Productive Green Roofs

Value-Added Design for Ground-Level Green Roofs

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ABSTRACT As an investigation of the functional value of ground level green roofs in Vancouver, this paper aims to provide evidence that ground level green roofs are operating below their environmental, social and economic potential. It examines more productive ways to design these spaces without diminishing their current ability to add aesthetic amenity and increase real estate value. Using a site in Yaletown as an example, a number of options for retrofitting intensive green roof features to improve their social, economic, or environmental value are explored through the identification and visualization of synergystic functions between climate, season, building, and use.

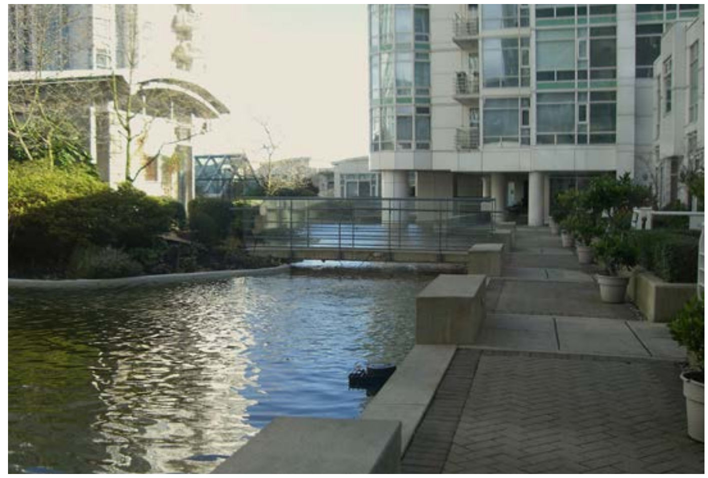

Figure 1. Podium access ground-level green roof, 'out-the-front-door' of townhouse condo units

INTRODUCTION

The past decade has seen a number of advances in the consideration of green roofs as viable public space. That being said, the design of many of these spaces limits the ways they might be used and the environmental benefits that might be gained through their application. Through capitalizing on the inherent synergies between climate, building, and context, these rooftop open spaces could provide significantly more value to their users and the environment.

The type of green roof that is explored in this paper is the ground-level courtyard green roof. While many of these green roofs are at grade, some also exist atop the podium level of block-wide building complexes (on the second or third floor). In all cases, these green roofs are above parking structures, seem to have very few, if any, structural limitations, and are directly accessible from many of the buildings' "townhouse" units. (Figure 1)

STUDY SITE

In order to conduct an in-depth study of the functionality of ground level green roofs, a site was chosen for investigation within Yaletown in Vancouver. (Figure 2). It is bounded by Pacific Boulevard to the north, False Creek to the South, David Lam Park to the west, and the Cambie Street Bridge to the east. It was chosen for a number of reasons including its notability as representing a 'Vancouverism' in its form of development and its success at integrating high density residential development with commercial development.

Figure 2. Study area, North-East False Creek Pacific Place development, Yaletown, Vancouver (Google maps)

Figures 3 through 7 are aerial images of the developments studied. These developments have commercial units, lobbies and gyms on the ground floors, large towers on at least 2 out of 4 of their block corners, and a mix of apartment-style and townhome-style residential units. The developer on all of these projects was Concord Pacific, who also owns the rest of the undeveloped oceanside frontage on the northeast shores of False Creek (CPCP).

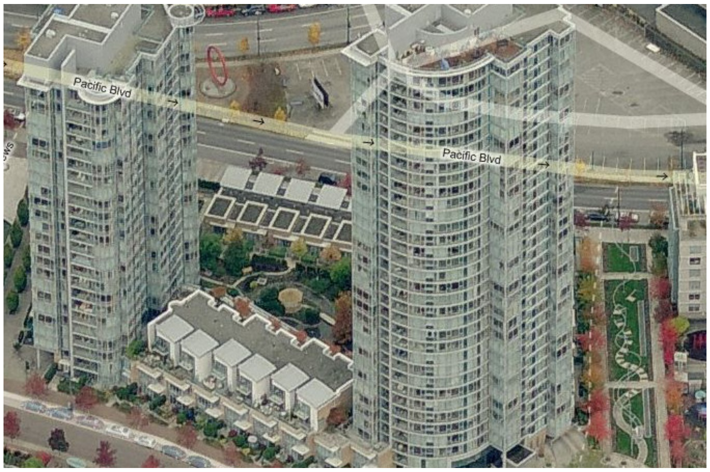

Figure 3. Quaywest, 2000.
1033 Marinaside Cr.

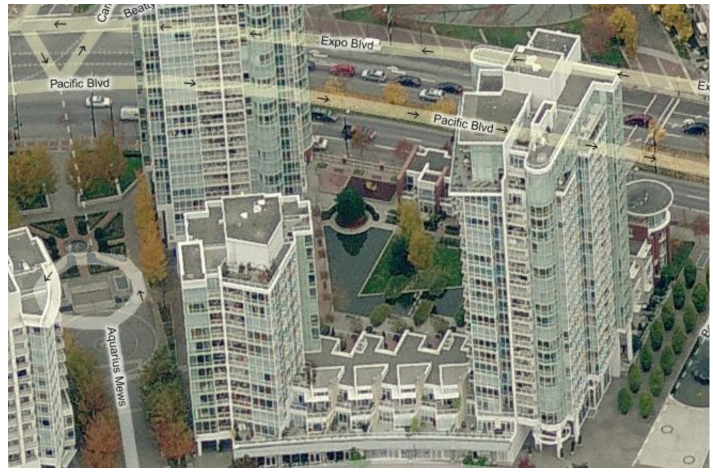

Figure 4. Marinaside Resort Residences, 2000.
1099 Marinaside Cr.

Figure 5. Roundhouse Cooperative Housing, 2002
1278 Marinaside Cr.

Figure 6. The Crestmark I, 1997
1288 Marinaside Cr.

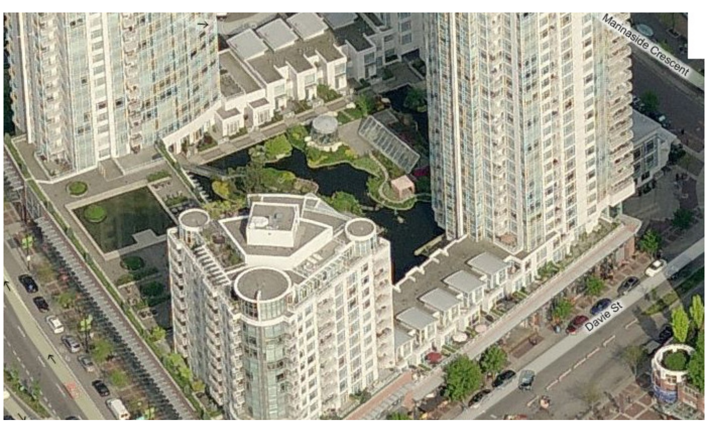

Figure 7. Aquarius Resort Residences, 2002.
1111 Marinaside Cr.

Initial investigation via aerial photographs revealed that approximately 18% of this 15 acre site is occupied by ground-level green roofs, which is approximately 11,240 m^2 or 1 out of 6 city blocks.

An observation of these spaces reveals that they can be broken down into four different landscape types: lawn, impervious (paved) surface, water features, and intensive garden plantings. Lawn makes up about 20% of the total green roof surface area, and impervious surfaces, which include paths, shelters, structures, and decking make up about 25%. Water features occupy approximately 39% of the total green roof surface area, and intensive plantings, which consist of shrubs, small trees and ground covers occupy about 16%.

Figure 8. Presence of ground-level green roofs in study site

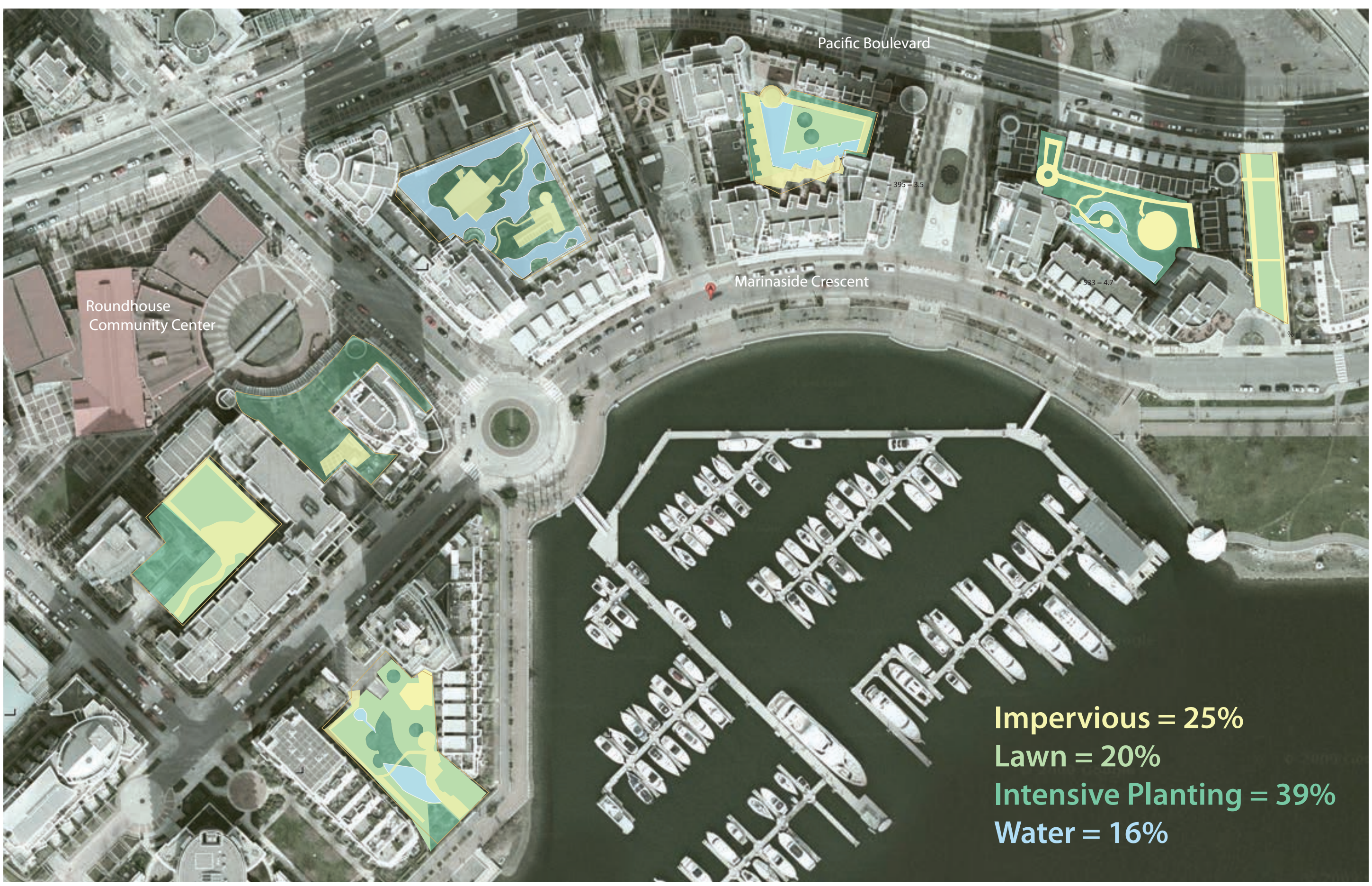

Figure 9. Breakdown of landscape types within study site

EVALUATING FUNCTIONAL VALUE

Once the green roofs were broken down into landscape types, I was able to use a set of simplified characteristics to evaluate their current environmental, economic, and social value. In terms of environmental value, I focussed on those values which are commonly cited as being potential benefits of green roofs: managing water, raising energy efficiency, improving air quality, and increasing urban habitat.[6] Social value was analyzed based on three broad categories which are generally associated with public or shared landscapes. These are aesthetic value, recreational value, and potential for interaction or community building.

Finally, economic value was considered in terms of increase in real estate value, the costs associated with green roof maintenance, and opportunity cost. For the purpose of this paper, economic value is only considered in terms of additional cost or savings to what is currently in place in these spaces. In all cases, the functional value of the various landscape types was determined as a comparative value set against other landscape options.

ENVIRONMENTAL VALUE ASSESSMENT

One of the most commonly cited benefits of green roofs is their ability to manage water effectively. This, however, is more true in some climates than others. In order to investigate the ability of the green roofs within my site to manage water, I looked at two different aspects of water management: drainage (stormwater runoff) and water use (irrigation and water feature requirements).

Using the rational method to calculate the runoff generated by each of the four landscape typologies identified, I was interested not only in the total runoff produced in a year, but also the seasonal breakdown of when throughout the year the greatest amount of water is being discharged. Seasonal breakdown of the data is important in determining whether or not these green roofs might be made more productive by changing their use over the course of the year. More than 60% of the water that lands on these green roofs was found to be entering storm drains annually, with the greatest concentration of runoff occuring in the winter months. During the summer months, however, there is almost no runoff from the green roof surfaces. (Figure 10).

While there is an extreme excess of rainwater throughout the winter, the summer yields very minimal amounts of precipitation in Vancouver. During the dry season, not only is irrigation needed for rooftop plants to survive, but water also needs to be pumped into the water features on these rooftops in order to maintain their water levels due to a high rate of daily evaporation. Through speaking with various maintenance personnel for the green roofs within my site, I found that all of these developments use potable water for irrigation and water feature maintenance. Using crop coefficients, I estimated the amount of irrigation needed to sustain these roofs as well as the amount of potable water needed to maintain water feature levels in the dryest months. (Figure 11)

The water needs for the various water features were calculated using numbers provided by maintenance personnel. The site with the largest water feature (totalling approximately 1045m^2 in area) has 600 gallons (2.73 m^3) of water pumped into it daily throughout the summer season. Averaged out over the total area for water features in the study area, this becomes quite a significant amount of water that needs to be pumped into the water features annually to maintain their water levels.

As can be seen from the data collected and calculated on the following page, impervious surface has an extremely low value for mitigating stormwater, but a high value in summer as it requires no water for maintenance. Lawn is of mid-level functional value for mitigating stormwater most of the year, except in summer when it is of high value, but it also requires a fair amount of water input during those months. Intensive planting plays the extremes. While it is of high value for mitigating stormwater runoff most of the year, it is extremely water intensive throughout the summer months, making it of low functional value in terms of water consumption. Finally, water features are of relatively low value for mitigating stormwater in winter (given they are designed to overflow), and they also require a lot of water in the summer months to maintain water levels. This makes them a source of low functional value for managing water year round.

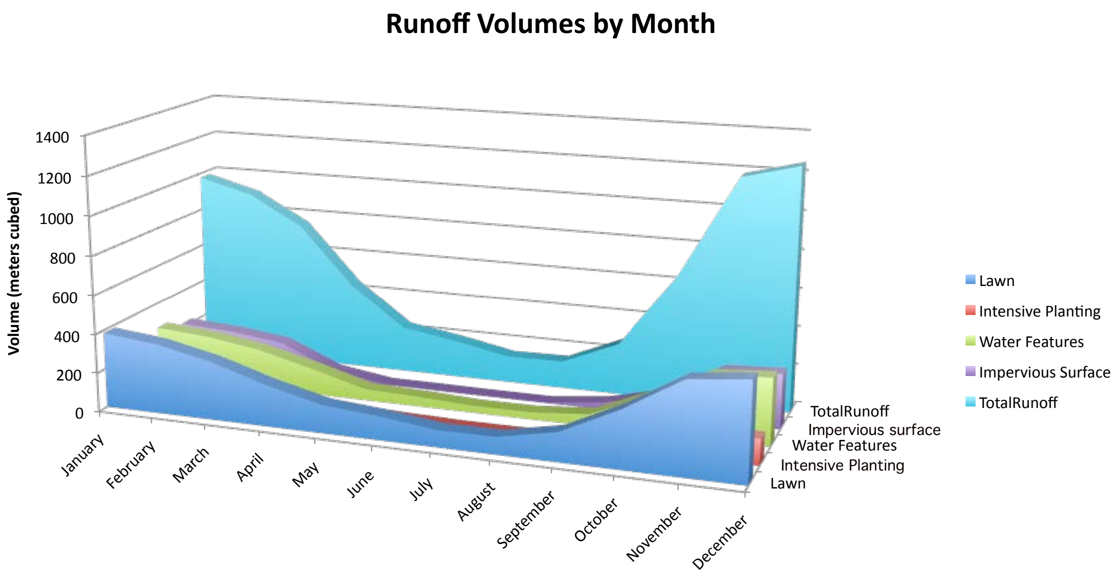

Figure 10.
Runoff from site as calculated by month using the rational method

MONTH	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Storm Water Runoff												
Impervious Surface	386m^3	358 m^3	298 m^3	213 m^3	144 m^3	121 m^3	87 m^3	89 m^3	147 m^3	291 m^3	467 m^3	497 m^3
Lawn	268 m^3	248 m^3	206 m^3	137 m^3	59 m^3	50 m^3	36 m^3	37 m^3	61 m^3	187 m^3	324 m^3	344 m^3
Intensive Planting	103 m^3	95 m^3	79 m^3	50 m^3	30 m^3	19 m^3	13 m^3	14 m^3	23 m^3	68 m^3	124 m^3	132 m^3
Water Features	219 m^3	203 m^3	169 m^3	48 m^3	6 m^3	5 m^3	3 m^3	3 m^3	37 m^3	109 m^3	265 m^3	282 m^3
Total Runoff	**976 m^3**	**904 m^3**	**752 m^3**	**448 m^3**	**239 m^3**	**195 m^3**	**139 m^3**	**143 m^3**	**268 m^3**	**655 m^3**	**1180 m^3**	**1255 m^3**

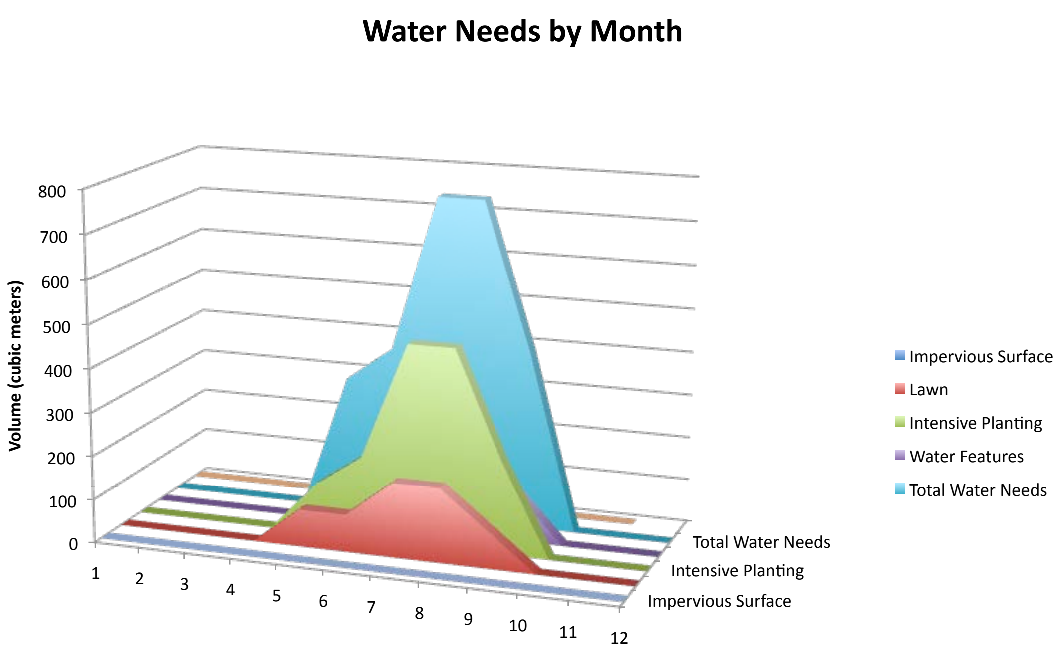

Figure 11.
Water needs on site by month as calculated using the crop coefficient method and maintenance data.

Water Needed												
Impervious Surface	0	0	0	0	0	0	0	0	0	0	0	0
Lawn	0	0	0	0	86 m^3	86 m^3	171 m^3	171 m^3	86 m^3	0	0	0
Intensive Planting	0	0	0	0	115 m^3	189 m^3	459 m^3	459 m^3	211 m^3	0	0	0
Water Features	0	0	0	0	110 m^3	115 m^3	120 m^3	120 m^3	115 m^3	0	0	0
Total Water Needs	**0**	**0**	**0**	**0**	**311 m^3**	**390 m^3**	**750 m^3**	**750 m^3**	**412 m^3**	**0**	**0**	**0**

The environmental value of ground-level green roofs is not restricted to their ability to manage water. One must also consider the effect of these spaces on energy efficiency. On one hand, green roofs can act as a buffer to more efficiently heat and cool buildings, but on the other hand, they require a certain amount of energy to maintain.

In terms of energy savings, green roofs have been claimed to have exceptional insulative qualities. While this is certainly true for the dry season in Vancouver, the BBC has dispelled this myth for rainy seasons in wet climates. While green roofs with dry soils can keep a home up to 4 degrees cooler when it is above 25 degrees outside (reducing the energy needed for air conditioning by up to two thirds), dry roofs with wet soils (as would be the case most of the winter in Vancouver) actually have poorer insulative qualities than that of a standard roof. This is because the interstitial spaces in soil (which provide the basis for the insulative properties of soil) are filled with water (BBC Bloom). Since the spaces I am dealing with in this paper are predominantly above parking garages and maintenance facilities, their insulative properties are relatively insignificant no matter what the season.

The real potential for energy savings within these Yaletown green roofs comes from the properties of light and reflection associated with various landscape features. The two major players in this case are water features and areas of intensive planting. Water features reflect a significant amount of light creating additional heat and light within adjacent buildings. This can be an extremely valuable function throughout the winter months; however, this service is of low or negative value during the warm summer months.

Intensive planting does the opposite. During the summer months it can provide much needed shade to a limited number of the building's units, reducing the amount of air conditioning required through the use of passive cooling. Appropriately placed deciduous trees can allow light to enter the buildings in the winter when passive heating is desired and shade out the sun in the summer months, when passive cooling is most valuable. Thus, intensive planting can have a high value in the summer and a rather neutral value in the winter while water features are only of high functional value for energy savings in the winter and are actually of negative value in the summer months.

The other major factor contributing to the energy efficiency of ground-level green roofs is maintenance requirements. Ignoring the initial or embodied energy of the materials used in constructing a green roof, the amount of energy needed to maintain intensive green roofs can be huge. According to Portland's water energy statistics, 0.001 lb of carbon are used per gallon of water that needs to get pumped into a building and Portland is a city that claims to have a particularly low energy water distribution system (McKenzie). Given that 2371 m^3 of water are needed over the site each summer, this would be the equivalent of expending approximately 0.27 metric tons of CO_2 annually for pumping water alone, and that is if we assume Vancouver to have a relatively equal water distribution system to Portland.

The energy involved in maintaining the lawn portions of these green roofs is also quite significant. According to the American Environmental Protection Agency, one gas-powered lawn mower emits as many pollutants as 8 new vehicles driving 55 mph for the same period of time. Given that there are approximately 2250m^2 of lawn across the site (a little more than half an acre), we can assume it would take at least one hour of mowing per week for 6 months to maintain all of the lawns across the site. This is approximately 24 hours of mowing annually. If we assume the average vehicle gets 21.5 miles to a gallon, then 24 hours of mowing would be the equivalent of expending 12,000lbs or 5.4 metric tons of CO_2 into the atmosphere. Even if we were able to halve the CO_2 emmissions by using more eco-friendly mowers, the carbon emmissions would still be high. Analyzing the carbon emmissions required for maintaining green roof landscapes indicates that lawns are of the lowest relative value in terms of energy costs; however, the energy required to pump water to intensive planting areas and water features is not insignificant.

The ability to improve air quality is another key environmental benefit often associated with green roof applications in cities. Additional green space not only has the ability to filter pollutants from the air, it can also contribute to minimizing the urban heat island effect. Although local research is yet to focus on issues of air quality, we can borrow some statistics from other cities to indicate the potential that these green roofs hold for improving air quality. According to the magazine Scientific American, researchers in

New York have determined that green roofs can cool near-surface air temperature by an average of 16.4 degrees Celsius per unit area (slightly behind that of street trees) (Moise). Furthermore, at the University of Ryerson in Toronto, a study has been done to indicate that rooftop vegetation has a significant filtration capacity for pollutants such as CO, NO_2, 0_3, PM_{10}, and SO_2. In fact, the filtration capacity of green roofs is such that with 100% green roof cover in the city, Toronto could save 2.5 million dollars annually on the filtration of airborn pollution (REBGR). Finally, researchers at Michigan State University have drawn the link between the amount of carbon that can be sequestered in green roofs and soil depth, indicating that the higher the soil depth the greater the potential of the green roof to sequester carbon (Getter).

Given these statistics, along with what is known about the soil and plant processes for filtering air pollution, we can assign relative functional values to the four landscape types on the site for their ability to improve air quality. Impervious surface and water features both have extremely low functional values in terms of improving air quality. As a matter of fact, concrete impervious surfaces are probably having a negative rather than positive effect on air quality. Water features would have some positive impact on mitigating urban heat island throughout the summer, but this benefit would be less prevalent during Vancouver's winters. Lawn has a relatively low ability to sequester carbon or filter pollutants given its limited soil depth and small leaf surface. That being said, it does hold a mid-level value in the summer for mitigating heat island effect. For the most part, intensive planting is the only really high value landscape type for improving air quality year round. Evergreen species in particular have the ability to impact air quality year-round as they do not die off in the winter.

The final consideration identified when evaluating the potential environmental value of ground-level green roofs in Vancouver is that of habitat quality. It is clear that none of the green roofs I studied were intended as functional habitat; however, water features and intensive planting areas still hold some value for species of waterfowl, invertebrates, and micro-organisms. (Figure 12)

Figure 12.
Ducks enjoying the habitat created in the courtyard of the Aquarius Resort Residences

SOCIAL VALUE ASSESSMENT

The functional social value of each of the ground-level green roofs studied was evaluated on the design intention and functionality as a whole as well as the landscape components utilized -- impervious surface, lawn, intensive planting, and water features. This evaluation was conducted through observation and comparison to the surrounding context as well as literature on good placemaking. Social value in this case can be defined as the value these spaces hold for residents. Figures 13 and 14 indicate some of the social amenities found in these courtyards.

Social value was evaluated on three main criteria:

Aesthetics - the visual or therapeutic value associated with the landscape or land use type

Recreation - the amenities or uses provided by the space or landscape type

Community Building - the opportunity for interaction, engagement, and stewardship of the landscape

Across the board, the intention these landscapes seems to be providing aesthetic amenity. There is minimal consideration for how these spaces might be utilized to build community and encourage interaction among neighbours. Narrow paths and small playgrounds with no affiliated seating for adults seem to be the norm. There are very few gathering spaces or covered areas on these green roofs, much less ones with the capacity to hold any more than a private gathering.

Figure 13.
Ground-level green roof courtyard playground at Quaywest

Figure 14.
Ground-level green roof courtyard playgrounds at Roundhouse Cooperative Housing (left) and The Crestmark (right)

When breaking the green roofs down into their landscape types, intensive planting and water features provide the most aesthetic benefit, while impervious surfaces (such as those used for the childrens' playgrounds and paths) provide the greatest potential for recreation. The lawns are some of the only spaces conducive to gathering; however, even these are rarely framed as appealing spaces to inhabit.

IDENTIFYING SYNERGIES

Now that the relative value of the ground-level courtyard green roofs along Northeast False Creek has been assessed, we can more effectively identify the particular strengths, weaknesses, and relationships between the various components of these spaces. This is an integral step in identifying how these roofs might be better utilized throughout the year to yield a higher productive value for both the environment and the developments' residents. By looking at not only the features of the green roofs themselves, but also the way they interact with the buildings that surround them, the Vancouver climate, and the context in which they are situated, we can identify potential synergies between climate, context, and use in which the greater function of the green roof exceeds the value of its components.

For instance, intensive plantings and lawn were identified as having the highest environmental value for mitigating stormwater, filtering pollutants from the air, reducing the urban heat island effect, and providing habitat. They also have a very high aesthetic value for residents; however, these plantinga also have high costs as a result of high water and maintenance needs and, thereby, energy needs. Through the substitution of lawn and intensive planting for food growing space, some of the water and energy costs associated with this type of planting can be offset by producing food. Furthermore, the maintenance and produce could be shared by local residents, greatly increasing opportunities for recreation, community building, and possibly even economic gain.

Figure 17. Using urban agriculture to offset the high water and energy use associated with planted areas in Vancouver, making them more environmentally and economically viable.

A second identifiable gap that was derived from the functional value analysis of this site is the gap between water availability and water needs throughout the year in Vancouver's climate (Figure 18). One way this has been dealt with in more contemporary projects is to build a cistern system for storing rainwater to be used for irrigation at a later date (Figure 19). This method not only allows you to store water across seasons for irrigation, it can also provide additional water for building uses. In the case of ground-level green roofs, they are already conveniently positioned above above parking garages, which can function quite easily as ideal places to house cisterns.

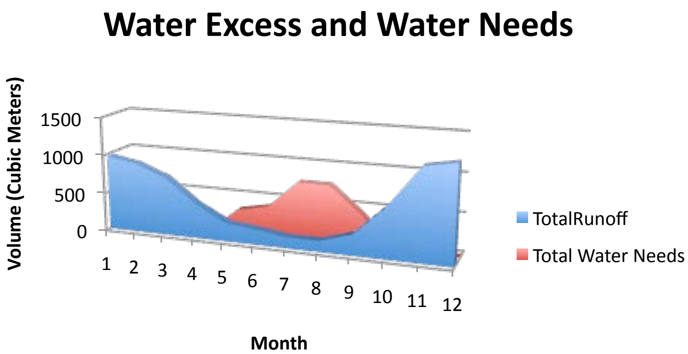

Figure 18.
The seasonal gap between water availability and water use

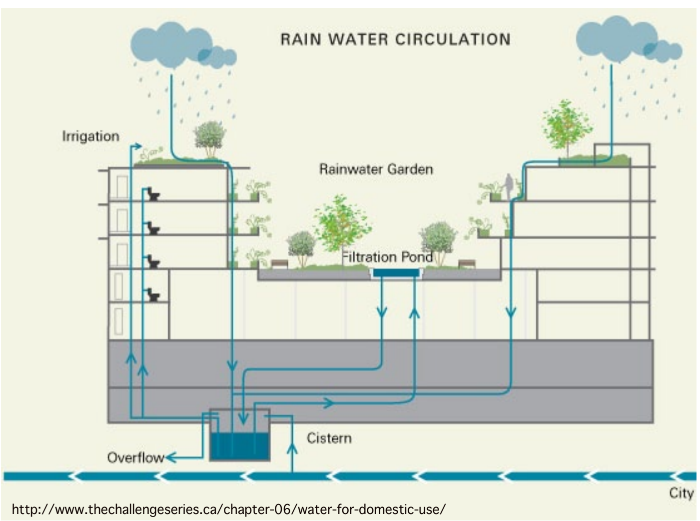

Figure 19.
Current application of rainwater harvesting using a cistern system.

Millenium Project, Southeast False Creek

Contrary to popular belief, Vancouver actually gets enough sun that solar panels could be retrofitted to provide the energy for filtering and pumping stored water. Despite its rainy reputation, Vancouver actually gets comparable amounts of sunshine to Miami, even more in the summer months when the majority of water pumping would need to take place (Solar in BC's Climate). Figure 20 shows an example of how the green roof courtyard at Aquarius residences might be retrofitted for the production of solar power.

Although cistern systems are a great way to capitalize on the excess of water in Vancouver throughout the winter, they are not without their drawbacks. Cisterns require a high level of maintenance in order to ensure that the water is properly filtered and that microbial growth does not flourish within the cistern. The space required for storing any significant volume of water is also at a premium. The average underground parking spot in the Yaletown neighbourhood sells for anywhere between $38,000 and $45,000 (Concord Pacific Parking and Storage Sales). If you add up the cost of several parking spaces, combined with the infrastructure needed to effectively filter and store water, the cost is out of reach of the average developer.

Figure 20. Digital representation of the pool covering at Aquarius Residences retrofitted with solar panels to produce the energy needed to pump water throughout the gardens.

A more cost effective method of storing and reusing rainwater might be to capitalize on the storage capacity of rooftop water features. In this case, overflow water from the water features in the rainy season could go directly towards greywater uses in the building without requiring excessive space for storage. Since the water in these water features is primarily potable water and direct rainwater, very little filtration would be required before directing the water to indoor uses such as toilets and laundry. Furthermore, water features could be designed with sections of varying depth and refined bottom surfaces so that rather than topping up the water features with potable water in summer, the water levels would be allowed to fall making room for more public open space during the summer when people most desire being outside (Figure 21). In this scenario, the benefits of additional heat and light in the winter from the reflective surface of the water are not lost and the potential to gain spaces for community interaction on a seasonal basis are gained. (Figures 21 & 22)

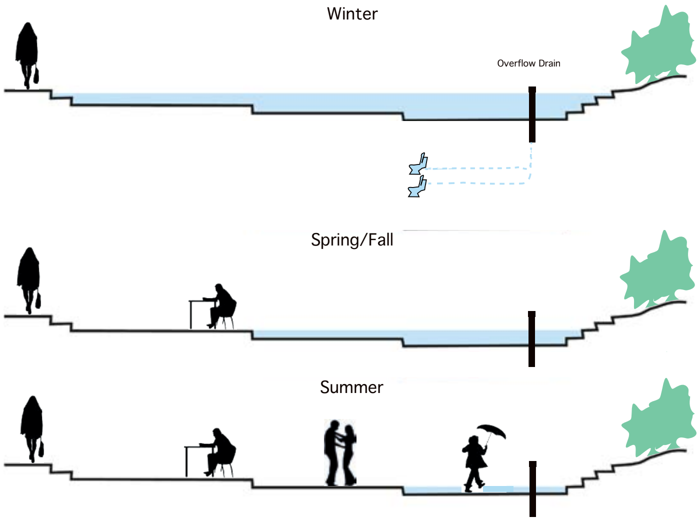

Figure 21. Conceptual diagram re-imagining the seasonal use of water features to capitalize on reflected light in the dark and rainy season while allowing water levels to drop in the summer for added gathering space and a reduction in potable water use.

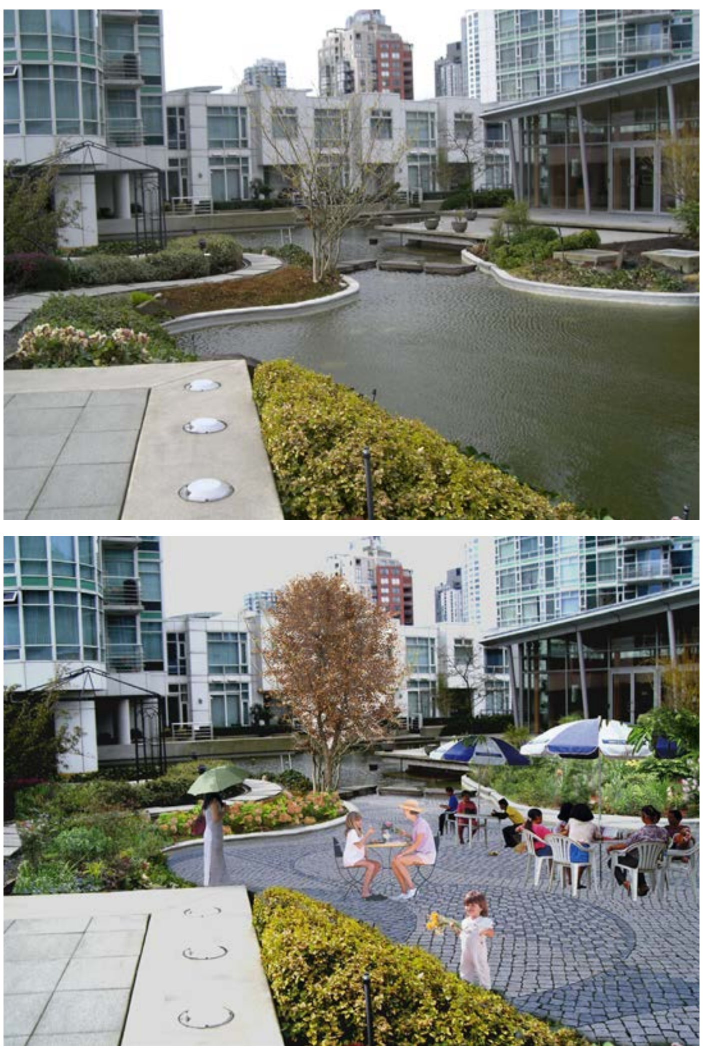

Figure 22. Digital visualization of water feature use between winter and summer seasons in order to conserve water in summer and provide additional gathering space outdoors in summer.

When discussing the synergies between context, climate and use of a space on a rooftop, it is also important to consider the potential integration with the buildings as well. Danish architect Bjarke Ingels claims "we have to become designers of ecosystems, systems of both ecology and economy that channel not only the flow of people through our cities and buildings but also the flow of resources, like heat, energy, waste and water" (Ingels). He does this through capturing waste heat off buildings and transforming it into adjacent uses, among other things. If this were to be done in the scenario present at the Aquarius Resort Residences in Yaletown, the waste heat produced from the Urban Fare grocery on the first floor could be captured and used to heat both a courtyard greenhouse and the interior swimming pool.

The Vegetables produced on the roof could then go directly back to stocking the shelves at the grocery store as well as directly to the residents that tend to them. Figure 23 combines this waste, energy, heat, and food system with the elements of water management already discussed to show how solar and waste energy might be combined with the capture of rainwater to heat swimming facilities, produce food, and provide water to household amenities such as toilets and laundry machines.

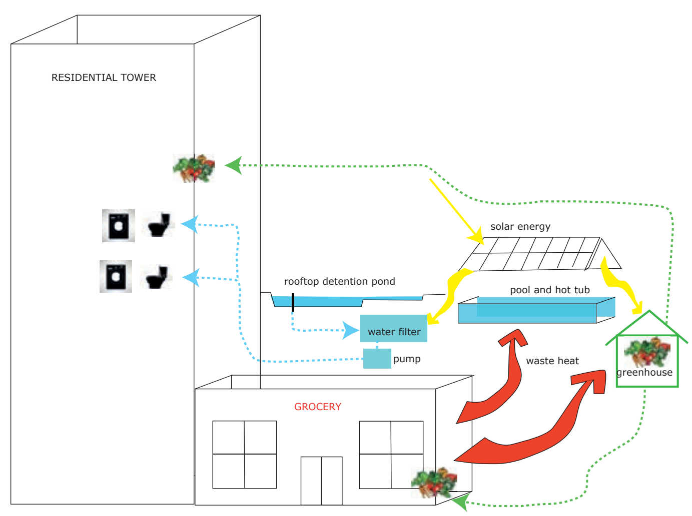

Figure 23. Diagram of using waste heat, energy, and water cycles to produce food, provide water for toilets and laundry machines, and heat the swimming pool.

DESIGN RELEVANCE

This type of design exploration is becoming more and more relevant as developers seek new ways to build within sustainable guidelines such as those set out by LEED or the Living Building Challenge. It is especially relevant in Vancouver where this type of higher density development is popping up all over the place. Broadway Street and the Cambie corridor are prime examples of places within the city that are mimicking the Yaletown style of development. The design guidelines that emerge from an exploration such as this one deal more with the design process than the physical features of the roofs themselves. The following list details some of the design thinking that can be derived from this analysis:

1. Each intervention on a green roof should hold at least two functions.

Ground-level green roofs are not only associated with structures, and more specifically parking structures, they also tend to be associated with high density development. As such, these spaces need to be capitalized on not only as aesthetic amentities but as functional open space. They should be treated as spaces that can be utilized to help manage some of the negative impacts of urban living for both people and the environment.

2. Any green roof intervention that is energy and/or resource intensive should be offset by an intervention that produces energy and/or acts to conserve resources.

Similar to the concept of net zero buildings, green roofs should not only be net zero installations, they should have the potential to have a significant positive net impact. Thus, for any intervention that has a negative impact on resource or energy use, a related intervention that offsets the negative impact should be implemented at an equal or greater scale. For instance, if intensive planting beds are going to require a given amount of irrigation water, then the green roof should act to someway store and reuse the same amount of water.

3. Low-tech solutions should be considered first and foremost as they are often the most efficient and economically feasible solutions.

Solutions involving heavy use of engineering, large space requirements and technological infrastructure are typically too expensive and risky for developers to undertake. Furthermore, they require a certain level of sophistication in maintenance to keep them operating as planned. By exploring low-impact options, you can often find ways to reach the same net impact with less cost and risk involved.

4. Each intervention should capitalize on at least two synergistic relationships with other elements in its context.

Adapting green roof features to reflect their context within neighbouring land uses, their climate, and the features of surrounding buildings can open up doors to creating spaces that not only operate effectively for their environments, but also improve the atmospheric quality within surrounding buildings and the social quality of life for those who inhabit the buildings. Overlaying a cultural richness to those features that are designed for economic or environmental function can greatly increase the overall functional value of a ground-level green roof.

5. Always consider post-construction maintenance.

By keeping maintenance top of mind, we can make smarter decisions right down to the details of our designs. For instance, drought-tolerant evergreen species of plants such as Arbutus menziesii and Pinus contorta are not only going to be the easiest to maintain in a rooftop context, they also provide the greatest year-round benefit to air quality and water management.

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