surfaces – over 75% tone	1298 m²	954 m²	- 344 m²
Partially Sealed Surfaces – under 25% tone	0 m²	827 m²	+ 827 m²
Partially Sealed Surfaces – 25% to 75% tone	0 m²	213 m²	+ 213 m²
Semi-open Surfaces – under 25% tone	670 m²	670 m²	+ 0 m²
Rating	**+ 0.26**	**+0.35**	**+ 0.09**

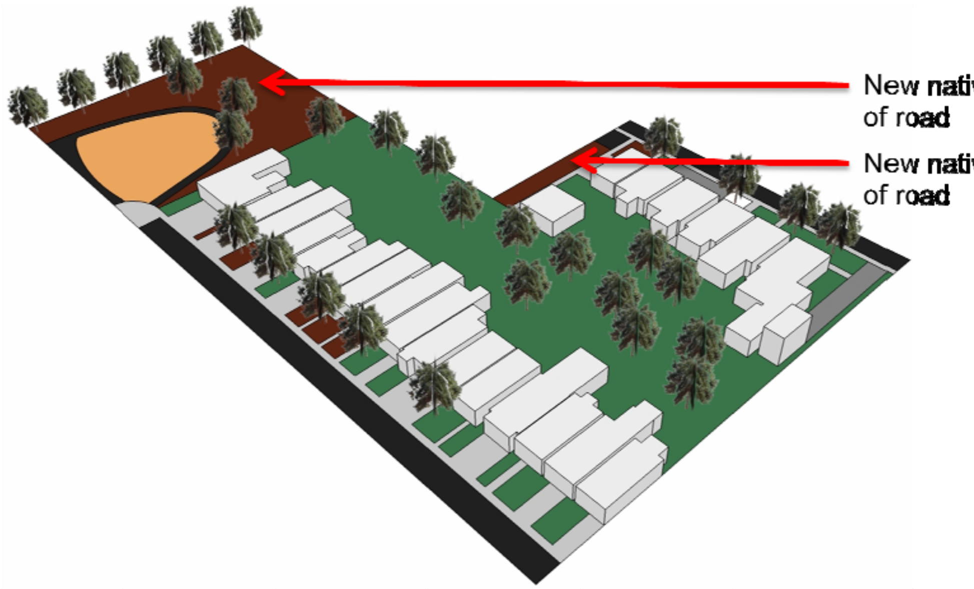


Figure 5-55 - Block G - Proposed Site Plan

The rating of 0.40 is not quite achieved in this design, there is a possibility of adding green roofs, or more native vegetation in backyards, this combination could raise the rating to 0.40. There is also terminating Kenworthe Avenue which currently terminates at the park 45 meters sooner and replaceing it with native vegetation and 7 trees would also achieve a rating of 0.40.

Study Area Summary

The existing rating for the entire study area was -0.10, this rating would be considered insufficient by the Site Standards System. With the removal of surface parking, removing dead end streets, replacement of a toxic automovie storage company and the addition to hundreds of trees the study area now has a rating of +0.63. This rating would be high enough for a new development. The ecological benefit in this area would benefit greatly over what was here before, the resultant bio-life has more space to flurish. This additional ecological area would increase the bio-diversity in the area. The amount of sealed surfaces was reduced and rainwater would now be able to be infiltrater the ground on site and not need to transported to the lake. The increase in the vegetation would increase the evapo-traspiration in the area and cool the ambient air, this in combination with all of the aformentioned design moves would reduce the effects of the UHI in this area.

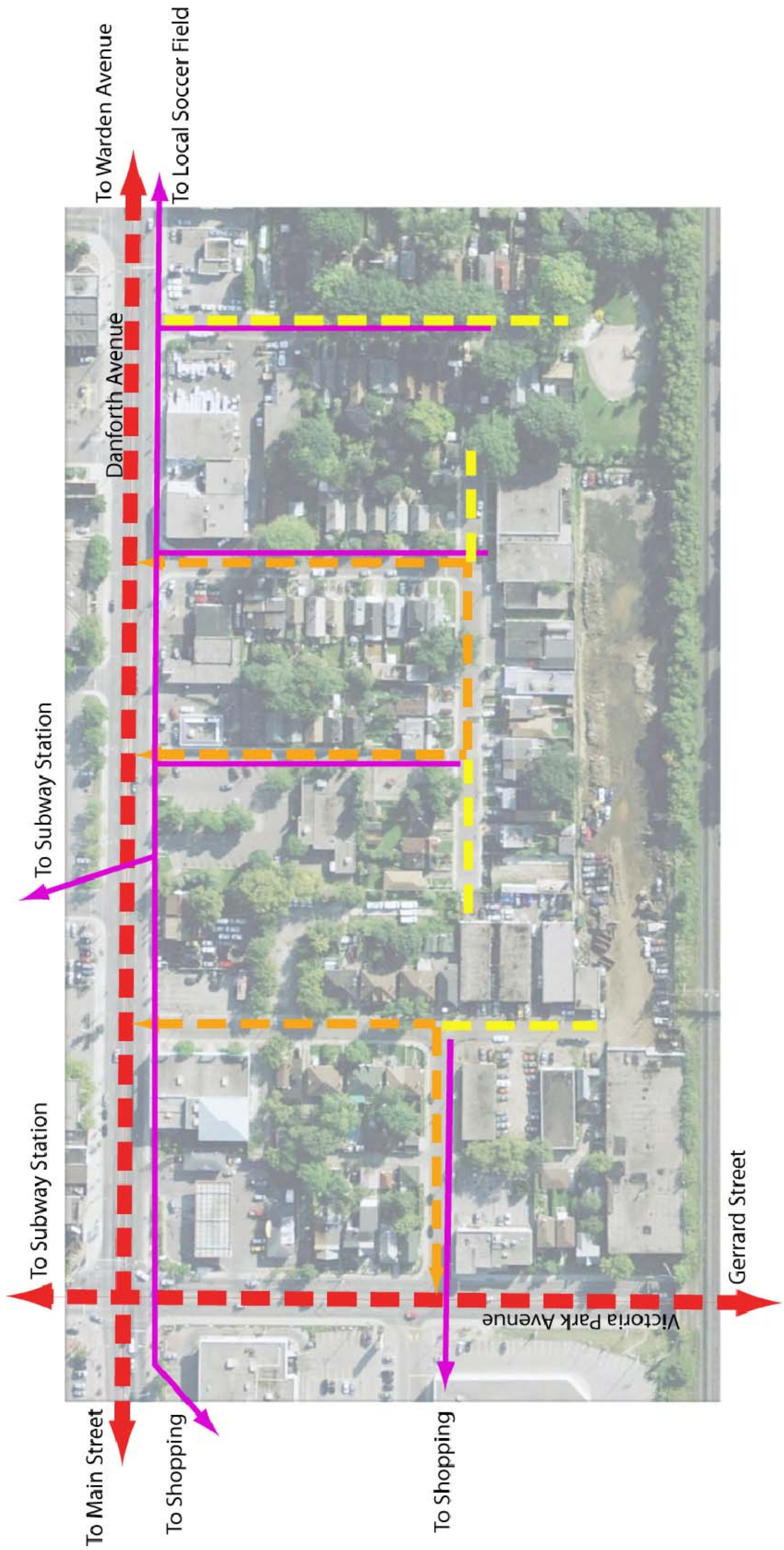


Figure 5-56 - Existing Site Plan for the Study Area

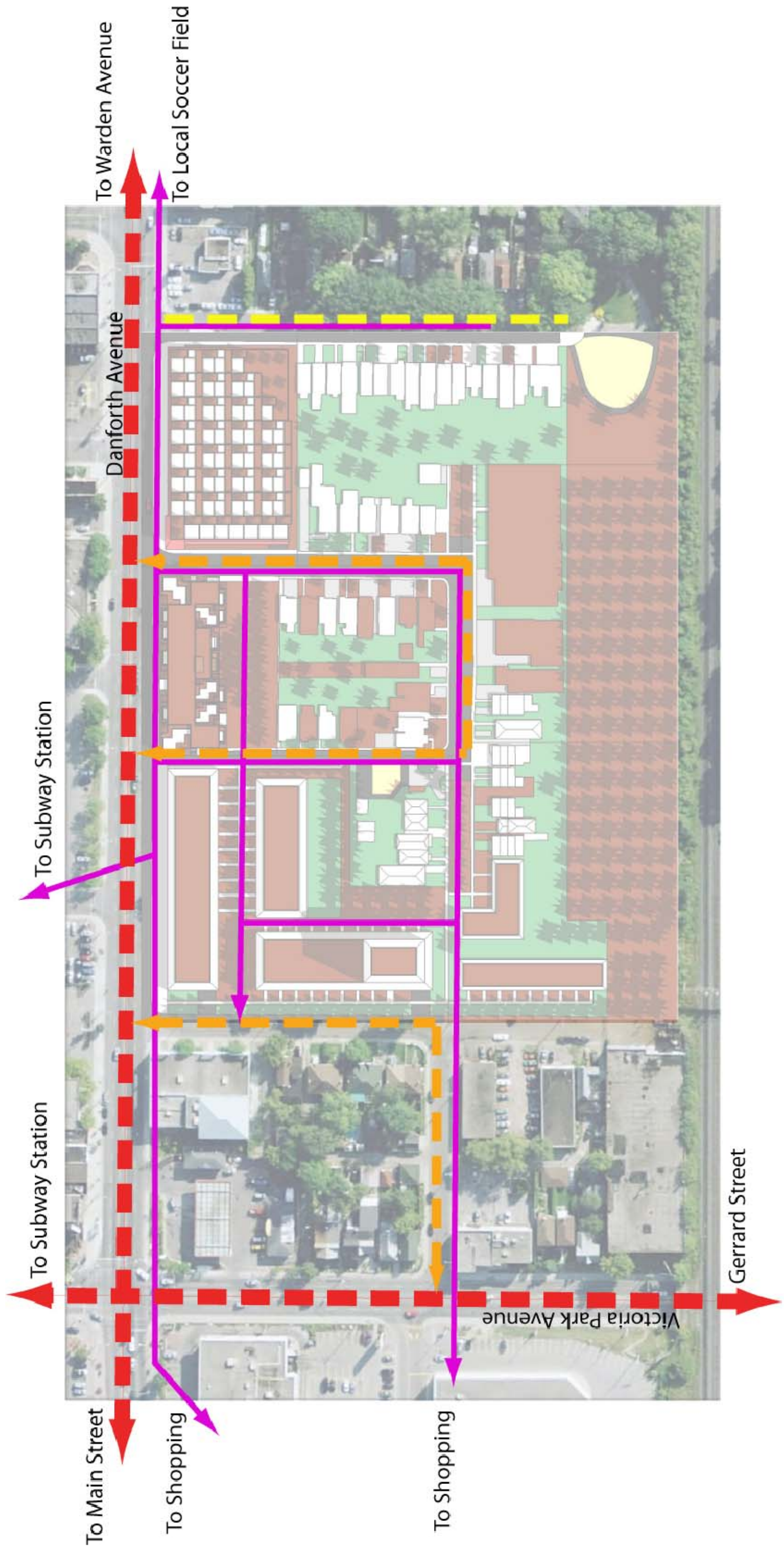


Figure 5-57 - Proposed Site Plan for the Study Area

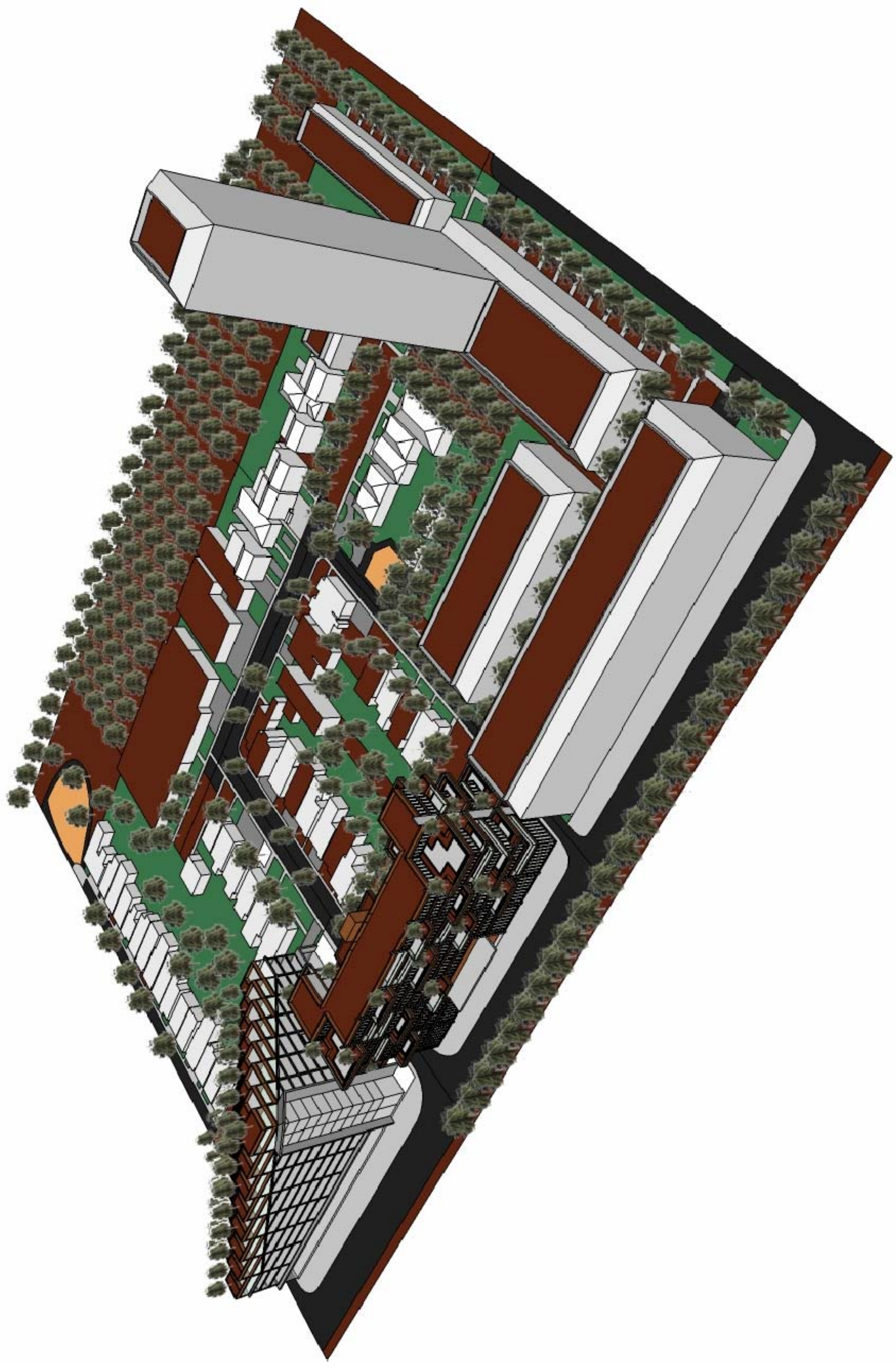


Figure 5-58 - Aerial Perspective of the Study Area

6.2 Summary of Architectural Impact

The architectural impact of the Sustainable Site System leads to a more ecologically responsive design. This system is just a tool to encourage development in a responsible manner which is currently not required. The response could be extreme like Block C or it could be responsible site management design, like Block B. The impact of the street on the rating is a large component of the negative rating. This will encourage developers and the city to work together to improve the street design. Large parking lots would have a very difficult time with this system due to the negative properties that they exhibit, but with the appropriate site design it would be possible to minimize the negative rating. The system's goal scores of 0.40 for renovations and 0.60 for new developments in the city of Toronto are achievable and not unrealistic. The main concept which need tot be taken away from this process is that the existing site designs must change in order to respond to the negative effects of the city.

7.0 Conclusion

This thesis looked at the negative impacts from current city planning and construction and developed the sustainable site system and how it can reduce and or eliminate those impacts. City planning has had the most negative effects on Hydrology, Bio-Diversity and Heat Island effect. Although, some cities have begun to address the issues of the Heat Island effect, their responses do not address the underlying issues of the hydrological cycle and the loss of bio-diversity.

The development of the Sustainable Site System looked at Hydrology, Bio-Diversity and the Heat Island effect. The system uses those three categories as the input variables which determine the ratings for the various site materials. The Sustainable Site System has an ability to respond to various inputs and synthesize the information into a useable material scoring system. The system allows it to be applied to many climatic regions around the world. A series of examples from different climatic regions in Canada has confirmed this.

Lastly the Sustainable Site System was tested on various densities and designs which would be common in application. The system demonstrated that new and innovative site design would be required to achieve the required rating; this also means that the existing designs which are currently being built would fail under this system, but with minor considerations and alterations, the projects would be able to pass. Additional design innovations using public street areas to increase the rating of adjacent properties were successful. This system would encourage the synergy between the developer and the city to improve public and private spaces for the betterment of the community and city at large.

While the system only addresses a single site at a time, over time as more buildings are constructed and renovated the positive impact on the city as a whole will be more prevalent.

The goal of this system is to reduce the Heat Island effect. The hydrological cycle can begin to heal itself and the temperature of the water in the lakes and rivers will decrease back to what they were historically, and ground water levels in aquifers and wells would be restored. Lastly the bio-diversity in the city would increase the natural wildlife.

The Sustainable Site System achieves the adaptability and flexibility which current systems do not achieve. This systems is easy to apply and integrate into any city's regulatory system. This system can be in addition or work in conjunction with other systems. The Sustainable Site System is a tool to help heal the environment which we all live in.

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Appendix A - Tables

Table 24 - Toronto Green Roof By-law requirements

Gross Floor Area (Size of Building)	Coverage of Available Roof Space (Size of Green Roof)
2,000 - 4,999 m^2	20%
5,000-9,999 m^2	30%
10,000-14,999 m^2	40%
15,000-19,999 m^2	50%
20,000 m^2 or greater	60%

Source: (City of Toronto, Toronto Green Roof By-law, 2009)

Table 25 - Toronto Green Development Standard - Urban Heat Island Reduction

(Table Modified by Jorden Lefler)

Urban Heat Island Reduction: At Grade Reduce ambient surface temperatures, and provide shade for human health and comfort	AQ 4.1	Use high-albedo surface materials for at least 50% of the site's non-roof hardscape. **OR**
		Use open grid pavement for at least 50% of the site's non-roof hardscape. **OR**
		Shade within 5 years at least 50% of hardscape, including surface parking areas, walkways and other hard surfaces3. **OR**
		Use a combination of high-albedo surface materials, open grid pavement and shade for at least 50% of the site's non-roof hardscape
	AQ 4.2	Plant large growing shade trees at the equivalent of 6-8m intervals starting from the property line: along all street frontages, along all open space frontages and along all public walkways, excluding driveways and easements
	AQ 4.3	If surface parking is permitted and provided, plant shade trees at a minimum ratio of one tree planted for every five parking spaces supplied
	AQ 4.4 (Voluntary)	Use high-albedo surface materials for at least 75% of the site's non-roof hardscape. **OR**
		Use open grid pavement for at least 75% of the site's non-roof hardscape. **OR**
		Shade at least 75% of hardscape, including surface parking areas, walkways and other hard surfaces. **OR**
		If surface parking is provided, plant internal shade trees at a minimum ratio of one tree planted for every three parking spaces supplied. **OR**
		Install a Green wall on an exterior surface that is either free-standing or part of a building to a minimum height of one-storey. **OR**
		Use a combination of high-albedo surface materials, open grid pavement and shade for at least 75% of the site's non-roof hardscape.
Urban Heat Island Reduction: Roof Reduce ambient surface temperatures on/from rooftops	AQ 5.1	For buildings included in the City of Toronto Green Roof By-law install a green roof to meet the requirements of the By-law.
		For buildings not covered by the Green Roof By-law do one of the following for available roof space: Install green roof with 50% minimum coverage. **OR**
		Use cool roofing materials for 100% of the roof. **OR**
		Use a combination of both for a minimum of 75% of the roof.
		For all City owned buildings and all Agencies, Boards, Commissions, Corporations and Divisions, new buildings will provide a green roof with total area coverage equal to at least 50% of the building footprint. Cover the remaining available roof space with cool roofing materials.

Source: (City of Toronto, Making a Sustainable City Happen The Toronto Green Development Standard 2006, 2006)

Table 26 - Water Quality, Quantity and Efficiency

(Modified by Jorden Lefler)

Stormwater Retention (Water balance) Minimize stormwater that leaves the site	WQ 2.1	Retain stormwater on-site to the same level of annual volume of overland runoff allowable under pre-development conditions.
	WQ 2.2	Retain at least the first 5 mm from each rainfall through rainwater reuse, onsite infiltration, and evapo-transpiration. **OR**
		Ensure that the maximum allowable annual runoff volume from the development site is no more than 50% of the total average annual rainfall depth.
	WQ 2.3 (Voluntary)	Retain 25mm from a 24 hour rainfall event for rainwater reuse, onsite infiltration and/or evapo-transpiration.
Water Efficiency Reduce demand for potable water through greater efficiencies and by the use of non-potable water.	WQ 4.1	Use water efficient plant material for at least 50% of landscaped area (including vegetated roofs and walls).

Source: (City of Toronto, Making a Sustainable City Happen The Toronto Green Development Standard 2006, 2006)

Table 27 - Ecology

(Table Modified by Jorden Lefler)

Urban Forest: Tree Protection Preserve the urban forest	EC 1.2	Retain all trees that are 30cm or more DBH (diameter at breast height) in accordance with the City of Toronto Private Tree Protection By-law.
	EC 1.3	Where property is located within a Ravine Protected Area retain trees of all diameters.
	EC 1.4	Where applicable, protect and retain trees of all diameters adjacent to City of Toronto streets and roadways and City-owned Parkland in accordance with the Trees on City Streets and Parkland By-laws.
Urban Forest: Encourage Tree Growth Enhance the urban forest	EC 2.1	Plant a minimum of one tree on-site for every 30m2 of post development site area covered by soft landscaping.
	EC 2.2	**Trees in hardscaping (hard landscaping):** For 2 or more trees planted in primarily hardscaped areas, provide a minimum of volume of 15m3 of high quality soil per tree. A single tree planted in hardscape requires a minimum volume of 30 m3 of soil.
	EC 2.3	**Trees in softscaping (soft landscaping):** Provide trees planted in softscaping with a minimum volume of 30 m3 of high quality soil.
	EC 2.4	Provide a watering program for trees for the first 2 years after planting.
Natural Heritage: Site Protect, restore and enhance the natural heritage system. Protect and increase biodiversity.	EC 3.1	Ensure that at least 50% of vegetation species used in landscaping are native.
	EC 3.2	Do not plant any invasive species on properties along streets abutting ravines and natural areas.
	EC 3.3	Where a development setback from the top-of-bank of a valley, ravine or bluff or a buffer area is required by the City, all plants must be native species.
	EC 3.4 (Voluntary)	100% of tree species planted must be native species on properties or streets abutting ravines and natural areas
	EC 3.5 (Voluntary)	Where a setback from top-of-bank is required, the setback must be planted and all plants must be native species.
Soil Quality and Planting Conditions: Provide growing conditions to support long-term plant survival and growth	EC 4.1	Retain and reuse all uncontaminated on-site soil in areas not covered by the building and parking footprint or hard surfaces **OR**
		Adjust or replace with soil of equal or better quality.

Source: (City of Toronto, Making a Sustainable City Happen The Toronto Green Development Standard 2006, 2006)

Table 28 - BAF Variant 1

Street / Land **Calculation example**		Total area (m²) **479**	Developed area (m²) **279**	Undeveloped area (m²) **200**	Existing- BAF 0.06 **BAF 0.3**
Surface type / weighting- factor per m²		Portion of each surface type relative to the total area in m²			
		Amount	EEA* Amount	Planned	EEA* Planned
1.	Sealed surfaces **0.0**	**140**	**0**		
2.	Partially sealed surfaces **0.3**			**85**	**25.5**
3.	Semi-open surfaces **0.5**	**59**	**30**		
4.	Surfaces with vegetation unconnected to soil below and with < 80 cm of soil covering **0.5**				
5.	Surfaces with vegetation unconnected to the soil below and with > 80 cm of soil covering **0.7**				
6.	Surfaces with vegetation connected to the soil below**1.0**	**1**	**1**	**115**	**115**
7.	Rainwater infiltration per m² of runoff area **0.2**				
8.	Vertical greenery up to a maximum of 10 m in height**0.5**				
9.	Greenery on rooftop **0.7**				
	Ecologically effective surface area		**31**		**140.5**
BAF =	ecologically effective surface area / total land area		*** EEA =** Portion of the **E**cologically **E**ffective surface **A**rea		
BAF =	**140.5 / 479**		**Existing BAF 0.06**		**Planned BAF 0.3**

Source: **(German Senate Department for Urban Development, BAF - Biotope Area Factor, 2010)**

Table 29 - BAF Variant 2

Street / Land **Calculation example**		Total area (m²) **479**	Developed area (m²) **279**	Undeveloped area (m²) **200**	Existing- BAF 0.06 **BAF 0.3**
Surface type / weighting- factor per m²		Portion of each surface type relative to the total area in m²			
		Amount	EEA* Amount	Planned	EEA* Planned
1.	Sealed surfaces **0.0**	**140**	**0**	**21**	**0**
2.	Partially sealed surfaces **0.3**			**100**	**30**
3.	Semi-open surfaces **0.5**	**59**	**30**		
4.	Surfaces with vegetation unconnected to soil below and with < 80 cm of soil covering **0.5**				
5.	Surfaces with vegetation unconnected to the soil below and with > 80 cm of soil covering **0.7**				
6.	Surfaces with vegetation connected to the soil below**1.0**	**1**	**1**	**79**	**79**
7.	Rainwater infiltration per m² of runoff area **0.2**				
8.	Vertical greenery up to a maximum of 10 m in height**0.5**			**10**	**5**
9.	Greenery on rooftop **0.7**			**41**	**29**
	Ecologically effective surface area		**31**		**143**
BAF =	ecologically effective surface area / total land area		*** EEA =** Portion of the **E**cologically **E**ffective surface **A**rea		
BAF =	**143 / 479**		**Existing BAF 0.06**		**Planned BAF 0.3**

Source: **(German Senate Department for Urban Development, BAF - Biotope Area Factor, 2010)**

Table 30 - Base Site Rating

				Native Vegetation				Non-Native Vegetation				Sum of points received by each material
				Maintenance				Maintenance				
				Low		High		Low		High		
Material		Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade	
Vegetation 80cm or less				0.75	0.54	0.61	0.39	0.61	0.39	0.54	0.32	41.43
Vegetation 80cm or more				0.88	0.66	0.73	0.52	0.73	0.52	0.66	0.45	51.43
Vegetation connected				1.00	0.79	0.86	0.64	0.86	0.64	0.79	0.57	61.43
Vertical Vegetation				0.75	0.54	0.61	0.39	0.61	0.39	0.54	0.32	41.43
Tree		25.00	19.64									44.64
Sealed Surface <25% Permeability	<25% Gray tone	-0.54	-0.32									-8.57
	26% - 74% Gray tone	-0.59	-0.38									-9.64
	>75% Gray tone	-0.64	-0.43									-10.71
Partially Sealed Surface 26% - 74% Permeability	<25% Gray tone	-0.16	0.05									-1.07
	26% - 74% Gray tone	-0.21	0.00									-2.14
	>75% Gray tone	-0.27	-0.05									-3.21
Semi-open Surface >75% Permeability	<25% Gray tone	-0.07	0.04									-0.36
	26% - 74% Gray tone	-0.13	-0.02									-1.43
	>75% Gray tone	-0.18	-0.07									-2.50
											Average Site Rating	**0.46**

Table 31 - Climatic Statistic

	Base	Vancouver		Uranium City		Toronto		Halifax	
	Points	Data	Points	Data	Points	Data	Points	Data	Points
Ground Water level	**1.0**	Decre.	**1.0**	Const.	**0.0**	Decre.	**1.0**	Const.	**0.0**
Moister Index	**2.0**	1.44	**0.0**	0.59	**1.0**	0.86	**1.0**	1.49	**0.0**
10 yr. 15 minute Rain Event	**2.0**	10mm	**0.0**	8mm	**0.0**	25mm	**2.0**	15mm	**1.0**
50 yr Daily Rain Event	**2.0**	112mm	**1.0**	54mm	**0.0**	97mm	**0.0**	150mm	**1.0**
Water Pollutants	**1.0**	Low	**0.0**	Low	**0.0**	Low	**0.0**	Low	**0**
Fauna Bio-Diversity	**1.0**	Decre.	**1.0**	Const.	**0.0**	Dec	**1.0**	Decre.	**1.0**
Flora Bio-Diversity	**1.0**	Const.	**0.0**	Const.	**0.0**	Const.	**1.0**	Decre.	**1.0**
Plant density	**1..0**	Decre.	**1.0**	Const.	**0.0**	Decre.	**1.0**	Decre.	**1.0**
Heat Island Effect	**2.0**	0.1 °C	**0.0**	0 °C	**0.0**	1.8 °C	**1.0**	1.4°C	**0.0**
Total Points	**14.0**		**4.0**		**1.0**		**7.0**		**5.0**