Green Roofs in an Urban Development

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ABSTRACT

The purpose of this project was to determine the impact of green rooftops on an urban development, specifically Fan Pier, Boston. This information was used to predict the influence green roofs could have on the development and its surrounding environment. Storm water management, increased air quality, and increased aesthetic appeal are the major advantages that green roofs can provide Fan Pier. This project is meant to help motivate Boston to develop research and make changes to mitigate environmental issues.

AUTHORSHIP

Each member of the project team contributed equally to all aspects of this report. The team members include:

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EXECUTIVE SUMMARY

For urban areas, it is nearly impossible to avoid certain environmental crises; air quality, temperature, and storm water runoff each suffer in an urban environment. The environment of the proposed development for Fan Pier, South Boston will not be an exception. The City of Boston hopes to find a way to mitigate the environmental issues facing Fan Pier, as well as the rest of the city. By conducting an investigation about green roof systems, the project team hopes to determine whether or not green roofs would adequately allay at least some of the environmental issues that Fan Pier's proposed development will face.

The project team found that the most impressive impact that green roofs could have on the development are with respect to storm water runoff. It was determined that by installing 2.5 inch extensive green roofs on all of the available roof space, then up to 67 percent of all rainfall, 708,297 ft^3, would be retained; likewise, if 4 inch grass and herbaceous green roofs were installed, then up to 71 percent, 342,344 ft^3, would be retained. This would significantly reduce the amount of polluted storm water runoff that would be dumped into the Boston Harbor, benefiting the environment greatly.

It was also discovered that if the total available rooftop space (272,632 ft^2) of the proposed development for Fan Pier were to be greened, then the plants would remove approximately 5,065 kg of particulates from the air. It was also determined that the plants could create enough oxygen for up to 16,880 people.

Furthermore, the project team calculated that if the entire development on the Fan Pier property were greened, then the Urban Heat Island effect in the area would be slightly reduced and the air temperature would decrease by 0.01 – 0.02^{o}F. Although not a

significant environmental impact, the temperature decrease is still noticeable and could increase considerably if more roof tops on properties surrounding Fan Pier are greened.

Based upon the data collected, the project team recommends the implementation of green roof systems on the rooftops of the proposed Fan Pier development. Greening the roofs would significantly mitigate some environmental problems that the development could face. Hopefully, other developers will notice the impact that the greened development will have on the environment, and follow Fan Pier's lead.

The project team has found that although green roofs are known to increase property values, result in tax incentives, and be generally visually appealing, they are considerably expensive, costing \$2 - \$18 per ft^2. Because of this high expense, the project team recommends that only the lower rooftops be greened, and that cool roofs be employed on the highest rooftops. The cost of cool roofs is approximately \$1.25 per ft^2, only \$0.25 per ft^2 more than a conventional black roof. These roofs are a cheaper alternative to green roofs and have milder, yet still notable, benefits on the environment.

The project team hopes that the investigation conducted will bring awareness to an effective means of mitigating some of the severe environment problems that affect urban areas, such as Fan Pier.

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CHAPTER ONE: INTRODUCTION

Rapid population growth is causing urban areas to expand at an alarming rate. As a result of this rise, the space to develop buildings is declining. The densely developed buildings trigger many environmental issues, such as the disappearance of vegetated surfaces, Urban Heat Island effect, high amounts of surface water runoff, an increasing amount of pollutants in the air, as well as many other issues (Mentens, 2005; Wong, 2003). These environmental issues are further discussed in Chapter Two of this report. In the past, cities that could not deal with their problems became less desirable to live in, and eventually change was necessary (Murphy, 2005).

One of the largest issues facing society today is the effect of urban development on its surrounding environment. The concentration of large populations of people in an urban area creates unique pressures on the environment, most of which are poorly understood. As the population of the globe increases, an increasing number of cities will sprawl outward to its suburban areas in the need for more space. Understanding how cities impact the environment around them is crucial to the ongoing success of our growing society.

How the environment and cities interact with one another is also closely tied into the economy (IndEco, 1994). Waste removal and storage has always been an issue plaguing city planning. The cost to heat buildings in the winter, cool them in the summer, light them at night, and protect them against the elements drives financial and non-renewable energy resources away from other pressing concerns. Urban developments require time and resources to be available to maintain and improve the city.

Ideally, city planners and managers would find a way to resolve all of these problems at once. However, most solutions are expensive to implement and maintain, such as water treatment plants and large sewer systems (City of Clovis, 2006). The environment gives rise to problems for cities that require the use of non-renewable energy resources such as gas and oil. In the winter, non-renewable fuel is burned to create heat that combats cold weather. In the summer, it is burned to create electricity that drives air conditioners (Policy Guide on Energy, 2004). A city's large concrete buildings and asphalt roads absorb heat over the course of the day, which radiates back out into the surrounding environment. The energy absorbed by these structures dissipates back into the environment at a much slower rate then the heat energy absorbed by natural cover. As a result, the temperature rises drastically during the day and cannot subside naturally at night. Light reflecting off glass also increases this effect, which is referred to as the Urban Heat Island effect (Green Roofs for Healthy Cities, 2005). Attempting to compensate for the heat, the city uses more energy to cool its inhabitants, increasing the temperatures and compounding the problem of the hot summer temperatures. All the while this use of energy is pumping pollutants into the atmosphere increasing the greenhouse gas effect (Lashof, 1990).

Over the years, many solutions have been presented to cities attempting to solve various environmental issues. These proposals have only been able to address very specific environmental issues, solving only one problem at a time (Green Building, 2006). Vegetative roofing solutions, or green roofs, provide a host of potential solutions to the previously mentioned urban problems. Green roofs have a wide variety of societal benefits, including environmental, public, economic, and social (Green Roofs for Healthy

Cities, 2005). Storm water runoff retention and aesthetic appeal to the public are the two major environmental and societal benefits that green roofs provide. Green roofs also help reduce Urban Heat Island effect and air pollution levels; however the scientific study of these environmental issues is still in its infancy. Green roof coverings provide benefits to urban structures by shielding there roof edifices from harmful sunrays. The inhabitants of the city are also provided with cleaner air and a more appealing atmosphere to work in (Green Roofs for Healthy Cities, 2005).

The cost of living in the city continues to rise as the cities grow. Rising economic costs in the city's population strain each person's standard of living (Economics Versus the People, 2002). To be comfortable in one's home, heating and air conditioning become a necessity in the city. Green roofs provide suitable solutions to the economic strains. Costs, in the long run, will decline as cities use less resources and non-renewable energy (Pidwirny, 2000).

Green roofs have the potential to be used as public spaces for the good of the entire community. Similar to parks, they provide a quite serine place for their visitors, letting them escape from the busy city below. Embracing ones self in a natural setting can have numerous psychological benefits as well as physical. Hospitals all over the world have begun to experiment with natural environments.

Besides the aesthetic appeal and cost of more green areas in a city landscape, green roofs improve air quality, insulate buildings, collect rainwater and even create jobs for the city (Green Roofs for Healthy Cities, 2005). The jobs created range from building the green roofs, to planning what plants are needed. Estimates indicate that there would be a significant rise in employment when green roofing is used (Green Roofs for Healthy Cities, 2005).

The Environment Department of the Boston city government is interested in discovering the benefits that green roofing could provide for the city of Boston. Specifically, our sponsor is focusing the research the project team is conducting on Fan Pier, located in South Boston. Like any major city, Boston suffers from a number of environmental problems. With a new urban development plan being proposed for Fan Pier, the city's Environment Department is seeking a way to allow the development to be built without increasing the city's already serious environmental problems.

The goal of this project is to provide Boston's Environment Department with information about green roofing so they may present The Fan Pier Land Co. with the opportunity to make a well informed decision regarding the adoption of green roof technology for their properties. The Fan Pier Land Co. plans to construct the development shown below, in Figure 1.

Figure 1
Fan Pier Development

The proposed development for Fan Pier, in South Boston (The Fan Pier Land Co., 2001).

. To complete this goal the project team must meet certain objectives. First, the team must collect data for storm water run off, temperature variance, and air pollution levels on the current state of Fan Pier. Secondly, the team must quantify the contribution green roofs can make toward affecting the Urban Heat Island effect, storm water runoff, air quality, and business economics in Fan Pier. Thirdly, the project team will determine the social implications, using the collected data, of green roofs in Boston. Boston will act as a microcosm in which the resulting social implications can be applied to other major cities. Lastly, after completing this project, the project team will identify areas for further investigation, for both our benefit and any persons/organizations involved in similar studies. By examining case studies, interviewing experts, and recording field observations within the city, our group will determine whether green roof offer a viable solution to afore mentioned environmental issues. The project team will use the methodology, discussed in Chapter Three, to obtain the necessary data which will assist us in determining how green roofs will influence the environment surrounding Fan Pier; the project team will also determine whether or not the installation of a green roof will create a viable solution to major urban development problems (Glascock, 2006).

CHAPTER TWO: BACKGROUND

The purpose of this chapter is to explain the background of the main issues involved with this project. Fan Pier, environmental issues—Urban Heat Island effect, air quality control, and storm water runoff—and the benefits and limitations of green roofs are all essential aspects of this investigation. Each of these facets is explained thoroughly in the following sections of this chapter.

Fan Pier Impact on the South Boston Waterfront

Fan Pier, located in the South Boston Waterfront District, was once an integral part of Boston's maritime industry. As seen in Figure 2, below, the property is located in between the Fort Point Channel and Pier 4; Boston Harbor borders its northern coast. The site was formerly used to unload cargo ships onto rail cars for distribution throughout the Northeast. Since the completion of the Moakley Federal Courthouse, in 1999, the Fan Pier site has abandoned its maritime involvement with Boston. Due to advances in modern shipping, such as significantly larger cargo ships and the decrease in railroad use, the original Fan Pier site has become inaccessible and obsolete.

Figure 2
Fan Pier Location

An aerial view showing the location of Fan Pier in South Boston (Adapted from http://local.google.com/).

The site, Fan Pier, is currently undeveloped; the only buildings that stand on the parcel are the Moakley Federal Courthouse and the Institute of Contemporary Art (ICA). The Moakley Federal Courthouse was erected on the site of the old rail car tracks. The space between the Federal Courthouse and Pier 4 is now filled, due to the process of dredging throughout the 1970's. This area of unused space was transformed into a parking lot for Boston commuters. The major landmarks of the site can be viewed below in Figure 3.

Figure 3
Current Fan Pier Layout

An aerial view of Fan Pier, identifying major landmarks (Adapted from http://local.google.com/).

Currently, the Fan Pier site occupies 643,080 sq. ft. (14.8 acres) of land and 266,719 sq. ft. (6.1 acres) of water equating to 20.9 acres of development area valued at $40.5 million.

In 2001, The Fan Pier Land Company submitted a proposal for development to the city of Boston for approval. The proposal, entitled *The Fan Pier Development: Final environmental Impact Report/Final Project Impact Report*, describes the proposed development of eight buildings and two parks, as well as two underground parking garages, which are to be constructed on the site of Fan Pier. The report will be analyzed in great detail and discussed in Chapter Four of this report.

Environmental Issues

Environmental problems are a serious threat to the city of Boston. Urban Heat Island Effect, storm water runoff, and air pollution are leading causes for environmental concerns (Green Roofs for Healthy Cities, 2005).

Urban Heat Island Effect on an Urban Development

The large amounts of concrete roads, sidewalks, walls and roofs found in urban areas are a leading cause in temperature increase within a city environment (Shufro, 2005). Most building materials in modern construction, such as concrete and steel, cannot absorb very large amounts of heat before they start to heat up dramatically and then radiate that heat to surroundings, increasing the temperature. Green Roofs for Healthy Cities (2005) defines the Urban Heat Island effect as the difference in temperature between a city and the surrounding countryside. It is caused by sealed impermeable surfaces absorbing energy and redirecting a portion of it to other hard surfaces. Heat is radiated after the sunset and forms a dome of higher temperatures over a city.

A typical asphalt roof surface can reach temperatures up to and exceeding 150^{o} Fahrenheit (F) on a 95^{o} F day. The cooling ability of a green roof maintains a roof surface temperature of approximately 75^{o} F according to Markham and Walles (2003). The Environmental Protection Agency concluded that the surface temperature of a rooftop with a vegetated layer can be cooler than the air temperature surrounding it, whereas the surface of a traditional rooftop can be up to 90^{o} F warmer than the surrounding air temperature (Happe, 2005). Green roofs achieve this temperature change through transpiration, the evaporation of water from plants during photosynthesis. Environment Canada, a division on the Meteorological Service of Canada, researching the environmental effects caused by green roofs, found that “greening,” or the process to “green” a roof, about six percent of a city’s buildings would reduce summer temperatures 1 to 2 degrees (Happe, 2005).

The reduction in temperatures within the limits of a city reduces a city’s energy consumption especially during the summer months. As the temperature increases, the city’s people turn on their air conditioning units for cooling. Markham and Walles (2003) have stated that if the temperature can be reduced, energy savings, due to the reduction in cooling system use, are estimated to reach up to $650,000 per year. Green roofing not only causes less energy consumption due to reduced use of air conditioning units and other electrical based cooling systems, but also prevents and removes pollutants from the air. The roofs obstruct approximately 2 tons of greenhouse gas emissions and 30 tons of other pollutants from the air as according to Markham and Walles (2003). The reduction of these pollutants over a city prevents smog and other gases from creating layers above the city causing heat to be circulated back where it came from. Consult the section on air quality to learn more about gas emissions.

Stromberg (2005) points out that one green roof alone will not make an impact. A number of roofs together in an urban environment could mitigate the heat build-up, cool the area and reduce the amount of harmful gases and pollutants in a city. Although the population of the city is partially at fault for increasing the Urban Heat Island effect, Tom Liptan, an environmental specialist with Portland’s Bureau of Environmental Services, says that there is no judicial penalty for a building's Urban Heat Island contribution

(Stromberg, 2005). He means that although the people contribute to the effect, the city does not hold them responsible for the environment they live in. A reduction of the Urban Heat Island effect would create a healthier environment for the citizens of a city to in which they could prosper (Stromberg, 2005). .

Air Pollution Control

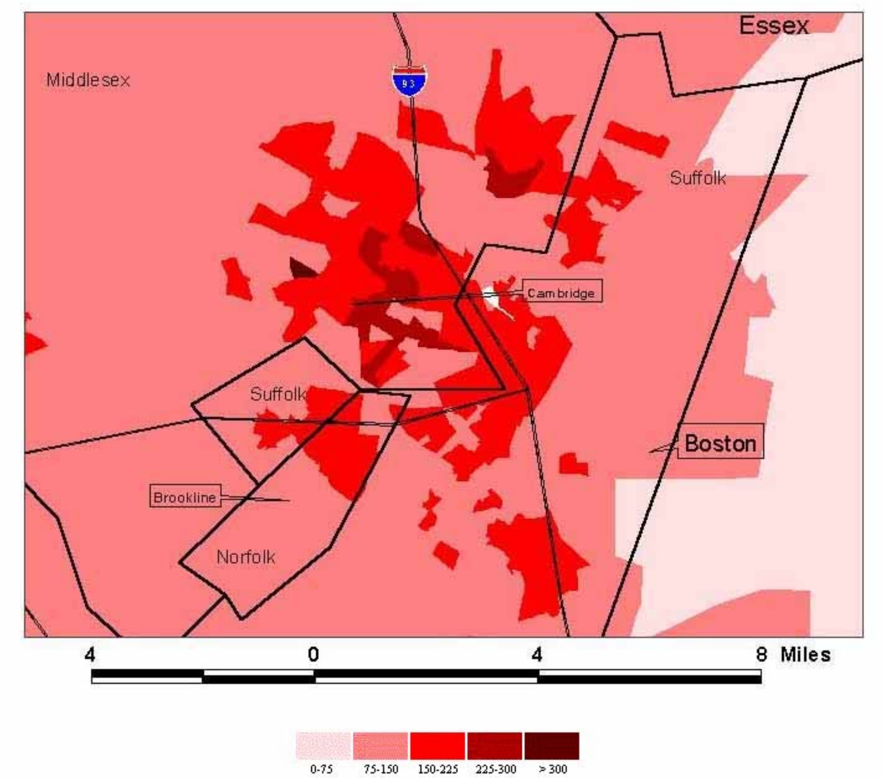
The air that humans breathe is composed of seventy-eight percent nitrogen, twenty-one percent oxygen, and one percent argon (Weather & Climate Basics, 2003). Argon is only hazardous in very high levels of exposure (Argon, 2001). However, certain human activities release other substance into the air, some of which can cause harm to humans, animals, and plants. There are two types of pollution that result from these substances released into the air. One type is the release of particles into the air, which is a result of burning fuel for energy. An example of particulate matter is the smoke that results when diesel fuel is burned. This type of pollution is often referred to as "black carbon" pollution (Indoor & Outdoor Air Pollution). The second type of pollution is a result of noxious gases such as sulfur dioxide, carbon monoxide, nitrogen oxides, and chemical vapors being released into the air. Once these chemicals are in the atmosphere, they undergo certain chemical reactions causing both smog and acid rain (Indoor & Outdoor Air Pollution, nd).

It is commonly accepted that both smog and acid rain are very large environmental problems for urban areas (Indoor & Outdoor Air Pollution; Effects of Acid Rain, 2003; Smog Fact Sheet, 2002). The pollutants released from countless automobiles cause urban areas to suffer from smog, especially during the warmer months of the year. Acid rain is considered to have very serious effects: killing trees, poisoning soil, changing the chemistry of bodies of water, and harming wildlife (Indoor & Outdoor Air Pollution). Numerous studies have been conducted on global warming, and although it remains a somewhat controversial subject, it is still considered to be an additional problem that arises as a result of air pollution; the build up of carbon dioxide, caused by burning fuels and cutting down trees, acts as a blanket and traps heat close to the surface of the planet. With this increase in heat, there is danger of the polar ice caps melting; the water levels will rise, and the climate conditions will change severely (Global Warming – Impacts, 2000). One more serious effect of air pollution is ozone depletion. The release of chlorofluorocarbons, which can come from cooling systems and refrigerator equipment, causes holes in the ozone to open up and allows harmful ultraviolet radiation to reach the earth (Indoor & Outdoor Air Pollution, nd). The effects of high exposures of ultraviolet radiation are sunburn, cataracts, and development of skin cancer (Suntanning, 2003). Although the hole in the ozone layer has begun to close, the rate at which it closes is directly related to the amount of air pollution that humans create; the more pollution that is produced, the slower the hole in the ozone layer will close. Allowing the hole to remain open, increases the associated risks mentioned above (Indoor & Outdoor Air Pollution, nd).

The city of Boston is no exception to the list of cities adversely affected by pollution. According to the National Park Service, the air quality for the Boston Region does not meet EPA standards (Boston Harbor Islands, nd). About half of the pollutants in the Boston area are a direct result of emissions from automobiles. The other pollutants come from off-road diesel engines used in construction equipment, generators, trains, and ships, as well as power plants, and other industrial facilities (Air Beat, nd).

The National Resource Defense Council developed a map, shown in Figure 4[⊥] below, demonstrating the different levels of carcinogens found in the air in Boston and surrounding areas (National Resource Defense Council, nd). Benchmarks for "safe" concentrations of toxins in the air have been developed by the U.S. Environmental Protection Agency; the benchmarks represent levels at which one out of one million people will be at risk of developing cancer. The darkest areas in Figure 4 designate levels that are more than 400 times greater than the EPA's "safe" concentrations (National Resource Defense Council, nd). These high levels of air pollution create a serious threat to the inhabitants of Boston.

Figure 4
Air Quality in Metro Boston



The risk factor for a combination of 31 toxics as a multiple of EPA's safe level, in Suffolk County (National Resource Defense Council, nd)

Storm Water Runoff

One of the major benefits of green roofs is that they can absorb and control the amount of water runoff that reaches the sewer systems of cities. Villarreal and Bengtsson (2004) found that a green roof of a thickness of four centimeters could absorb as much as 62 percent of the water from a particular rain event. This is a significant amount of water that does not reach the sewer system. The water that the green roof cannot retain does eventually reach the sewers, but in a greatly reduced volume and at a much slower rate than the actual rainfall rate. This reduction in water volume leads to a reduction in Combined Sewer Overflows (CSO) discharge and thus a reduction in the amount of raw sewage being dumped directly into the environment. This is one of the many visible benefits of green roofs (Toxic Hazards, 2005).

Weather creates some very large urban problems, precipitation in particular. In modern urban environments there are few natural areas that absorb water. Virtually all the rain that falls in a city is funneled into the sewer system. This can create huge problems for those sewer systems (Toxic Hazards, 2005). During heavier than normal rainfall periods, the sewer systems of many cities can be overwhelmed. As a result, the excess flow must be discharged through the CSOs. In most cities, sewage and storm runoff is carried in the same pipes and this is where the problem arises. When CSOs discharge, untreated sewage is expelled along with the excess storm water. Because many CSOs discharge directly into water sources like rivers and harbors, the effects of expelling untreated sewage into these sources is of great concern (Toxic Hazards, 2005).

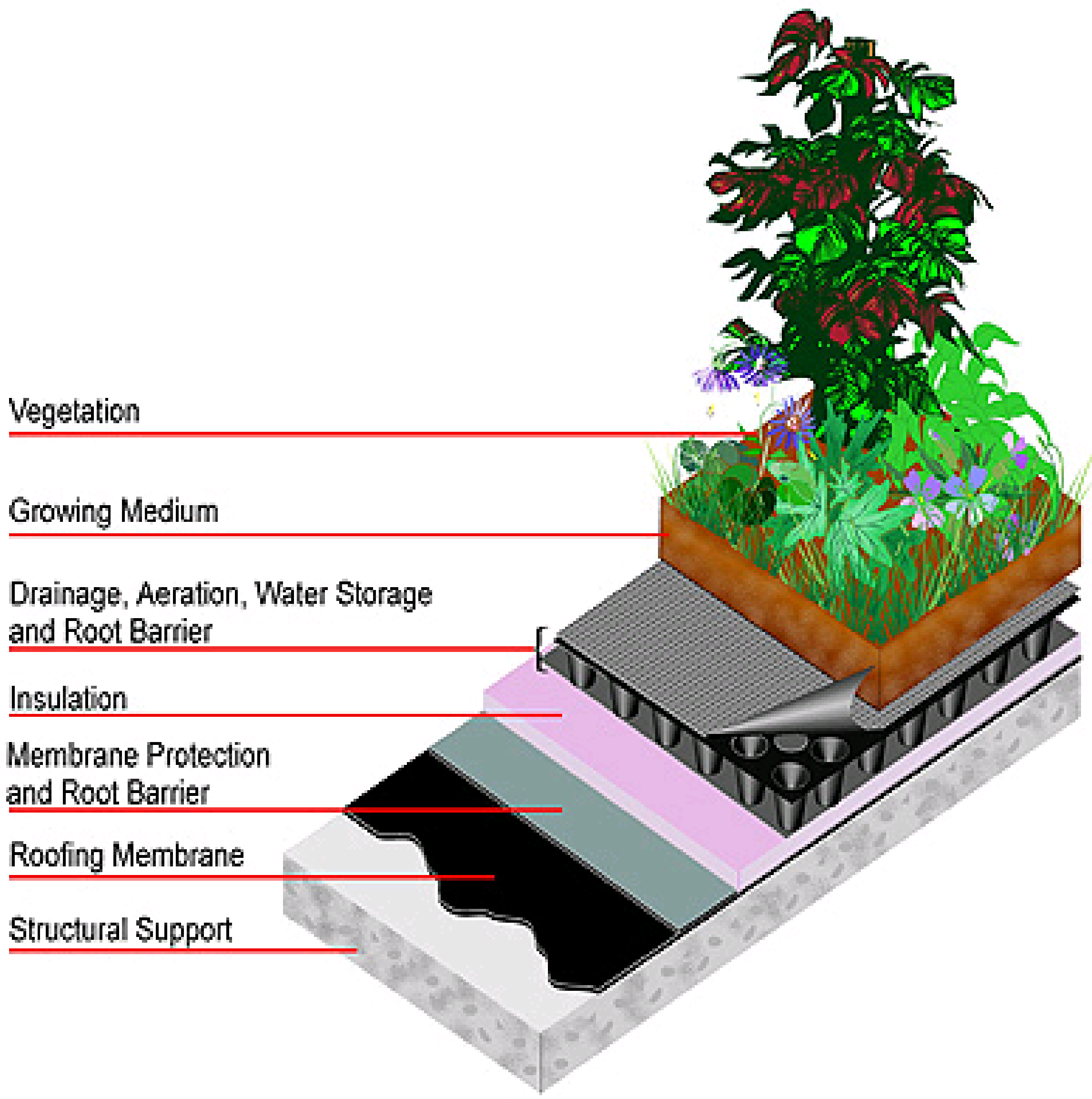
Experiments conducted in Boston's Fort Point Channel in 1997 by Adams (1998) measured how long discharged sewage remained in the channel. This study found that discharged sewage remained in the channel for up to 2.5 days before the channel was fully flushed out by the tides. During that time, much of the suspended sewage also settled at the bottom of the channel contaminating the sediment there as well. That particular CSO can discharge as often as once a week and it is not the only CSO that empties into Fort Point Channel (Adams, 1998). There would be less rain water overflow in Boston Harbor if green roofs could absorb a percentage of the rainfall. Colin Cheney, a long time green roofs expert, notes that storm water control is a prime motivator for the installation of a green roof.

As little as 0.05 inches of rain can trigger a flood. A study conducted in New York City demonstrated that even a small amount of rain fall is capable of triggering a disastrous flood. When any of the city's fourteen sewage treatment plants is overwhelmed, the overflow, raw sewage, dumps into the Hudson River, the East River or the New York Bay (Shufro, 2005). The same principle is applicable to the sewage system near Boston Harbor.

Green Roof Anatomy

Green roofing is a relatively new technology for North Americans. However, European states, specifically Germany, have established material, construction, and maintenance standards for developing modern green roofing systems. Green roof designs can be developed by individual contractors, contracting companies, or landscape architects. Materials differ from project to project depending on function, plants, geographic region, and manufacturer of the green roof. The green roof systems have seven basic elements, which can be observed in Figure 5, below: water proofing membrane, root barrier, insulation, drainage layer, filter fabric, growing medium, and plants.

Figure 5
Green Roof Layers



An image, displaying the different layers that make up a typical green roof (Great Lakes Water Institute Green Roof Project, 2005).

Besides the structural support, the lowest layer on the green roof is the waterproof roofing membrane. This layer safe guards the roof from any water leakage and therefore is the most important element of the green roof. As shown below in Figure 6, the membrane layer is heat welded to the roof of the building (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005).

Figure 6
Heat Welding

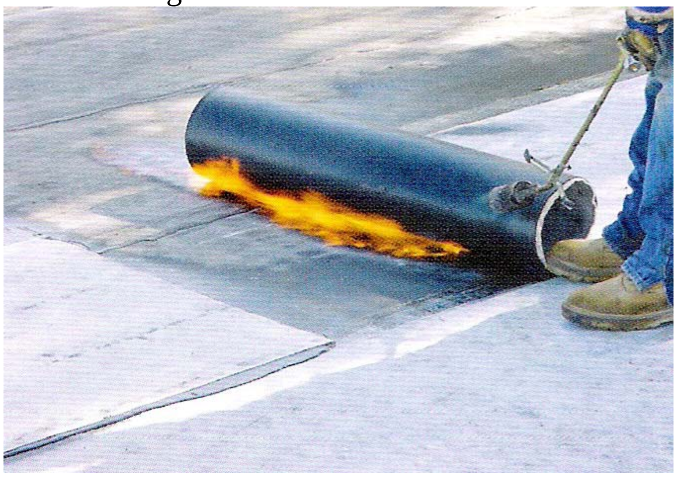


Photo demonstrating the heat welding of the membrane layer (Chrisman, 2005).

The techniques for testing this layer for leaks have been standardized in Germany, but as of 2004, North America still has no testing protocols for water leaks. North America has developed a warranty system that guarantees the integrity of the green roof membrane for a certain time period. This policy allows green roofs to continue to be built and researched as standards are developed for North America (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005).

The next layer in the green roof system is the membrane protection and root barrier. Its purpose is to prevent penetration of the waterproofing membrane layer and the roof deck from aggressive roots. This layer aids the longevity of the roof structure. The extended roof life is one of the many benefits of the green roof system. The root barrier may or may not be needed depending on the type of membrane used. If the membrane is composed of organic materials that plants naturally like to feed on then the root barrier is needed to prevent root invasion. Membranes that are made with synthetic materials are naturally root-repellent and do not require the extra root barrier (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005).

Following the root barrier is the insulation layer, which is shown below, in Figure 7. This layer is not a structurally necessary component of a green roof. Most building codes do require an insulation layer however. Standard roof construction requires the insulation layer to prevent heat loss from the building. The green roof system is therefore more effective in minimizing energy use in the summer than in the winter. Additional insulation layers can be added to the structure to maximize energy savings by reducing heat and air conditioning use. The insulation layer is typically installed above the waterproofing membrane, but could be installed below. Installing the layer above the membrane helps further protect the membrane and also allows the layer to be salvaged when re-roofing the building (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005).

Figure 7
Insulation Layer

Photo showing pieces of insulation to be installed in a green roof (Chrisman, 2005).

The key to a successful green roof is to have good drainage. The drainage layer, seen in Figure 8 below, provides the irrigation for plant propagation, prevents over saturation, ensures roots are ventilated, and allows extra space for roots to grow. The layer also helps to retain rain water with specially made crevices in many different patterns such as egg carton and honeycomb. These crevices help the plants in a drought by storing excess water. Flat roof buildings require the drainage layer to be present to direct water off the roof to prevent puddle formation during rain storms. On the other hand, if the roof's slope is greater than five degrees, water flows naturally off the pitched roof making the drainage layer unnecessary except to aid with extra water retention (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005).

Figure 8
Drainage Layer

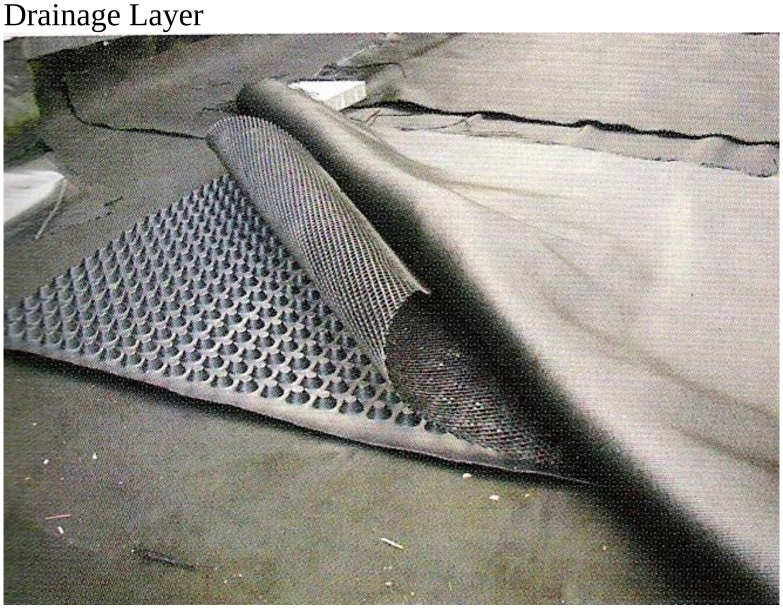


Photo of a typical drainage layer used in green roofing (Chrisman, 2005).

The filter fabric layer is placed in between the drainage layer and the growing medium layer. The main function of the filter fabric is to ensure that the growing medium layer stays in place. It is constructed with polyesters or polypropylenes (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005).

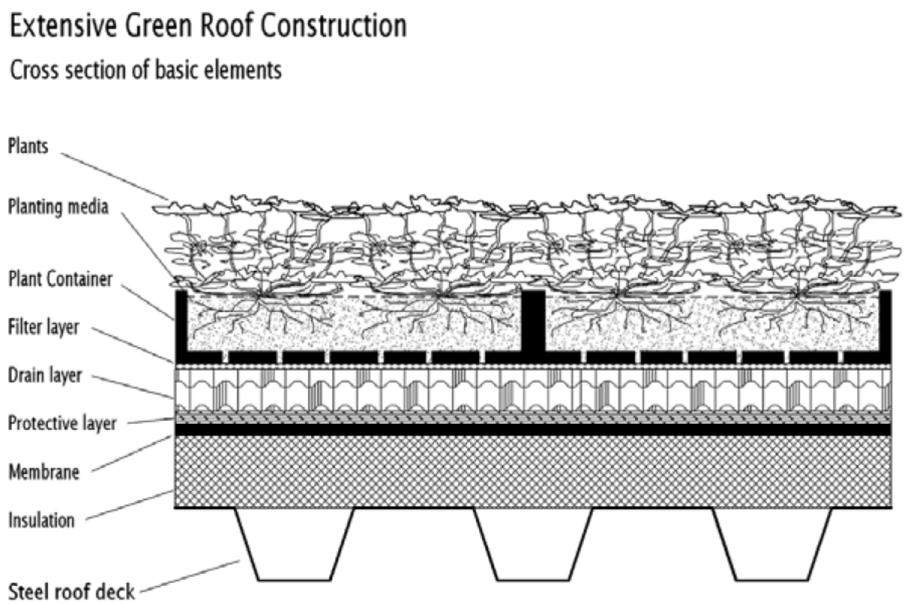
The foundation of the entire green roof system is the growing medium layer. This layer provides the plants with the nutrient base and space to grow. Typical growing materials such as humus and topsoil are too heavy for a green roof and therefore do not allow necessary drainage, aeration, and replacement of organic materials that are needed in a green roof. Green roof soils are made from different composite and mineral bases with minimal organic material. These soils are known as substrates. A green roof substrate is determined by water retention capacity, weight, aeration, and nutrient retention attributes. Course soils have low water retention, but allow for the greatest amount of aeration. The root system can rot without sufficient air. Finer soils have the ability to absorb and hold water and nutrients in reserve for dry periods. A mixture of these types of soils allows the roof to retain the most water and nutrients and also provide the roots with proper aeration. A good green roof will contain lightweight aggregate, such as clay or expanded shale, and organic matter. The use of on-site materials helps recreate habitats and environmental conditions for local birds and animals (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005).

The final layer of the green roof system is the plant layer. Green roofs are the most effective when the plants have fully grown. To allow the plants the opportunity to fully develop, many factors must be considered before constructing the green roof. The natural climate and microclimate created, weight of the plants selected, how the plants seed to further propagate, and the longevity of the plants for maintenance must all be considered (Chrisman, 2005; Great Lakes Water Institute Green Roof Project, 2005). The plant layer can be developed using two general classifications. These classifications are used by the green roof industry to further identify the construction materials needed for a project.

Extensive

This type of green roof is typically low-profile and performance based (Wark, 2003). Shown in Figure 9, an extensive green roof contains only one or two plant species and a minimal growing medium depth. This configuration minimizes weight load on the structure's roofwhile continuing to be aesthetically pleasing (Wark, 2003). A typical growing medium ranges from 1.6 – 4 inches. These depths cause a structural load of 10 – 20 pounds per square foot after a rain storm (Wark, 2003). As the depth of the growing medium increases, the benefits of the extensive green roofs also increases by maximizing thermal and water management performance. Figure 10 illustrates an implementation of an extensive green roof.

Figure 9
Extensive green roof



A cross section view of an extensive green roof (Wark, 2003).

Figure 10
Implementation of an extensive green roof

A building with an extensive green roof installed (Wark, 2003).

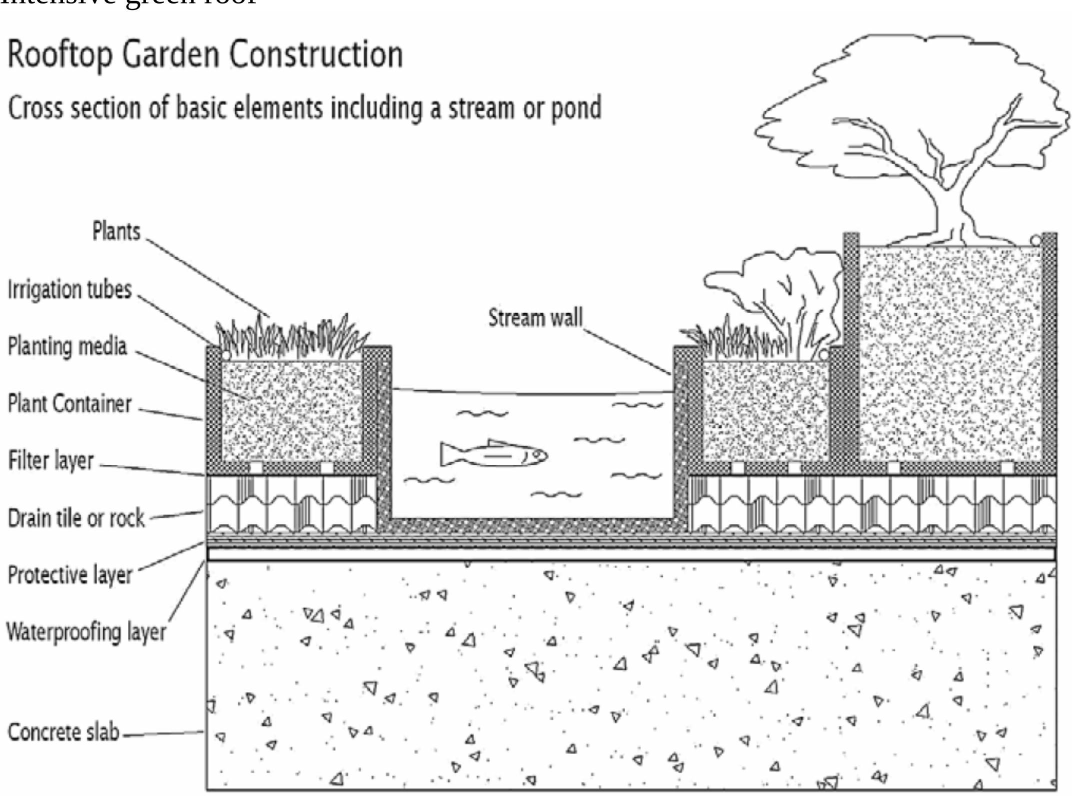
Intensive

An intensive green roof is more complex of a design than that of an extensive green roof. This type of green roof is frequently referred to as rooftop gardens. The green roof has a resemblance to park like settings, usually containing a variety of plant types (Wark, 2003). This can be seen in Figure 11. A typical intensive green roof growing medium is usually greater than that of any extensive green roof. The maximum depth of this system is determined by the structural support offered by the building (Wark, 2003). Some of the intensive green roofs can support fairly large trees and water pathways. This type of environment is popular for public access and recreation areas. Figure 12 shows the several layers that make up the complexity of an intensive green roof.

Figure 11
Implementation of an intensive green roof

A building with an intensive green roof installed (Wark, 2003).

Figure 12
Intensive green roof



A cross section view of an intensive green roof (Wark, 2003).

Green Roofing Assessment

Green roofs are poorly understood in North America. (Green Roofs for Healthy Cities, 2005) However, European knowledge of green roofing systems has been growing since ancient times (Wark, 2003). The amount of time and resources that European cities have distributed to the projects has proved to be valuable. The increase in European knowledge about green roofs has been a direct result of the European government legislative and financial support. Government funding in support of the systems illustrates that the government can foresee the many tangible and intangible benefits of green roofing (Green Roofs for Healthy Cities, 2005). Europe has made significant progress in perfecting the art of green roofs despite hardships and initial investments (Green Roofs, nd).

Limitations Facing Green Roofs

The European green roofing technologies are much more established than North American technologies. The lack of knowledge on the subject seems to be a leading cause of a city's unwillingness to implement a green roof system (Wark, 2003). Without quantifiable data, government workers may not have the information needed to institute cost incentives, develop building code standards, or promote the green roof conservation practice.

The cost of installation of a green roof system is also an implementation barrier. The initial cost of installation of an extensive – just grass or moss – green roof will cost its owner $9-$24 per square foot and the cost of an intensive grows even larger from that number due to the additional building materials needed (Green Roofs for Healthy Cities, 2005). Two places that are conducting research on the installation process are Pennsylvania State University and Michigan State University. The roof structure needs to be taken into consideration before implementing a green roof (Green Roofs Research Program, nd).

In many cities, it is the local building code standards that are lacking and are often a barrier standing against the construction of green roofs. This can add to both the cost and time of the construction. In 2001, the American Society for the Testing of Materials (ASTM) established a Green Roof Standards Task Group to provide national standards for the practice. At the last meeting in April 2005, five new standards were approved. Two standards are underdevelopment: Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems and Guide for Use of Expanded Shale, Clay or Slate (ESCS) as a Mineral. These standards create a basis for further research. They also give developers guidelines for placing green roof systems on their buildings if desired.

Another aspect that must be considered before a green roof can be installed is the type of plant species to place in the green roof. Until more research is conducted into the environments in which plant species can thrive on rooftops, the costs to determine the layout and plant species of the green roofs remains high. Deciding which specific plants are to be installed can be a difficult and time consuming process. If the contractor misjudges the appropriate species for the area, the project can experience set backs. For the time being however; this issues of plant upkeep still remains a major cost concern (Green Roof Research Program, nd).

Arguments in Favor of Green Roofs

Many cities worldwide have experienced the numerous benefits of green roof systems. As one of the leading green roof cities in America, Chicago has developed a large knowledge base on the subject. “Green roofs meet a number of our objectives in the city," said Sadhu Johnston, assistant to the mayor for green initiatives in Chicago. Meeting more then one environmental issue at a time is a major concern that green roofs may help to resolve. The first is that they help to moderate temperature in the city. The Urban Heat Island effect is a significant issue for all big cities. Green roofing provides an excellent barrier between the sun’s heat and the building the green roof occupies. Through the daily water collection and evaporation cycle, plants on vertical and horizontal surfaces cool cities in hot summer months, as proposed by Green Roofs for Healthy Cities (2005).

Air Quality

Green roofs are also known to improve air quality in urban environments. One square meter of leaf surface supplies enough oxygen, through photosynthesis, to supply one person's requirements for an entire year. Since the foliage in plants binds dust, all green roofing solutions further improve air quality by reducing dust (Dollar and Sense, 1999). In a city, the quality of the air can be linked to the presence of stationary and mobile air pollution sources such as factories and automobiles. Vegetated surface seem to be the only surface that is sorely lacking. Cars and industries are constantly pumping harmful gasses into the air humans breathe, gasses that have been related to cancer and other long term debilitating diseases.

Extended Roof Life

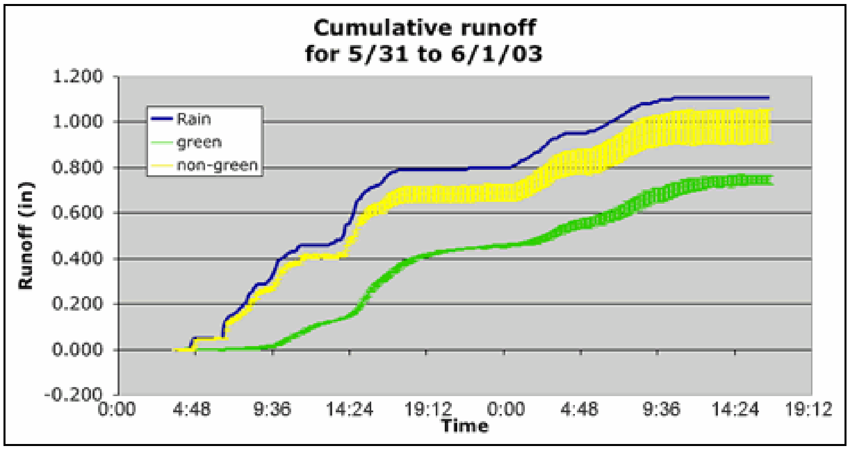
Furthermore, green roofs extend the life of a roof from fifteen to twenty years to fifty to sixty years (Leslie, 2005). The vegetation from the green roof extends the life of roof because less solar energy reaches the roof substrate, the surface on which a plant or animal grows or is attached. The green roof receives less UV radiation damage. This decreases the damage over time due to repeated contraction and expansion of the roof caused by daily temperatures fluctuations, contributing to a longer life of the roof (Happe, 2005).

Storm Water Retention

Green roofs also help regulate storm water runoff by absorbing storm water and holding it for a 48-hour period. According to Happe (2005), Amy Moran, a North Carolina State graduate student, has written that the results of a test showed a decrease in runoff volumes and peak runoff volumes of approximately 85 percent on a green roof surface. The soil medium being used for the study was four inches deep, lightweight, and consisting of roof garden soil mix of 55 percent PermaTill, 30 percent U.S. Golf Association root zone sand, and 15 percent approved compost. Vegetated roofs function as a storm water filtration and retention system, slowing down runoff and removing airborne particulates. Moreover, unlike metal roofs, green roofs do not contribute additional pollutants to a watershed (Happe, 2005). By contrast, in a natural watershed, rainwater flows more slowly into streams, feeding shallow groundwater and recharging aquifers deeper down. Natural soils and organisms also clean storm water by the time it enters a stream. Green roofs can help building owners and urban areas respond to these problems. From the study, it was concluded that green roofs can significantly reduce storm water runoff, filter particulates out of the rainwater, and break down other pollutants (Happe, 2005).

Other studies have also concluded that green roofs significantly reduce storm water runoff in urban areas. During the summer time, depending on the plants and depth of growing medium, green roofs retain 70 - 90 percent of the precipitation that falls on them; in the winter, they are capable of retaining between 25 - 40 percent (Green Roofs for Healthy Cities, 2005). A roof with an extensive green roof of grass 4 - 20cm tall can hold 10 - 15cm of water (Green Roofs for Healthy Cities, 2005). Pennsylvania State University's Green Roof Research team conducted a study to measure the difference in storm water runoff between a green roof and a non-green roof. In the graph presented below, in Figure 13, one can see that, over the course of two days, there is a significant reduction in storm water runoff from the green roof compared to the non-green roof (Green Roof Research, 2004).

Figure 13
Cumulative Runoff at Penn State



A graph, created by Pennsylvania State University's Green Roof Research team, demonstrating the cumulative runoff from 5/31/03 to 6/1/03 (Green Roof Research, 2004).

In nature, 30 percent of water from rainfall is used by plants, 30 percent percolates to aquifers, 40 percent returns to the atmosphere; therefore, the surface runoff is negligible. In cities, 5 percent of rain water goes to aquifers, 15 percent returns to the atmosphere, and 75 percent to surface runoff (Green Roof Benefits, 2005). During a major rainstorm, about 1.25 gallons of rainwater is generated per square foot. A simple 2.5 inch extensive green roof retains about 0.5 gallon per square foot, or 40 percent of the rainwater that falls. Furthermore, during the same storm 2.5 inches of mixed sedum and grass retains 67 percent, and 4 inch grass and herbaceous vegetation retains 71 percent (Green Roof Benefits, 2005). This data can be applied to the potentially green roofed development in Fan Pier.

The green roofs ability to absorb and control water runoff is one of its more marketable benefits. The water that the roof does not absorb will eventually reach the sewer system, but it is often purer than when it fell to earth. The EPA states that the root system of the green roof utilizes bacteria and fungi to filter out pollutants like nitrogen and phosphorus (Happe, 2005; Green Roofs for Healthy Cities, 2005). This benefit increases as the root system and the roof mature with time. The growing medium of a green roof typically contains 15 - 20 percent organic matter. The organic matter contains humic acid, which is responsible for removing pollutants from storm water. Humic acids occur naturally in organic matter and are harmless when conveyed away in storm water drains (Green Roof Research, 2004; Dollar and Sense, 1999; D. Beattie, personal communication, April 4, 2006). The London Ecology Unit found that green roofs can absorb up to 95 percent of pollutants like cadmium, copper and lead and up to 16 percent of zinc from rainwater (1993). When this filtration capability is combined with water reuse systems, they can together eliminate the presence of excess storm water. Figure 14, below, illustrates the drastic reduction in pollutants after storm water has been filtered by a green roof.

Figure 14

Photo illustrating the filtration power of green roofs; the difference in pollutants in the water is lucid (Green Roof Research, 2004).

By acting as a natural filtration system, green roof systems will aid in mitigating the water pollution problems that currently face Fan Pier and those that will continue to face Fan Pier once it is developed. Because the storm water drainage system for the proposed development of Fan Pier leads directly into the harbor, it would be extremely beneficial to the water quality of the Boston Harbor (Steve Shea, personal communication, April 11, 2006).

The water retention capabilities of green roofs also benefit other areas, such as temperature control. The evaporation and transpiration of water from the soil of the green roof carries away heat, which is a great benefit especially in the summer months. This cooling effect can be measured in terms of surface temperature. On a day that reaches 95^{o} F in cities asphalt roofs can often have a surface temperature of up to 150^{o} F. Green roofs can maintain surface temperatures of 75^{o} F as shown in the Urban Heat Island effect section above. This provides a significant bonus to the building which experiences lower energy needs and a much longer roof life. It is estimated that a green roof will double or even triple the life of a roof surface. In turn, the eventual cost of the roof can be significantly reduced with the green roof acting as a barrier between the under laying roof materials and the elements. (Hortsman, 2004*)*.

An urban development can also neglect nature by not providing green space and wildlife habitat areas (Scholz-Barth, 2004). Green roofs cannot be seen as replacements for true natural areas, but they do provide green corridors and wildlife habitats in an urban setting. Chicago's City Hall did not have a wildlife habitat specifically as an objective when the city created their roof design, yet their roof has provided enough cover and clean air to have animals occupy the green roof (Millett, 2004). Green Roofs for Healthy Cities (2005) have stated that, one square meter of grass roof can remove approximately 0.2 kg of airborne particles from the air every year. Beneficial birds, butterflies, and insects are attracted to green roofs for the clean environment the roofs supply over the city. Green roofs make the area much more pleasant while creating additional habitat for the animals and insects (Scholz-Barth, 2004).

Furthermore, storm water runoff from an urban roof is typically hotter than the body of water it drains into; in Fan Pier's case, this would be the Boston Harbor. Hot water draining into Boston Harbor can have an adverse effect on the sea-life, just as pollutants would (Dollar and Sense, 1999). Reducing the amount of storm water runoff would not only reduce the amount of pollutants pumped into the harbor, but also reduce the amount of water at aberrant temperatures. The temperature of Boston Harbor is at 36 - 66^{0}, varying due to winter and summer conditions, respectively (Northern Atlantic Coast, 2002). The higher temperature of the storm water runoff could interfere with the sea life in a negative way (Dollar and Sense, 1999).

Along with the numerous storm water related environmental benefits that result from green roofs, there are many financial benefits associated with the influence green roofs have on storm water runoff.

Buildings with green roofs produce less waste water than conventionally roofed buildings, which, in turn, reduces the demand on municipal services. Producing less waste water reduces the required amount of sewer piping. This creates a serious reduction in the cost of installing a new storm water infrastructure (Green Selling Tip, 2005; Dollar and Sense, 1999; Wilson, 2005). According to Jeff Oberdorfer, the Executive Director of First Community Housing's extensive green roof project in Silicon

Valley, CA, having a green roof aids in lowering the firm's long term operational savings; because money is not being spent on water drainage, the company is able to pay off property debt sooner and even launch additional housing projects (Living Roof, 2006). For some projects, the infrastructure savings are so significant that they can pay for other costs associated with the property (Wilson, 2005). The money that contractors save on infrastructure installation, due to storm water reduction, could then be used towards other amenities that the property owner may desire.

Reducing the amount of water that requires drainage is not the only financial benefit of a green roof. For future decades, the freshwater supply is thought to be a much greater concern than energy supply. It is possible to collect the filtered water drained from the green roofs and store it for use in landscape irrigation (Living Roof, 2006). Buildings such as the Solaire high-rise apartment building in New York City and the Pennsylvania DEP office building in Norristown, Pennsylvania, include self-contained water collection and treatment systems to provide non-potable water for toilet flushing and irrigation from wastewater (Wilson, 2005). Reducing the costs for utilities, such as water for irrigation, decreases the annual operating costs. Lowering operating costs increases the overall value of the buildings in the Fan Pier Development (Wilson, 2005).

In the proposed development for Fan Pier, there are two parks which will need to be irrigated in order to keep them looking attractive and inviting (Fan Pier Land Co., 2001). Using water collected from the green roofs to water the parks could be an excellent means of reducing landscaping and water costs. Because the roofs are at a higher elevation than the parks, a gravitational irrigation system could be implemented, providing plenty of water pressure to supply the parks with water. According to *The Fan*

Pier Development report, the proposed development will use six gallons per minute for irrigation (Fan Pier Land Co., 2001); this water could be significantly reduced by implementing a gravity irrigation system fed by green roof drainage. This idea has already been utilized by Ford Motor Company's River Rouge building, which has a 10.4 acre roof, with successful results (Newman, 2005).

Another benefit associated with a green roof's ability to retain water is that in the summer, the green roof will hold rainwater, allowing for slow evaporation, which aids in cooling the building, reducing air conditioning use (Newman, 2005). This can lead to a reduction in energy costs as well as a reduction the number of chlorofluorocarbons emitted into the air, providing both financial and environmental benefits.

Human Resource Benefits

There are other ways in which green roofs provide financial benefits. The concern for a healthy, safe, and appealing work environment is the main objective of Human Resource (HR) departments. By providing these qualities to a workplace, the HR department strives for a more efficient and stable employee staff. If a company installs a green roof, also used as an open space, the company can benefit from increased productivity, easier employee recruiting, reduced employee turnover, improved worker productivity, and improved learning rates (Wilson, 2005; Green Solution from Weston, nd; Green Roofs for Healthy Cities, 2005).

The first benefit for the HR department is the increase in productivity of the employees. The improvement in productivity can have immediate results associated with it. A United States office building on average spends $318 per sq. ft. (Wilson, 2005; Green Selling Tip, 2005). If the HR department can increase their worker productivity by just 1 percent, the savings associated with this increase could offset total energy costs in the average building (Wilson, 2005; Green Selling Tip, 2005). A study from Carnegie Mellon University has shown that productivity can increase due to the visual appeal of a green roof. The subjects were looking onto a green roof of a separate building. The study found that the increase of productivity was in the range from 0.4 percent to 18 percent (Wilson, 2005). An increase in productivity due to green roofs could further equate to more savings for a company. The increased productivity associated with the green roofs demonstrates a correlation between productivity rates and green open spaces.

Green, comfortable, and healthy buildings provide employees with a more pleasant place to work in. Due to the environment created, the employee turnover rate will be reduced (Wilson, 2005; Green Selling Tip, 2005). For a company to find quality employees is a challenge, made easier through a reduced employee turnover. The high cost of employee recruiting and training is reduced when the current employees want to stay in their job. A Michigan company estimated the cost of recruiting and training a new employee to be $12,000 for a nonprofessional worker and $35,000 for a professional employee (Wilson, 2005; Green Selling Tip, 2005). The ability a company has to retain its current employees greatly reduces the cost of finding and training new employees. This can be shown through the United States Navy in an effort to retain their military personnel. Due to the significant cost of recruiting and training new personnel, the US Navy implemented green roofs for their housing in hopes to retain current members (Wilson, 2005; Green Selling Tip, 2005). The green roofs provided a more natural environment on the military base to retain their trained military personnel. This effectively reduces the amount of recruiting the particular military base needed to conduct.

The Fan Pier development has planned for three office building sites (Fan Pier Land Co., 2001). Each building may contain one or more HR departments depending on how much square footage a particular company can take up. This raises an opportunity for each HR department to use a green roof system to their advantage through aesthetics. With the increase in productivity from the aesthetically pleasing environments, the newly developed office spaces have the potential to integrate itself into the South Boston business sector at a rapid pace. The increased economic standing in the business sector will lead to more established companies that retain employees therefore reducing employee turnover costs.

Public Relations Benefits

Complementing the HR department of a company is the Public Relations (PR) department. This department deals with how the company is viewed within the community and business world. Every company wants the competitive advantage in the job market to further expand their company. The competitive advantage can be gained through the implementation of sustainable design principles (Green Solution from Weston, nd)

The advantage can be gained through the positive public image of the company's building. The positive public image can be realized through a commitment to healthy, environmentally responsible building (Wilson, 2005; Green Selling Tip, 2005). A positive public opinion can lead to much of the success of a company. Ford Motor Company, for example, has profited greatly from its facility's green features. The Rouge

Plant was covered in dozens of national magazines, including five pages in *Time* magazine, and television reports. For Ford to purchase the kind of coverage it received for developing a green roof would have cost hundreds of thousands, if not millions, of dollars in print and televised media (Wilson, 2005; Green Selling Tip, 2005). Through the success of buildings like this one, green roof development, design, and construction has prospered. New opportunities and projects have fallen into the laps of many green building experts as a result of the publicity (Green Selling Tip, 2005).

Public relations are integral in getting a business noticed and establishing a good reputation for the company. Constructing green roofs systems early in the Fan Pier development would expose the public to the development and its businesses to a wider market base. The positive public image of a new development creates the opportunity for the public to want to work, visit, and conduct economic activity at the Fan Pier buildings.

Tax Incentives for Green Construction

Green construction allows many opportunities for a company to take advantage of financial incentives from the government. Virtually every state in the United States promotes environmentally friendly construction through tax reductions (Meyerson, 2005). Beyond the incentives provided by local and state governments, the U.S. Green Building Council has established programs to aid the cost of initial investment. The Leadership in Energy and Environmental Design program provides the owners of the buildings with certain incentives and tax reductions. The U.S. Green Building Council estimates that the process adds approximately 2 percent to the initial costs, but yields a full return on investment (Meyerson, 2005). Table 1, below shows the distribution of states and which tax incentive programs each state offers. Figure 15, below, graphically represents this data to illustrate the distribution of incentive programs among the United States. Property tax reduction is the prevailing type of tax reduction used in the United States for green construction. Massachusetts is the only state to offer all four incentive programs.

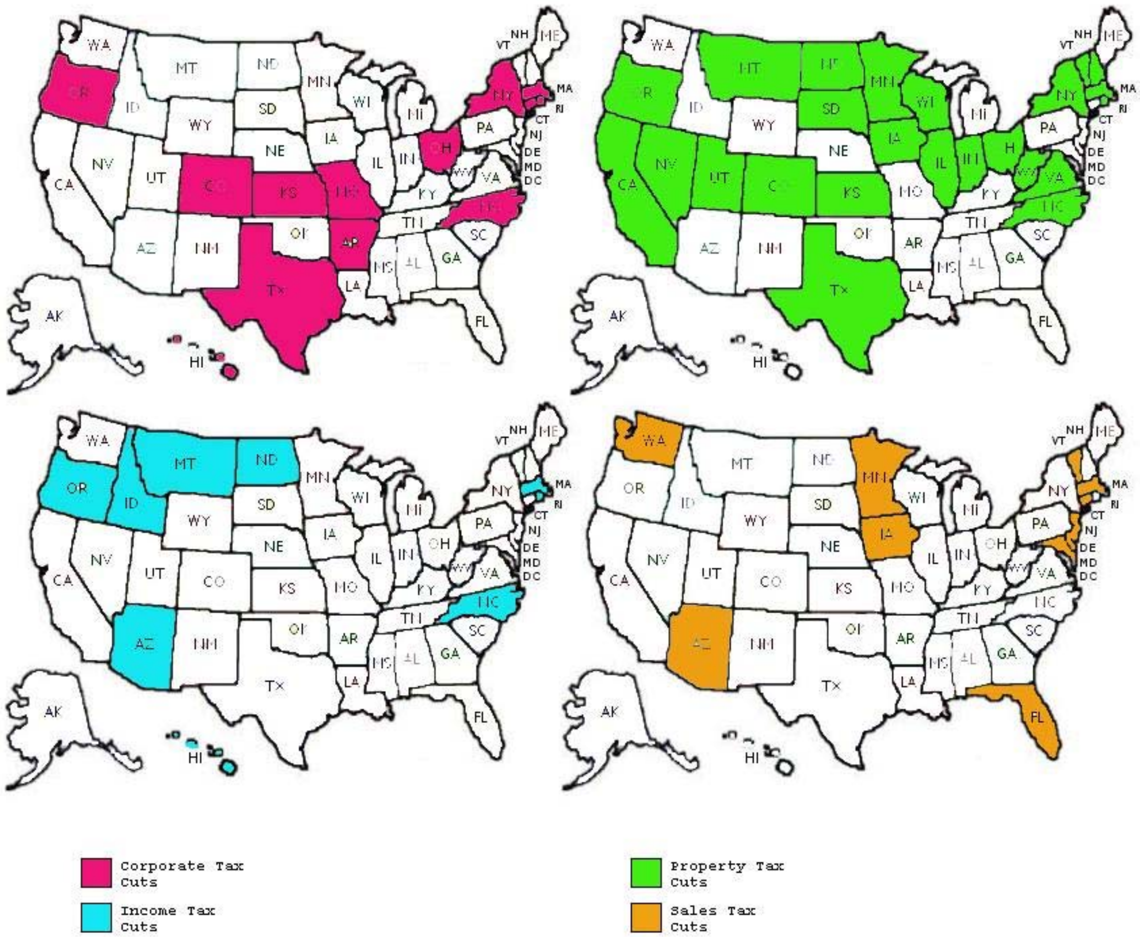
Table 1

Tax Incentives for Green Construction

State	Income Tax	Corporate Tax	Property Tax	Sales Tax
Alabama	x			
Arizona	x			x
Arkansas		x		
California			x	
Colorado		x	x	
Connecticut		x		x
Florida				x
Hawaii	x	x		x
Idaho	x			
Illinois			x	
Indiana			x	
Iowa			x	x
Kansas		x	x	
Maryland				x
Massachusetts	x	x	x	x
Minnesota			x	x
Missouri		x		
Montana	x		x	
Nevada			x	
New Hampshire			x	
New Jersey				x
New York		x	x	
North Carolina	x	x	x	
North Dakota	x		x	
Ohio		x	x	
Oregon	x	x	x	
Rhode Island	x	x	x	
South Dakota			x	
Texas		x	x	
Utah			x	
Vermont			x	x
Virginia			x	
Washington				x
West Virginia			x	
Wisconsin			x	

States with tax incentives for green construction (Meyerson, 2005).

Figure 15
Tax Incentives for Green Construction



States With Tax Incentives for Green Construction (Adapted from Meyerson, 2005).

Tax reductions for the Fan Pier development would benefit the owners of the site. The development is estimated to contribute $15 to $20 million in property taxes alone. A property tax break would help the developers place the savings into other parts of the development.

Lower Construction Cost

Green construction projects can turn out to be an expensive investment. Apart from tax incentives for building the greened area, the construction cost of infrastructure and materials can be reduced (Wilson, 2005). For example, the management of storm water can be a significant investment for the owners of a building. If innovative storm water systems, as discussed above in *Storm Water Runoff*, are implemented in a building development, it can reduce water requirements and pipeline size (Wilson, 2005).

A reduction in infrastructure and the creation of green space can also speed the permitting and approval process. Local citizen groups and planning commissions can slow down the developmental process. A development designed to minimize the loss of open spaces or result in less storm water runoff, for instance, can reduce the concerns of the commissions (Wilson, 2005). On the other hand, development schemes that become complicated because of restructuring could make the approval process longer. Regulatory and citizen groups can be unfamiliar with certain technologies or techniques and therefore require more time to review the project (Wilson, 2005).

Downsize Mechanical Equipment

Many green building strategies, materials, and products require less maintenance or reduce the need for cleaning than those used in conventional roofing.

Green roofs are known for their durability. Because the building is required to withstand a decent load resulting from the weight of the green roof, many new buildings are designed to overcompensate for the stress it will experience (Wilson, 2005). This means that the building itself will be more durable than necessary, extending the life of the building and all its components. Green roofs can extend the life of a roof, in particular. Green roofs can increase the durability of the roof membrane, appreciably, by protecting it from exposure to UV light and thermal shock. When the durability of the building is high, there is less of a need for purchasing and renting mechanical equipment for maintenance (Wilson, 2005).

Green roofs' ability to aid in reducing energy consumption can often make it possible to downsize mechanical equipment as well as perimeter heating systems. As mentioned in the previous section, *Storm Water Runoff*, in Chapter Four, green roofs can help in cooling a building, thus reducing air-conditioning use (Dollar and Sense, 1999). With air-conditioning equipment, the cost is fairly proportional to the cooling capacity, so a reduction in cooling load directly translates into savings from initial capital investment and ongoing operational costs (Wilson, 2005).

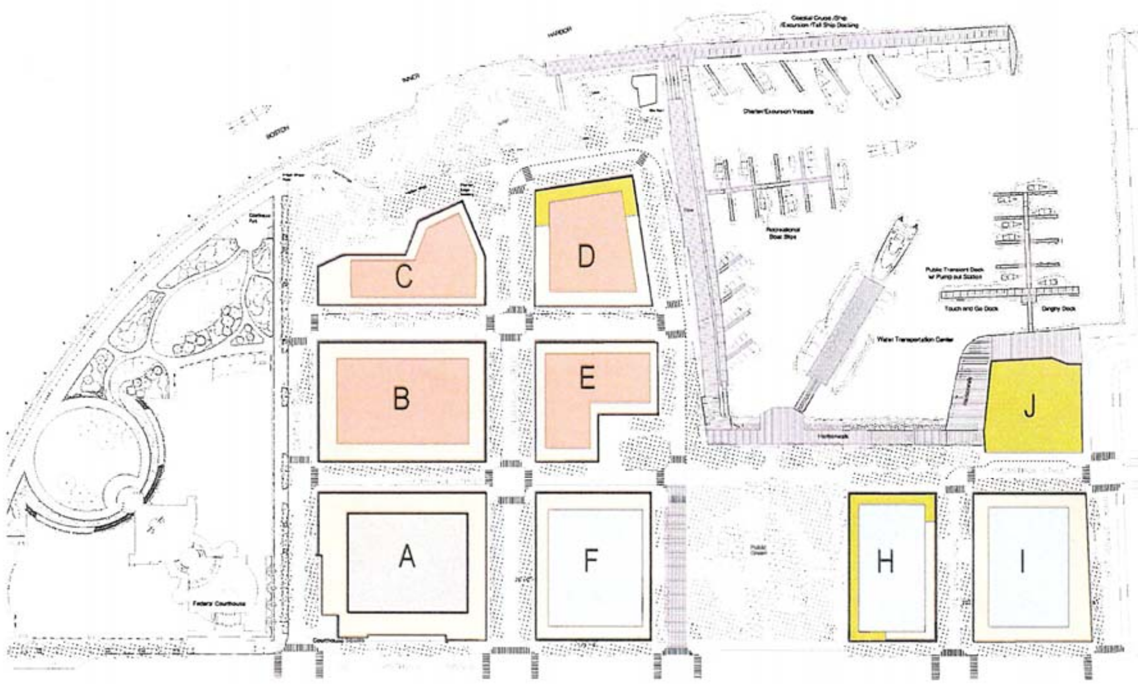
Increase Sale of Homes and Retail Space

Buildings with green roofs, whether they are office space or high-rise residential property, often lease out quicker than conventional buildings, and often with higher rental prices (Green Selling Tip, 2005). Reasons for this include media exposure about environmental and health features, marketing materials that flaunt the low operating costs or enhanced comfort, and word-of-mouth comments about the look and feel of such buildings. Developer Joe Van Belleghem of Build Green Developments, Inc., in Victoria, British Columbia, credits green features for the rapid lease-out of his Vancouver Island Technology Park during a period of downtime in the high-tech sector. Minimizing the number of months for which lease space remains unoccupied reduces carrying costs and increases profits (Green Selling Tip, 2005; Wilson, 2005).

This can be applied to the Fan Pier project because there are 1,091,200 square feet of proposed residential area and 1,223,380 square feet of office space which will all need to be rented out to the public. In addition to the office and residential space, their will be 478,000 square feet of hotel space (Fan Pier Land Co., 2001). In order to keep all of the space occupied, The Fan Pier Land Co. will need an amenity that is not found in other properties. Green roofs are one known way to attract lessees (Bryan Glascock, personal communication, March 30, 2006; John Dalzell, personal communication, April 4, 2006).

Green homes and condominiums often sell more quickly than their conventional counterparts. Developers Tom Hoyt of McStain Enterprises, Inc., of Boulder, Colorado, and Dennis Wilde of Gerding/Edlen Development Company of Portland, Oregon, report rapid sales of green buildings (Green Selling Tip, 2005; Wilson, 2005). Fast sales mean lower carrying costs and lower interest on swing loans, both of which increase bottom-line profits. Buildings B, C, D, and E of the proposed Fan Pier development, seen below in Figure 16, make up 1,091,200 square feet of residential space that are looked down on by the high rise office in plot F and the hotel in plot A. Buildings B, C, D, and E are already located close to the water; adding green roofs will enhance their appeal to potential lessees.

Figure 16
Development Layout



An aerial view of the proposed Fan Pier development, with each building labeled (Fan Pier Land Co., 2001).

In the proposed plans for Fan Pier, there are very tight constraints on the energy uses for the public facilities (Fan Pier Land Co., 2001). By instituting a green roof system and the possibility of saving up to a quarter of their total energy operational costs per year it could free up funding for other public activities, benefiting everyone from school children to the elderly (Green Selling Tip, 2005).

In addition to the beneficial social implications, greening the roof can greatly increase property value. The over all aesthetic appeal increases the value of the property and the marketability of the building as a whole, particularly for accessible green roofs. For example, American and British studies show that sufficient tree cover adds 6 - 15 percent to the value of a home. Green roofs offer the same visual and environmental benefits (Green Roofs for Healthy Cities, 2005). Although the amount varies greatly based on the construction of the green roof, according to AM Appraisal Associates, “any green space is good green space,” meaning that people will pay for green space especially if they have access to it (AM Appraisal Associates, personal communication, April 5, 2006).

With the 1,091,200 square feet of residential area in the Fan Pier proposal, almost a third of the area’s total value could be supplemented with this 6 - 15 percent increase. With any income-generating (rental) property, reducing operating cost can boost the property value. This occurs because the lower operating costs increase the building’s net operating income (Green Selling Tip, 2005). According to the publication Benefits Guide: A Design Professionals Guide to High Performance Building Benefits, published by the New Buildings Institute, increasing the net operating income of a building increases the building’s appraised value by ten times the annual cost savings, a capitalization rate (cap rate) of 10 percent. For example, a 75,000 ft^2 (7,000 m^2) office building that saves \$0.50/ft^2 (\$5/m^2) per year in operating costs (\$37,500 per year) will see the value of the building increase by \$375,000. A higher building value can increase the loan amount available from lending institutions.

Considering the size of the proposed project at the Fan Pier site, the savings could be substantial. Considering the total square footage of the proposed building footprint is approximately 272,632 square feet, using the formula proposed above, it can be deduced that the development as a whole could save as much as \$136,316 per year. Depicted below, Table 2 shows the parcels, their purposed functions, their footprint sizes, and the amount, in dollars, it would save each year by installing green roofs.

Table 2

Savings in Carrying Costs and Loans

Plot	Function	Sq. ft..	~ savings ($)
A	Hotel	48,405	24,202.50
B	Residential	39,646	19,823
C	Residential	23,129	11,564.50
D	Residential	24,708	12,354
E	Residential	28,380	14,190
F	Office	33,600	16,800
H	Office	25,200	12,600
I	Office	33,180	16,590
J	Cultural/ Civic	16,384	8,192

Savings based on the square feet of building foot print when entirely greened saving $0.50/ft^2$ (Wilson, 2005).

Increasing Morale

The development of green roofs can also improve the morale of an employee or citizen. An improvement in morale will provide an employee with a more comfortable environment to complete work that needs to be done, in turn, increasing productivity. Using green roofs to reduce drafts, minimize floor-to-ceiling temperature stratification, and control noise improves the comfort in building. The efforts to improve employee morale through comfort benefit the employee psychologically (Green Selling Tip, 2005; Green Roofs for Healthy Cities, 2005). Psychological studies have shown that green, open spaces have a restorative effect on a human subject. The natural views hold the viewers' attention, diverting their awareness away from themselves and work related problems, thereby improving one's health (Green Roofs for Healthy Cities, 2005).

Green open areas have also improved health beyond office buildings to hospitals. Patients in the same hospital, recovering from the same operation, were studied for the restorative effects of one's view. The views consisted of a landscaped courtyard versus a brick wall. Patients who had the green view had short post-operative stays, took fewer moderate and stronger painkillers, and had fewer negative evaluation comments from the nurses (Green Roof for Healthy Cities, 2005). Views of the outdoors and connections to nature have been shown to promote more rapid healing in hospitals (Wilson, 2005; Green Selling Tip, 2005). Hospitals have this virtue due to the materials used, moisture control, pollution prevention, contamination rejection, and ventilation strategies employed by green buildings, making them healthier buildings (Green Selling Tip, 2005). Green building features are also being viewed as strategies for reducing health care costs (Wilson, 2005). The health benefits can be illustrated with the Massachusetts General Hospital Healing Garden in Boston, MA. Figure 17, below, shows the green roof constructed for the hospital. The rooftop garden is located outside the Yawkey outpatient cancer ward to provide the patients with an outdoor and indoor facility to enjoy nature and boost the patient’s morale.

Figure 17
Mass. General Hospital Green Roof: View 1

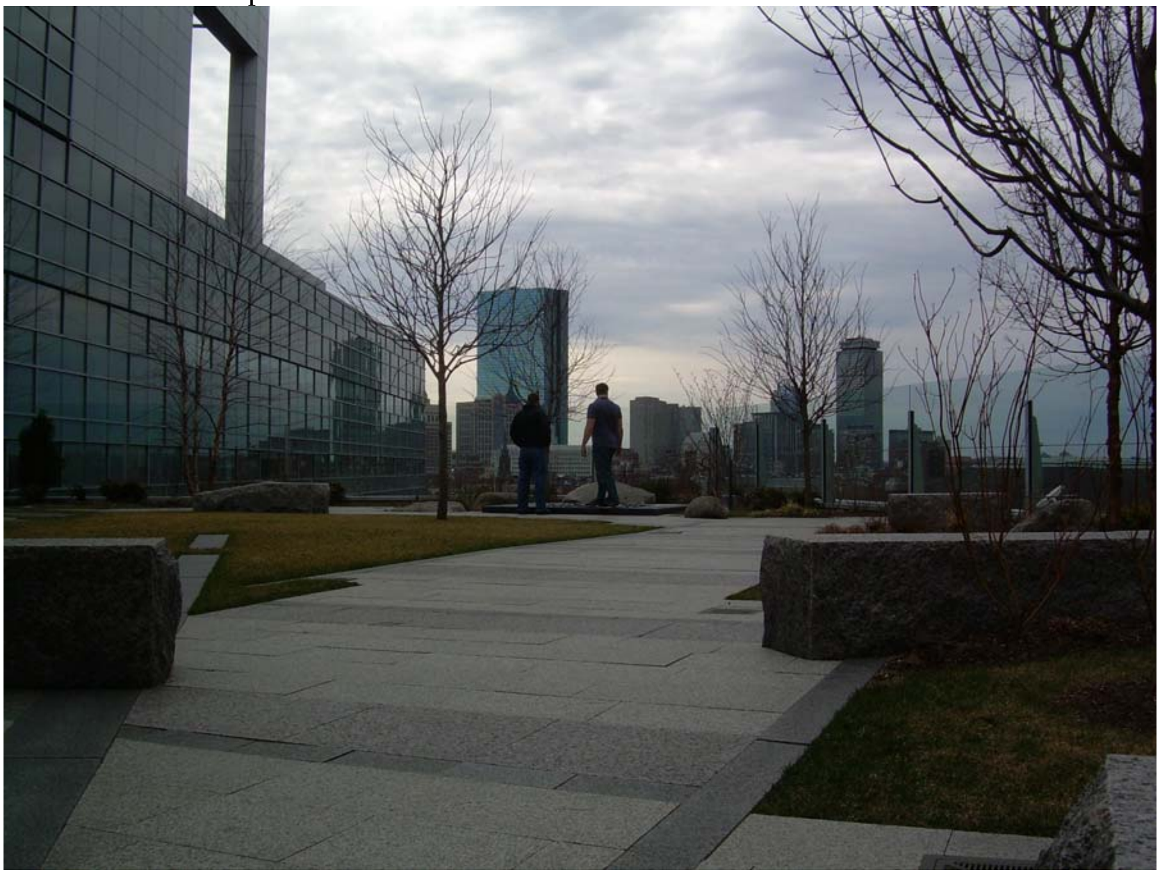


Photo taken atop the intensive green roof, located on top of the Yawkey building at Massachusetts General Hospital.

An increase in employee morale and health will provide the Fan Pier business sector with happier workers that take fewer days off due to illness. The green areas will also extend to the public visiting the development. Visitors will be able to conduct activities in a nice, natural environment away from city congestion. This could prompt the visitors to look into establishing their lives in the development. A healthy environment to raise a family and conduct business will add to employee and citizen morale.

Green Roofs Synopsis

Green roofs can help building owners and urban areas respond to the many problems that have been discussed above. They can significantly reduce storm water runoff, filter particulates out of the rainwater, and break down airborne pollutants. They can also reduce a building's cooling costs by 20 to 30 percent for a single-story building and reduce sound transmission. They can reduce the Urban Heat Island effect, resulting in lower cooling loads for all buildings and a reduction in the creation of smog. It is also estimated that a green roof will double or even triple the life of a roof membrane.

In summation, the major negative aspects of green roofs seem to come from the up-front cost of its construction and initial upkeep. The structural integrity of buildings with green roofs must be greater than those without them in order to account for the additional weight. Additionally, the cost of plant material can be quite expensive when compared to a traditional roof. However, the initial cost of a green roof must be weighed against its long term benefits. Green roofs are planted in a light weight and porous material that can be capable of absorbing a large percentage of the rain water and would be particularly useful in areas at or below sea level. Also, a green roof will prevent UV damage and general wear and tear that would normally affect a traditional roofing material. Finally, green roofs are capable of dissipating heat in the summer months and insulating in the winter, which regulates the temperature of the buildings and can also regulate the temperatures in the cities at large as well. In the end, any developer investigating whether or not to invest in a green roof will have to weigh their large initial cost against their long term benefits.

CHAPTER THREE: METHODOLOGY

This chapter explains how the project team met our objectives and ultimately accomplished our goal.

Goal

Provide Boston's Environment Department with information about green roofing so they may present The Fan Pier Land Co. with the opportunity to make a well informed decision regarding the adoption of green roof technology for their properties.

Objectives

- Collect data on Urban Heat Island effect, storm water runoff, and air quality of the current and proposed conditions of Fan Pier.
- Quantify the contribution green roofs can make toward affecting the Urban Heat Island effect, storm water runoff, and air quality in Fan Pier.
- Determine the social implications of green roofs in Boston.
- Identify next steps and areas for further study.

Data Collection

Previous research was found in articles and case studies pertaining to green roofing. The project team investigated both published and unpublished articles in order to find data relevant to green roofs in the areas of air quality, Urban Heat Island effect, storm water runoff, and business. Previous case studies were thoroughly examined, and existing conditions of South Boston were determined. Numerous articles have been written on the effects of green roofs; the project team explored as many as possible, in order to gain as much information concerning green roofs and how they would most likely influence the current conditions of Fan Pier.

The Fan Pier Development Report was investigated in order to gain enough information to predict the impact that green roofs would have on the future development. In 2001, the Boston Conservation Commission accepted The Fan Pier Land Co.'s proposal, *The Fan Pier Development*; its construction is imminent. The project team examined the proposal thoroughly. The team obtained information, such as building foot prints, property square footage, and roof top drainage plans for later analysis.

By interviewing eight experts, the project team was able to obtain information that simply could not be found in any text sources. Bryan Glascock—our liaison for this project, Director of the Environment Department for the City of Boston, and coordinator for the upcoming Annual International Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show—organized the meetings with many individuals that had access to information that was essential to our project. The project team spoke with Kim Lundgren, who is the New England Regional Director for the International Council for Local Environmental Initiatives (ICLEI), about Urban Heat Island effect, air pollution, and storm water runoff. She attempted to arrange a telephone conference with an expert of Urban Heat Island and air quality, but unfortunately the expert was unavailable during the time this project was conducted. Bryan also put us in contact with John Dalzell and Carolyn Bennett, both from the Boston Redevelopment Authority (BRA). John Dalzell, the Senior Architect for the BRA, gave us many suggestions for the *Recommendations and Conclusions* section, Chapter Five of this report, especially regarding the financial benefits of green roofing. Carolyn Bennett, the Digital Cartographer and Geographic Information Systems Manager for the BRA, gave us access to maps of Fan Pier now and artistic renditions of what it will look like in years to come. The maps were later used in creating images of the proposed Fan Pier Development with green roofs on the rooftops. The project team also spoke with the BRA's Chief Economist, John Avault; he provided us with an economic analysis for green roofing and green technologies. Also, the team spoke with Steve Shea, a representative from the Boston Water and Sewer Commission to obtain data regarding storm water runoff. Unfortunately, they were not able to provide us with any new data; they were, however, able to confirm much of the data that the project team had already collected. Barbara Deutsch—the coordinator for the 2005 Annual International Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show—inspired the project team to generate the artistic renditions of the Fan Pier development with vegetated roofs; the images can be found Chapter Five of this report.

Through our own investigation, the project team was able to establish our own contacts with experts within the field of green roofing. Through snowball sampling, the project team was able to come in contact with Jörg Breuning, who is the founder of Green Roof Service, LLC. His profound horticultural knowledge and unmatched hands-on experience helped to give us direction with much of our data collection and analysis; however, his access to numerical data was limited. After reading an article about David Beattie, the Director of the Department of Horticulture at Pennsylvania State University, our group found his contact information and held a short telephone conference with him. He provided us with useful information and helped confirm much of the data that the project team had already collected.

Calculations were made to predict the effects that green roofs will have on the Fan Pier development. From the data found in *The Fan Pier Development* report, the project team calculated the many plausible results due to installing green roofs; the calculations were based on equations found in the articles and case studies that were investigated. Air pollution levels, storm water reduction, and financial effects were all calculated to make the effects of green roofs obvious and comprehensible. The actual calculations are discussed fully in Chapter Four.

All of the collected and calculated data were analyzed and related directly to the proposed Fan Pier development. In order to make this project valuable, all of the collected data had to be applied to the development proposed for Fan Pier. The project team predicted how the Fan Pier development would be affected by the installing of green roof systems. The team estimated the effects that green roofs would have on the air quality, Urban Heat Island effect, storm water runoff, and financially.

In order to give a visual image of the Fan Pier development with green roofs installed, the project team created an artistic rendition of the green roofed buildings. Using Adobe Photoshop, the project team was able to generate an image of what the Fan Pier development would look like if it were to be green roofed. This gives the reader of this report a visual view of the concept that is the Fan Pier development with green roofs. Barbara Deutsch, the coordinator of last years Annual International Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show, which was held in Washington D.C., told us that just by printing an image in the Washington Post of what an area could look like if it was entirely green roofed, the Casey Trees Endowment Fund was able to raise several million dollars to begin construction (Barbara Deutsch, personal communication, March 21, 2006). The image that they used is shown below, in Figure 18. The project team hopes that generating an image, similar to the one in Figure 18, will influence The Fan Pier Land Co. to invest in Green Roofs, in the same way that contributors did in Washington, DC.

Figure 18
Washington, DC Present and Future

Image created by the Casey Trees Endowment Fund to show the same area both without and with green roofs (Casey Trees Endowment Fund, 2005)

Presentation

The results of this project will be displayed in the Annual International Greening Rooftops for Sustainable Communities Conference, Awards and Trade Show. Upon completing our study, our project team assembled a poster that demonstrated our findings. The poster contained the artistic renditions that the project team created of the proposed green roofs for the proposed development, as well as our project's mission statement and the conclusions drawn from the project; it will be displayed at the Annual International Greening Rooftops for Sustainable Communities

Conference, Awards and Trade Show, which is to be held in Boston, in May 2006. It was the intention of this conference to raise awareness about the current environmental problems facing this world and how green roofs may be one of many solutions. The project team hopes to contribute in raising awareness in this field.

We presented our findings to the Environment Department of Boston. The project team will present data and conclusions in great detail to the Environment Department of Boston. The evidence will then be used towards a proposal for installing green roofs in the Fan Pier development. Our intention is to aid in giving The Fan Pier Land Co. the opportunity to make an educated decision as to whether or not green roofs would be appropriate for the buildings proposed for the development of Fan Pier.

CHAPTER FOUR: RESULTS AND DISCUSSION

Introduction

The data discussed below is relevant to the following areas of study in green roofs: air quality, Urban Heat Island effect, aesthetics, and storm water, several areas of study in green roofs do not have substantial data supporting their arguments.

Storm Water Runoff

Of all the environmental issues that green roofs are capable of combating, storm water runoff is certainly the most significant. Green roof systems aid in reducing the amount of storm water runoff, as well as filtering pollutants out of the water that does runoff. The data discussed below is intended to demonstrate the impact that green roofs could have on the storm water runoff problem that may potentially face Fan Pier.

Removal of Pollutants

As stated in Chapter Two, the growing medium is known to remove pollutants such as oil and heavy metals from the rainfall that runs off of roof tops. Removing these chemicals from the storm water runoff will reduce the amount of pollution that is discarded into Boston Harbor.

If the storm water is filtered, then it is possible to collect the drained water and reuse it for the irrigation of another green space. This concept is discussed more fully, in the later section, "Financial Benefits."

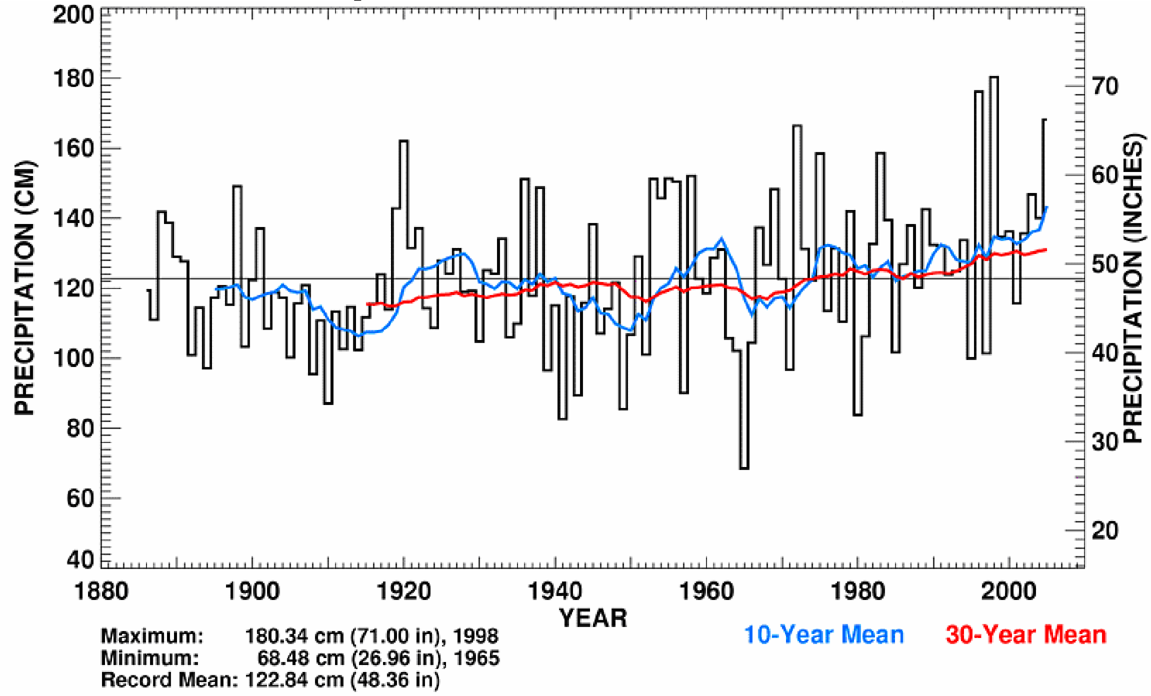
Through leading by example, Fan Pier could potentially inspire other waterfront properties to utilize green roof systems to filter the water that is pumped into the harbor.

Storm Water Retention

As discussed in Chapter Two, it is known that 2.5 inches of mixed sedum and grass retains 67 percent, and 4 inch grass and herbaceous vegetation retains 71 percent (Green Roof Benefits, 2005). This data can be applied to the potentially green roofed development in Fan Pier. Figure 19, shown below, is a graph demonstrating the annual rainfall for the Metro Boston area. From this graph, it can be assumed that Fan Pier, on average, experiences 46 - 52 inches annually. The Fan Pier property covers 643,080 square feet of land; approximately 272,632 square feet will be roof top space. This means that the roofs alone will be subject to 1,044,181 - 1,180,497 cubic feet of rainwater. With just the simple 2.5 inch extensive green roof, mentioned in the previous paragraph, the amount of rainwater that runs off of the roofs could be reduced to 626,509 - 708,297 cubic feet. Utilizing the 4 inch grass and herbaceous vegetation green roof, rooftop runoff could be reduced to 302,813 - 342,344 cubic feet. These data are shown visually in Figure 20, below.

Figure 19

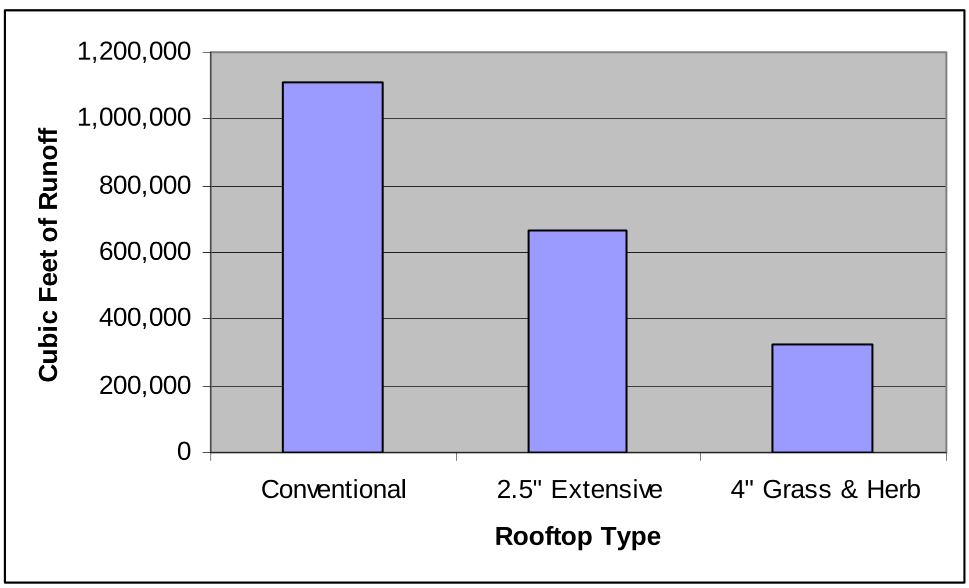
Metro Boston Annual Precipitation



Annual precipitation for the Metro Boston area, measured at the Blue Hills Observatory in East Milton, MA (Annual Precipitation, 2006).

Figure 20

Runoff Reduction for Fan Pier Development



Graph demonstrating the difference in runoff between conventionally roofed and green roofed developments in Fan Pier for one year of rainfall.

Reducing the overall amount of storm water runoff generated by a building's rooftop can have numerous effects of significant value. By retaining a great deal of storm water, green roofs can decrease stress on sewer systems at peak flow periods (Green Roofs for Healthy Cities, 2005). Although the proposed development for Fan Pier does not lead into a combined sewer system, less storm water runoff results in a less-involved private water drainage system that simply drains into the harbor that neighbors the property; this can result in a much lower installation cost for a drainage system which leads into Boston Harbor, which will be discussed in the following section, "Financial Benefits."

Although the Fan Pier development will not be, the surrounding properties are tied into a combined sewer system. If green roofs were to spread from the Fan Pier development to surrounding buildings, the stress on the sewer system would be significantly reduced, thus reducing the cost of sewage treatment for property owners. At 0.50 cents/gal for sewage treatment (Steve Shea, personal communication, April 11, 2006), utilizing a 2.5 inch extensive green roof and retaining 67 percent of storm water runoff would be very beneficial.

Even though green roofs filter out some pollutants from storm water, they cannot possibly eliminate all of them. This is why it is also important that they reduce the amount of water that drains into natural waterways. Reducing the runoff of storm water runoff, in combination with filtering the water, will notably reduce the amount of pollutants that flow into Boston Harbor.

Table 3, below, shows the rate of storm water runoff due to a design storm. A design storm is storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built (Drainage Glossary of Terms, 2006). The table shows the rates of water runoff for both the existing conditions and for the propose conditions of Fan Pier. The runoff rates for two different green roofing systems were calculated based on the data demonstrated in Figure 20, above.

Table 3
Fan Pier Runoff Rates

Design Storm	Existing Conditions (cf/s)	Proposed Conditions (cf/s)	With 2.5" Extensive (cf/s)	With 4" Grass & Herb (cf/s)
2 year	1.75	1.42	0.4686	0.4118
10 year	2.63	2.13	0.7029	0.6177
25 year	3	2.44	0.8052	0.7076
100 year	3.76	3.04	1.0032	0.8816

Fan Pier runoff rates resulting from design storms (Fan Pier Land Co., 2001)

Due to its location, Fan Pier will be draining all of its storm water runoff directly into Boston Harbor. Currently, the water running into the harbor contains pollutants, such as air pollutant deposition, oil, and heavy metals, that further contaminate the already fragile ecosystem of the Harbor, as well as disrupting Boston Harbor's tourism and maritime industries. Greening the roofs of these buildings will help to reduce these numbers even further and limit the washout into the harbor.

Air Quality

With the large number of people and the high emission rate of toxic gasses, cities like Boston need to maximize green area to not only improve the quality of the air, but also the quality of life (Glascock, personal communication, March 17, 2005).

Filtration of Airborne Particulates

A green roof will not only absorb heat, decreasing the tendency towards thermal air movement, but will also filter the air moving across it. As thermal currents carry the wind over and through a city, the particulates in that air column are dragged along the surface of streets and buildings alike. With just 1 m^2 (10.76 ft^2) of grass roof, approximately 0.2 kg of airborne particulates can be removed from the air every year (Dollar and Sense, 1999). In densely populated urban areas, any disease can spread like wild fire through the inhabitants. Green areas naturally filter out both organic and inert particulates in the air, reducing the number people breathe in. At just under a half pound per square meter/year, planted roof surfaces can serve to cleanse urban air of both nuisance dust as well as smaller particles such as PM 2.5, particulate matter less than 2.5 microns which can be inhaled deep into the lungs. The particulates removed from the air by green roofs are both large and small; the smaller particulates are known to be carcinogenetic. The current proposed Fan Pier project is 3,034,000 total square feet, while the total building footprint is 272,632. The current amount of proposed green space is unknown and many vary from what is currently seen in the artist's renditions. If green roofs were to be constructed on all of these roofs, it would add up to an additional 272,632 square feet of green space or 25,327.51 square meters. Using the above formula it can be said that by greening all the roofs in the Fan Pier development, approximately 5,065.5 kilograms of particulates can be removed every year (Fan Pier Land Co., 2001).

Carbon Dioxide/Oxygen Exchange

Through the process of photosynthesis, plants convert carbon dioxide, water and sunlight/energy into oxygen and glucose. This cyclical process supplies animals and humans with oxygen and food. It is possible for 1.5 m^2, or 16.15 ft^2, of uncut grass to produce enough oxygen per year to supply 1 human with their oxygen intake requirement (Green Roofs for Healthy Cities, 2005). If the buildings proposed for the Fan Pier development were all to be built with green roof systems on the total footprint of 272,632 square feet, the green space they provide would produce enough oxygen for approximately 17,000 people for an entire year (Fan Pier Land Co., 2001). By increasing the total oxygen in urban areas, it becomes increasingly easier for those with respiratory problems such as emphysema and asthma are able to breathe easier.

It is the understanding of the project group that the total atmospheric percentage of oxygen will remain at or around 20.5 percent; it is, however, lower in some urban areas than this world average. It becomes obvious that by having more green areas in urban developments there is an increase in the amount of oxygen produced by these areas (Green Roof Benefits, 2005). Socially, the applications of this are far-reaching and diverse. Although it is beneficial to everyone, the removal of particulates is extremely valuable for individuals with respiratory complications. South Boston residents that suffer from debilitating respiratory diseases, such as asthma, could benefit tremendously from the additional oxygen being discharged into the air by these green spaces.

Global Impact

Through the proper utilization of green roofs, it is possible to reduce global warming impacts. Global warming is a problem that affects the entire planet and is a major concern for everyone. It is also a key issue for this project when looking at the environmental implications of this proposal in concern with our project. The construction of new buildings as proposed for the Fan Pier site means the use of more energy and the generation of more heat and green house gasses. By implementing a green roof system on the proposed building developments, it is possible to regulate green house gases via a natural means of air filtration. The fewer gasses that escape into the atmosphere, the quicker the ozone will be able to repair itself (Wilson, 2005).

By utilizing green roof systems on the proposed buildings of Fan Pier, the air quality due to overall emissions of that area could be greatly improved from its current standing as a parking lot. The lot is 643,080 square feet most of which is impermeable surface, having the parking lot is bad enough the addition of non-greened building will only compound the problem with additional heat and energy demands. If these proposed buildings were to be greened they would augment the permeable surface while diminishing the demand for energy. The improvements on this one parcel of land may inspire developers to install green the roofs on other purposed buildings in the expanding South Boston area.

Urban Heat Island Effect

The Urban Heat Island effect, as it has been discussed above, is a serious concern for urban areas. Excessive heat results in a myriad of serious problems like increased ozone formation and also costs urban areas millions in energy spending. The presence of green roofs helps to combat the effects of the heat island by reducing the temperature of the roof surface and the temperature of the surrounding air via evapotranspiration and by reflecting the sun's energy. Studies have shown that greening 5 percent of cities rooftops could lower the temperature of that city by 2 – 4^{o}F. Given this information the project group calculated that if all the available roof space in Fan Pier were greened then it would reduce the temperature of Boston by 0.0104-0.0208^{o}F. Another method of combating

Urban Heat Island Effect is the use of cool roofs. (Appendix B) The team calculated that if all the roof space in Fan Pier was cool roof area then it would result in a 0.0208 percent reduction in smog, which is the equivalent of taking 5200-8700 cars off the road. The resulting reduction in temperature from reduced temperatures would save the city an estimated $60,700. While these numbers seems small one must keep in mind that Fan Pier accounts for only 0.026 percent of Boston's total land area. These numbers are only estimates and much more research and data are needed before a truly accurate picture of how green roofs impact on the Urban Heat Island Effect can be determined.

CHAPTER FIVE: RECOMMENDATIONS AND CONCLUSIONS

After conducting the investigation discussed above, the project team has developed the following recommendations:

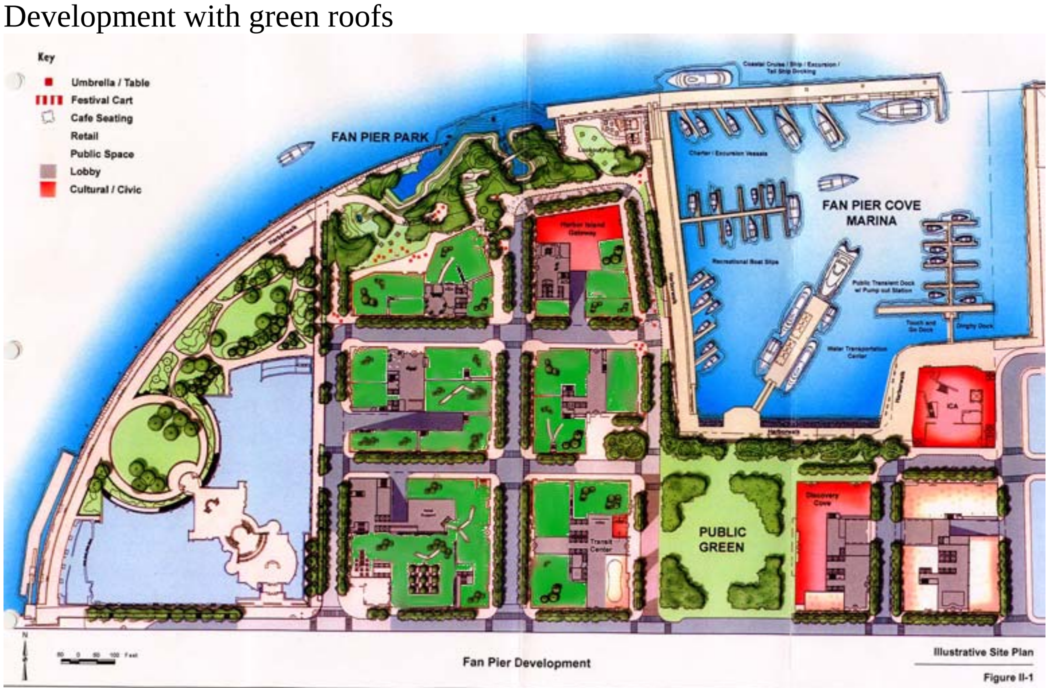
1. The first recommendation of the project team includes areas for which further investigation is necessary. Because green roofs are a relatively new technology in the United States, available data is minimal. We recommend that more research be conducted on green roofs impact on air quality, Urban Heat Island effect, storm water management, and, most importantly, business economics. Although some data exists in each of these areas, definitive conclusions are difficult to draw because there is simply not enough quantitative information regarding the impact of green roofs on urban areas.

2. If the future research yields the results we expect, green Roofs would significantly benefit the environment surrounding the Fan Pier development, and the project team recommends that The Fan Pier Land Co. installs them on the rooftops of their proposed buildings. The evidence presented above shows that implementing green roof systems on the proposed development will positively impact the air quality, Urban Heat Island effect, storm water management, and the visual appeal of the property. Artistic renditions of what the Fan Pier development would look like with green roofs can be seen below, in Figure 22 and Figure 24, and correspond with the original drawings of the proposed development, as seen in Figure 21 and Figure 23, respectively.
3. Because green roofs are significantly more expensive than conventional roofs, it would be impractical to install green roofs on every available roof top of the proposed development. The project team recommends that The Fan Pier Land Co. install cool roofs on the higher level rooftops, which are out of sight, and green roofs on the lower rooftops. An artistic rendition of what this might look like can be seen in Figure 25. Cool roofs are an inexpensive and environmentally beneficial alternative to green roofs; an explanation of cool roofs can be found in Appendix B.

Figure 21
Development without green roofs

An aerial view of the proposed Fan Pier development (Fan Pier Land Co., 2001).

Figure 22
Development with green roofs



A artistic rendition of the proposed Fan Pier Development with Green Roofs (Adapted from Fan Pier Land Co., 2001).

Figure 23
Development without green roofs

The proposed Fan Pier development as presented by The Fan Pier Land Co.

Figure 24
Development with green roofs

The proposed Fan Pier development with green roofs.

Figure 25
Development with cool roofs and green roofs

An artistic rendition of the Fan Pier Development with both cool and green roofs.

Appendix A

Boston Environment Department (Environment Department, 2006)

The Environment Department of the Boston City Government provides a great number of services to the inhabitants of the city. The Environment Department is located at Boston City Hall. The department is a subdivision of the Environment and Energy Department. Our sponsor, Bryan Glascock, is the acting director of the Environment Department. The department oversees many public programs established to maintain and improve Boston's environment. This organization has reached into several different areas of the city to improve its condition. The Environment Department aims to protect Boston's historic sites, buildings, landscapes, and waterways. The Boston Harbor, Air Pollution Control, Recycling, and Historic Preservations Commissions were established by the Environment Department to protect the built and natural environments of Boston and also to provide information on environmental issues affecting the city.

The Environment Department also provides public services to keep the public well informed and safe. These responsibilities include:

- Environmental reviews
- Electrical safety
- Parking freezing to control air quality
- Hold public hearings
- Provide forms and instructional guidelines

The department has also studied many specific sites in significant detail. The studies establish causes and recommendations to improve the site's quality. The department analyzes projects for potential environmental impacts on the City of Boston and its residents. The reviews identify specific environmental impacts and suggest potential solutions. Studies are conducted in local industrial, commercial, mixed use and residential developments, transit and transportation, and new or amended regulations. Some local Boston sites that studies were done include:

- Gaiety Theatre
- Aberdeen Architectural Conservation District
- The Modern Theatre
- George Milliken House
- Mission Church Complex

The department and the City of Boston is the local host for the 4th Annual International Greening Rooftops for Sustainable Communities Conference and Trade Show, May 11th & 12th 2006 at the Hynes Convention Center. The conference will feature presentations on planted roof systems and green technologies that help meet environmental, aesthetic, and energy conservation goals. The conference has provided a legacy in each previous host city. Chicago, Portland, and Washington D.C. have hosted the conference before Boston this year. These cities have greatly increased their green roof per square foot of roof space since the conference has come and left. The Environment Department and Boston hope that this legacy continues to make its impact after the conference has finished.

Boston has more than thirty green roofs systems already established in the city. The Federal Reserve, Ritz-Carlton, World Trade Center, Four Seasons Hotel, Massachusetts General Hospital, Harvard, and MIT are several examples of places green roofs already exist. The expansion of green roofs will help the Environment Department to combat many plaguing environmental issues that have risen in the Boston metropolitan area.

Boston Redevelopment Authority (Boston Redevelopment Authority, 2006)

The Boston Redevelopment Authority, or BRA, was established in 1957 by the Boston City Council and the Massachusetts Legislature. Currently located in Boston City Hall, the BRA has assumed authoritative power previously held by the Boston Housing Authority and the City Planning Board. The powers acquired by the BRA include the power to buy and sell property, the power to acquire property through eminent domain, and other development authorities over a broad area. The city of Boston relies on the BRA to fulfill many responsibilities which include:

- Reviewing, making recommendations, and drafting master plans for major construction and redevelopment activity
- Acquiring, selling, and leasing real estate to promote public policy objectives
- Issuing revenue bonds and notes to finance projects
- Owning and operating three industrial parks

The BRA has developed a staff of Geographic Information System experts. The organization has developed an extensive map system of the city of Boston. Carolyn Bennett, the Digital Cartographer and GIS Manager at the BRA, will provide our project with the necessary GIS maps, models, and development analysis for our specific area in South Boston.

Also from the BRA, John E. Avault was able to supply us with invaluable economic related information. Mr. Avault is the Chief Economist for the BRA and works in Boston’s Planning & Economic Development Office.

International Council for Local Environmental Initiatives
(About ICLEI, 2006)

The International Council for Local Environmental Initiatives, or ICLEI, is an association that is committed to sustainable developments. It was established in 1990 when more than 200 local governments from 43 countries assembled at the World Congress of Local Governments for a Sustainable Future at the United Nations in New York City. ICLEI was recognized at this meeting as the international agency for local governments. ICLEI began with the idea that a cumulative effect would be achieved if many cities could work in a partnership and therefore create a measurable effect on a global scale. The organization works with local governments to create international performance-based, results-oriented campaigns and programs. The focus of the campaigns is to help the local government achieve their sustainable development goals in air quality, climate, water, and other issues. They do this through a step-by-step process that:

- Generates political awareness of key issues
- Establishes action plans toward defined, concrete, measurable targets
- Meets the targets through project implementation and evaluation

ICLEI provides the governments with technical consulting, training, and information services to build capacity, share knowledge, and support local government in implementing sustainable developments at the local level. The organization believes that creating locally-designed initiatives best achieve local, national, and global sustainability.

Available contacts from this organization include Kim Lundgren and Ryan Bell. Kim Lundgren is the New England regional director for ICLEI; she operates directly out of the environment department in Boston's city hall. Ryan Bell is the program manager for ICLEI. He operates out of ICLEI's headquarters in Oakland, CA.

Appendix B
Cool Roofs

A cheaper and more manageable alternative to green roofs is the use of "cool roofs." These are roofs that have a simple reflective membrane laid down instead of an asphalt surface. Cool roof membranes have very large solar reflectance values, most as high as 80 percent with some membranes going as high as 90 percent (EPA, 2006; Efficiency Partnership, 2006). As a result of this reflective property, cool roofs can reduce temperatures on roof tops from highs of over 170^{o} F down below 100^{o} F (California Energy Commission, 2006). The result is that buildings with cool roofs can save between 20 – 70 percent on their cooling energy costs (Heat Island Group, 2000; EPA, 2006; Cool Communities, 2002; Efficiency Partnership, 2006). Cool roofs are also very competitive with traditional roofing materials. The EPA estimates that asphalt or gravel roofs cost $1.25/ft^2 to install while most cool roof membranes cost $1.50/ft^2 to install (EPA, 2006).

Being cooler helps a city in many ways. It is known that for every degree above 70^{o} F the incidence of air pollution increases by 3 percent. (Efficiency Partnership, 2006) The Lawrence Berkley National Laboratories (LBNL) conducted a study on the UHI effect on Los Angeles. They concluded that if 15 percent of the cities "heat sink" areas had cool roofs then it would result in a 6^{o} F reduction in the ambient air temperature and a 12 percent reduction in smog. (Cool Communities, 2002; Efficiency Partnership, 2006) This would save the city approximately $35 million in energy costs and would be the equivalent of taking 3 - 5 million cars off the road. (Heat Island Group, 2000; EPA, 2006; Efficiency Partnership, 2006) These benefits have such wide spread potential that they must be taken into serious consideration by any urban area looking for a way to combat environmental problems.

Cool roofs provide a viable alternative to green roofs in areas where green roofs are impractical, not desired, or too costly. Cool roof materials are also more widely available and can be obtained in a number of varieties which means that less research has to be conducted by developers which also lowers costs. Because a typical cool roof is a membrane surface, it can be applied much more easily than a green roof's many layers of substrate and plant material. The membrane's light weight and negligible water retention also means that it can be applied without compromising the roof's structural integrity. For these reasons cool roofs provide a very attractive alternative to green roofs for developers who are looking for a way to lower energy costs without the investment that green roofs require.

Cool roofs, however, cannot be used as a substitute for green roofs because they do not provide all of the same benefits. Because all the water runs off a cool roof, other methods must be found to deal with it. One possible solution is to capture the water in a catch basin for other uses such as irrigation. They also do not provide mush aesthetic value and can not be counted as open spaces. Their highly reflective properties are also undesirable for roofs that overlooked by other buildings or rooms. Because of this, cool roofs are not always the best solution, but they are another option for environmentally conscious developers.

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