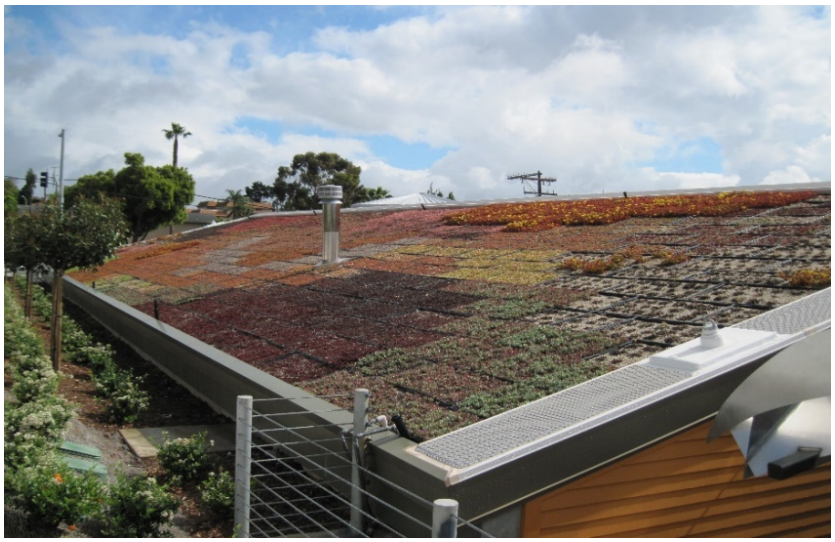
Green Roof TC-33



Design Considerations

- Roof Strength
- Climate
- Maintenance Access

Targeted Constituent	Removal[1]
Sediment	
Nutrients	
Trash	
Metals	
Bacteria	
Flow Control	

Description

Green roofs (vegetated roofs) are vegetated areas installed on gently sloped or flat rooftops. Green roofs are able to reduce stormwater runoff and improve water quality by intercepting rainfall that would otherwise be routed to a downspout; instead stormwater is filtered through the media, or evapotranspired by the vegetation. Two design styles exist to incorporate a wide variety of building types: extensive, media depth between 4 and 6 inches, and intensive, media depth greater than 6 inches. Extensive green roofs are most common because of the structural requirement, particularly for redevelopment. Intensive green roofs are most often incorporated into new development.

California Experience

Green roofs have been implemented for new development and redevelopment areas to accomplish a number of goals including regulatory requirements, aesthetics, and economics. The San Diego County Operations Center incorporates an extensive green roof to enhance visual aesthetics and provide an inviting roof top environment for employees and guests (Figure 1). The Vista Hermosa Park Ranger Station and Facility Buildings also incorporated an extensive green roof to reduce the impervious area and footprint of the park (Figure 2). An extensive green roof at the California Academy of Science in San Francisco provides an example to patrons and converts an otherwise unusable space into an additional recreational opportunity and makes the academy more sustainable by increasing the insulation and reducing energy lost through the roof (Source: www.calacademy.org) (Figure 3). Finally, Kaiser Center created an intensive green roof with a park-like setting in Oakland (Figure 4).

[1] Pollutant removal generally occurs through stormwater volume reduction

Figure 1. Extensive Green roof at the San Diego County Operations Center.

Figure 2. Extensive Green roof at the Vista Hermosa Park Ranger Station and Facility in Los Angeles, CA

Source: www.calacademy.org

Figure 3. Extensive Green roof at the Academy of Science in San Francisco, CA

Source: kaisercenterroofgarden.com

Figure 4. Intensive green roof at the Kaiser center in Oakland, CA

Advantages

- Vegetated roofs may improve property values and provide air quality benefits.
- Can extend expected roof-life and reduce building energy demand.
- Reduces heat island effect and provide passive recreation areas.

Limitations

- Roof structure must be able to support additional weight from soil and vegetation.
- May require irrigation in arid and semi-arid climates.

Performance

Hydrologic and water quality performance of green roofs varies with footprint, media depth, roof angle and vegetation type but an average of 45-75% of annual runoff can be expected to be retained (Berndtsson 2010). In comparison, unplanted soil media has been observed to offer significantly reduced rooftop retention capability (Berndtsson 2010; Schroll et al. 2011; Wolf and Lundholm 2008). Studies investigating the quality of stormwater discharging from green roofs is limited, but in general it is expected that phosphorus and nitrogen concentrations are exported from green roofs (Berndtsson 2010). Table 1 below details expected effluent concentrations and removal processes for each pollutant.

Table 1. Typical pollutant removal for constituents and removal processes

Pollutant	Typical Removal	Median Effluent Concentration[1]	Removal Processes	References
Sediment	High (-195% to 91%)	19 mg/L	Sedimentation and filtration.	Geosyntec Consultants and Wright Water Engineering 2012; Knight et al. 2013; Winston et al. 2011; Scholes 2007
Metals	Medium	TAs: 0.88 µg/L, TCd: 0.18 µg/L, TCr: 2.63 µg/L, TCu: 7.19 µg/L, TFe: 616 µg/L, TPb: 1.88 µg/L, TNi: 2.95 µg/L, TZn: 24.3 µg/L	Removal with sediment.	Knight et al. 2013; Geosyntec Consultants and Wright Water Engineering 2012
Total phosphorus	Low (-126% to 40%)	*0.173* mg/L	Settling with sediment, can be a net source or sink via breakdown or uptake of plant material	Geosyntec Consultants and Wright Water Engineering 2012; Knight et al. 2013; Winston et al. 2011;
Total nitrogen	Low TN: -17 to 40% TKN: -18 to 39%, $NO_{2,3}$-N:-18 to 43%	TN: 1.13 mg/L, TKN: 1.10 mg/L, $NO_{2,3}$-N: 0.19 mg/L	Settling, sedimentation (TKN) and plant uptake.	Geosyntec Consultants and Wright Water Engineering 2012; Knight et al. 2013; Winston et al. 2011;
Bacteria	Low (likely exports pathogens)	N/A	Limited sedimentation, desiccation, predation, and photolysis at surface.	US EPA 2012

[1] Underlined effluent concentrations were (statistically) significantly lower than influent concentrations, as determined by statistical hypothesis testing on the available sampled data. Effluent concentrations displayed in *italics* were (statistically) significantly higher than influent concentrations.

Suitability and Design

Green roofs can be installed on a wide range of buildings. Structures that do not traditionally incorporate heavy overhead loads (e.g. residential homes) can utilize an extensive green roof which incorporate a shallow soil depth (between 4 to 6 inches) thus a lower weight. Alternatively, intensive green roofs can be utilized on buildings with greater strength, allowing for greater soil depth (greater than 6 inches), deeper rooting vegetation, and increased water quality and stormwater volume benefits. Typical static loading per unit area for intensive green roofs is 15 to 55 pounds per square foot, and 75 to 150 pounds per square foot for extensive (Tolderlund 2010). Regardless of design type fundamental green roof design guidelines include:

- Structure evaluated by a qualified structural engineer to ensure proper support exists.
- Sized to fully capture the local regulatory requirements.
- Incorporate watertight liner to prevent rainwater from intruding the underlying structure.

Table 2 details a number of core construction components and corresponding design considerations for an intensive green roof. An extensive design will also likely incorporate a drip irrigation system, and walkways for foot-traffic.

Table 2. Cost of design components and associated considerations

Component	Cost	Design Consideration
Soil Media Recommended mix	$2.00–$4.75/ft^2	Minimum 4 inches of media: 80–90% lightweight inorganic materials such as expanded slates, shales, or pumice. No more than 20% organic materials (potential for leaching nutrients).
Soil Media Barrier No. 8 aggregate (min 2 inches thick) Filter Fabric Root Barrier	$0.28/ft^2 $0.45/ft^2 $2.25/ft^2	Clean washed synthetic or inorganic aggregate material such as no 8 stone or suitable alternatives. Filter fabric prevents migration of the media into the soil media barrier. Needled, non-woven, polypropylene geotextile. Root barrier placed directly above waterproof liner to protect from roots.
Underdrain Pipe (includes drainage stone, with 5-foot spacing)	$3.60/ft^2	4-inch diameter minimum, schedule 40 PVC pipe with perforations (slots or holes) every 6 inches at 0.5% slope. Provide cleanout ports/observation wells for each underdrain pipe.
Hydraulic Restriction Layer 30-mil liner	$0.35/ft^2	Protect the roof deck and underlying structure from intruding stormwater.
Vegetation	$1.50–$3.50/ft^2	Low-lying, drought tolerant species which can thrive without supplemental irrigation. Construct on slopes from 1% to 30%. Slopes approaching 30% require media

Component	Cost	Design Consideration
		retention practices (e.g. baffles or geo-grids). Should be able to withstand harsh rooftop environment

To protect the existing roof outlets (e.g., drains, scrubbers) 12 inch setbacks should be maintained and filled with washed no. 57 stone. A setback of 24 inches should be maintained between ventilation ducts and HVAC components. Additionally, sufficient access to the roof and around vegetation must be provided to allow routine maintenance.

Vegetation

Extensive green roof vegetation should consist of low-growing, highly drought-tolerant species that can survive in the harsh environment of a rooftop. Common vegetation types include grasses and succulents. There is greater flexibility in intensive green roof vegetation and should match the plant palate of the surrounding area. Irrigation may be required to maintain the vegetation.

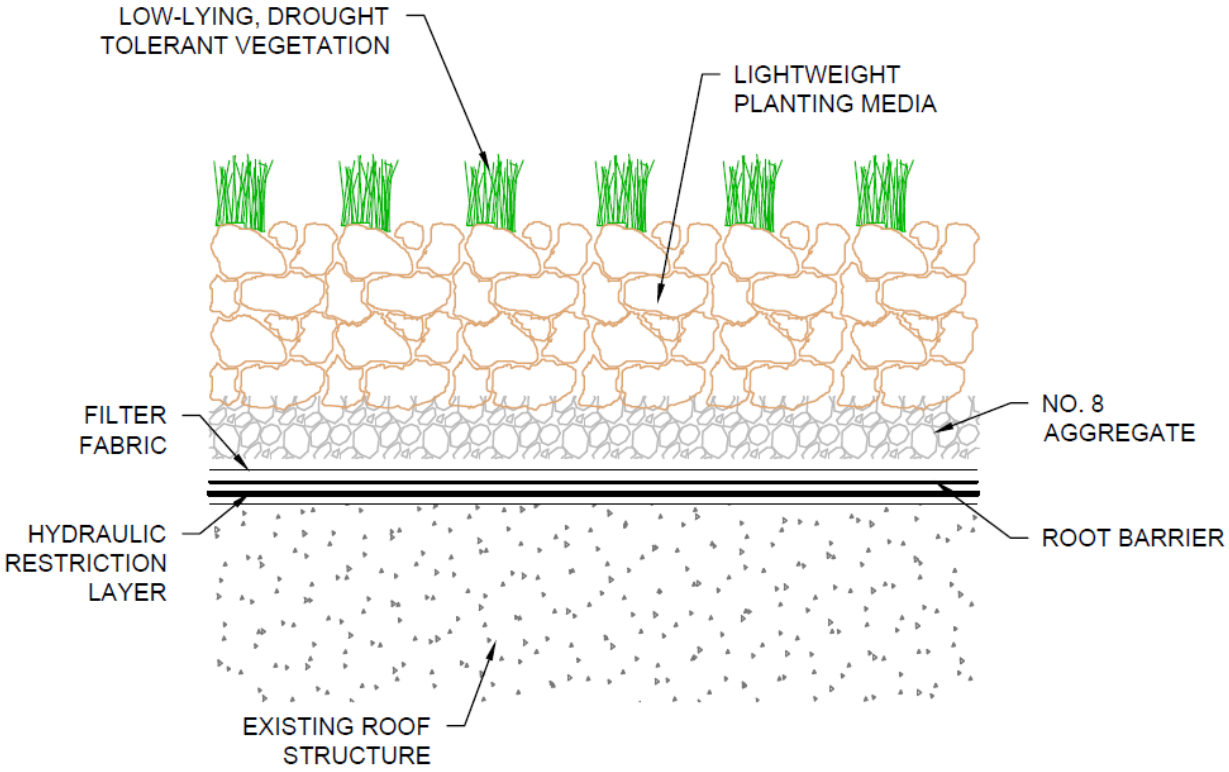
Maintenance

Maintenance tasks for green roofs consists primarily of maintaining vegetation and drainage structures.

Table 3. Maintenance tasks for green roofs

Frequency	Cost	Activity
Routine Maintenance (required monthly to every 2 years)		Inspect and replace wind-scoured, and eroded media and vegetation. Inspect drains, gutters and downspouts for clogging. Inspect liner for leaks. Remove and replant dead or dying plants. Remove undesired vegetation.
Routine (small)	3.95/ft^2	
Routine (medium)	\$1.13/ft^2	
Routine (large)	\$0.79/ft^2	
End of Life Replacement (service life of 20 years)		Remove and replace plants, media, and replace the roof membrane.
Replacement (small)	\$6.69/ft^2	
Replacement (medium)	\$3.87/ft^2	
Replacement (large)	\$3.53/ft^2	
Note: Small System = 500 ft^2; Medium System = 2000 ft^2; Large System = 4000 ft^2		

Schematic



INTENSIVE GREEN ROOF DETAIL

NOT TO SCALE

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