Urban Tree Planting Practices

Urban forestry provides communities with improved aesthetics, habitat, shade, carbon sequestration, and a reduced urban heat island effect. In addition to these benefits, planting urban trees can also assist a community with stormwater management.

Urban trees can reduce runoff velocity and volumes, by intercepting rainfall, spurring evapotranspiration, and encouraging infiltration and groundwater recharge, while simultaneously consuming infiltrated water through its root system. However, as with all green infrastructure practices, planting locations serve as critical both for maximizing a tree's targeted stormwater benefits, as well as for ensuring its ongoing health and survival. Species selection is particularly critical when planting in urban rights-of-way, where flooding can occur routinely, where tolerance to road salt is a necessity for survival, and where a parkway's size and dimension can serve to constrain the growth of a tree's root structure.

While trees can provide benefits for stormwater management on their own, combining tree planting with bioretention practices will serve to increase the volume of stormwater captured and treated, particularly in urban areas where impervious surfaces and compacted soils can often outweigh the positive impact that trees can make on reducing runoff volume and velocity. Box tree filters serve as an example of combining tree planting with bioretention practices. Much like a stormwater planter, box tree filters provide various layers of filtering media, including mulch, engineered soil and gravel, which serves to assist with the capture and treatment of runoff, in addition to supporting the tree's root structure.

The decision around whether to pursue basic urban tree planting or a combined tree planting-bioretention approach will largely be a product of a project's scope, location, surrounding land uses, and budget. As trees are larger than any other plant used in green infrastructure practices, they bring a wide range of benefits, considerations, and complications beyond those related to stormwater management.

Urban Stormwater Tree Planting

Location & Spacing Methods

Planting trees for stormwater management requires making deliberate choices around site location and spacing in addition to species. Generally speaking, species planted for stormwater management should be planted where runoff collects, near the bottom of slopes, and close to the right of way. Planting locations that are close to the right of way mean that species which are tolerant to road salt, sediment, and runoff inundation should also be selected, which often means species that grow naturally in lowland, floodplain locations. Different species also require different soil types (ranging from sandy to clay-based) and different soil pH levels (ranging from acidic to alkaline). Planting locations must also avoid disruptions to above and below ground utilities, in addition to providing shade (based on the site's existing sun exposure) and protection from wind. Generally speaking, the spacing for an urban tree should be equivalent to its expected width at full maturity with the understanding that urban trees planted in small parkways seldom reach the full size of a naturally growing specimen. In other words, a tree that is expected to reach a full crown width of 30 feet should be planted approximately 30 feet from a tree of the same species.

Planting Methods

Irrespective of the species or delivery method, it is critical to keep the roots moist before the planting process begins. When digging a hole for tree planting, it should be sized twice as wide as the root ball. Once the tree is placed in the hole, the top-most root should be within 1" of soil's surface. If planting a bare root tree, roots should be distributed evenly, making sure roots are straight, and not bent, crossed, or "J" rooted. Once the backfilling of soil begins, the tree must be kept standing straight, and the backfilled soil must cover the top of the highest-most woody root. The backfilled soil should then be heel over with a boot or pressed with a shovel to remove air pockets. The entire backfilled area must then be watered, and layered with 2–4" of mulch. The mulch should be kept away from the trunk, and the mulching should not take on a volcano-like shape around the tree.

Customization Options

Recommended Species

Varying species will serve to be appropriate green stormwater infrastructure installations, based on soil moisture, planting location, salt tolerance, and their ability to be included in a bioretention practice, amongst other considerations. Table 10 provides a summary of preferable tree species for green stormwater infrastructure throughout the Great Lakes region.

Table 10: Recommended tree species for green stormwater infrastructure

Scientific Name	Common Name	Soils	Compatible BMPs	Street Tree	Floodplain Tree	Salt Tolerant
Acer saccharum	Sugar maple	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	No	Low
Acer freemanii	Freeman Maple	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	No	Low
Acer rubrum	Red Maple	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	Low

Scientific Name	Common Name	Soils	Compatible BMPs	Street Tree	Floodplain Tree	Salt Tolerant
Betula nigra	River Birch	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	Low
Celtis occidentalis	Hackberry	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	Medium
Ostrya virginiana	American Hophornbeam	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	Low
Tilia americana	American Basswood (Linden)	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	No	Low
Populus tremuloides	Quaking Aspen	Dry/Mesic	Bioswale	No	No	High
Prunus serotina	Black Cherry	Mesic/Wet	Rain Garden	No	No	High
Quercus alba	White Oak	Dry/Mesic	Rain Garden	No	No	High
Quercus Bicolor	Swamp White Oak	Dry/Mesic	Bioswale, Rain Garden, Box Tree Filter	Yes	Yes	High
Quercus macrocarpa	Bur Oak	Mesic/Wet	Bioswale, Rain Garden, Box Tree Filter	Yes	No	Medium
Quercus Rubra	Red Oak	Mesic/Wet	Bioswale, Rain Garden, Box Tree Filter	Yes	No	High
Quercus palustris	Pin Oak	Mesic/Wet		Yes	Yes	Low
Ulmus americana	Hybrid American Elm	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	High
Metasequoia glyptostroboides	Dawn Redwood	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	Low
Taxodium distichum	Common Bald Cyprus	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	Medium
Thuja occidentalis	Northern White Cedar	Mesic/Wet	Rain Garden	No	No	Medium

Scientific Name	Common Name	Soils	Compatible BMPs	Street Tree	Floodplain Tree	Salt Tolerant
Amelanchier laevis	Allegheny Serviceberry	Dry/Mesic	Rain Garden	No	Yes	Low
Juniperus virginiana	Eastern Red Cedar	Dry/Mesic	Bioswale	No	No	Low
Gymnocladus	Kentucky Coffeetree	Mesic/Wet	Rain Garden, Storm. Planter Box Tree Filter	Yes	Yes	High
Liquidanbar Stiraciflua	Sweetgum Happidaze	Mesic/Wet	Rain Garden, Box Tree Filter	Yes	Yes	Medium
Platanus occidentalis	American Sycamore	Mesic/Wet		Yes	Yes	Medium
Platanus x acerifolia	London Planetree	Mesic/We		Yes	Yes	Medium
Populus deltoides	Eastern Cottonwood	Mesic/Wet		Yes	Yes	Medium
Gleditsia triacanthos	Honeylocust	Mesic/Wet		Yes	Yes	High
Acer saccarinium	Silver Maple	Mesic/Wet		Yes	Yes	Medium
Catalpa speciosa	Northern Catalpa	Mesic/Wet		Yes	Yes	Medium

Planting Formats

Irrespective of the species or the location, a defining choice in undertaking urban tree planting will be selecting a bare root tree, a container tree, or a balled-and-burlap tree, all of which present varying strengths and weaknesses.

Bare Root Trees

"Bare root" tree stock is oftentimes the most inexpensive choice for planting, as they are the smallest and lightest option, making them the easiest format to transport. In turn, bare root trees are an economical choice for planting projects that include a large number of trees. Instead of being cultivated in a soil mixture, bare root trees are typically cultivated by wrapping the root system in a moisture-retaining material, such as sphagnum moss peat, sawdust or wet paper. Bare root tree stock must be planted when they are completely dormant, and this can only occur in the Spring or Fall, before the tree's leaves appear, or after its leaves fall (but before the ground freezes). The tree's roots must be kept moist at all times, because if the roots dry out, the tree dies. In turn, preserving moisture in the root system and a shorter planting season window are the primary constraints of bare root stock.

Container Trees

"Container tree" stock (trees grown in plastic containers) tend to be slightly more expensive to plant than bare root stock (on account of their size and weight), but are widely available, can be sourced year round, and can be planted while dormant or leafing. While in the containers, trees require intensive watering (1-2 times a day) to prevent the root system from drying out. Root girdling (when the roots grow in a circular form) can also be a problem with container trees, if the tree is kept for too long in its container, which can ultimately lead to the tree's death.

Balled and Burlap Trees

Balled and Burlap stock (B&B) is grown with a firm ball of soil surrounding its roots, and wrapped with burlap with twine, nails or wiring. B&B stock is very heavy, making it more expensive to transport than bare root or container stock. They are structurally very sound however, making them an ideal planting choice for large caliper trees. They can also be planted during any time in the growing season, though supplemental watering after planting is critical during hot and dry weather.

Maintenance

Watering

Watering bags (i.e., tree gators, either donut-shaped or other types) should be installed at the time of planting. Watering bags should be checked weekly, and filled with water as needed during the first growing season. Bags should be removed during the dormant season to protect the tree from fungus and molds. After the first year, the bags should be checked every two weeks, and should be filled as needed. Watering bags can be completely removed after two growing seasons.

Mulching Trees

Trees must be mulched, at a depth of 2-4 inches, at the time of planting. Mulch must be maintained in a level circular area around the base of each tree. Mulch must not be piled or mounded near the tree trunk. One year after planting, mulch should be evaluated, and if needed, additional mulch must be added to maintain 2-4 inches of depth.

Staking and Tying Trees

Trees that are planted near large open areas and are subject to high winds must be staked to improve firmness against the wind. This is particularly important for larger, "balled and burlapped" trees. One year after planting, trees must be evaluated for firmness, and if trees are stable, stakes can be removed. Upon completion of the second growing season, all stakes must be removed.

Pruning

Newly-planted trees should need little pruning if they were properly cared for in the nursery. In the first year after planting, the contractor must remove only dead or broken branches. After then, weakly-attached limbs and co-dominant leaders (a tree that has more than one main trunk that is similar in diameter) should be removed to promote healthy trees with good form.

Tree Protection

Tree mulch should help protect the base of newly-planted trees from lawn mower damage, by keeping mowers away from the tree base. However, to protect the newly-planted trees in areas where wildlife browsing may be an issue, trees must be protected using plastic mesh fencing or other tree guard products (such as tubes). After tree establishment, these structures can be removed.

Cost Information

Cost information is provided for each green infrastructure technique in Section 5 of this report. The Installed costs are based on project experience, bid tabs, and information from the RS Means trends, and the labor and bidding environment.

Table 11: Urban stormwater tree planting practice unit costs

	Item	Description	Unit Price	Unit
GI Technique	Urban Tree Planting	Tree (varies by tree species)	$400.00	EA
		Planting (varies by method)	$250.00	LS
Custom Options	Warranty	Planting Warranty	$60.00	EA

Specifications

Along with the construction documents, the design engineer should make site-specific customizations to the following sections of the standard specifications from the Illinois Urban Manual in order to have a full set of specifications for a green roof. Other sections can be included on an as-needed basis. Further instructions on the use of specifications are included in Appendix B. Specifications for engineered soil differ from those outlined in Appendix C.

Construction Specifications

707 - Digging, Transporting, Planting, and Establishment of Trees, Shrubs and Vines

Box Tree Filter

Box tree filters take in curbside runoff and treat it through physical and biological methods that are similar to other bioretention systems, before discharging it into existing storm sewer infrastructure. As a result, water that enters the storm sewers is cleaner, while trees and microbial communities uptake nutrients that would otherwise be washed into local streams, lakes, or wetlands.

Stormwater enters the unit through a curbside inlet into a concrete-encased area. Mulch, soil, engineered soil, and gravel filter out particulates and associated nutrients along with heavy metals and other inorganic compounds prevalent in urban runoff. Microbial communities in the root system of the tree remove organic carbon, nitrogen, and phosphorus to use them as part of their life cycle processes, while trees incorporate these nutrients into their biomass. From there, water flows through a surface inlet or external system connection to the existing stormwater infrastructure.

Customization Options

Box tree filter encasements have a range of standardized sizes, and an appropriate size can be determined by assessing the runoff reduction needs and physical constraints of the area. A variety of trees can be used in these units, with tree selection dependent on the climate, species native to the area, and the size of the installation. Slow growing, medium-sized trees will prevent degradation of the concrete encasement by the tree's root system. A manhole cover can be installed directly adjacent to the planted tree to allow easier access for future maintenance.

Maintenance

Typically, box tree filters need to be watered three times per week for the first four weeks after installation. Box tree filters require annual mulching through the first three years of establishment. Pruning and trimming of the tree as needed improves its health, growth, and appearance. Debris and litter caught in the tree grate should be removed monthly for the life of the installation.

Figure 8: Box tree filter in suburban setting

Cost Information

Cost information is provided for each green infrastructure technique in Section 5 of this report. The Installed costs are based on project experience, bid tabs, and information from the RS Means trends, and the labor and bidding environment.

Table 12: Box tree filter practice unit costs

	Item	Description	Unit Price	Unit
GI Technique	Box Tree Filter	Design/Engineering	15% of Construction Cost	LS
		Mobilization	$10,000.00	LS
		Excavation & Haul	$45.00	CY
		Hardwood Mulch	$45.00	CY
		Engineered Soil	$60.00	CY
		Gravel Subgrade	$45.00	CY
Required Component	Concrete Encasement	Curb installation, box tree filter	$45.00	CF
	Grate	Varies by size	$600.00	EA
	Underdrain	3" perforated PVC pipe, irrigation port or external system connection	$0.00	LF
	Perforated Pipe Cleanout		$1,000.00	LF
	Connection to existing storm infrastructure		$600.00	EA
Required Selection	Tree	Varies by species	$400.00	EA
Custom Options	Access to Concrete Encasement	Varies by species	$300.00	EA

Specifications

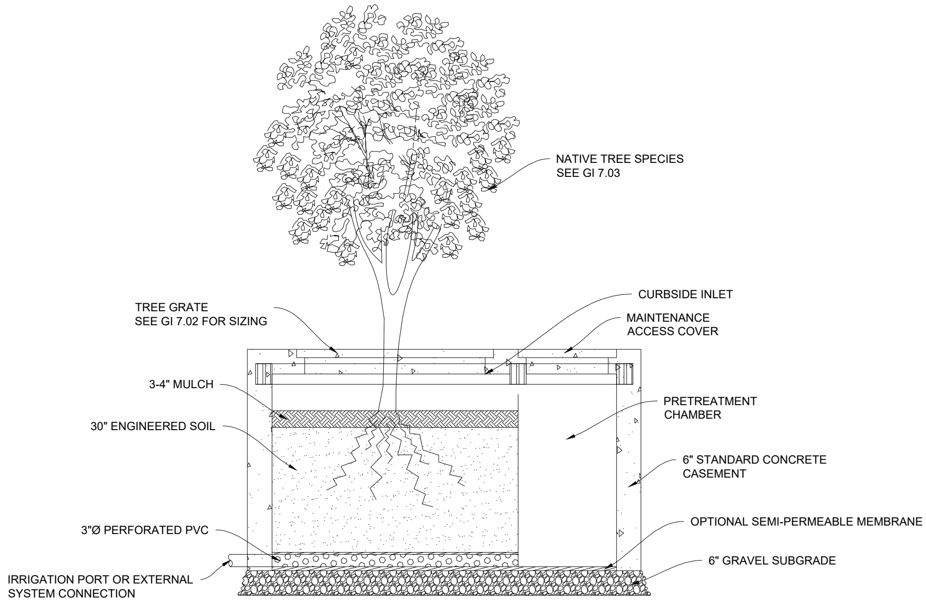
Along with the construction documents, the design engineer should make site-specific customizations to the following sections of the standard specifications from the Illinois Urban Manual in order to have a full set of specifications for a green roof. Other sections can be included on an as-needed basis. Further instructions on the use of specifications are included in Appendix B. Specifications for engineered soil differ from those outlined in Appendix C.

Construction Specifications

2 - Clearing and Grubbing
5 - Pollution Control
7 - Construction Surveys
8 - Mobilization and Demobilization
9 - Traffic Control
10 - Water for construction
21 - Excavation
23 - Earthfill
24 - Drainfill
25 - Rockfill
26 - Topsoiling
27 - Diversion and Waterways
32 - Structure Concrete
34 - Steel Reinforcement
35 - Concrete Repair
45 - Plastic Pipe
94 - Contractor Quality Control
592 - Geotextile
707 - Digging, Transporting, Planting, and Establishment of Trees, Shrubs and Vines
752 - Stripping, Stockpiling, Site Preparation and Spreading Topsoil

Material Specifications

521 - Aggregates for Drainfill and Filters
522 - Aggregates for Portland Cement Concrete
531 - Portland Cement
534 - Concrete Curing Compound
535 - Preformed Expansion Joint Filler
536 - Sealing Compound for Joints in Concrete and Concrete Pipe
539 - Steel Reinforcement (for Concrete)
547 - Plastic Pipe
592 - Geotextile
804 - Material for Topsoiling



BOX TREE FILTER TYPICAL SECTION

BOX TREE FILTER IN RESIDENTIAL INSTALLATION[5]

DESIGN GUIDANCE

TYPICAL LOCATION: CURBSIDE, AREA BETWEEN SIDEWALK AND STREET[1]

WIDTH: 4' MIN TO ALLOW FOR GRATE CLEARANCE, MAX WIDTH DEPENDENT ON SPACE AVAILABLE

LENGTH: MINIMUM 3'

CONTRIBUTING DRAINAGE AREA: ~1/4 ACRE PER UNIT

AVAILABLE OPTIONS: UNDERGROUND STORAGE, SEWER CONNECTION, GROUNDWATER INFILTRATION SYSTEM

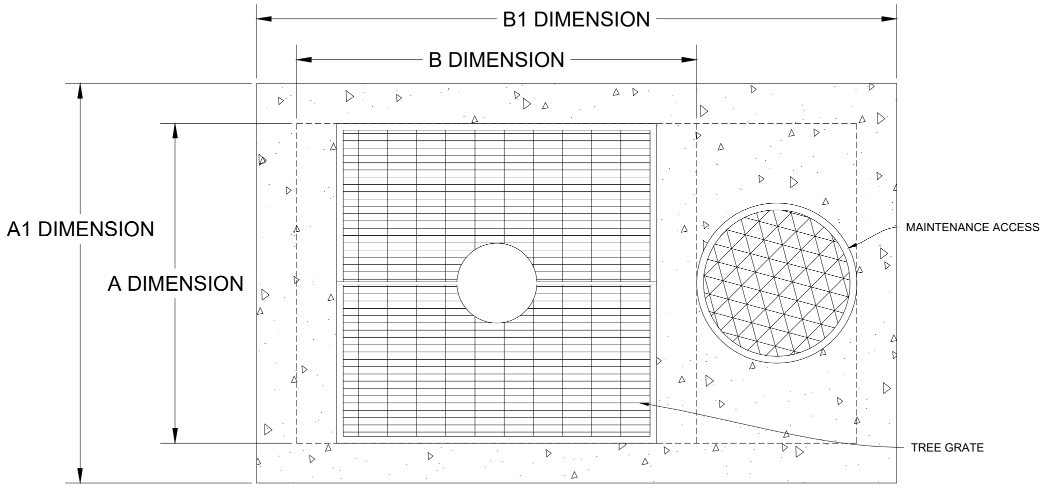
DETAILED DESIGN PRELIMINARY WORKSHEET

- ☐ NATIVE SOIL INFILTRATION[2]:_____________ IN/HR
- ☐ REQUIRED STORAGE CAPACITY[3]:__________ CUBIC FT
- ☐ CONNECT TO EXISTING STORM NETWORK: YES/NO[4]
- ☐ DISTANCE TO CURB >3 FT: YES/NO
- ☐ ADJACENT TO CURBSIDE: YES/NO

1. COULD BE USED IN VARIOUS RESIDENTIAL, COMMERCIAL OR INDUSTRIAL APPLICATIONS.
2. NATIVE SOIL INFILTRATION CAN BE NO GREATER THAN 4 INCHES/HOUR.
3. STORAGE CAPACITY VARIES WITH UNIT SIZE. IF IS CAPACITY EXCEEDED, MORE UNITS MUST BE INSTALLED
4. CAPACITY OF DOWNSTREAM SYSTEM TO BE ANALYZED BY DESIGNER.
5. HTTP://ACTREES.ORG/NEWS/TREES-IN-THE-NEWS/NEWSROOM/RHODE-ISLAND-CASE-STUDY-FILTERING-STORMWATER-WITH-TREES/

NORTHWESTERN UNIVERSITY 2016	BOX TREE FILTER	A COLLABORATION OF: delta institute; NORTHWESTERN UNIVERSITY
GI 8.01 1 OF 3 SCALE: NTS		

Box Tree Filter Size Selection



TOP VIEW AND SIZE SELECTION DETAIL

TABULATION									
POD SIZE		FOOT PRINT (OD)		TREE / GRATE QUANTITY SEE NOTE X	RATED FLOW CAPACITY (GPM / CFS)	MAX. DRAINAGE AREA TREATED [1] (ACRE)	MAX. DRAINAGE AREA TREATED [2] (ACRE)	MAX. DRAINAGE AREA TREATED [3] (ACRE)	MAX. DRAINAGE AREA TREATED [4] (ACRE)
A DIM	B DIM	A1 DIM	B1 DIM						
4'	4'	5'	7'	1 EA	16 / 0.036	0.18	0.22	0.30	0.44
4'	5'	5'	8'	1 EA	20 / 0.045	0.23	0.28	0.38	0.56
4'	6'	5'	9'	1 EA	24 / 0.054	0.27	0.33	0.44	0.67
4'	7'	5'	10'	1 EA	28 / 0.062	0.31	0.39	0.52	0.78
4'	8'	5'	11'	1 EA	32 / 0.071	0.36	0.44	0.59	0.89
4'	9'	5'	12'	1 EA	36 / 0.080	0.40	0.50	0.67	1.00
4'	10'	5'	13'	1 EA	40 / 0.089	0.45	0.56	0.74	1.11
4'	11'	5'	14'	2 (MAX)	44 / 0.098	0.49	0.61	0.82	1.23
4'	12'	5'	15'	2 (MAX)	48 / 0.11	0.55	0.69	0.92	1.38
5'	4'	6'	7'	1 EA	20 / 0.045	0.23	0.28	0.38	0.56
5'	5'	6'	8'	1 EA	25 / 0.056	0.28	0.35	0.47	0.70
5'	6'	6'	9'	1 EA	30 / 0.067	0.34	0.42	0.56	0.84
5'	7'	6'	10'	1 EA	35 / 0.078	0.39	0.49	0.65	0.98
5'	8'	6'	11'	1 EA	40 / 0.089	0.49	0.61	0.82	1.23
5'	9'	6'	12'	1 EA	45 / 0.10	0.50	0.63	0.83	1.25
5'	10'	6'	13'	1 EA	50 / 0.111	0.55	0.70	0.93	1.39
5'	11'	6'	14'	2 (MAX)	55 / 0.123	0.62	0.77	1.03	1.54
5'	12'	6'	15'	2 (MAX)	60 / 0.133	0.67	0.83	1.11	1.66
6'	4'	7'	7'	1 EA	24 / 0.054	0.27	0.33	0.44	0.67
6'	5'	7'	8'	1 EA	30 / 0.067	0.34	0.42	0.56	0.84
6'	6'	7'	9'	1 EA	36 / 0.080	0.40	0.50	0.67	1.00
6'	7'	7'	10'	1 EA	42 / 0.094	0.47	0.59	0.78	1.18
6'	8'	7'	11'	1 EA	48 / 0.11	0.55	0.69	0.92	1.38
6'	9'	7'	12'	1 EA	54 / 0.12	0.60	0.75	1.00	1.50
6'	10'	7'	13'	1 EA	60 / 0.134	0.67	0.83	1.11	1.67
6'	11'	7'	14'	2 (MAX)	66 / 0.147	0.74	0.92	1.23	1.84
6'	12'	7'	15'	2 (MAX)	72 / 0.160	0.80	1.00	1.33	2.00

[1] C = 1.00, I = 0.20 inch / hour
[2] Commercial Development where; C = 0.80, I = 0.20 inch / hour
[3] Detached Multi-Unit Residential where; C = 0.60, I = 0.20 inch / hour
[4] Suburban Residential where; C = 0.40, I = 0.20 inch / hour

C - values from San Diego County Hydrology Manual (2002)
I - values reflect Uniform Intensity Approach targeting 85%-ile storm (CASQA).

SIZING SELECTION FOR BOX TREE FILTER[1]

DESIGN GUIDANCE

SIZE SELECTION

- CONCRETE ENCASING PURCHASED AS WHOLE UNIT
- SIZING DEPENDENT OF DRAINAGE AREA
- STANDARD MANUFACTURER DIMENSIONS
- TREE SELECTION RESTRICTED BY SIZE OF UNIT

BOX TREE FILTER MAINTENANCE GUIDELINES		
TASK	FREQUENCY	TIMEFRAME
ESTABLISHMENT WATERING	3XWEEK	FIRST 4 WEEKS AFTER INSTALLATION
MULCHING	ANNUALLY	THROUGH 3 YEARS
TRASH REMOVAL	1XMONTH	ONGOING
TRIM TREE	AS NEEDED	ONGOING

1 TABLE FROM: http://www.kristar.com/index.php/low-impact-development-lid/treepod-biofilter

NORTHWESTERN CIVIL AND ENVIRONMENTAL ENGINEERING 2016

GI 8.02
2 OF 3
SCALE: NTS

BOX TREE FILTER
SIZE SELECTION

A COLLABORATION OF:

delta institute

NORTHWESTERN UNIVERSITY

Box Tree Filter Notes

RECOMMENDED TREE SPECIES FOR BOX TREE FILTERS			
COMMON NAME	GENUS	SPECIES	FAMILY
RED MAPLE	ACER	RUBRUM	ACERACEAE
RED OAK	QUERCUS	RUBRA	FAGACEAE
SWEETGUM HAPPIDAZE	LIQUIDAMBAR	STYRACIFLUA	HAMAMELIDACEAE
SWAMP WHITE OAK	QUERCUS	BICOLOR	FAGACEAE
HACKBERRY	CELTIS	OCCIDENTALIS	CANNABACEAE

1."A COMPARATIVE ANALYSIS OF CONVENTIONAL STREET TREE PITS AND STORMWATER TREE PITS FOR STORMWATER MANAGEMENT IN ULTRA URBAN ENVIRONMENTS." CHARLES RIVER WATERSHED ASSOCIATION, MAR. 2009. WEB.<HTTP://WWW.CRWA.ORG/HS-FS/HUB/311892/FILE-642201447-PDF/OUR_WORK_/BLUE_CITIES_INITIATIVE/RESOURCES/CRWA_STORMWATER_TREES_URBAN_ENVIRONMENT.PDF>.

NOTES

1. SCHEDULE PRE-INSTALLATION MEETING WITH THE DESIGN ENGINEER 72 HOURS IN ADVANCE OF GREEN INFRASTRUCTURE CONSTRUCTION.
2. AREAS IN AND AROUND GREEN INFRASTRUCTURE SHOULD BE PROTECTED DURING EARTH MOVING AND CONSTRUCTION TO PREVENT COMPACTION THAT WOULD REDUCE INFILTRATION RATES. ALSO PROTECT AREA THROUGHOUT CONSTRUCTION FROM SEDIMENT TRANSPORT THAT WOULD CLOG THE INFILTRATION CAPACITY OF NATIVE AND ENGINEERED SOILS.
3. MULCH SHOULD BE REPLACED ANNUALLY OR AS NEEDED, DEPENDING ON RAIN FREQUENCY FOR BEST RESULTS.

TREE NOTES

1. BOX TREE FILTER TREE DETAILS:
   a. THE BOX FILTER SHOULD BE POPULATED WITH A SINGLE TREE FOR EACH GRATE OPENING.
   b. NATIVE SPECIES WITH DROUGHT RESISTANT CHARACTERISTICS SHOULD BE PRIORITIZED.
   c. SELECT A SLOW GROWING TREE OF MEDIUM SIZE TO PREVENT DEGRADATION OF CONCRETE ENCASEMENT BY ROOT SYSTEM.
2. GROWING MEDIUM SHALL BE PLACED ADJACENT TO STORMWATER PLANTER.
3. GROWING MEDIUM TO BE EITHER CU STRUCTURAL SOIL, SILVA CELL MATERIAL OR APPROVED EQUAL
4. VOLUME OF GROWING MEDIUM TO BE DETERMINED ACCORDING TO THE ABOVE MANUFACTURER'S RECOMMENDATIONS.
5. SELECTION OF THE TREE WILL BE BASED ON REGIONAL AVAILABILITY AND PRICE.

ENGINEERED SOIL SPECIFICATIONS

1. WHEN A PROPRIETARY TREE BOX FILTER IS USED, THE MANUFACTURERS ENGINEERED SOIL SHOULD BE USED AS MAY BE REQUIRED TO MAINTAIN THE MANUFACTURERS WARRANTY.
2. WHEN DESIGNING A NON-PROPRITARY TREE BOX FILTER, THE ENGINEERED SOIL MIX SHALL BE A BLEND OF 70% TO 90% COARSE SAND AND 10% TO 25% COMPOST BY VOLUME AND MEET THE FOLLOWING REQUIREMENTS:
   a. COMPOST SHALL BE WELL AGED AND MEET WISCONSIN DNR TECHNICAL SPECIFICATION S100
   b. ORGANIC MATTER CONTENT OF MIX FROM 3-5% BY WEIGHT
   c. PROPORTION OF CLAY (HYDROMETER ANALYSIS) SHALL BE 2% TO 5%
   d. pH OF MIX SHALL BE 5.5 TO 8.0
   e. THE ENGINEERED SOIL THICKNESS SHALL BE ADEQUATE TO SUPPORT THE ROOTING DEPTH OF THE SELECTED TREE OR SHRUB SPECIES.
2. ENGINEERED SOIL MAY BE OBTAINED OFF SITE OR CREATED BY TESTING NATIVE SOILS AND MIXING WITH IMPORTED MATERIALS AS NEEDED PROVIDED THE MIX MEETS THE SPECIFICATIONS ABOVE
3. ENGINEERED SOIL SHALL BE DRY AND FRIABLE AND UNIFORMLY MIXED. ITS CHARACTERISTICS SHALL BE VERIFIED BY MATERIALS TESTING PRIOR TO PLACEMENT.
4. PLACE DRY AND FRIABLE SOIL IN 8-12 INCH LIFTS.
5. AFTER PLACEMENT, LIGHTLY COMPACT DRY SOIL BY HAND TAMPING. DO NOT USE A VIBRATORY COMPACTOR. AFTER PLANTING OF THE TREE, WATER THE SOIL SURFACE UNTIL WATER APPEARS IN THE UNDERDRAIN. PROVIDE ADDITIONAL SOIL AS NEEDED TO PROVIDE PROPER COVER OF THE ROOT BALL.
6. TO PRESERVE INFILTRATION CAPACITY OF NATIVE SOIL, KEEP MACHINERY AND CONSTRUCTION SITE RUNOFF OUTSIDE OF GREEN INFRASTRUCTURE AREA.

NORTHWESTERN UNIVERSITY 2016 WITH EDITS BY ECT, 2021	BOX TREE FILTER NOTES	A COLLABORATION OF: delta institute NORTHWESTERN UNIVERSITY
GI 8.03 3 OF 3 SCALE: NTS		

Green Roof

A green roof transforms an otherwise impervious surface into one capable of retaining and filtering stormwater. A substrate of growing media is planted with vegetation and absorbs stormwater that would otherwise flow through a traditional system of gutters and sewers. By retaining the stormwater, green roofs allow for natural processes like evaporation and transpiration to occur, slowly releasing water to the atmosphere. The system also reduces the rate of runoff for water that cannot be absorbed, especially for smaller and more frequent rain events.

The primary stormwater benefit of a green roof is the reduction in runoff rates it provides for an otherwise impervious roof. Most green roofs are not designed to store the volume of rainwater that a typical detention basin can accommodate. Even still, a modest amount of retention can be anticipated. The capacity of the green roof will be determined by the thickness of the substrate layer, the slope of the roof, the amount and time of rainfall, and antecedent rainfall.

A green roof can be installed on a new or existing structure with the load bearing capacity to support it. A green roof adds a considerable amount of weight to a building compared to a gray roof. It is necessary to consider factors of human traffic, weather and climatic conditions, and temporary installations in addition to the saturated weight of the green roof itself when calculating the maximum load capacity.

Customization Options

There are two primary types of green roofs. The first and most common is a layered system which is built in place on the roof. The second type of green roof uses a modular system containing pre-vegetated plastic trays. The modular trays tend to be more expensive than a layered green roof, but can be cost competitive on smaller roofs or on roofs where building the layers in place is problematic, such as on top of very tall buildings. The modular trays also offer the instant appeal of mature vegetation on the day of installation.

Figure 9: Green roof in urban setting

The deck is the structural portion of the roof that supports everything above it. It can be constructed from concrete, wood, metal, plastic, gypsum, or composite, though concrete is recommended when a green roof is involved. Corrugated metal decks require an additional support and insulation layer. There is usually a division in trades and in the responsibility for designing the roof and the green roof components. The building's roof deck and waterproofing layer (roof membrane) are almost always designed by an architect and constructed by trained roofers. The design of the green roof components on the other hand can come from a variety of sources, such as a landscape architect or a manufacturer. They are also frequently installed by companies specializing in green roofs. The waterproofing layer of the roof should be protected at all times during the construction of a green roof. This can be especially important when multiple trades and designers are involved. Because the construction can require large buckets of material to be deposited onto the roof, a thick spongy protection fabric is often the first thing to be put down.

A layered green roof is built as its name implies - by stacking its components in layers. The protection fabric protects the membrane from the minor impacts of placing and moving green roof components around. It is often a non-woven, synthetic poly-propylene fiber mat similar in appearance to the felt blankets movers use to protect furniture. Additional protection, however, is required when a bitumen-based membrane is used or when the roots could be in contact with polystyrene insulation. In these applications a root barrier made of polyethylene sheets is placed over the protection fabric. The drainage layer is one of the most critical components of a green roof system.

The type of drainage layer further divides a layered green roof into two sub-types. Layered systems can use aggregate drainage layers made of light-weight expanded clay, or pumice. Alternatively, they can use manufactured drainage boards which can be molded plastic sheets or composite geotextiles. Proprietary green roof systems, such as those available from Hydrotech and Carlisle, use manufactured drainage boards. No matter the type of drainage layer used, a separation fabric is placed over it to contain the growing media above it. The separation fabric is usually a thin, non-woven, needle-punched, poly-propylene sheet. It is designed specifically to allow water to pass through it, but not soil particles. The growing media above it is also specially designed. Green roof soils are generally light-weight and composed of a mixture of drainage aggregate and organic material. They are manufactured to limit the amount of fines that might otherwise clog the separation fabric below. A layered green roof also needs edges to contain the material in the system. This can be as simple as a parapet wall extension, or may involve the use of aluminum or stainless steel angled edge restraints.

The thickness of the growing media can vary and does not need to be uniform across the entire area. Intensive green roofs have a thicker layer of substrate (greater than 6 inches), which allows for greater variety in plant selection, but require more maintenance, are more costly, and weigh more. Semi Intensive green roofs with 4 to 6 inches of soil and extensive green roofs with 2 to 3 inches of soil have thinner substrate layers that can only support drought-tolerant and self-seeding plants but require fewer labor and financial investments and weigh less. Along with the thickness of the substrate layer, plant selection depends on climate, locality, plant growth rate, and size at maturity. Modules, plugs, vegetated mats, seeds, nursery containers, and cuttings are all viable planting options, each with their own benefits and disadvantages. The maximum width and length are scalable, limited by the area and design constraints of the roof.

Maintenance

A green roof needs to be watered usually 3 times per week during the first 4 weeks after installation. During the first year of establishment, the plants will need to be watered and weeded regularly through October and during any subsequent years in which there is a drought. If mulch is used it may need to be supplemented annually through the first three years of establishment. Debris removal must occur monthly for the life of the roof garden. Trimming, removal, and replacement of dead plants must occur on an as-needed basis.

Cost Information

Green roofs are unique compared to the other green infrastructure techniques found in this toolkit due to the diverse range of customization options and the role their building's design plays in their development. Due to this, the cost for installing a green roof is highly variable. A reasonable budget for an extensive layered green roof would be $25-40 per square foot; a semi intensive layered green roof would be $35-50 per square foot; and an intensive layered green roof would be $45-100 per square foot.

Specifications

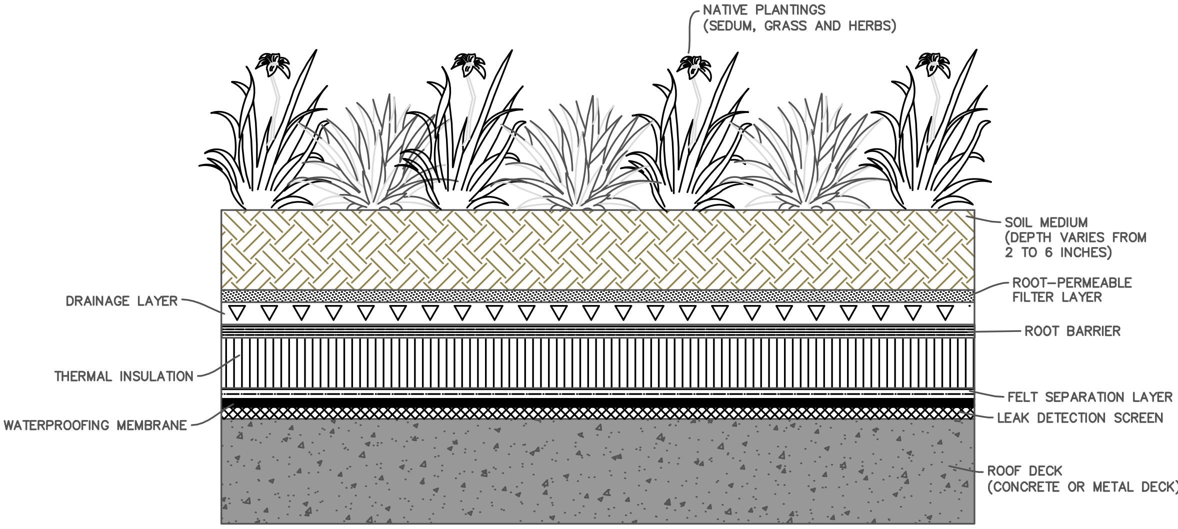
Specifications are an important component in the design of green infrastructure. Along with the construction documents, the design engineer should make site-specific customizations to the following sections of the standard specifications from the Illinois Urban Manual in order to have a full set of specifications for a green roof. Other sections can be included on an as-needed basis. National standards for the design of green roofs have been developed and should be considered. ANSI/SPRI RP-14 establishes wind design standards and ANSI/SPRI VF-1 established fire design standards. Further instructions on the use of specifications are included in Appendix B. Specifications for engineered soil used in green roofs differ from those outlined in Appendix C.

Construction Specifications

5 - Pollution Control
7 - Construction Surveys
8 - Mobilization and Demobilization
9 - Water for Construction
26 - Topsoiling
32 - Structure Concrete
34 - Steel Reinforcement
35 - Concrete Repair
97 - Flexible Membrane Liner

Material Specifications

531 - Portland Cement
804 - Material for Topsoiling



GREEN ROOF TYPICAL SECTION

EXTENSIVE GREEN ROOF INSTALLATION[1]

DESIGN GUIDANCE

TYPICAL LOCATION: ROOFTOP OF A BUILDING OR HOUSE[2]

THICKNESS OF GROWING MEDIUM: 2 TO 6 INCHES

AVAILABLE OPTIONS: NATIVE PLANT SELECTION (GRASSES, SUCCULENTS AND HERBS)[3]

GROWING MEDIUM: EXPANDED SHALE, VOLCANIC PUMICE, SCORIA, SAND, PEAT AND CRUSHED BRICK MATERIAL[4]

DETAILED DESIGN PRELIMINARY WORKSHEET

- ☐ NEW BUILDING: YES/NO
- ☐ DEAD LOAD REQUIREMENTS: _________ LB/FT^2
- ☐ LIVE LOAD REQUIREMENTS: _________ LB/FT^2
- ☐ REQUIRED STORAGE CAPACITY: ________ CUBIC FT
- ☐ MEDIUM DEPTH: _________ IN
- ☐ NATIVE SOIL INFILTRATION: ____________ IN/HR
- ☐ CONNECT TO EXISTING STORM NETWORK: YES/NO
- ☐ SLOPE OF ROOF: _________%
- ☐ COMPLIANCE WITH LOCAL FIRE CODES: YES/NO
- ☐ NATURAL OR ARTIFICIAL DRAINAGE SYSTEM: _________
- ☐ ROOFTOP SPACE: _____________ FT^2

1. IMAGE CREDIT: © 2021 ENVIRONMENTAL CONSULTING & TECHNOLOGY, INC.
2. COULD BE USED IN VARIOUS RESIDENTIAL, COMMERCIAL OR INDUSTRIAL APPLICATIONS
3. SEE GI 9.02 FOR NATIVE PLANTS
4. SEE GI 9.03 FOR GROWING MEDIUM SPECIFICATIONS

Northwestern University 2016	EXTENSIVE GREEN ROOF	A COLLABORATION OF: delta institute NORTHWESTERN UNIVERSITY
GI 9.01 1 OF 3 SCALE: NTS		

Native Plantings

BOTANICAL NAME	COMMON NAME	FAMILY	PLANTING MEDIUM (IN.)	HEIGHT UP TO (IN.)	NATIVE TO ILLINOIS?
		GRASSES			
BOUTELOUA CURTIPENDULA	SIDE OATS GRAMA	POACEAE	6	30	YES
SPOROBOLUS HETEROLEPIS	PRAIRIE DROPSEED	POACEAE	6	30	YES
ANDROPOGON GERARDII	BIG BLUE STEM	POACEAE	4 - 6	36 +	YES
		HERBACEOUS PERENNIALS			
CAMPANULA ROTUNDIFOLIA	HAREBELL	CAMPANULACEAE	6	12	YES
PHLOX SUBULATA	MOSS PHLOX	POLEMONIACEAE	6	5	NO
ANTENNARIA DIOICA	PUSSYTOES	ASTERACEAE	4	10	NO
AGASTACHE FOENICULUM	ANISE HYSSOP	LAMIACEAE	6	25	YES
ARTEMISA CAUDATA	BEACH WORMWOOD	ASTERACEAE	4 - 6	36	YES
		HERBS			
THYMUS PRAECOX	MOTHER OF THYME	LAMIACEAE	4	2	NO
ALLIUM CERNUUM	NODDING ONION	AMARYLLIDACEAE	6	36	YES
		HARDY SUCCULENTS			
SEDUM SEXANGULARE	TASTELESS STONECROP	CRASSULACEAE	4	4	NO
SEDUM KAMTSCHATICUM	ORANGE STONECROP	CRASSULACEAE	4	5	NO
SEDUM ACRE	GOLDMOSS STONECROP	CRASSULACEAE	4 - 6	7	NO
SEMPERVIVUM	HEN AND CHICKS	CRASSULACEAE	4	8	NO

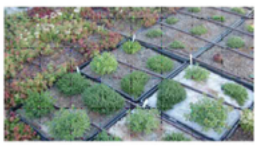
SUGGESTED PLANTING SPECIES[1]

PLANT MODULE[3]

PLANT PLUGS[4]

VEGETATED MATS[5]

NURSERY CONTAINERS[6]



CUTTINGS[7]

SEEDS[8]

PLANT INSTALLATION METHODS

DESIGN GUIDANCE[1]

MODULES
- MOST EXPENSIVE METHOD
- SOLD BY COMPANIES LIKE GREEN GRID AND GREEN ROOF BLOCK

PLUGS
- MOST PRECISE INSTALLATION METHOD
- OPTIMUM PLANTING: APRIL 15—MAY 15 AND SEPT 01—OCT 15.

VEGETATED MATS
- WORK WELL FOR SLOPING ROOFS
- DIFFICULT TO TRANSPORT AND MAY REQUIRE EXPERTISE

SEEDS
- LONGER ESTABLISHMENT PERIOD AND LEAST EXPENSIVE

NURSERY CONTAINERS
- USE TO PLANT DISCRETE AREAS OF A ROOF

CUTTINGS
- VIABLE AND POPULAR METHOD, ESPECIALLY FOR SEDUM

NATIVE PLANTING MAINTENANCE GUIDELINES[1]

TASK	FREQUENCY	TIMEFRAME
ESTABLISHMENT PERIOD	–	FIRST 12 TO 18 MONTHS
HAND WEEDING	–	IS NEEDED MORE DURING ESTABLISHMENT PERIOD
PLANT IRRIGATION	DAILY TO PERIODIC	FIRST THREE WEEKS OF ESTABLISHMENT PERIOD
FERTILIZATION	ANNUALLY	FIRST SIX YEARS

1 SNODGRASS, E.C., & SNODGRASS, L.L. (2006). *GREEN ROOF PLANTS: A RESOURCE AND PLANTING GUIDE*

2 HAWKE, RICHARD. 2015. "AN EVALUATION STUDY OF PLANTS FOR USE ON GREEN ROOFS." (38).

3HTTP://GREENROOFOUTFITTERS.COM/

4 HTTP://PIZZONURSERY.COM/PRODUCTS/

5 HTTP://GREENROOFSOLUTIONS.COM/VEGETATED-MATS.HTML

6 HTTP://WWW.AMERINURSERY.COM/GROWING/EVALUATING-ZEOLITE-IN-AN-EXTENSIVE-GREEN-ROOF-SUBSTRATE/

7 HTTP://WWW.VEGETALID.COM/SOLUTIONS/GREEN-ROOFS/WITH-PLANT-CUTTINGS.HTML

8 HTTP://WWW.ZMESCIENCE.COM/ECOLOGY/SEED-SIZE-NUMBER-INCREASED-0543543/

Northwestern University
2016

GI 9.02
2 OF 3
SCALE: NTS

NATIVE PLANTINGS

A COLLABORATION OF:

delta institute

NORTHWESTERN UNIVERSITY

delta institute

ECT Environmental Consulting & Technology, Inc.

Extensive Green Roof Notes

NOTES

1. THE DECKING OF A GREEN ROOF CAN BE CONSTRUCTED FROM CONCRETE, WOOD, METAL, PLASTIC, GYPSUM, OR COMPOSITE. HOWEVER, CONCRETE IS THE RECOMMENDED STRUCTURAL MATERIAL FOR GREEN ROOFS DUE TO THEIR STRENGTH AND DURABILITY.
2. GREEN ROOF CAN BE SUPPLIED AS PRE-ASSEMBLED MODULAR SYSTEMS OR AS A LAYERED SYSTEM.
   a. MODULAR SYSTEMS TYPICALLY COME AS COMPLETE TRAYS THAT ARE TRANSPORTED TO THE ROOF AND LAID ACCORDING TO MANUFACTURER'S REQUIREMENTS. THE TRAYS CAN BE PROVIDED READY FOR PLANTING OR PRE-PLANTED.
   b. LAYERED SYSTEMS ARE CUSTOM DESIGNED FOR THE SPECIFIC APPLICATION AND GENERALLY COMPOSED OF THE COMPONENTS SHOWN IN DETAILS GI 9.01. THE REMAINDER OF THE NOTES ON THIS SHEET ARE PROVIDED TO GUIDE DESIGN OF LAYERED SYSTEMS.
3. AS WITH ANY ROOF, A 100% WATERPROOF MEMBRANE IS REQUIRED TO PREVENT ANY LEAKS AND DAMAGE TO THE ROOF DECK. THE REPARE OF LEAKS IN THE MEMBRANE WILL REQUIRE REMOVAL OF ALL OR A PORTION OF THE GREEN ROOF SYSTEM. LEAK DETECTION SYSTEMS ARE COMMERCIALLY AVAILABLE TO IDENTIFY THE LOCATION OF LEAKS TO AVOID REMOVAL OF THE ENTIRE ROOF SYSTEM TO FIND THE LEAK. LEAK DETECTION SYSTEMS ARE INSTALLED PRIOR TO THE GREEN ROOF SYSTEM. COMMON METHODS FOR WATERPROOFING ARE MODIFIED BITUMEN MEMBRANES, SINGLE-PLY MEMBRANES AND LIQUID APPLIED METHODS.
4. AN INSULATION LAYER IS NEEDED TO PROVIDE COOLING ENERGY SAVINGS TO THE BUILDING. THE LAYER CAN BE INSTALLED EITHER BELOW OR ABOVE THE WATERPROOF MEMBRANE. IF THE INSULATION LAYER IS INSTALLED ABOVE THE WATERPROOF MEMBRANE, IT IS KNOWN AS AN INVERTED ROOF MEMBRANE ASSEMBLY (IRMA) SYSTEM.
5. FOR MOST MEMBRANE TYPES, A ROOT BARRIER IS REQUIRED TO PREVENT ROOT INTRUSION THAT COULD DAMAGE THE WATERPROOFING OR INSULATING LAYERS. IT NEEDS TO BE INSTALLED ABOVE THE WATERPROOFING MEMBRANE. THE ROOT BARRIER LAYER IS OFTEN MADE FROM PVC OR HDPE (HIGH DENSITY POLYETHYLENE) SHEETS.
6. DRAINAGE SYSTEMS MAY EITHER BE AGGREGATE SUCH AS EXPANDED CLAY OR SHALE OR MAY BE PROPRIETARY DRAINAGE BOARDS OF VARIOUS TYPES. DRAINAGE BOARDS ARE OFTEN LIGHTER WEIGHT THAN AGGREGATE BUT MAY HAVE LOWER WATER HOLDING CAPACITY THAN AGGREGATE.
7. A PERMEABLE POLYPROPYLENE FABRIC MUST BE INCLUDED BETWEEN THE GROWING MEDIUM AND THE DRAINAGE LAYER TO AVOID CLOGGING.
8. PLANT SELECTION WILL DEPEND ON DIFFERENT FACTORS SUCH AS PLANT EXPOSURE TO SUNLIGHT, WIND, SHADE, HUMIDITY, AND TEMPERATURE FLUCTUATIONS.
9. APPLICABLE ASTM STANDARDS FOR GREEN ROOF SYSTEMS ARE:
   - ASTM E 2396 – STANDARD TEST METHOD FOR SATURATED WATER PERMEABILITY OF GRANULAR DRAINAGE MEDIA [FALLING-HEAD METHOD] FOR GREEN ROOF SYSTEMS
   - ASTM E 2397 – STANDARD PRACTICE FOR DETERMINATION OF DEAD LOADS AND LIVE LOADS ASSOCIATED WITH GREEN ROOF SYSTEMS
   - ASTM E 2398 – STANDARD TEST METHOD FOR WATER CAPTURE AND MEDIA RETENTION OF GEOCOMPOSITE DRAIN LAYERS FOR GREEN ROOF SYSTEMS
   - ASTM E 2399 – STANDARD TEST METHOD FOR MAXIMUM MEDIA DENSITY FOR DEAD LOAD ANALYSIS OF GREEN ROOF SYSTEMS
   - ASTM E 2400 – STANDARD GUIDE FOR SELECTION, INSTALLATION, AND MAINTENANCE OF PLANTS FOR GREEN ROOF SYSTEMS
   - ASTM WK 575 – PRACTICE FOR ASSESSMENT OF GREEN ROOFS
   - ASTM WK 4239 – STANDARD TEST METHOD FOR SATURATED WATER PERMEABILITY OF GRANULAR DRAINAGE MEDIA [FALLING-HEAD METHOD] FOR GREEN ROOFS

GROWING MEDIUM SPECIFICATIONS

1. THE MEDIUM CONSISTS OF A LIGHTWEIGHT, POROUS LAYER.
2. IT IS USUALLY OF 2 TO 6 INCHES OF DEPTH.
3. MEDIUM DEPTH WILL AFFECT PLANT SELECTION AND RATE OF VEGETATION GROWTH.
4. THE SUBSTRATE SHOULD HAVE 75 TO 90% OF INORGANIC MATERIAL.
5. INORGANIC MATERIAL PROVIDES VERTICAL STABILITY AND PREVENTS SHRINKAGE.
6. THE MEDIUM WILL DEPEND ON THE TYPES OF PLANTS TO BE PLANTED ON THE ROOF, CLIMATIC CONDITIONS, DEAD AND LIVE LOADS REQUIREMENTS AND DRAINAGE NEEDS.
7. MATERIALS THAT ARE RECOMMENDED AS A GROWING MEDIUM ARE EXPANDED SHALE, EXPANDED SLATE, VOLCANIC PUMICE, SAND, CRUSHED BRICK MATERIALS AND BAKED CLAY.
8. THE REST SHOULD BE ORGANIC COMPOST AND NOT SOIL SINCE SOIL CONTAINS SILT THAT CAN CLOG AND DISRUPT THE DRAINAGE SYSTEM.

MAINTENANCE GUIDELINES

1. THE ANNUAL MAINTENANCE OF AN EXTENSIVE GREEN ROOF COSTS APPROXIMATELY $2.90/M^2 ($0.27/FT^2). MEANWHILE, THE ANNUAL MAINTENANCE OF A CONVENTIONAL BLACK ROOF COSTS $0.2/M^2 ($0.02/FT^2).
2. THE GREATEST MAINTENANCE OCCURS DURING THE FIRST TWO YEARS (ESTABLISHMENT PERIOD) AND IT IS CRITICAL FOR LONG-TERM SUCCESS OF THE ROOF. SPECIFICALLY, PLANT IRRIGATION IS CRUCIAL DURING THE FIRST THREE WEEKS OF THE ESTABLISHMENT PERIOD.

Northwestern University 2016 WITH EDITS BY ECT, 2021	EXTENSIVE GREEN ROOF NOTES	A COLLABORATION OF:
GI 9.03 3 OF 3 SCALE: NTS		delta institute NORTHWESTERN UNIVERSITY

Permeable Pavement

Permeable pavement allows the infiltration of rainwater through the jointing material placed in the spaces between the pavers. Permeable pavers are ideal for right-of-way applications, such as parallel parking lanes or gutter retrofits. This technique can also be used for green alley applications, parking areas, and pedestrian pavements. Permeable pavements are ideal retrofitting existing pavements and for redevelopment sites where it can often be difficult to provide adequate space for other green infrastructure practices.

When runoff flows over a surface of permeable pavement, it infiltrates through open graded stone layers that have a porosity of approximately 40%. Porosity is an expression indicating the ratio of open void space that is available to hold the total the total volume of the soil and gravel material. Larger, open-graded aggregate will have a higher rate of porosity than sand or dense-graded aggregate (which can possess a broader range of aggregate size within its mix). Many jurisdictions require porosity values of 30-36% during design, to provide a factor of safety. After rainwater is stored in the stone layer, it can then infiltrate into the subgrade soil. The design should consider the infiltration capacity of the subgrade soils when designing the system and determine whether there is a need for an underdrain that is connected to the storm sewer network or other outlet. If the infiltration rate is greater than 0.5 in/ hr, then the volume of runoff infiltrated during the event may be sufficient, so as to not require an underdrain as part of the permeable pavement's design for managing runoff volumes. Concrete containment curbs are placed around the installation to prevent lateral movement.

Customization Options

Permeable pavement can be located anywhere there is existing impervious surface area, including residential, commercial and industrial locations. The minimum width of a permeable pavement design is 2 feet, and the maximum length and width are scalable. Oftentimes the pavers will be used on the edge of a road or in the parallel parking lane adjacent to the drive lane. Large storm events can discharge to an existing or proposed storm sewer inlet. There are many manufacturers for permeable pavers, allowing for many size, color and layout pattern configurations.

"Permeable pavement" systems can be topped with other permeable surfaces such as artificial turf and rubber-surfaces (both commonly used in playgrounds) to accommodate a range of site uses. Permeable pavement systems can be sized to provide both storage for infiltration, water quality, and detention purposes. Depending on the run-on area that drains to the permeable paving, an 18-inch section of open graded base aggregate will be sufficient to provide detention storage.

The engineer should resist the temptation to "overdrain" the pavement system, which can lead to reduced time for infiltration and less efficient detention for larger storms. In many cases underdrains will only be necessary at the downstream end of the pavement slope. Underdrains can utilize the resistance to flow from the aggregate to slow drainage within the aggregate base, to improve detention performance. The engineer should design the underdrain system, including underdrain spacing and sizing, to meet the desired performance goals. In most cases, the system should be designed to avoid upflow runoff out of the surface of the permeable pavers at the downstream end, to avoid the flowing water from washing out the aggregate in the paver joints.

Maintenance

Care should be taken to avoid the runoff of sediment from adjacent areas onto the permeable pavers as much as possible. Sand should not be used for winter traction on permeable paving systems, since the sand will clog the openings. When infiltration through the pavers becomes unacceptable, a vacuum truck is required to remove joint material and sediment accumulated between the pavers. The joint material will then need to be replaced. Frequency of replacement will depend on site conditions and sediment loading. Maintenance costs from manufacturers is estimated to be approximately $0.60 per square foot a year.

Cost Information

Cost information is provided for each green infrastructure technique in Section 5 of this report. The installed costs are based on project experience, bid tabs, and information from the RS Means trends, and the labor and bidding environment.

Table 13: Permeable pavement practices unit costs [1,2,3]

	Item	Description	Unit Price	Unit
GI Technique	Permeable Pavement	Design/Engineering	15% of Construction Cost	LS
		Mobilization	$10,000.00	LS
		Excavation & Haul	$45.00	CY
		Porous unit Pavers (Machine Installed)	$10.00	SF
		Geotextile Fabric	$5.00	SY
		ASTM No. 8 Stone bedding	$95.00	CY
		ASTM No. 57 Stone base	$65.00	CY
Required Component	Curb	Flush Curb	$25.00	LF
	Curb	Curb & Gutter section	$25.00	LF
Custom Options	Subbase Layer	ASTM No.2 Stone	$65.00	CY
	Underdrain	4" HDPE perforated storm pipe	$20.00	LF
	Perforated Pipe Cleanout		$600.00	EA
	Storm Sewer	12" HDPE storm sewer	$65.00	LF
	Connection to existing storm sewer		$600.00	EA

1 Installed cost include material and labor based on bid tabs from related projects and RS Means.

2 Unit price based on a small (500 sf) urban alley retrofit project with hand placement of the permeable pavers. For larger installations, pavers can be machine installed, which increases efficiency and reduces the unit price. Unit prices for specific projects will vary based on scale, complexity, labor environment, and material cost trends. A detailed estimate should be prepared by the design engineer.

3 The system storage capacity can be increased by enlarging the stone envelope. Stone void space ratio is 40% and the unit weight is 100 lb/cf. 4 Multiply permeable pavement perimeter length by the unit price.

Specifications

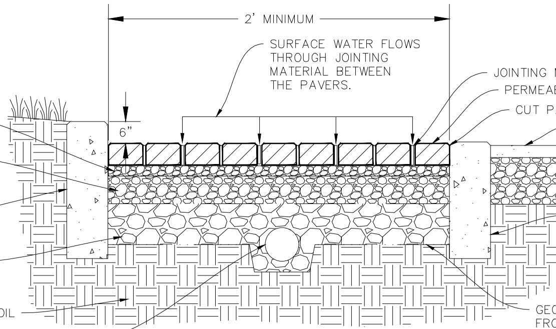
Although permeable pavers function differently than stormwater planters, the construction required to build them is very similar to a stormwater planter, because they are both surrounded by concrete curbing. The main difference is that permeable pavers do not use engineered soil or plants. Refer to Appendix C for more information on how to customize the standard specifications from the Illinois Urban Manual.

Construction Specifications

2 - Clearing and Grubbing
5 - Pollution Control
7 - Construction Surveys
8 - Mobilization and Demobilization
10 - Water for Construction
21 - Excavation
23 - Earthfill
24 - Drainfill
25 - Rockfill
32 - Structure Concrete
34 - Steel Reinforcement
35 - Concrete Repair
44 - Corrugated Polyethylene Tubing
46 - Tile Drains
94 - Contractor Quality Control
95 - Geotextile
752 - Stripping, Stockpiling, Site Preparation and Spreading Topsoil

Material Specifications

521 - Aggregates for Drainfill and Filters
522 - Aggregates for Portland Cement Concrete
531 - Portland Cement
534 - Concrete Curing Compound
535 - Preformed Expansion Joint Filler
536 - Sealing Compound for Joints in Concrete and Concrete Pipe
539 - Steel Reinforcement (for Concrete)
548 - Corrugated Polyethylene Tubing
592 - Geotextile Permeable Pavers - Manufacturer specific



PERMEABLE PAVEMENT SECTION

PERMEABLE PAVERS[1]

DESIGN GUIDANCE

TYPICAL LOCATION: PARALLEL PARKING LANE WITHIN RIGHT OF WAY OR IN PARKING AREA OF REDEVELOPMENT

WIDTH: 2' MIN, SCALEABLE

LENGTH: SCALABLE

CONTRIBUTING DRAINAGE AREA: VARIES ON SCALE

AVAILABLE OPTIONS: UNDERDRAIN
UNDERGROUND STORAGE (GI 11.01)

DETAILED DESIGN PRELIMINARY WORKSHEET

- ☐ NATIVE SOIL INFILTRATION[2]: ____________ IN/HR
- ☐ REQUIRED STORAGE CAPACITY[3]: __________ CUBIC FT
- ☐ CONNECT TO EXISTING STORM NETWORK: YES/NO[4]
- ☐ DEPTH TO GROUNDWATER TABLE > 2 FT: YES/NO[5]

1. AQUA ROC PAVERS BY BELGARD SHOWN IN ALLEY RETROFIT (PHOTO BY GUIDON DESIGN)
2. NATIVE SOIL INFILTRATION NEEDS TO BE GREATER THAN 0.5 INCHES/HOUR. IF IT IS NOT, AN UNDERDRAIN MUST BE INCLUDED.
3. IF STORAGE CAPACITY EXCEEDS AVAILABLE FOOTPRINT SPACE, INCREASE THICKNESS OF DRAINAGE AGGREGATE OR CONSIDER UNDRERGROUND STORAGE.
4. IMPACT ON DOWNSTREAM SYSTEM TO BE ANALYZED BY DESIGNER.
5. IF NO, TECHNIQUE MAY NOT MEET CODE WITHOUT A LINER.
6. CONCRETE CONTAINMENT CURB MUST BE INSTALLED ON ALL SIDES OF THE PERMEABLE PAVERS.
7. THE THICKNESS OF THE BASE AND SUBBASE SHOULD BE SIZED TO MEET THE STRUCTURAL REQUIREMENTS OF THE APPLICATION AS WELL AS THE STORMWATER GOALS.

GI 10.01
1 OF 2
SCALE: NTS

PERMEABLE PAVEMENT

A COLLABORATION OF:

Permeable Pavement Notes

PERMEABLE PAVEMENT NOTES

1. NATIVE SOIL INFILTRATION RATE TO BE 0.5 INCHES/HOUR OR GREATER. IF NOT, THEN AN UNDERDRAIN IS REQUIRED.
2. RUN-ON TRIBUTARY RUN-ON AREA SHALL NOT EXCEED 3:1 RELATIVE TO THE PERMEABLE PAVEMENT AREA. RUN-ON SHALL BE DISTRIBUTED OVER THE AREA OF THE PERMEABLE PAVING TO AVOID HYDRAULICALLY OVERLOADING THE SURFACE AND BYPASSING RUNOFF.
3. AGGREGATE BASE AND SUBBASE COURSE THICKNESS DEPENDENT ON TRAFFIC LOADING AND SUBGRADE SOIL PROPERTIES AS WELL AS REQUIRED STORAGE TO MEET STORMWATER GOALS AND/OR REGULATORY REQUIREMENTS.
4. THE SUBBASE COURSE SHALL BE CRUSHED STONE OR CRUSHED GRAVEL MEETING ASTM GRADATION #57 OR #2. #2 STONE MAY BE USED WHEN THE SUBGRADE SURFACE IS FLAT. #57 STONE IS PREFERRED WHEN THE SUBGRADE IS SLOPED DUE TO ITS SLOWER DRAINGE RATE PROVIDING MORE TIME FOR INFILTRATION AND DETENTION.
5. FULL EXTENT OF POROUS PAVEMENT SHALL BE FENCED OFF DURING CONSTRUCTION TO PREVENT COMPACTION OF SUBGRADE AND STOCKPILING OF CONSTRUCTION MATERIALS OVER SURFACE.
6. PERVIOUS PAVEMENT SURFACES SHALL BE PROTECTED FROM SEDIMENT DURING THE ENTIRE CONSTRUCTION PROCESS.
7. IF DURING EXCAVATION OF NATIVE SOILS, THE BOTTOM OF THE TECHNIQUE IS EXPOSED TO RAIN, HAND RAKE THE SURFACE TO A DEPTH OF 3" TO REMOVE CRUSTED SURFACES AND RESTORE INFILTRATION CAPACITY.
8. AGGREGATE BASE COURSE SHALL BE WASHED ON-SITE TO REDUCE WASH LOSS TO 0.5%. ROCK SHOULD BE HOSED OFF WHILE ON TRUCK OR AFTER STOCKPILING. HOSE OFF AS PILE IS UTILIZED AS FINES WILL MIGRATE TO LOWER LEVELS OF PILE.

MAINTENANCE GUIDELINES

1. PREVENT RUN-ON OF SEDIMENT IN RUNOFF FROM ADJACENT AREAS.
2. SWEEP/VACUUM ONE OR TWO TIMES PER YEAR.
3. TO PREVENT CLOGGING OF THE SURFACE, SAND SHALL NOT BE USED DURING WINTER TO IMPROVE TRACTION.IF ABRASIVES ARE REQUIRED, CLEAN ASTM #8 OR #9 STONE SHALL BE USED.
4. WHEN INFILTRATION RATES THROUGH THE JOINTS BECOMES UNACCEPTABLE, USE A VAC TRUCK TO REMOVE JOINT MATERIAL ALONG WITH ACCUMULATED SEDIMENT. REPLACE JOINT MATERIAL. FREQUENCY OF THIS MAINTENANCE WILL VARY BASED ON SEDIMENT LOADING.

MATERIALS SPECIFICATIONS

1. BASE COURSE

1.1. ALL AGGREGATES BENEATH THE PAVEMENT SHALL BE CRUSHED STONE OR CRUSHED GRAVEL AND MEET THE FOLLOWING:

1.1.1. MAXIMUM WASH LOSS OF 0.5%

1.1.2. MINIMUM DURABILITY INDEX OF 35

1.1.3. MAXIMUM ABRASION OF 10% FOR 100 REVOLUTIONS AND MAXIMUM OF 50% FOR 500 REVOLUTIONS

1.1. UNLESS OTHERWISE APPROVED BY THE ENGINEER, COARSE AGGREGATE FOR THE AGGREGATE BEDDING LAYER SHALL MEET THE FOLLOWING GRADATION (ASTM NO. 8)

US STANDARD SIEVE SIZE	PERCENT PASSING
$\frac{1}{2}$"	100
$\frac{3}{8}$"	85-100
4	10-30
8	0-10
16	0-5

1.2. UNLESS OTHERWISE APPROVED BY THE ENGINEER, COARSE AGGREGATE FOR THE AGGREGATE BASE COURSE SHALL MEET THE FOLLOWING GRADATION (ASTM NO. 57)

US STANDARD SIEVE SIZE	PERCENT PASSING
$1\frac{1}{2}$"	100
1"	95-100
$\frac{1}{2}$"	25-60
4	0-10
8	0-5

1.3. UNLESS OTHERWISE APPROVED BY THE ENGINEER, COARSE AGGREGATE FOR THE AGGREGATE SUBBASE COURSE SHALL MEET ASTM NO. 57 OR NO. 2 GRADATION.

1.4. GEOTEXTILE FABRIC SHALL SHALL BE WOVEN, MONOFILAMENT GEOTEXTILE CONFORMING TO THE FOLLOWING:

A. MINIMUM FLOW RATE OF 145 GAL/MIN/FT2 ASTM D-4491
B. GRAB TENSILE STRENGTH 365 X 200LB ASTM D-4632
C. GRAB ELONGATION MAX 24 X 10% ASTM D-4632
D. TRAPEZOID TEAR MIN 115 X 75 LBS ASTM D-4533
E. CBR PUNCTURE RESISTANCE MIN 675 LB ASTM D-6241
F. APPARENT OPENING SIZE 4060-90 U.S. STANDARD SIEVE.

GI 10.02
2 OF 2
SCALE: NTS

PERMEABLE PAVEMENT NOTES

A COLLABORATION OF:

Underground Storage

Underground storage can be an effective green infrastructure technique in situations when large storage volumes are required, in areas with routine localized flooding and combined sewer overflows, to reduce the volume and rate of stormwater entering the sewer system. Underground storage can provide an effective detention solution in areas where surface level detention basins are spatially infeasible, particularly in urban areas. Generally, runoff enters the system and fills up a stone base beneath the chambers. Once the voids in the stone base are filled, then the open area of the chamber acts as efficient open storage, holding a high volume of water per unit of footprint area.

Depending on the infiltration rate of the underlying native soil, the underground storage system will either discharge directly into the groundwater or slowly through a perforated underdrain connected to an outlet. A weir or orifice within the outlet structure can be designed to control the storage depth within the system, allowing for higher infiltration volumes. The discharge of stored stormwater (above or below ground) to the existing storm network is a traditional approach to stormwater management, with the rate controlled using orifices or other devices. For the underground storage system to be truly a green system, it must infiltrate stormwater into the ground, or be paired with other green infrastructure practices such as permeable pavement and/or bioretention systems.

Customization Options

The layout options for underground storage are both flexible and scalable. A design engineer can arrange the system to fit a desired shape and can select the height of the storage chambers and length of the system to meet the required storage volume. There are several manufacturers of underground chamber systems, as well as other underground storage solutions available. The technical designer should consider the particular requirements of the chosen system.

The system can be paired with other green infrastructure techniques. When placed under bioretention, runoff is filtered through the engineered soil layer and flows directly into the underground storage through the stone layer. Large storm events enter through the overflow structure that can be connected to the chambers. Permeable pavers filter runoff as well and direct flow through the underlying stone layer that is hydraulically connected to the stone envelope around the underground storage.

Figure 10: Underground storage chambers for stormwater

Source: https://commons.wikimedia.org/wiki/File%3AParking_lot_stormwater_detention_system.jpg

Maintenance

The underground storage system should include inspection ports that are used to observe the amount of accumulated sediment within the system. Once the accumulation has reached a level indicated by the manufacturer, the system needs to be cleaned via JetVac, which sprays water on the inside of the chambers, loosens the sediment, and vacuums it out of the system. Maintenance of the system is accessed using a manhole structure and distribution pipe manifold. The inspection port should be inspected semi-annually or per manufacturer guidelines. Maintenance costs will vary based on the size of the installation and ease of access. A standard JetVac maintenance should cost $1,500 -$ 2,500.

Cost Information

Cost information is provided for each green infrastructure practice in Section 5 of this report. The installed costs are based on project experience, bid tabs and information from the RS Means Building Construction Costs Data (2012 edition), which is an industry standard compilation of unit costs for various construction activities. The costs in the table below can be used to scope a project, but a project specific cost estimate should be prepared by the design engineer that takes into account the project scale and complexity, material cost trends, and the labor and bidding environment.

Table 14: Underground storage practices unit costs[1],[2],[3],[4]

	Item	Description	Unit Price	Unit
GI Technique	Underground Storage	Design/Engineering	15% of Construction Cost	LS
		Mobilization	$10,000.00	LS
		Excavation & Haul	$45.00	CY
		Chamber System	$7.50	CF
		Geotextile Fabric	$5.00	SY
Custom Options	Underdrain	4" HDPE Perforated underdrain	$20.00	LF
	Surface restoration		$3.00	SF
	Outlet Control/Overflow Structure		$3,500.00	EA
	Storm Sewer	12" HDPE storm sewer	$65.00	LF
	Connecting to existing storm structure		$600.00	EA

1 Installed cost include material and labor based on bid tabs from related projects and RS Means.

2 Unit price based on an 8,500 cubic foot installation beneath a commercial parking area (see GI 11.01). Pricing from various manufacturer's range from $5-7. Unit prices for specific projects will vary based on scale, complexity, labor environment, and material cost trends. A detailed cost estimate should be prepared by the design engineer.

3 The system storage capacity can be increased by enlarging the stone envelope. Stone void space ratio is 40% and the unit weight is 100 lb/cf.

4 Surface treatment costs will vary based on chosen surface application

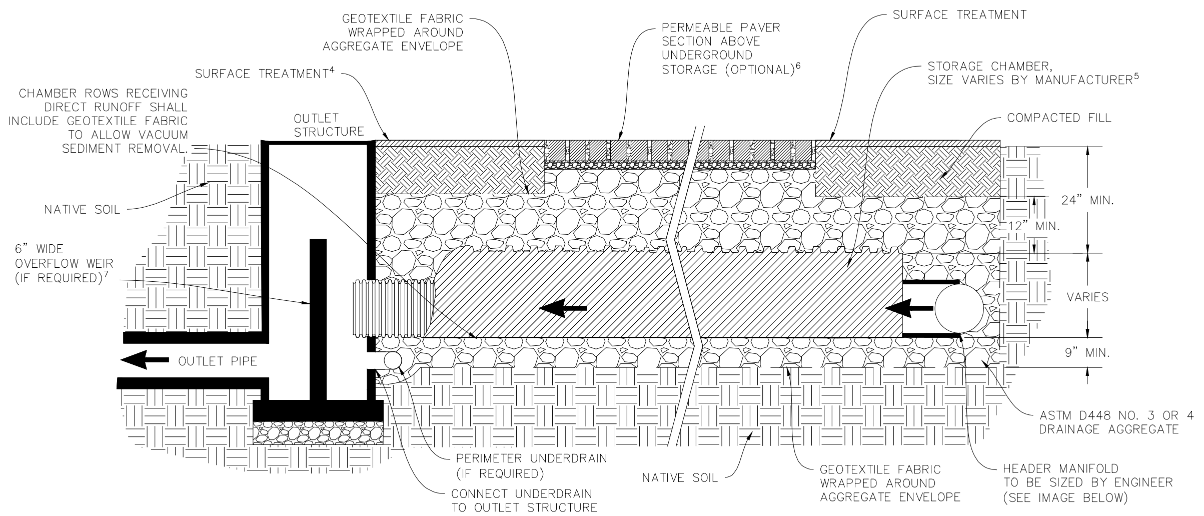
Specifications

The underground storage technique utilizes many of the same construction techniques and materials as the other green infrastructure techniques, but it does not inherently include concrete or plantings. Please note that the underground storage technique can be paired with various surface treatments, including any of the other green infrastructure techniques. The design engineer should customize the specifications included in the construction documents to reflect all the items included in the design. Refer to the instructions on using the Illinois Urban Manual standard specifications included in Appendix B.

Construction Specifications
2 - Clearing and Grubbing
5 - Pollution Control
7 - Construction Surveys
8 - Mobilization and Demobilization
21 - Excavation
23 - Earthfill
24 - Drainfill
25 - Rockfill
44 - Corrugated Polyethylene Tubing
46 - Tile Drains
94 - Contractor Quality Control
95 - Geotextile
752 - Stripping, Stockpiling, Site Preparation and Spreading Topsoil

Material Specifications
521 - Aggregates for Drainfill and Filters
536 - Sealing Compound for Joints in Concrete and Concrete Pipe
548 - Corrugated Polyethylene Tubing
592 - Geotextile Underground Storage – Manufacturer specific

Underground Storage



UNDERGROUND STORAGE SECTION

STORMTECH SUBSURFACE CHAMBERS ARE AN EXAMPLE OF UNDERGROUND STORAGE[3]

DESIGN GUIDANCE

TYPICAL LOCATION: VACANT LOTS, DEMOLITION OR REDEVELOPMENT SITES, BENEATH OR ADJACENT TO OTHER GI TECHNIQUES

LENGTH AND WIDTH: SCALABLE

CONTRIBUTING DRAINAGE AREA: VARIABLE

AVAILABLE OPTIONS: OVERFLOW STRUCTURE
UNDERDRAIN
UNDERDRAIN WITH WEIR

SURFACE TREATMENT: PERMEABLE PAVEMENT
BIORETENTION
NATIVE PLANTINGS
TURF
PAVEMENT

DETAILED DESIGN PRELIMINARY WORKSHEET

- ☐ NATIVE SOIL INFILTRATION[1]:__________ IN/HR
- ☐ REQUIRED STORAGE CAPACITY__________ CUBIC FT
- ☐ CONNECT TO EXISTING STORM NETWORK[2]: YES/NO
- ☐ DEPTH TO GROUNDWATER TABLE > 2 FT[4]: YES/NO

1. NATIVE SOIL INFILTRATION NEEDS TO BE GREATER THAN 0.5 INCHES/HOUR. IF IT IS NOT AN UNDERDRAIN MUST BE INCLUDED.
2. CAPACITY OF DOWNSTREAM SYSTEM TO BE ANALYZED BY DESIGNER.
3. HTTP://WWW.STORMTECH.COM/
4. IF NO, TECHNIQUE IS NOT SUITABLE.
5. SIZE OF CHAMBER VARIES BY MANUFACTURER AND STORAGE VOLUME DESIRED. DESIGN ENGINEER MUST ACCOUNT FOR MANUFACTURER'S REQUIREMENTS AND TOLERANCE.
6. UNDERGROUND STORAGE CAN BE PAIRED WITH PERMEABLE PAVEMENT AND BIORETENTION SYSTEMS. DIRECT STORM SEWER DISCHARGE TO UNDERGROUND STORAGE IS DISCOURAGED WITHOUT MAINTENANCE ACCESS TO REMOVE ACCUMULATED SEDIMENT AND DEBRIS. INSPECTION PORTS MUST BE PROVIDED TO MONITOR SEDIMENT ACCUMULATION AND DRAINAGE RATE.
7. OUTLET CONTROLS CAN BE INCLUDED TO PROVIDE BOTH RETENTION AND DETENTION STORAGE AND MEET PROJECT GOALS AND/OR REGULATORY REQUIREMENTS.

GI 11.01
1 OF 2
SCALE: NTS

UNDERGROUND STORAGE

A COLLABORATION OF:

Underground Storage Notes

NOTES

1. SURFACE TREATMENT IS FLEXIBLE AND DEPENDENT ON THE SITE AND USE. OPTIONS INCLUDE TURF, NATIVE PLANTINGS, PAVEMENT, PERMEABLE PAVEMENT AND BIORETENTION.
2. HEADER MANIFOLD DISTRIBUTES RUNOFF TO THE CHAMBERS. RUNOFF CAN FLOW FROM INLETS OR THE OVERFLOW STRUCTURE OF OTHER GI TECHNIQUES(RAIN GARDEN, STORMWATER PLANTER, HYBRID DITCH, AND PERMEABLE PAVERS). MANIFOLD MUST BE SIZED BY DESIGN ENGINEER
3. IF NATIVE SOILS HAVE POOR INFILTRATION (<0.5 IN/HR), AN OUTLET FROM THE SYSTEM SHALL BE PROVIDED.
4. INSPECTION PORTS SHALL BE PROVIDED TO MONITOR SEDIMENT ACCUMULATION AND DRAINAGE RATE.
5. MAINTENANCE ACCESS SHALL BE PROVIDED TO ALLOW REMOVAL OF ACCUMULATED SEDIMENT.
6. CHAMBER ROWS RECEIVING DIRECT RUNOFF SHALL INCLUDE A WOVEN FABRIC LAYER AT THE BASE OF THE CHAMBER TO FACILITATE VACUUM REMOVAL OF ACCUMULATED SEDIMENT.
7. MATERIAL MUST BE APPROVED BY SITE ENGINEER PRIOR TO INSTALLATION. MANUFACTURER SHOULD SUBMIT INFORMATION REGARDING THE STRUCTURAL INTEGRITY, SAFETY FACTOR FOR DEAD AND LIVE LOADS, AND THE 50 YEAR CREEP MODULUS DATA.
8. A CROSS SECTION SHOULD BE PROVIDED THAT THE STRUCTURAL EVALUATION IS BASED ON.
9. MATERIAL AND END CAPS ARE TO BE PRODUCED IN AN ISO 9001 CERTIFIED MANUFACTURING FACILITY.
10. MATERIAL SHOULD NOT BE INSTALLED UNTIL A REPRESENTATIVE FROM THE MANUFACTURER HAS A PRE-CONSTRUCTION MEETING WITH INSTALLER.
11. MATERIAL TO BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S GUIDANCE.
12. MATERIAL SHOULD BACKFILLED OVER THE CHAMBERS ACCORDING TO MANUFACTURER'S WRITTEN INSTRUCTIONS.
13. JOINTS BETWEEN CHAMBERS SHOULD BE PROPERLY SEALED TO PREVENT INTRUSION OF BACKFILL MATERIAL.
14. MAINTAIN MINIMUM SPACING BETWEEN MATERIAL PER MANUFACTURER'S RECOMMENDATIONS.
15. STONE SURROUNDING MATERIAL MUST BE CLEAN, CRUSHED, ANGULAR OPEN GRADED STONE MEETING THE MEETING THE MANUFACTURERS REQUIREMENTS
16. TAKE PROACTIVE STEPS TO PROTECT THE SUBSURFACE STORMWATER MANAGEMENT SYSTEM FROM CONSTRUCTION SITE RUNOFF.
17. CARE MUST BE TAKEN WITH THE TYPE AND PLACEMENT OF CONSTRUCTION EQUIPMENT. REFER TO MANUFACTURER'S RECOMMENDATION.
18. SITE ENGINEER IS RESPONSIBLE FOR DETERMINING BEARING RESISTANCE OF SUBGRADE SOILS AND THE DEPTH OF FOUNDATION STONE.
19. PERIMETER STONE MUST EXTEND HORIZONTALLY TO EXCAVATION WALL IN ALL SITUATIONS.
20. GEOTEXTILE FABRIC SHALL BE WOVEN, MONOFILAMENT GEOTEXTILE CONFORMING TO THE FOLLOWING:
    a. MINIMUM FLOW RATE OF 145 GAL/MIN/FT2 ASTM D-4491
    b. GRAB TENSILE STRENGTH MIN 365X200 LB ASTM D-4632
    c. GRAB ELONGATION MAX 24X10% ASTM D-4632
    d. TRAPIZOID TEAR MIN 115X75 LBS ASTM D-4533
    e. CBR PUNCTURE RESISTANCE MIN 675 LB ASTM D-6241
    f. APPARENT OPENING SIZE 4060-90 U.S. STANDARD SIEVE

MAINTENANCE GUIDELINES		
TASK	FREQUENCY	TIMEFRAME
INSPECT UNDERGROUND STORAGE	SEMI-ANNUALLY/ AS NEEDED	FIRST YEAR/ ONGOING
JETTING AND VACTORING	ANNUALLY/ AS NEEDED	FIRST YEAR/ ONGOING

GI 11.02
2 OF 2
SCALE: NTS

UNDERGROUND STORAGE NOTES

A COLLABORATION OF: