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Benefits of Greenroofs

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BENEFITS OF GREENROOFS

By

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FOREWORD

For many years, greenroofs have been utilized by European architects and developers, who have realized their many benefits. The United States has, to date, been slow to embrace the concept. The intent of this report is to reveal the benefits of greenroofs in hopes of stimulating their use in this country.

SUMMARY

Greenroofs are beneficial ecologically, economically, aesthetically, and physiologically. They help keep the environment stable, save money, add beauty to the landscape, and provide a place of relaxation. These greenroof systems need to be used more extensively in the United States as they are in Europe. They will help alleviate the problems conventional roofs create.

1.0 INTRODUCTION

Human race has been captivated by the possibilities of growing plants on roof tops for over 2,000 years. The Hanging Gardens of Babylon, a ziggurat created by Nebuchadnezzar around 600 BC, is believed to have been planted with exotic plants on a series of terraces watered by slaves. Numerous examples reappear throughout history. Because of the high price of land in Rome, owners of villas put gardens on their

Figure 1. Hanging Gardens of Babylon

roof instead of the ground to supplement their living quarters. In Iceland, the roofs of homes were planted with grass to provide more insulation. Also the sod homes in the plain states had grass roofs to keep the home warm in the winter and cool in the summer.

Figure 2. Grass Roofed Homes in Iceland

The earliest roof gardens of the modern era date to the post war era, often in conjunction with parking structures. In 1955, Mellon Square in Pittsburg, Pennsylvania (design by Simonds & Simonds), was created over a large parking structure to provide open space in the midst of a dense urban landscape. The Kaiser Center roof garden in Oakland, California (designed by Theodore Osmundson), soon followed in 1960. It was the largest continuous roof garden in the world (Osmundson, pg. 92). Osmundson continued to specialize in this area, writing books on the subject, and inspiring generations of landscape architects to continue development of roof top garden technology. These earlier roof top gardens had, as their primary benefit, the creation of useful and aesthetically pleasing spaces on an otherwise desolate and wasted surface. But in the 1970's experimentation with the green roof grew as a response to the growing environmental concerns, particularly in Germany. In the 1980's the green roof market quickly expanded in Germany. By 1998, Germany installed 35 million square meters of green roof (www.greenroofs.com).

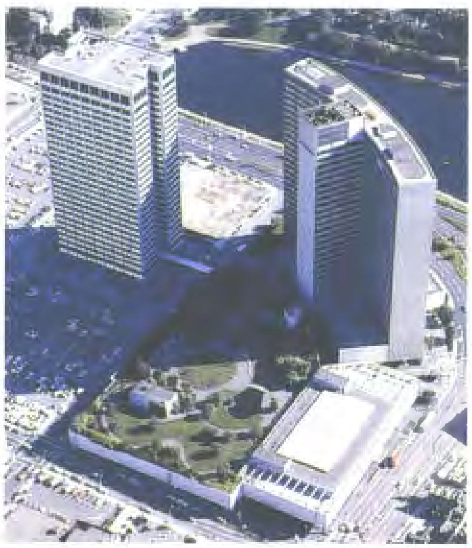

Figure 3. Kaiser Center

According to J. William Thompson, the greenroofs movement in North America resembles an infant struggling to crawl (Thompson, pg. 13). This industry is now just beginning to gain a foothold here in North America. "I record this assessment with some regret because green roofs have been tested and proven for decades in Germany and, if applied more widely (and more successfully) on this continent, could go a long way toward greening America's cities and suburbs" (Thompson, pg. 13). The Europeans have discovered that greenroofs are very beneficial. These benefits fit into four categories:

Ecological

Economical

Aesthetic

Psychological

This thesis will explain the benefits of greenroofs in each of these categories.

By definition a greenroof is a vegetated roof cover with growing media and plants that take the place of bare membrane, gravel ballast, shingles or tiles (www.greenroofs.com). Greenroofs are also called eco-roofs, nature roofs, or roof greening systems. There are two different types of greenroofs, extensive and intensive. An extensive greenroof is low-profile, thin and has less layers, lighter, less expensive, and very low maintenance. They can be constructed on roofs with slopes up to 33%. They are not intended for heavy loads. Intensive greenroofs are high-

Figure 4. Extensive Greenroof

Figure 5. Intensive Greenroof

profile, thick and have more layers, heavier, more expensive, and require more maintenance. They are constructed on relatively flat roofs that can handle heavy loads such as waterfalls, ponds, gazebos, trees, and shrubs.

2.0 ECOLOGICAL

Many ecological benefits are derived from the use of greenroofs. Not only do greenroofs help cool urban areas, they also provide habitat for wildlife, create a sustainable design, deter stormwater runoff and soil erosion, and clean the air we breathe.

2.1 Reduction in Urban Heat Island Effect

The urban heat island effect is a problem affecting many large cities and areas where there are acres of flat impervious areas such as parking lots, streets, and rooftops. These surfaces absorb the heat and reradiate it as thermal infrared radiation. This effect causes the temperature of the area to rise. Usually downtown temperatures are 10 degrees F warmer than surrounding areas (www.greenroofs.com). This 10 degree rise in temperature can double the amount of ozone produced. Some areas have been known to

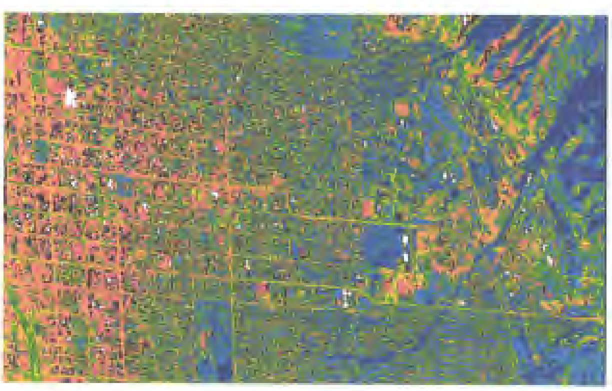

Figure 6. Heat Radiation of Salt Lake City

reach very high temperatures. In July of 1998, Salt Lake City had rooftops and other structures reach 160 degrees F (www.science.msfc.nasa.gov). Figure 4 shows the heat radiation. The red indicates hot areas. The blue represents cool areas. Downtown Salt Lake is extremely hot. This is due to the many acres of paving, rooftops, and plantless areas. Meteorologists suspect that large areas of asphalt paving have caused thunderstorms to develop in the afternoon. This in turn causes the city's storm sewers to be overwhelmed. This absorption of heat also causes the nighttime temperature of urban areas to be warmer as well. In contrast, vegetated areas are much cooler. Urban forests are encouraged to help keep developed areas cool, and greenroofs aid in this effect. A study in Toronto shows that an ungreened roof reached 158 degrees F (70 degrees C) and a greened roof reached 77 degrees F (25 degrees C) (Dunnett, pg. 29).

2.2 Reduce Ambient Air Temperatures and Increase Humidity Levels

Greenroofs help the vertical mixing of ambient air, producing lower temperatures. It is also important to have moisture in the air because dry air can cause problems with breathing. When plants capture precipitation, humidity levels increase through the process of transpiration which also provides a cooling effect. Additional cooling occurs as dew is released during the day through vaporization (Thompson, pg. 46). In urban areas where greenroofs have been installed, warmer air above hard surfaces rises, lowering temperatures above the vegetated roof cover (www.greenroofs.com). But there needs to be more than just one roof that is greened. An extensive network of roof gardens in an urban area could reduce the temperature by several degrees by covering heat-retaining spaces with more reflective ground cover (Osmundson, pg. 31). With more greenroofs, large air temperature fluctuations can be mitigated in urban areas.

2.3 Provide Habitat for Wildlife

With development there is the loss of wildlife habitat. Greenroofs help replace some of this habitat. They can help reconnect corridors for wildlife that live in urban settings. "In highly populated areas, greenroofs could represent island habitats, or better yet, stepping stones using a series of them for wildlife movement" (www.greenroofs.com). A diversity of wildlife could inhabit greenroofs, including beneficial insects, birds, bees, and butterflies. Studies have been completed that show that butterflies can reach up to 20 stories high and birds can reach up to 19 stories high (www.greenroofs.com). At the Mountain Equipment Co-op in downtown Toronto, Canada, the greenroof attracted raccoons, possum, and a duck. The duck even laid eggs and the eggs hatched there (Johnson, pg. 24). Native plant gardens do better when there is wildlife, working in a symbiotic relationship. The greater the diversity of plant life, the more diversity of wildlife will inhabit that space. Through the use of greenroofs, the enhancement of biodiversity is closely linked to the habitat or vegetation type that is being used as a model for the greenroof (Dunnett, pg. 37).

2.4 Sustainable Design

A sustainable design is a design that meets current needs as well as the needs of the future. One of greenroofs' greatest sustainability factors is the reduction or conservation of a structure's heating and cooling resources (www.greenroofs.com). A greenroof is also self-maintaining, requiring a minimal input of outside resources and energy. Greenroofs are becoming more popular and beneficial to the environment and the needs of people. Greenroofs will become a major part of future design. When developed on a greater scale, roof gardens can play a significant role in maintaining a healthy ecosystem, especially in built-up areas (Osmundson, pg. 29). Also, food production aids in the sustainability of the greenroof (see section 3.12).

2.5 Stormwater Management

Many of the nation's cities have overburdened sewer and stormwater systems. When development occurs, runoff is directed towards these systems. In a natural system, wetlands and floodplains handle this water even in times of extreme precipitation. A goal of development should be to return the water to where it would have fallen on the soil, which can be accomplished by retention ponds or by greenroofs. Stormwater can be retained on greenroofs or held in reservoirs to be reused for irrigation instead of running off the building contributing to the excess water below. Depending on rain intensity and greenroof soil depths, runoff can be absorbed between 15 to 90%, thereby considerably reducing the runoff and potential pollutants from traditional impervious roofing surfaces (www.greenroofs.com). The roof garden at the headquarters of Bazzani Associates in Grand Rapids, Michigan, absorbs 90% of the rainfall that falls on it (Davis, pg. 58). At the Tom Lipton house, when 4/10" of rain fell (about 40 gallons of water), only 3 gallons of water went to the ground as runoff (Thompson, pg. 50).

Runoff can affect the quality of natural waterways. In many older cities, such as New York, the sewer system serves as a collection facility for stormwater runoff. A heavy downpour of ½" or more causes sewer to overflow into the storm tunnels leading directly into nearby waterways (Osmundson, pg. 31). 75% of rainfall in towns and cities is lost directly as surface runoff compared to 5% for a forested area, and in industrial and shopping centers the amount rises to 71-95% (Dunnett, pg. 43). Think of the possibilities for this excess water.

2.6 Control Sediment Transport and Soil Erosion

Greenroofs reduce water runoff, therefore reducing the amount of soil eroded by water. Sediment and soil is not as apt to clog streams and drainage channels. The vegetation of greenroofs holds the water back from running off more quickly. The soil in roof gardens can hold as much as 15-20% of the rain falling on planted areas for up to two months releasing it more slowly into a city's storm system (Osmundson, pg. 31). There needs to be a network of greenroofs for this to work. One roof is not enough to control a significant amount of runoff.

2.7 Vegetation Absorbs Pollutants

The vegetation on greenroofs absorb pollutants from rainwater and the air. Pollutants such as heavy metals and nutrients are bound to the soil instead of being transported downstream to rivers or groundwater. Over 95% of cadmium, copper and lead and 16% of zinc can be taken out of rainwater (www.greenroofs.com). The levels of nitrogen fall as well. Many cities get their water from streams and rivers that flow through the city. It is important to keep these waterways clean for use. Without a greenroof, roof runoff contains contaminants from the roofing materials that will flow down into the water supply. Plants also absorb carbon dioxide and release oxygen which recharges the atmosphere with clean air.

3.0 ECONOMICAL

Economics sometimes dictate how a building is to be built which results in building cheaper structures. This trend should be reversed and the investment in building structures with greenroofs will bring financial savings later. The economic benefits are reasons for cities, developers, and private residences to consider implementing a greenroof.

3.1 Reduction in Building's Energy Costs

A greenroof acts as a natural thermal insulator. It causes the structure to be cooler in the summer and warmer in the winter. This results in reduced electricity consumption to cool the structure in the summer and heat it in the winter. According to an article from the Environmental News Network, a 3 to 7 degree temperature drop translates to a 10% reduction in air conditioning requirements. For a one-story structure with a green rooftop, cooling costs can be cut by 20 to 30%. The Weston Design Consultants recently conducted an energy study for the city of Chicago which estimated that it would be possible to save $100,000,000 in saved energy annually with the greening of all of the city's rooftops. The bottom line is that "Peak demand would be cut by 720 megawatts - the equivalent energy consumption of several coal-fired generating stations or one small nuclear power plant (www.enn.com/news/enn-stories/2000/12/12302000/rooftops_40979.asp). Substantial savings can be achieved by implementing a greenroof. Indoor temperatures are 6-8 degrees F (3-4C) cooler with a greenroof when outdoor temperature is 77-86 degrees F (25-30C) (Dunnett, pg. 33).

3.2 Comparable to the Cost of Conventional Flat Roofs

When consideration of maintenance of a conventional roof and the reduced energy costs are taken into account, the lifetime cost of a greenroof is comparable to the cost of a conventional flat roof (www.greenroofs.com). Greenroofs are unobtrusive, low maintenance, and great stormwater managers. Conventional roofs need periodic repairs that can become very expensive. Greenroofs generally increase the life of a roof (see section3.4).

3.3 More Usable Space

Roofs are underutilized resources in urban and suburban areas. Greenroofs create usable spaces that would otherwise be wasted. Property values rise as a result of greenroofs because of the increased amenities (Osmundson, pg. 27). Greenroofs also provide an outdoor space for apartment tenants. Some examples are very extravagant, with terraces and plazas where people can interact. Some cities require that a certain amount of green space needs to be provided as part of a new development. Instead of buying expensive land to create a park, the park or garden can be built on top of the structure. This allows the space that would have been used for the park at ground level to be used for something else and uses the space on the roof that would otherwise be unusable (Osmundson, pg. 27). Greenroofs allow more area for recreational space for activities such as BBQ's, exercising, dog exercising, sunbathing, golf, and even fireworks. Boston's Post Office Square is an excellent example of increased recreation provided on the top of a parking structure.

Figure 7. Post Office Square

3.4 Roof Life Extended

Greenroofs shield the roof from the damaging effects of ultraviolet radiation, temperature, and mechanical damage. During times of temperature extremes, in the summer roofs can reach up to 176 degrees F and in the winter roofs can drop to -4 degrees F (www.greenroofs.com). These temperature differences can cause the roof to crack, fracture, and to weather. By implementing a greenroof it reduces stress on the roof, extended the roof's lifetime by as much as 20 years. Other estimates say that a greenroof can triple the life of a roof (www.greenroofs.com). Here is a comparison of a conventional roof and greenroofs in regards to cost per square foot and roof life (based on 2002 U.S. prices).

Conventional Roofing: $4-8.50 per sq ft (15-20 year roof life)

Extensive Greenroof: $10-20 (50-100 year roof life)

Intensive Greenroof: $20-40 (50-100 year roof life) (Dunnett, pg. 32)

It is evident and more practical to install a greenroof and have the roof last longer than to install a conventional roof and replace it several times over.

3.5 Noise Reduction

Greenroofs have great noise reduction properties. The thickness of the greenroof insulates the building from noise pollution. Greenroofs are especially beneficial in areas near airports. The amount of noise reduction depends mostly on the thickness of the soil substrate and additional factors such as leakage from skylights, but overall, up to a 50 decibel noise reduction is possible (www.greenroofs.com).

3.6 Possible Impervious Coverage Restrictions Reduction

As mentioned in section 2.5, the creation of greenroofs can cut down considerably on stormwater runoff, possibly reducing the need for large stormwater systems. Retention ponds or underground galleries might be eliminated entirely, resulting in significant cost-savings to the developer. Downstream stormwater treatment savings are also a possibility.

3.7 Creates Jobs

The greenroof industry is a specialized form of design and construction requiring a skilled labor force. As greenroofs become more popular, the greenroof industry will create more jobs. It will also increase the need for plants, specialized nursery gardens, architecture, landscape architecture, landscape and ecological design, engineering professionals, laborers, and maintenance crews. In Germany, the green roof market averages a 15-20% annual growth (www.greenroofs.com). This growth is bound to happen here in the United States.

3.8 Pro-Environment Attraction

Because greenroofs are pro-environment, they engender positive feelings from the public. A company or industry that says they are pro-environment should install a greenroof to create positive public relations. This positive view of the company would increase the revenue of the business or industry. These businesses could be recognized for what they have done or receive design awards which in turn would increase the business further by getting more public attention. The Carrabba's restaurant chain has utilized the greenroof idea to entice customers to dine there.

Figure 8. Carrabba's Restauraunt

3.9 Low Maintenance

After plants mature and become established, little maintenance is required. This is especially true for extensive greenroof systems. Dave Robinson of Mountain Equipment Co-op says, "The greenroof is virtually self reliant" (Johnson, pg. 24). These greenroofs will require less energy in the years to come.

3.10 Increases Property Value

Greenroofs enhance the structure that it occupies. An owner can charge higher rental rates for rental space because the garden is an attraction (Osmundson, pg. 27). Hotel owners can charge more for rooms that overlook a greenroof or that have direct access from the room to a greenroof. Greenroofs can also contribute to the renewal of an urban area. If you put a park on top of a parking structure it increases the value of the space enticing visitors to stay longer and to convince other businesses to build or stay nearby. This also results in an increase in tax dollars and more money for the neighborhood (Osmundson, pg. 27).

3.11 Financial Help

In Stuttgart, Germany the city government adopted a program of subsidizing half the cost of greening the city's roofs (Osmundson, pg. 31). Also "43% of German cities offer financial incentives for roof greening" (Osmundson, pg. 31). Financial aid is available for building greenroofs in Germany. The US Green Building Council's Leadership in Energy and Environmental Design (LEED) voluntary program of the United States, ranks structures on a credit system according to how environmentally friendly the structure is. The more credits the more incentives will be received.

3.12 Food Production

One of the best examples of roof top food production is the Fairmount hotel in Vancouver, British Columbia, Canada. Here, a garden grows all of the herbs used in the hotel restaurants, resulting in a savings of 25,000-30,000 Canadian dollars. This space is also used by the guests and room rates are also increased, (Dunnett, pg. 26). Tenants of apartment complexes can grow vegetables on greenroofs which helps alleviate the cost of having to buy vegetables in a store. The Evangelical Lutheran Church in America (ECLA) established a container garden on the roof of their parking garage in Chicago. In 1997, the garden produced 984 pounds of vegetables from 38 pools in a 1,625 square foot area. This yield was better than the average yield per acre on open fields for the nation (www.elca.org/dcs/Environmental/history.html). The food produced was donated for distribution among feeding programs in the city.

Figure 9. ECLA Container Garden

4.0 AESTHETIC

In the post World War II era, greenroofs were mostly constructed for their aesthetic qualities. Towards the end of the 20th century and the start of the 21st century other benefits were realized as explained before, but aesthetic values still are a major reason why greenroofs are implemented.

4.1 Visual Appeal

Plants on a roof look much better than a bleak expanse of wasted space. There are many design possibilities for greenroofs. The design can be simplistic or it can be very complex. The slope of the roof can also create many different designs. The gardens can be naturalistic, formal, informal, or native. Some people will question the beauty of a greenroof. With all landscapes, there is a continuum of function verses aesthetics that influences what the final product will be. The beauty of a greenroof is how it works (King, pg. 13).

4.2 Blend with the Environment

The greenroof can resemble the type of landscape that was in existence there before development. This will allow the greenroof and structure to blend in with the landscape.

Figure 10. LDS Conference Center

The LDS Conference Center roof garden in Salt Lake City, Utah is a native landscape that when one looks in any direction the landscape seems to continue from the edge of the roof. At ground level the building is a massive structure, but the use of planted terraces breaks down the visual mass.

4.3 No Eyesores

The vast expanse of many roofs creates an eyesore. By installing greenroofs these eyesores can be eliminated. Roof gardens atop office buildings may serve solely as a visual amenity instead of a dark ugly roof with its vents, pipes, mechanical equipment, and miscellaneous storage that detract from the value of any interior space that looks out onto the roof (Osmundson, pg. 15-18).

5.0 PYSCHOLOGICAL

Humans have a psychological response to natural beauty and diversity. Usually it is a calming feeling or a sense of peace. Greenroofs can visually ease the stress created by the lack of greenspace in an urban environment.

5.1 Quality of Life Enhanced

Green spaces enhance the quality of life. They provide a place to escape and to reflect. People are healthier when they have a green space to go to. Greenroofs are therapeutic spaces that affect both mental health and emotional stability. One would rather see a garden than an asphalt covered roof from their hospital room or from their office. These may be the only open spaces available in the built-up city. It allows city dwellers to maintain connection with nature. Roof gardens can bring a patch of country back into even the most overdeveloped urban space. Such a reminder of our place within nature is vital to our sense of well-being (Osmundson, pg. 28-29). The therapeutic effects of having green plants and nature around one are known to be considerable and include stress reduction, lowering of blood pressure, relief of muscle tension, and increased positive feelings (Dunnett, pg. 28-29). Thoreau even suggested that every community should have its own patch of woods where people could refresh themselves because nature has healing powers (Stegner, pg. 4).

5.2 Sense of Community

People can share the greenroof garden which would bring them together. There can be a community vegetable garden grown on a roof top. The maintenance and care or the garden would be done by the residents. This fosters human interaction and sharing time between individuals especially neighbors. Everyone can feel apart of the community by taking on certain tasks in the garden. It is also a place for employees to mingle in a more relaxed setting than in the work environment. Greenroofs are spaces to meet, socialize, and attend special events.

5.3 Sense of Peace

Greenroofs create an area that is a sanctuary from the busy chaotic modern city. A greenroof is "like a peaceful island within an urban jungle" (Osmundson, pg. 28). Quietness is one of the most notable qualities. The sounds from the busy streets below are kept below. From many greenroofs, one can see the distant views to give the feeling of being in the country or in the suburbs. The far off landscape seems to be an extension of the greenroof. Greenroofs are also safer. Access can be controlled, thereby making an environment safer from vandalism, assault, and other social problems which tend to plague public green space at ground level (Dunnett, pg. 24). Roof top gardens are places to escape city stress and a perfect setting for enjoying the finer things in life, (d'Arnoux, back cover).

6.0 CONCLUSIONS AND RECOMMENDATIONS

Concern for the environment is becoming more evident as development and urban sprawl continue to spread. Sustainable design is a must if the future generations are going to survive healthfully. Although many environmental problems need to be dealt with, greenroofs can help ease some of the burden. Greenroofs provide too many benefits in the areas of ecology, economics, aesthetics, and psychology to be overlooked. The industry in Europe has set the precedent. Now it is time for America to expand and continue to follow this valuable industry.

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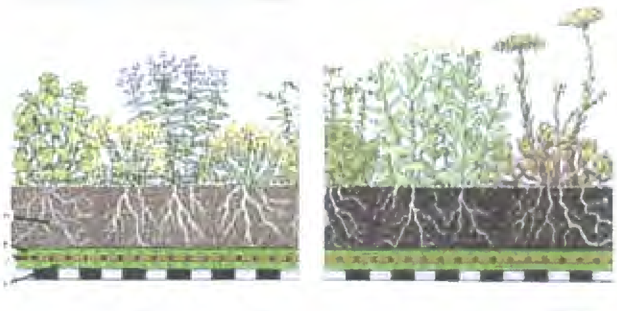
APPENDIX 1. Types of Greenroofs

Typical Extensive Greenroof Material Section from Optima:
Simple Plant Communities: Height: 2 – 3 inches

Light Weight **Heavier Weight**

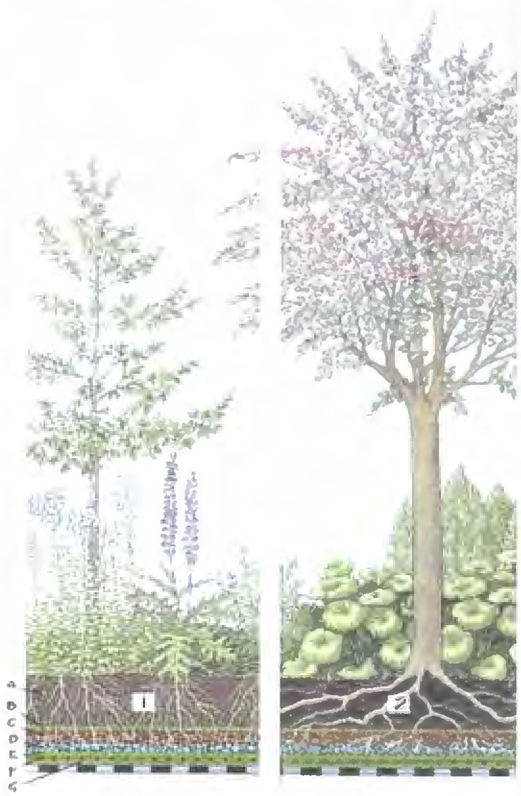


A –"Optima-Kennkorper" Extensive Soil Substrate
B – Insulation Layer
C - Root Barrier Course
D – Waterproof Membrane Protective Barrier

Source: Optima Planungs-Unterlage 9/97

Typical Intensive Greenroof Material Section from Opima
Diverse Plant Communities Useful for Achieving Architectural Accents

Light Weight **Heavier Weight** **Height: 36 inches – 15 feet**



A –"Optima-Kennkorper" Intensive Soil Substrate

B – Fleece Filter Fabric Screen

C – "Optima Perlite" Drainage Layer

D – Rainwater Retention Layer

E – Insulation Layer

F – Root Barrier Course

G – Waterproof Membrane Protective Barrier

Source: Optima Planungs-Unterlage 9/97
http://www.greenroofs.com/Greenroofs101/components.htm

APPENDIX 2. Plant Lists for Greenroofs in the United States

(www.greenroofs.com)

ROCK PLANTS & WILDFLOWERS

BOTANICAL NAME	**NATURAL HABITAT & NOTES**
Achillea millefolium	Native to Europe & Asia, Yarrow is naturalized here in the U.S. Once established, it's very drought tolerant.
Allium bivalve	Native to the U. S. Granite Outcrops
Centaurea cyanus	Annual; Coneflower or Bachelor's Button.
Chrysantheum leucanthemum	Native to Asia, Ox-Eye Daisy needs well drained soil.
Coreopsis lanceolata, tinctoria	U.S. native of the S.E.; also *C. auriculata, grandiflora, major, rundata, rosea, verticillata*
Cosmos bipinnatus, sulphureus	Native to Mexico, a self-seeding annual
Echinacea purpurea	U.S. native of the S.E.; also *E. pallida, paradoxa*
Gaillardia aristata, pulchella	Annual & perennial, Firewheel likes well drained soil
Hieracium venosum	Native to the U. S. Granite Outcrops
Liatris microcephala	Gayfeather is native to the U. S. Granite Outcrops
Oenothera speciosa	Showy Primrose is a native of North America east of the Mississippi; also *O. fruticosa, tetragona*
Opuntia drummondii	Prickly Pear is a native of U. S. Granite Outcrops
Phlox drummondii	U. S. native of the S.E.; also *P. carolina* complex, *glaberrima, maculata, paniculata, pilosa. P divaricata* native to eastern North America
Potentilla canadensis	Native of U. S. Granite Outcrops
Rudbeckia hirta	Black Eyed Susan is a U. S. native of eastern U. S.; also *R. fulgida, lacinat, maxima, nitida, triloba*
Sedum pusillum, smallii	Native of U.S. Granite Outcrops
Senecio smallii, tomentosa	Ragwort is native of U.S. Granite Outcrops; also *S. aureus, glabellus, obovatus,* native to eastern North America
Solidago spp.	Goldenrod is native to the eastern U.S. with numerous spp., such as *S. nemoralis, odora, pintorum, rigida, rugosa, sempervirens, speciosa,* and *ulmifolia*
Tradescantia hirsutocaulis	Spiderwort is native to U. S. Granite Outcrops
Yucca filamentosa	Native of U.S. Granite Outcrops

GRASSES

BOTANICAL NAMES:	**NATURAL HABITAT & NOTES:**
Andropogon ternarius, virginicus	Native of eastern U.S. & Granite Outcrops, abandoned fields; widely distributed, many species
Aristida purpurascens	Native from N. Carolina to Mississippi
Bouteloua curtipendula, hirsuta	Sideoats Grama and Hairy Grama are native to the Texas area
Panicum lithophilum, and spp.	Switchgrass is native to North America; also *P. virgatum*

APPENDIX 3. Case Studies
(1) LDS Conference Center, Salt Lake City, Utah, 2000

(Taken from Land Online)
http://www.asla.org/land/am04.html.
For landscape architects, the green roof at The Church of Jesus Christ of Latter-day Saints Conference Center in Salt Lake City is the preeminent must-see public space in Salt Lake City. It won the 2003 Green Roof Award of Excellence in the category of New Construction, Combination Extensive/ Intensive Green Roof and captured an ASLA 2003 Design Merit Award. The supreme achievement of the design is that it manages to subordinate a 1.5 million-square-foot building with a 21,000-person seating capacity to the existing natural and built environment. It is truly a modern marvel and a feat that reflects close and early collaboration between Olin Partnership and the architecture firm Zimmer Gunsul Frasca Partnership.

The roof is multileveled and more than eight acres in size, and much of it serves as a park. The public spaces feature water, stone, trees, and meadows, while planted terraces step up 65 feet to roof gardens planted with conifers and a meadow. The planting of the expansive rooftop meadow involved over a thousand volunteers who carried plants up to the roof in a bucket brigade and installed the native grasses and perennials by hand.

http://www.lincoln-highway-museum.org/Email/19/View-2-75.jpg

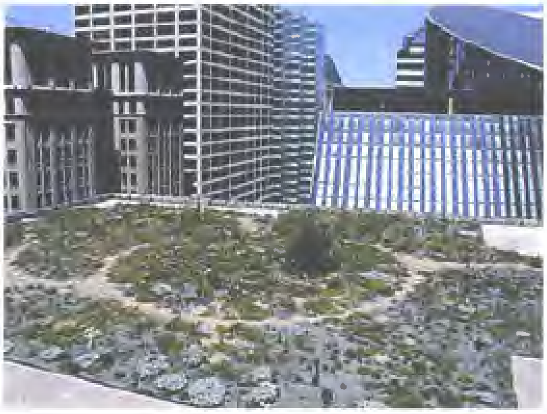
http://www.lincoln-highway-museum.org/Email/19/View-2-75.jpg

(2) Chicago City Hall, Chicago, Illinois, 2001

Mark Farina / City of Chicago

(Taken from www.greenroofs.com). As part of an EPA study and initiative to combat the urban heat island effect and to improve urban air quality, Mayor Richard M. Daley and the City of Chicago began construction of a 38,800 square foot semi-extensive greenroof in April 2000. Encompassing one square block and twelve stories high, this one million dollar plus retrofit application will serve as a demonstration project and test greenroof (John Beaudry, original project coordinator, Environment Department, City of Chicago, June 2000). The project was completed in the summer of 2001 and will monitored for plant survival as well as other environmental features.

"This is unique to Chicago," said Richard Price of the Virginia-based William McDonough & Partners, the architectural firm that is designing the garden. "No one else has looked at rooftop gardens to mitigate urban heat island effect, which is a process whereby highly urbanized areas with hard surfaces tend to be degrees hotter than green areas," (ENN.com, May 2000).



(3) The Ford Motor Company's Rouge River Plant Dearborn, Michigan, 2003

(Taken from www.greenroofs.com). According to the Ford Motor Company's press release dated November 3, 2000, the 600-acre, $2 billion Ford Rouge Center near Dearborn, Michigan, will undergo major redevelopment, laying the groundwork for sustainable manufacturing at one of the world's largest and oldest industrial icons. The above rendering by McDonough + Partners, rendered by Richard Rochon, includes numerous pilots of advanced environmental concepts and a new assembly plant with the nation's largest ecologically inspired living roof on an industrial building. About 454,000 square feet of assembly plant roofing will be covered with sedum, a succulent groundcover, and other plants. The roof will reduce stormwater runoff by holding an inch of rainfall. Also the living plants absorb carbon dioxide as part of photosynthesis, so oxygen is emitted and greenhouse gases are reduced.

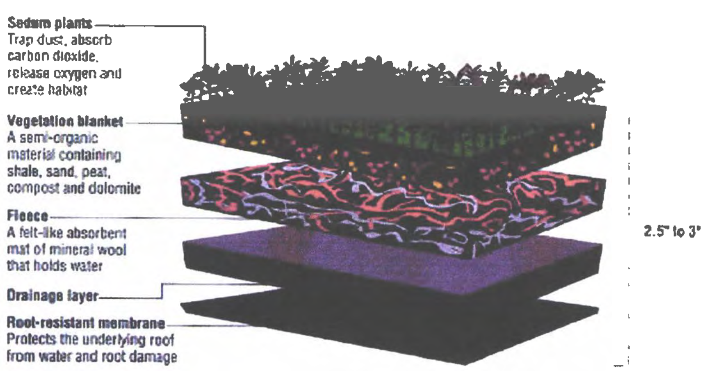
Redevelopment of the 1917 complex will form the foundation for the company's vision of balancing lean manufacturing with environmental sensitivity. "This is not environmental philanthropy; it is sound business, which for the first time, balances the business needs of auto manufacturing with ecological and social concerns in the redesign of a brownfield site," said Ford Chairman Bill Ford, whose great-grandfather Henry Ford constructed the complex. "This is what I think sustainability is about, and this new facility lays the groundwork for a model of 21st century sustainable manufacturing at the Rouge. "While most companies would rather move than invest in a 83-year-old site, we view this as an important reinvestment in our employees, our hometown and an American icon of the 20th century," Ford added.

The design of the new assembly plant includes people-friendly features such as overhead safety walkways, day lighting, team rooms, cooler air in the summer months and relaxing places to congregate. Tim O'Brien, Ford director of Environmental Quality, said project planners are designing a system, which, over time, "will use ecologically advanced methods for stormwater management, energy usage, air quality and soil restoration."

Aside from the huge greenroof, other environmental initiatives include:

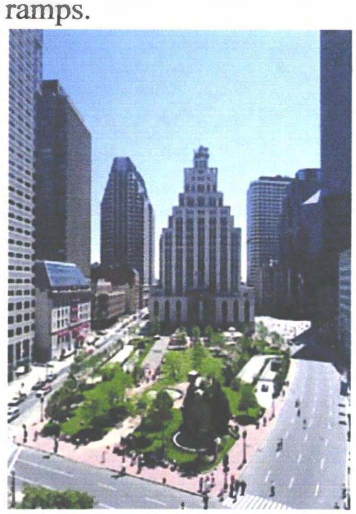
- Swales, or shallow green vegetated ditches seeded with indigenous plants; a pilot involving swales and retention ponds will be used to regulate water flow and evaporation and improve stormwater management on the site.
- Phytoremediation which uses natural plants to rid soil of contaminants; Michigan State University is partnering with Ford on this project -- believed to be the first such experiment on this scale with the challenging soil conditions on the site. If the pilot is successful, it will be used elsewhere on the site and potentially could become an ecologically friendly alternative to hauling contaminated soil to landfills in the future.
- Porous paving; a surface that filters water through retention beds with 2-3 feet of compacted stones is another pilot project that helps manage stormwater runoff.
- Greenscreens; trellises for flowering vines and other plants will shade and help cool the Rouge Office Building. If the screens prove successful, they will be used on the new assembly plant and other buildings.
- Renewable energy sources; the use of solar cells and fuel cells will be included in the project. For example, fuel cells will provide power for some computer systems in the new plant. The company also is evaluating the possibility of GeoExchange and wind power demonstration projects.
- Planting of more than 1,500 trees and thousands of other plantings to attract songbirds and create habitats.

FORD ROUGE CENTER
LIVING ROOF DESIGN



(4) Post Office Square, Boston, Massachusetts, 1990's

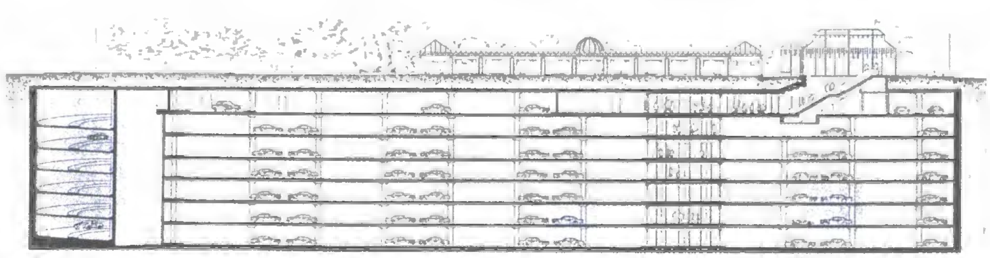
(Taken from www.ellenzweig.com) In the early 1990s, an unattractive and intrusive parking garage in Boston's financial district was replaced by a two-acre park with underground parking for 1,400 cars. Ellenzweig Associates played a key role in this dramatic transformation, designing both the garage and the park structures, including a pavilion, café, garden trellis and automobile ramps.



The park pavilions recall traditional steel and glass greenhouses by using abundant glass, lattice-like window frames and steep copper roofs. Because the park would be viewed from surrounding office towers as well as from the street, great care was taken to integrate structures and setting. The brick and granite paving of the park continues as flooring in the café; granite curbs reappear as the bases of window walls. The same granite is used again in bench details and as columns supporting the long trellis that shades the elegant park promenade.

The Post Office Square garage extends 80 feet below the street, the deepest building excavation in Boston. Ellenzweig Associates designed the ramps, stairs and ventilation shafts to have minimal impact on the park. The solution was to isolate the air intakes in a corner of the park and to incorporate exhaust vents into the automobile ramps, which are screened from pedestrians. Ticketing and cashiers are also located on the lobby level to avoid disturbing the park.

Post Office Square is a widely praised boon to downtown Boston. Crowds of office workers, shoppers, and tourists throng its café, benches and lawns, turning a formerly dour financial district into a lively urban neighborhood. Designed as a non-profit, privately financed facility for public use, Post Office Square will revert to city ownership once construction costs are repaid. Garage profits will be distributed to the City of Boston and its Park Trust Fund for the maintenance of neighborhood parks.



(5) Unisys Corporation (Formerly Sperry Univac), Frankfurt Germany

Landscape Architect: Hans Dorn
Architect: Meid and Romereirck, Frankfurt
Client: Sperry Univac

(Taken from Roof Gardens, By Theodore Osmundson, pg. 212-213)

The employees' dining area looks out directly onto a lush 8,500-square foot garden in the central open space of this American company's branch office in Frankfurt, one of Germany's largest cities. Although the site is directly over a parking garage, archives, and offices in the basement of the building, no trace of this fact is evident at garden level.

The wide tiled walks winding through the garage enable easy pedestrian circulation. IN addition, such generous widths provide ample space to arrange the portable white plastic stools, designed by the landscape architect, into informal groupings in good weather. A sparkling design feature when not in use, they complement the white globes when arranged decoratively. These stools, however, supply the only seating in the garden. Located as it is next to the employees' cafeteria, the garden would benefit more comfortable seating, along with the tables.

The planting medium in the garden is Novoflor, a German product sold by Frankische Rohrwerke. It is 30" deep for the trees, *Cedrus atlantica gluaca* (blue Atlas cedar) and *Crataegus monogyna* (English hawthorn). Shrubbery consists mostly of rhododendrons and azaleas.

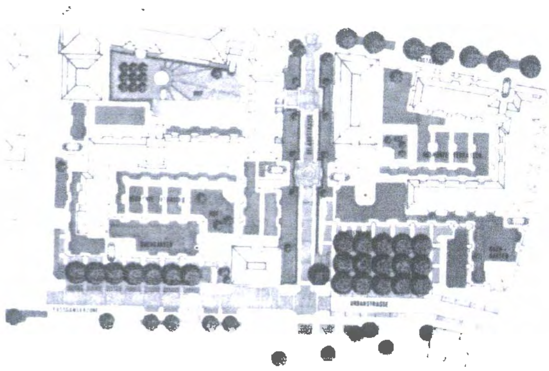
Specially designed tiles were arranged in the shape of Sperry Univac's logo, permanently embedded in the paving. A fountain, composed of two square, elevated concrete basins, splashes into a bed of round river stones nearby.

(6) Allianz Versicherungs-AG, Stuttgart, Germany

Landscape Architect: Hans Luz and Partner, Stuttgart
Architect: Brummendorf, Muller, Murr, and Reichmann, Stuttgart
Client: Allianz Verischerungs-AG

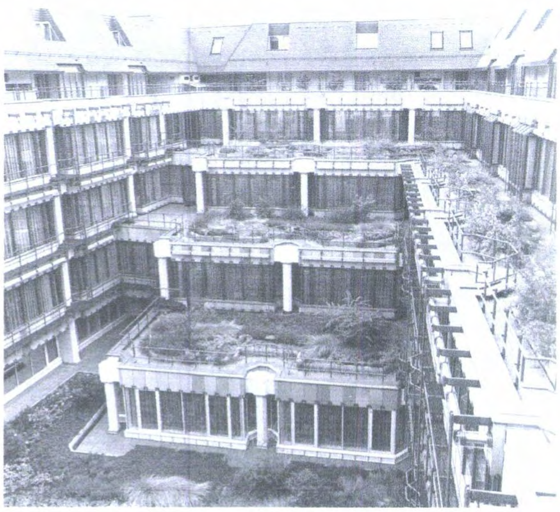
(Taken from Roof Gardens, By Theodore Osmundson, pg. 215-216)

The regional quarters of this insurance company has been in the heart of Stuttgart's historical center for over 100 years. When the company needed to enlarge its office space, its executives decided to retain the existing site and buildings, blending them with new construction. The architects succeeded in combining the old and the new with an almost seamless design solution.



In keeping with a widely accepted trend throughout Germany, the greening of roofs was a highly important consideration. The architect and landscape architect worked together to provide two series of stepped-down roofs atop offices surrounding the large courtyards of the main buildings. All other roofs, including those adjacent to the offices around the courtyards and those on the tops of the new buildings, are planted, giving the roofs a handsome, soft, green appearance.

Throughout the roof garden the Optima system of continuous self-watering by capillary action was used.



Planting was limited to low-growing species, to permit the views across the gardens and to reduce the weight on the roofs. The plants are primarily perennials and ornamental grasses, such as *Lavandula angustifolia* (English lavender), *Epimedium pinnatum* 'Elegans' (Persian epimedium), *Hemerocallus citrine* (daylilies), *Pennisetum compressum* (fountain grass), *Rudbeckia fulgida* 'Goldstrum' (black-eyed susan), and *Deschampsia caepitosa* 'Bronzeschleir' (tufted hair grass).

Although the plantings appear to be intensive, the courtyards are designed to be ornamental only and are not accessible. An exception are the gardens for the company's apartments on the highest roofs. Here the plantings are very residential in tone and include flowering cherries, forsythia, *Magnolia soulangeana* (saucer magnolia), tea and polyantha roses, and extensive lawn.

(7) Sunshine 60 Building, Tokyo, Japan, 1978

Landscape Architect: Araki Landscape Architecture
Architect: Mitsubishi Jisho
Client: Shintoshi Kaihatsu Center

(Taken from Roof Gardens, By Theodore Osmundson, pg. 243-245)
The tallest building in Japan, this 60-story office/commercial complex, completed in 1978, includes two major roof gardens.

The first, at ground level atop an underground garage, itself consists of two parts. Upon entering the front section from the adjacent street and sidewalk, one encounters formal rows of trees separated by symmetrical walkways. A small paved plaza separates this formal space from the second part of the roof garden. This back section, which is also at ground level, is startling, but only because it is so different from the first. It is a natural scene, with a series of wide waterfalls dropping over low rocky walls, surrounded by camellias, large boulders, and full grown trees, including *Sequoia sempervirens* (coast redwood), *Taxodium distichum* 'Rich' (bald cypress) and *Myrica rubra* 'Seib' (red wax myrtle). At its nadir the water spreads over the concrete paving, flooding it until flowing almost unnoticeably into flat drains in the pavement. It is then silently pumped back to the waterfall's zenith by large pumps, hidden in the garage below. The pumps can move 3 tons of water per minute from 30-ton-capacity tanks. The roof was designed to support 3 tons per square meter. The soil in the upper areas of this street-level garden is as much as 6 feet deep.

The second roof garden is accessible both from the buildings elevators and via broad stairways leading up four floors from the street below. The garden plaza is formal, consisting of heavy plantings of *Myrica rubra* 'Seib' in rectangular raised beds. The paved plaza serves as an alternate means of access to the building's upper floors, as well as providing outdoor space for relaxation and conversation. Benches throughout provide ample seating. Strong tile paving patterns and retaining walls of the Indonesian wood *serauganbatu* add visual interest to the plaza.

APPENDIX 4. Components

(Taken from www.greenroofs.com)

Waterproofing

The greenroofing system may consist of a liquid-applied membrane, a specially designed singly-ply sheet membrane, or a built-up roof system consisting of 3+ layers. Many of the oldest greenroofs are waterproofed with mastic asphalt, but bitumen sheets with polyester carriers and SBS modified coatings are becoming more common. In the early 1990's, PVC and EPDM products were developed. Root resistance can be achieved either by a laminated upper layer (usually copper) or by chemical additives in the coating. To ensure drainage capacity, the support to the waterproofing layer should have a slope of at least 1.5% (Hendriks and Hooker, March, 1994).

Depending upon the nature of the waterproofing membrane chosen (organic vs. synthetic), a root barrier layer may be needed to prevent the plant roots to penetrate and ultimately undermine the integrity of the waterproofing layer. For example, asphaltic bitumen is organic and roots could naturally attempt to penetrate the surface while seeking nutrients. A common practice on traditional roof gardens and intensive greenroofs is to pour a concrete protection slab over the membrane layer (Osmundson, 1999).

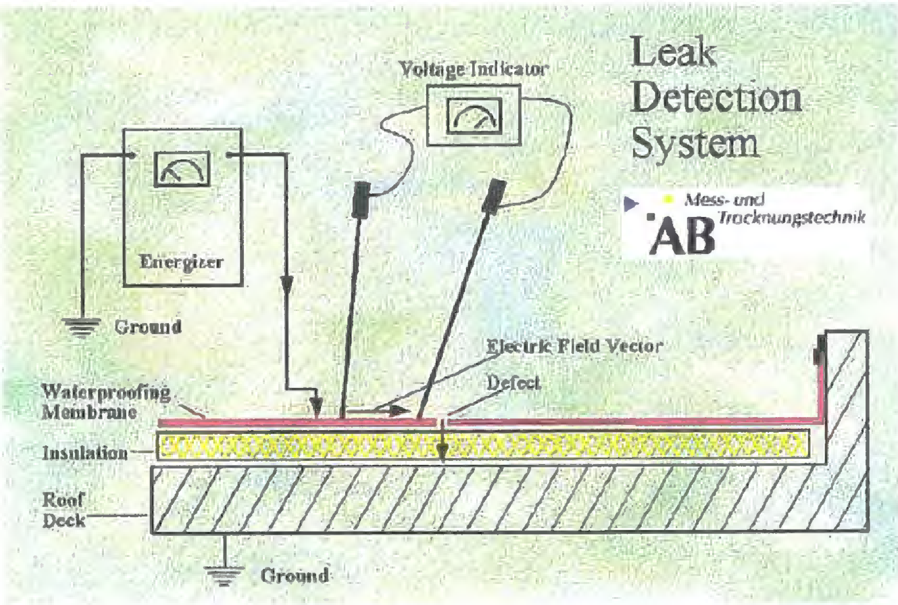
Design standards that are applicable to waterproofing systems include ASTM C981, ASTM C898, ASTM STP 1084, the Architectural Graphic Standard, and the NRCA Roofing and Waterproofing Manual (RCI's Greenroof Workshop, August 6, 2001).

Some believe the liquid-applied membrane provides a superior waterproofing and easier maintenance (McDonough + Partners, 1999). Because it is applied as a liquid, it must be installed directly on the roofing deck, requiring that existing roofing be completely removed. With certain limitations and particular code requirements, sheet membranes may be installed over existing roofing, although manufacturers prefer that existing roofing be removed. Sheet membranes can also be more difficult to repair. Most greenroof companies offer several choices of sheet membranes, providing a custom fit for each application.

Correct and meticulous application of the waterproof membrane is essential to the viability of the greenroof. Quality control is assured through knowledgeable roofing procedures and a water impermeability test immediately following membrane application, with a minimum duration of 24 hours but 48 hours preferred. Although the German technology, encompassing over thirty years of engineering standards and testing, has virtually eliminated the possibility of membrane leakage, there is at least one North American company offering a leak detention system. Roofscapes, Inc. offers such a system as well as integrated detection systems engineered by AB Mess- und Trocknungstechnik (AB). According to their website, Roofscapes can:

- Conduct water-tightness tests of existing roof surfaces prior to installing a Roofmeadow™ cover system

- Conduct annual surveys of green roofs to verify that the waterproofing system remains water-tight below the vegetated cover
- Quickly locate the source of any leaks



Courtesy of Roofscapes, Inc.; www.roofmeadow.com

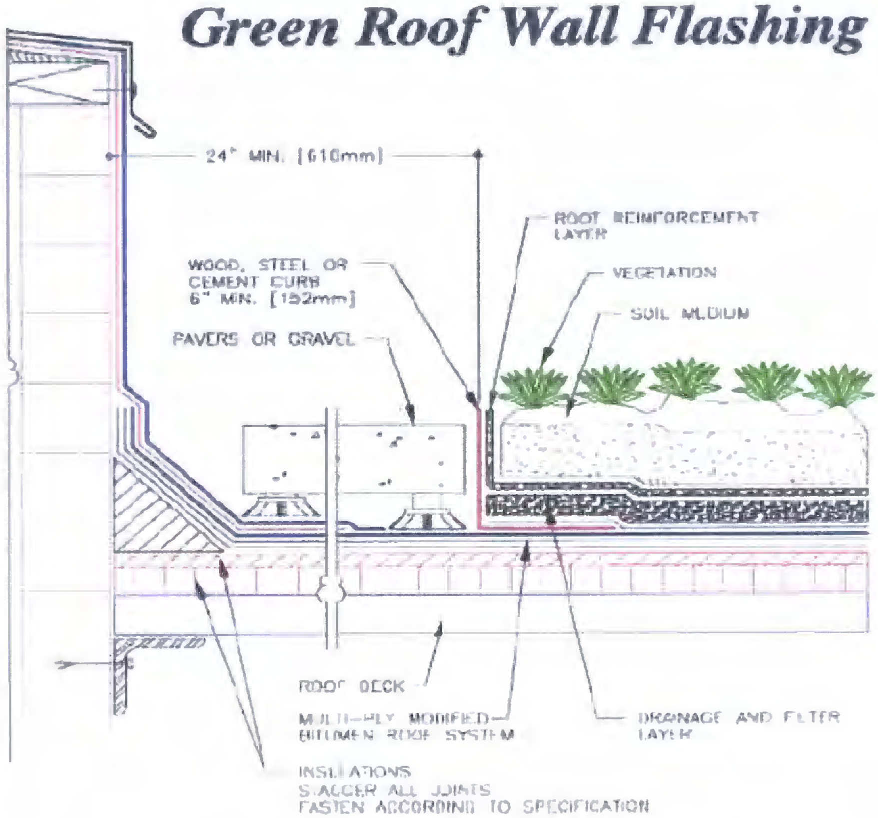
The AB system can locate pin-hole size defects with the same ease as large flaws. Please see the Roofscapes, Inc. website here for additional information and consultation: www.roofmeadow.com.

Source: ZinCo International 3/98 Brochure

According to ZinCo literature, it is essential to mark the position of the roof outlets before installing the protection layer, so that they can be located easily and the root barrier and protection mat cut out accordingly. Protection of the membrane from these components could include 10 mm or 1/3" of granular rubber (Hendriks and Hooker, 1994). Reliable detailing at penetration and perimeter areas with durable protection is critical. Any expansion joints which are not extended up through the waterproofing should remain free of plants. They can, for example, be covered by gravel or paving slabs so that they can be easily located and accessible at any time.

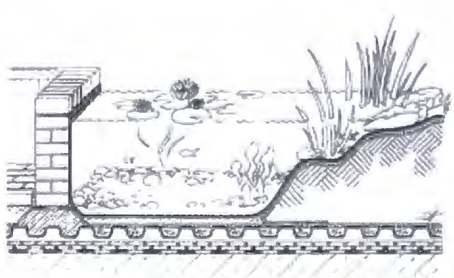
The Green Roof Wall Flashing detail below from The Garland Company shows a wood, steel, or cement curb with a 6" minimum.

Green Roof Wall Flashing



Courtesy The Garland Company

Water features such as waterfalls, fountains and ponds can be stunning greenroof architectural designs, but extra care is required. Risk can be eliminated by isolating the lining of the water feature, and ensuring a drainage and protection layer underneath. In the example of a pond detail from ZinCo shown below, the lining is laid onto a 30-50 mm or 1-2" bed of sand to distribute the load of water. The pond bottom is covered by rounded pebbles to protect the lining, and the perimeter of the pond lining is buried to protect against ultra violet light. If a leak does happen, the water simply seeps through the sand bed and is drained by the underlying drainage system. This system was applied to the BMW building greenroof, shown below by ZinCo International.




Source: ZinCo International 3/98 Brochure

Insulation

An insulation layer is optional, and prevents water stored in the greenroof system from extracting heat in the winter or cool air in the summer. They are generally applied on existing roofs in retrofitting projects that may require an increase in the insulation value. Each company has different insulation options, from being integrated with the drainage boards (ZinCo's Floratherm build-up), to Foamglas® cellular glass (Pittsburgh Corning Corp.).

Robert McMarlin of Pittsburgh Corning states that "Combining an impermeable, closed-cell insulation material such as cellular glass with the roof membrane is ideal for the flat roof system...since no water can accumulate, the danger of root invasion is eliminated." Due to its high compressive strength of 100 pounds per square inch, Foamglas® cellular glass insulation will not compact under the greenroof system weight. He also points out that because it is manufactured from the very abundant mineral silica (SiO_2), cellular glass is totally inorganic and requires no production of chlorofluorocarbon or hydrochlorofluorocarbon gasses (Western Roofing Magazine, May/June, 1996).

Drainage

Every greenroof must have a drainage layer to carry away excess water; on very shallow extensive greenroofs the drainage layer may be combined with the filter layer. Unimpeded drainage is assured in greenroof systems because the drainage layer is applied over the entire roof area. The drainage layer forms an extremely stable and pressure resistant sub-base (ZinCo International brochure). Some believe a drainage layer is not necessary on any sloped roofs due to nature's gravitational drainage capacity, but single-source greenroof companies will most likely specify one.

Drainage capacity must increase closer to the rainwater outlets, so large quantities of drainage material, usually rounded stones, are installed along the eaves and near outlets. These rainwater outlets need to be accessible for seasonal cleaning (Hendriks and Hooker, 1994).

(ZinCo International Green Roof brochure, 1998).

These areas could also allow a separation barrier of large rounded pebbles 500 mm or 20" wide around them from the vegetation.

Source: ZinCo International 3/98 Brochure

Some drainage systems are more multifunctional. For example, ZinCo's Floradrain line has troughs that provide up to 40 mm or 1.5" of water storage for the plants above, and a system of channels on the underside for drainage of excess water below. Special holes allow aeration to the roots, and an additional moisture retention mat below ensures a long-term water supply. The system provides additional protection to the underlying waterproofing element. The Floradrain FD 60 is strong enough to act as shuttering to concrete. This enables roadways, walls, and ballustrades to be constructed over the drainage layer, thereby allowing unimpeded drainage beneath (ZinCo, 1998).

Filter Fabric

The main function of the filter fabric/membrane is to hold the soil in place and still prevent small soil particles, such as plant debris and much, from entering and clogging the drainage layer below. Air and water are thus permitted to flow through while the drainage layer and the actual drains are protected. Careful placement is required with overlaps of at least 100 mm to 8 inches wide along vertical edges up to the plant material layer, and should be finished with a strip of self-adhesive bitumen membrane. Typical materials are lightweight water-resistant polyester fiber mats or polypropylene-polyethylene mats (Hendriks and Hooker, 1994). These filter fabrics are the relatively inexpensive typical non-woven, non-biodegradable landscape fabric types found at most home improvement stores.

Growth Media

The science of greenroof soil mixtures is very important to the market, especially in Germany where the major companies have PhD's in soil sciences either running the company or placed in high levels of management. Each of these companies also has patented their various soil substrate formulas.

The growing medium or soil substrate can be selected from several engineered factory mixes designed by the various single-source greenroof suppliers or they can be custom designed by a soil expert. This option is usually less expensive. By using a mixture of native soil upgraded with organic or mineral additives (peat, humus, wood chips, sand, lava, or expanded clay), it is possible to achieve optimum water retention, permeability, density and erosion control necessary to support the greenroof vegetation. But although sometimes successful in smaller projects, it is not advisable to use ordinary garden soil, as degeneration often results from compacting and acidification (Hendriks and Hooker, 1994).

Most current experts frown on using topsoil at all for fear of introducing unwanted properties. Generally, if you are mixing your own substrate, a good guideline is approximately 75-80% inorganic (i.e., expanded slate or crushed clay) to 20-25% organic (humus + some clean topsoil). This will provide essential drainage and soil air capacity, and sufficient organic nutrients for the shallow-rooted plants. Just remember that your weight requirements will be higher with a greater concentration of topsoil, and weeds and certain pathogens are always possible when ordinary garden topsoil is added. Certainly, it is recommended to consult with a growth media expert in your area to determine the correct mixture for your project.

The thinner the engineered soil layer, the higher the physical demands on the plants. Some of the problems in the past have been the result of too shallow soil depths, resulting in root damage from heat and frost fluctuations. Some greenroof companies will suggest a minimum 2 3/4" soil substrate depth, but again, a little higher depth of say at least 3" (or higher) is recommended for do-it-yourselfers who are mixing their own soil mix.

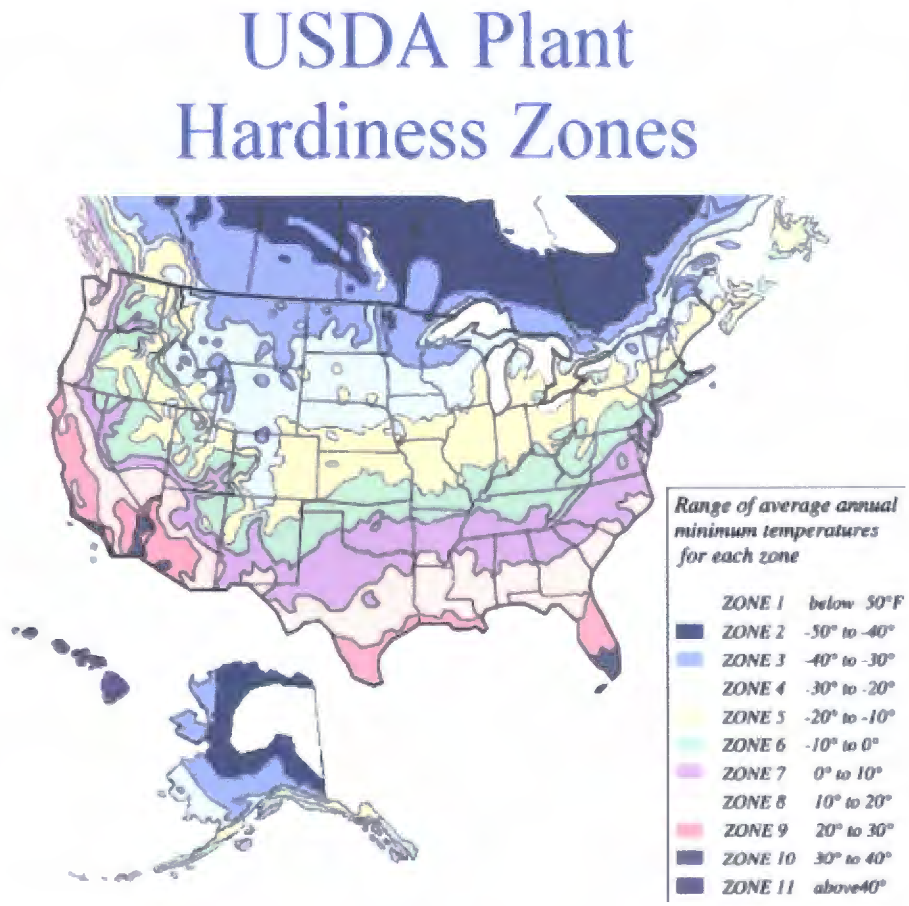
Plant Material

Source: Optigrün international AG, www.optigruen.de

The vegetation layer is the most vital and exciting part of the greenroof, and as such suitable and dependable plant material selection needs to be assessed on a per region basis. Characteristics of landscaping typically used in extensive greenroof systems include shallow root systems, regenerative qualities, resistance to direct radiation, drought, frost and wind. A much larger variety of plant selections is available for intensive roofscapes due to the greater possible soil depths (American Hydrotech, Inc. Product Literature, 1999).

Compatibility issues of greenroof type, anticipated use, temperature, humidity, rainfall, and sun/shade exposure are important elements for successful plantings of any kind. Most importantly for the artificial environment of a greenroof, native and culturally adaptable plants need to be reviewed for heat and drought tolerance, as most systems are designed to be low maintenance.

When choosing plants for appropriate regions, it is always advisable to review the U.S. Department of Agriculture's Hardiness Zone Map, which indicates a plant's tolerance for cold. Frost can be a particular problem for evergreens in dry periods. The soil must be deep enough to protect the roots from frost damage (ZinCo, 1998).



Equally, if not more, important is a plant's tolerance to the high heat variations found on a rooftop. The American Horticultural Society has recently developed a Plant Heat-Zone Map which charts 12 color-coded regions of the U.S. according to the annual average number of days an area experiences "heat days," or extreme temperatures above 86 degrees F or higher. For example, a black-eyed Susan, or Rudbeckia spp. thrives in a wide range of heat zones, from 1 to 9. It prefers full sun but can tolerate light shade (Danny C. Flanders, 1999).

Source: Optima© Planungs-Unterlage 9/97

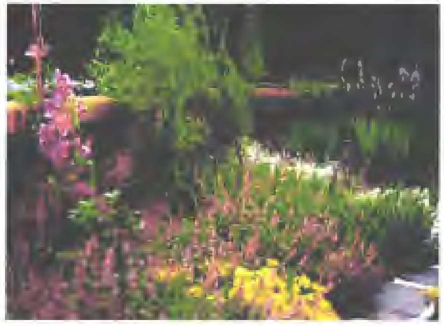
The desired seasonal visual impact of a greenroof may also dictate the plant material. The summer/ winter vegetative aspect changes just like it would in any landscape. What happens to the greenroof plants in the dormant season? Depending on the ratio of herbaceous to evergreen plants selected, the roofscape can have varying colors, heights and textures to create winter interest.

For example, a predominantly grass roof will appear beige and brown unless some evergreen and flowering species are included. During periods of drought, mosses could also appear beige, but will green up nicely after rainfall. To the left is a split screen of an extensive greenroof planted with sedums, mosses and grasses shown in early summer and winter (Optima, 1998).

Plant material can be applied to greenroofs by several means and, according to ZinCo, once a planting has been completed, a period of maintenance begins. Trees and large bushes on greenroofs create a lot of visual impact, and several critical points must be considered to ensure successful installation and problem free maintenance.

PLANT MATERIAL APPLICATION & MAINTENANCE

Plant material can be applied to greenroofs by several means: pre-vegetated mats or blankets; direct on-site planting of sedum cuttings and/or seed or root plants; hydro-planting; or any combination of these methods. Hydro-planting applications require expensive custom equipment, and is more common as an option in Europe for very difficult to reach, high, and sloped surfaces. Types of plantings selected dictate their planting times. Root plants can be planted throughout the entire growing period if they are sufficiently watered. Plants used for extensive landscaping are cultivated in special flat-bottomed planting trays. The sowing of sedum cuttings and/or seeds is restricted to spring and autumn (ZinCo, 1998).

Source: ZinCo International 3/98 Brochure

The ZinCo example above of an intensive greenroof garden at the Orthotech Dental Laboratory in Leipzig, Germany, shows how semi-mature shrubs were planted to give an instant garden effect.

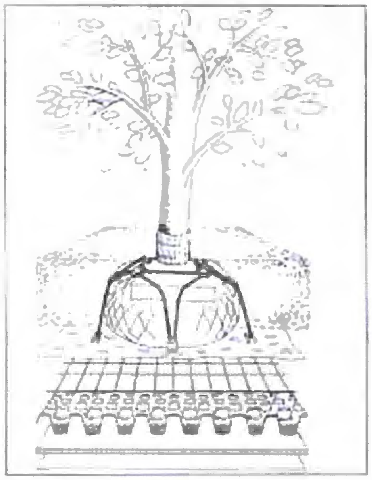
This covers a set period of time at the end of which the ground should be covered 60 to 70%. After the final inspection from the greenroof company, it is advisable to ensure regular maintenance of the greenroof (once or twice a year) by negotiating a maintenance contract. For example, Roofscapes, Inc. offers this service to their customers as well as certifying existing greenroofs that satisfy their demanding performance standards. However, simple extensive greenroofs should not require any regular maintenance after the first two years.


Source: ZinCo International 3/98 Brochure

In the same example as above, here you can see the newly planted greenroof on the left, and how it looks after one year on the right.

TREES AND LARGE BUSHES

Trees and large bushes on intensive greenroofs create a lot of visual impact, and several critical points must be considered to ensure successful installation and problem free maintenance. Load weights must be calculated, as they cause a greater concentrated load due to the additional tipping movement under wind pressure. Care must be given during and after placement. Trees with smaller leaves and a relatively small crown offer the best wind resistance, and the minimum soil depth for small trees is approximately 500 mm or 20". If the area on the main greenroof is shallower, retaining walls can be installed to create areas of deeper soil.



Source: ZinCo International 3/98 Brochure

Correct irrigation is very important. If the soil depth is greater than 500-800 mm or 20-31", irrigation from above is recommended as capillary action from below is reduced. Due to possible damage to the waterproofing integrity, normal stake posts cannot be used to anchor the trees. Thin, high-tension wires attached to the tree, see photo above left, is one possibility. However, the best solution is to use a "spider" of steel wire, enveloping the root ball and anchored to a steel grafting beneath, see diagram at right (ZinCo, March 1998).

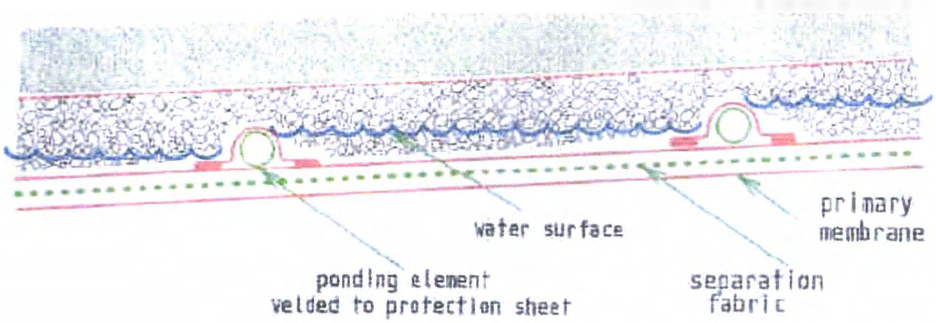
Water Storage

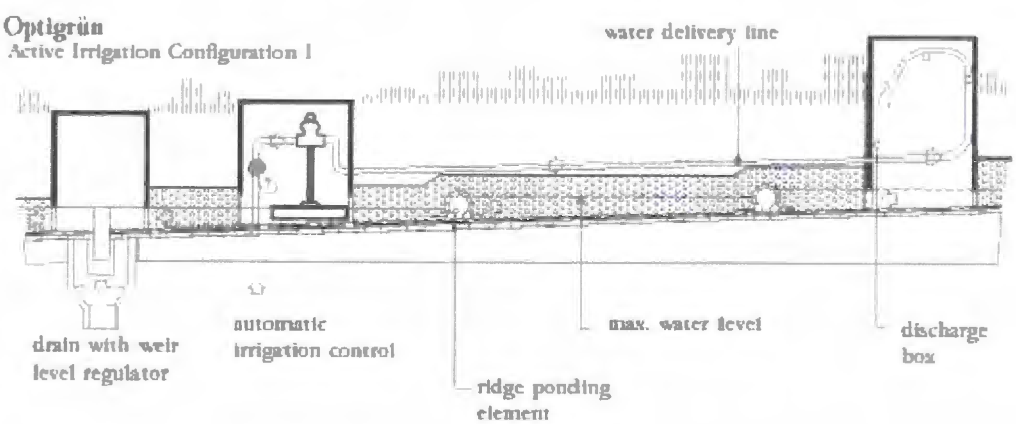
Greenroofs must be able to store water and not dry out too quickly, and greater plant diversity or the particular design parameters desired for certain greenroofs may require additional water.

According to Charlie Miller, "Ideally, even thin systems work optimally with two layers, separated by a geotextile. The lower level is very light-weight granular mineral material (usually a fired clay). The roots of the plants will penetrate through the geotextile and will concentrate along the bottom of this layer. Here they find the best conditions for survival (cool temperatures and more consistent moisture). If irrigation is included, we choose to introduce the water in the granular layer – further encouraging propagation of roots at the bottom. If the substrate is chosen to have good water retention qualities, this system will support a variety of plants without irrigation. When roots are encouraged to grow higher up in the profile, they are much more vulnerable to the effects of varying temperature and moisture," (Charlie Miller, personal communication, April 2000).

If the soil substrate/drainage system cannot hold a certain amount of free water, then additional forms of water storage may be necessary and can be supplied by several methods. Certainly, the most "ecologically correct" systems would be those that are considered sustainable, requiring no or little human intervention.

Completely self-sustainable passive water retention systems include using ponding elements welded directly to the protection membrane, and generally can be installed on roofs up to a 4% slope, as shown below, courtesy of Roofscapes, Inc., www.roofmeadow.com:

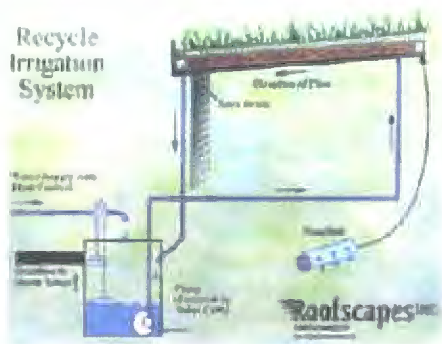


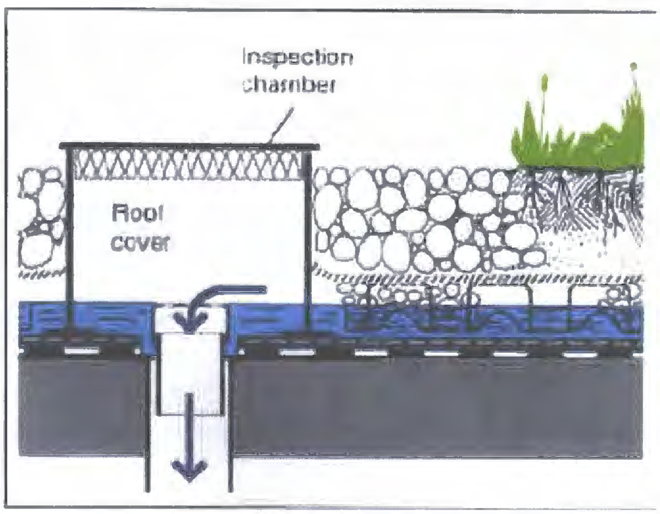


Or, a more active system incorporating the ponding ridges along with a drain with weir level regulator and an automatic irrigation control is seen above from **Optigrün, courtesy of Roofscapes, Inc.**

Optima, Optigrün and ZinCo have developed active, sustainable, solar powered automatic water collection and irrigation systems. These systems also have the added sophistication of a maximum and minimum on/off switch to make allowances for possible overnight rainfall filling the reservoir naturally. For the ultimate environmental self-irrigation system, an additional cistern can be incorporated to store excess rainwater which can be recycled later (Optigrün, 1998/1999; and ZinCo, 1998).

The drawings below show a solar-powered rainwater collection system from **Optigrün-Italy** on the left and an irrigation detail by **Roofscapes, Inc**. on the right.

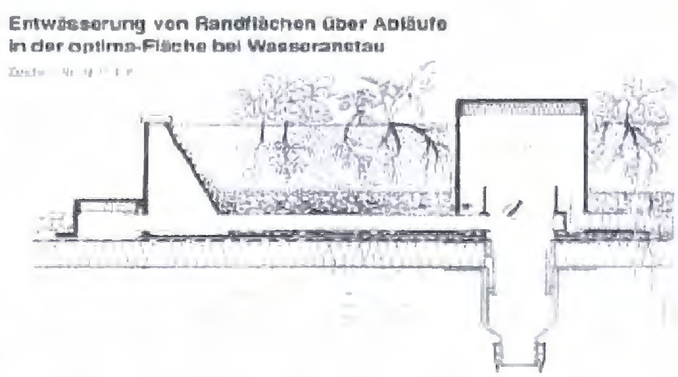




Source: ZinCo International 3/98 Brochure

For additional water retention capabilities, a damming piece can be installed into the outlets, with inspection chambers or adjustable terrace grills for easy maintenance. Shown at left is ZinCo's Floradrain FD 60, with its large drainage channels allowing up to 1.5" of water to be stored underneath. The water reaches the plants by capillary action, and the inspection chamber allows access for maintenance.

Optima has designed a self-regulating water retention, storage, and automatic irrigation system utilizing small tanks (1 ½'H) which retain rainwater that has percolated through the substrate. The system then hydraulically releases the stored water automatically when the water dips below the pre-determined minimum level.



Detail from Optima's Planungs-Unterlage 9/97 manual.

As stated earlier, some drainage systems also incorporate water retention capabilities; the stored water reaches the plants by capillary action. An optional reservoir board layer, available from some companies, can be installed to retain and store small amounts of water as well. Additionally, either a simple automatic drip irrigation system with a manifold delivering water at the base of the profile can be installed, or a more complete (and heavy and costly) irrigation system can be incorporated into any greenroof design.