GREEN ROOF COMPOSITION
A green roof is an engineered version of a natural soil profile. Rain falls on the plants and substrate of the green roof, where some of the water is retained and some percolates through the filter membrane and into the drainage layer. When the substrate and drainage layer have reached saturation, any excess water will leave the roof through a drainage system. The protection layer acts as a barrier to prevent stormwater and plant roots from entering the roof structure below.

GROWING MEDIA AND PLANTS
Ideal green roof plants in Los Angeles must be drought-tolerant and have shallow root depths. We identified two types of plants that fit these qualifications: sedums and native grasses. The ideal growing medium for a green roof has a high field capacity, or ability to hold water. Perlite, vermiculite, sand and organic matter are often used for green roofs because they are light and highly water-absorbent.

We used actual precipitation and pan evaporation data collected by the Los Angeles Department of Public Works. We focused on five precipitation stations with a wide range of maximum daily rainfall and geographically diverse locations. Our data set allowed us to run model simulations over a period of 53 years – September 1949 to May 2002.

The model calculates runoff with three key parameters: crop factor, depth and field capacity. To determine the ranges for our parameters, we performed an extensive literature review and solicited expert opinion. We looked for available plants and growing media that would thrive in Los Angeles.

Vegetation must be able to survive long periods of intense sunlight and drought with short bursts of intense severe rainfall and flooding. The growing medium provides a base for plants and is typically a mixture of organic and mineral components.

For the model runs, we selected the following parameter ranges:
- Crop Factor: Scaling factor for plant evapotranspiration, ranged from 0.2 to 1.2.
- Field Capacity: Ability of growing media to retain water, ranged from 30 to 40 percent.
- Depth of growing media: varied from 2 to 6 inches.

MODEL RESULTS
Our model outputs show an average annual stormwater runoff reduction of 21 percent for low parameter values and 64 percent for high parameter values at the five stations over the modeling period of 53 years.

Stormwater reduction varies across stations because of geographic variability in rainfall.

Low parameter values
- Depth: 2 inches
- Crop Factor: 0.2
- Field capacity: 30 percent

High parameter values
- Depth: 6 inches
- Crop Factor: 1.2
- Field capacity: 40 percent

FROM ROOF TO WATERSHED
To estimate the average amount of potential green roof area in the Los Angeles River watershed, we used satellite imagery and impervious surface data from the National Land Cover Database.

Our analysis estimates that the watershed has approximately 2.25 billion square feet of roof area that is suitable green roof installation.

The map below shows percentage levels of imperviousness in the Los Angeles River watershed.

Findings
- Green roofs can reduce annual stormwater runoff in Los Angeles by 21 to 64 percent.
- A green roof’s ability to reduce runoff depends both on its composition and on antecedent moisture.
- A green roof with high parameter values reduces runoff significantly more than a roof with low parameter values.
- When several storm events occur in succession, water is retained until the roof reaches its water-holding capacity. Once the roof is saturated, additional precipitation becomes runoff.
COST-BENEFIT ANALYSIS

Costs of construction and maintenance of a green roof fall on the private owners of the building. Benefits of a green roof are primarily enjoyed by the public.

<table>
<thead>
<tr>
<th>Green Roof Component</th>
<th>Low ($)</th>
<th>Med ($)</th>
<th>High ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>3.00</td>
<td>3.50</td>
<td>4.00</td>
</tr>
<tr>
<td>Insulation and Deck Protection</td>
<td>6.00</td>
<td>8.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Drainage and Filter</td>
<td>3.00</td>
<td>3.50</td>
<td>4.00</td>
</tr>
<tr>
<td>Growing Media</td>
<td>3.00</td>
<td>5.50</td>
<td>8.00</td>
</tr>
<tr>
<td>Sedums (2 per sq. ft)</td>
<td>1.60</td>
<td>1.60</td>
<td>1.60</td>
</tr>
<tr>
<td>Grasses (2 per sq. ft)</td>
<td>1.60</td>
<td>2.02</td>
<td>2.80</td>
</tr>
<tr>
<td>Drip Irrigation System</td>
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<td>3.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Architecture and Engineering</td>
<td>1.01</td>
<td>1.36</td>
<td>1.72</td>
</tr>
<tr>
<td>Total Initial Costs</td>
<td>21</td>
<td>28</td>
<td>36</td>
</tr>
</tbody>
</table>

The following policy tools may be helpful to help establish green roofs in the Los Angeles River watershed:

- **LEED Standards** – In 2002, the City of Los Angeles required that all new city building projects achieve LEED certification and allocated $10 million annually to help reach those requirements. Green roofs can help meet up to 15 LEED certification requirements.
- **Proposition Q** – In 2004, the citizens of Los Angeles voted to authorize the city to issue bonds to clean up the streams, rivers, beaches, and ocean affected by polluted stormwater runoff. Up to $500 million may be spent to protect public health and help meet Federal Clean Water Act standards; $75 million of those bonds go directly to projects designed to capture, clean, and reuse stormwater. Green roof projects may qualify for funding.
- **Los Angeles River Revitalization Master Plan** – Green roof projects could work in concert with this ambitious plan to reclaim major parts of the Los Angeles River by improving water quality and greening the neighborhoods surrounding the river.
- **Additional Considerations** – Los Angeles can emulate other successful green roofs cities by designing zoning laws for green roofs and creating incentives for their application. A city employee or politician who champions green roof use may also be a critical policy component.

POLICY IMPLICATIONS

Green roofs are appealing in urban settings because they provide multiple benefits beyond stormwater reduction, including building energy savings, urban heat island reduction and aesthetic value. There is potential for green roofs to play a significant role in Los Angeles’s environmental future, but a robust incentive program is necessary to foster city-wide green roof construction in Los Angeles.

The project conducted research on the feasibility of a green roof and five specific green roof components for Los Angeles: Design, Insulation and Deck Protection, Drainage and Filter, Growing Media, and Sedums and Grasses. We estimated the costs of these components and compared them to those used in other successful green roofs cities by designing zoning laws for green roofs and creating incentives for their application. A city employee or politician who champions green roof use may also be a critical policy component.

The table above shows an estimated cost-per-square-foot metric for the installation of an typical extensive green roof, focusing on local sources and prices whenever possible.

Adding the installation costs to the 40-year maintenance costs for a green roof yields a total lifetime cost for the roof of $33 to $94 per square foot. Total costs for 2.5 million square feet of green roofs in Los Angeles over 40 years would be from $83 million to $235 million.

Benefits

- **Runoff is generated when rain falls on impervious surfaces.** As water flows across these surfaces, it accumulates pollutants including fecal coliform, heavy metals, oils and trash. In Los Angeles, stormwater runoff flows untreated into waterways and eventually to the ocean, where it poses dangers to humans and wildlife. Research in Los Angeles has found that contact with polluted stormwater increases the incidence of stomach flu, respiratory infections, ear infections, and rashes. Additionally, the Los Angeles River and Harbor are both in violation of Clean Water Act standards because of poor water quality.

- **Best management practices (BMPs), such as catchment basins, constructed wetlands and green roofs, use physical and biological processes to manage stormwater problems.**

- **Green roofs generate multiple benefits beyond stormwater management.** Our project investigated the usefulness of green roofs in the Los Angeles River watershed.

STORMWATER MANAGEMENT

Runoff is generated when rain falls on impervious surfaces. As water flows across these surfaces, it accumulates pollutants including fecal coliform, heavy metals, oils and trash. In Los Angeles, stormwater runoff flows untreated into waterways and eventually to the ocean, where it poses dangers to humans and wildlife. Research in Los Angeles has found that contact with polluted stormwater increases the incidence of stomach flu, respiratory infections, ear infections, and rashes. Additionally, the Los Angeles River and Harbor are both in violation of Clean Water Act standards because of poor water quality.

To deal with these problems, some communities in southern California have implemented restrictions on runoff. The use of stormwater management practices that have been employed in Los Angeles include infiltration basins, vegetated strips, and channelization.

Best management practices (BMPs), such as catchment basins, constructed wetlands and green roofs, use physical and biological processes to manage stormwater problems. Green roofs generate multiple benefits beyond stormwater management. Our project investigated the usefulness of green roofs in the Los Angeles River watershed.

QUESTION AND APPROACH

Green roofs have been effective stormwater management tools in New York, Portland, and Chicago, but have not been used in cities such as Los Angeles, where the semi-arid climate presents unique challenges. To determine if there are environmental and economic benefits to using green roofs in Los Angeles, this project:

- **Characterized stormwater issues in Los Angeles**
- **Determined plant and growing media options**
- **Obtained precipitation and evapotranspiration data**
- **Modeled green roof stormwater behavior**
- **Performed statistical analysis of model output**
- **Estimated costs and benefits**
- **Researched policy implications**

STUDY SITE: THE LOS ANGELES RIVER

The Los Angeles River watershed receives 381 mm (15 inches) of precipitation annually, almost exclusively in the winter months. Summers are hot and dry with almost no precipitation. Rainfall events tend to be intense and brief, but with several inches of rain – and can lead to high volumes of stormwater runoff. While the northern Los Angeles River watershed is characterized by steep, vegetated foothills, the southern lower watershed is highly urbanized and thus has a high percentage of impervious surfaces. The river flows from the foothills in the north through the city of Los Angeles and into the Pacific Ocean at Long Beach.

Figure 1: The Los Angeles River Watershed is outlined above.

Figure 2: The Los Angeles River has been paved in many places with impervious concrete and thus runoff flows quickly through the channel without infiltrating into the ground.

ACKNOWLEDGEMENTS

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Additional Considerations: Los Angeles can emulate other successful green roofs cities by designing zoning laws for green roofs and creating incentives for their application. A city employee or politician who champions green roof use may also be a critical policy component.

CONCLUSIONS

- When extrapolated across the 2.5 million square feet of potential green roof area, costs of green roof installation and maintenance far outweigh the benefits from stormwater reduction.
- Green roofs have many other benefits, such as energy savings, urban heat island reduction and aesthetic value, that are less tangible and were not quantified in this study. Future studies should focus on these other benefits.