Water Management Strategies:

A case study based exploration of local projects

Summer Internship 2007

Matt Martenson, Intern

in collaboration with

Jonathan Morley & Rachael Meyer

The Berger Partnership PS

Landscape Architecture

1721 8th Avenue N
Seattle, WA 98109
v 206.325.6877
f 206.323.6867

bergerpartnership.com

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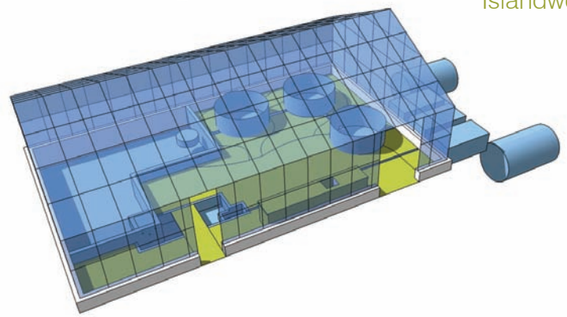


Contents

Summer Internship 2007

SYSTEM COMPARISON: Green Roofs

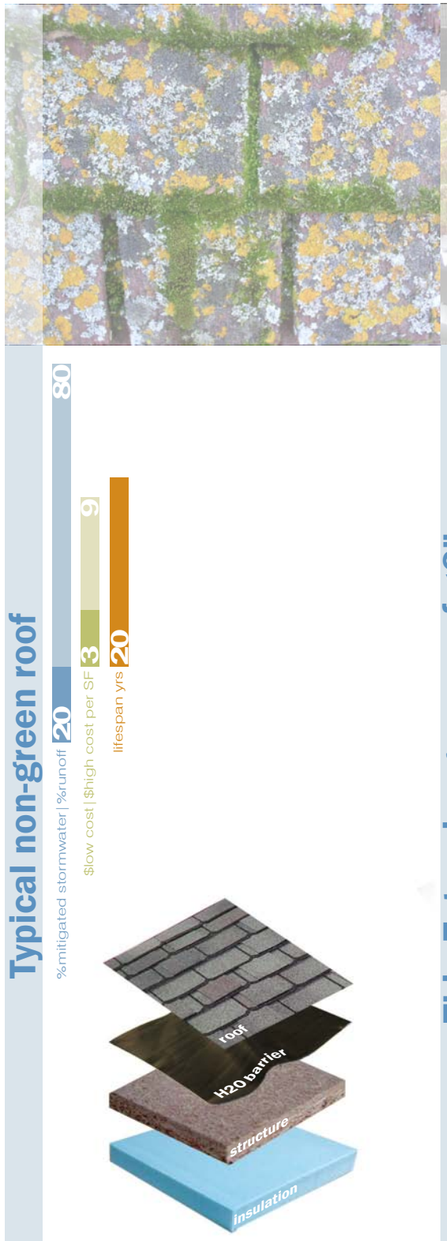
typical non-green roof . thin-extensive green roof . extensive green roof . semi-intensive green roof . extensive green roof

Typical non-green roof

%mitigated stormwater | %runoff 20 | 80

$low cost | $high cost per SF 3 | 9

lifespan yrs 20



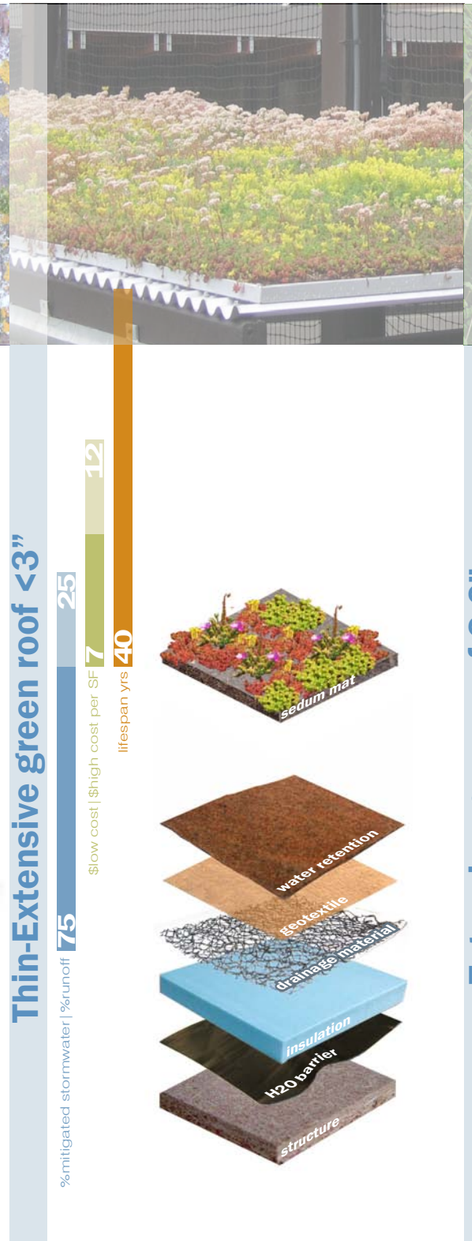
benefits: inexpensive

Thin-Extensive green roof <3”

%mitigated stormwater | %runoff 75 | 25

$low cost | $high cost per SF 7 | 12

lifespan yrs 40



benefits: increased: biodiversity options, stormwater management capacity reduced: heating and cooling costs, heat island effect, no irrigation required

design considerations: structural loading, exposure

Extensive green roof 3-6”

%mitigated stormwater | %runoff 95 | 5

$low cost | $high cost per SF 10 | 20

lifespan yrs 40

benefits: increased: biodiversity options, stormwater management capacity reduced: heating and cooling costs, heat island effect

design considerations: structural loading, high impact from predatory birds, exposure, structural loading, irrigation may be necessary

Semi-Intensive green roof 6-10”

%mitigated stormwater | %runoff 70 | 30

$low cost | $high cost per SF 10 | 22

lifespan yrs 40

benefits: increased: biodiversity options, stormwater management capacity reduced: heating and cooling costs, heat island effect

design considerations: structural loading, reduced impact from predatory birds, exposure, structural loading, irrigation may be necessary

Intensive green roof >10”

%mitigated stormwater 100

$low cost | $high cost per SF 12

lifespan yrs 40

benefits: increased: pedestrian access, biodiversity options, stormwater management capacity reduced: heating and cooling costs, heat island effect

design considerations: pedestrian safety, structural loading, plant maintenance, shading from plants, comparatively high irrigation demand

graphics by The Berger Partnership

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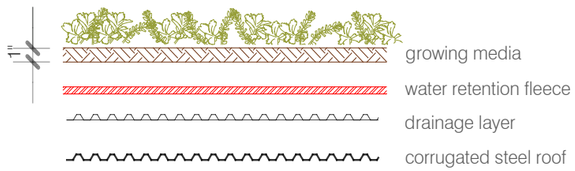
green roof | cistern

CASE STUDY: Bertschi School

2227 10th Avenue East . Seattle, WA 98102

Attributes:

designer(s)/builder(s): Miller Hull Partnership (Arch.), Weisman Design Group (L.Arch.)
completed: 2007
size: 480 sq/ft
cost: $8.00 sq/ft for materials, $2.00 sq/ft installation cost and shipping cost were waived
type: extensive green roof
exposure/slope/aspect: partially shaded, nearly flat
plants: sedum mix
irrigation: temporary soaker hose has been used occasionally
growing media: Xero Flor sedum mat
products/layers: Xero Flor 301 System
maintenance: none (to date, 8/20/07)
features: the green roof runoff is directed to a cistern system, this Xero Flor system is laid directly onto the corrugated metal roof, with no root protection layer or waterproof membrane



drainage issue diagram

Xero flor sedum mat teaching tool

roof profile and drain

mechanical filter and cistern

solar panels, green roof, walkway

Lessons Learned:

(1) The gutter for the green roof is set away from the green roof. This results in at least 50% of the water being lost as indicated in the **drainage issue diagram** above. Extra care should be taken to ensure that green roof / cistern drainage systems are adequately connected. (2) This green roof is in a highly visible location at a school which has a stated commitment to sustainable practices, yet it is not accessible. Bertschi school has provided an accessible sample Xero Flor system located at ground level where it can be used as a tool to teach students about green roofs. (3) This green roof covers an otherwise uninsulated walkway. Choosing to place a green roof in an uninsulated environment negates the insulation benefits that green roofs can provide. (4) Using waterproof/resistant materials such as corrugated metal can eliminate the need to have waterproof membranes and root barriers. This results in a simplified green roof.

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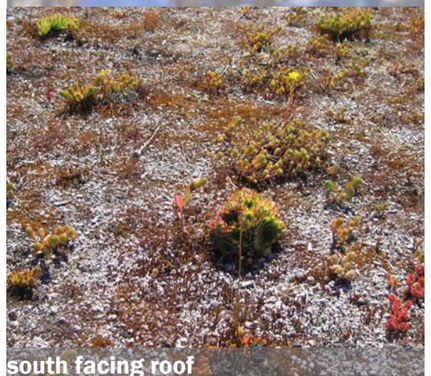
Attributes:

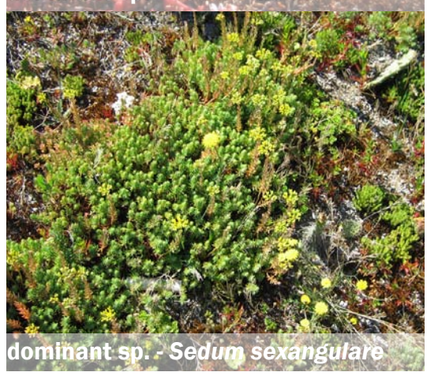
designer(s)/builder(s): Boxwood Architects, Teufel Nursery, Sika Sarnafil (green roof company)
completed: 2002
size: 3,500 sq/ft
cost: $10 sq/ft
type: extensive green roof
exposure/slope/aspect: full sun, 10°-15° slopes, north facing, south facing, and west facing (3 roofs).
plants: approximately 6 of the following species: *Allium schoenprasm, Delopserma nubigeum, D. cooperii, Echeveria sp., Petrohagia saxifrage, Sedum floriferum, S. album, S. sexangulare, S. spurium 'Roseum', S. pinofolium, S. reflexum, S. sarmentosum, S. boehmii, Sempervivum sp.,*
irrigation: hand watering
growing media: 2.5-3"
products/layers: Sarnafil: System 1000
maintenance: no weeding, seasonal handwatering, sedum have been cut and spread
features: a sensor system installed beneath the waterproof membrane can detect leaks, 1000 gal. cistern
notes: cacti were planted over 1 yr. ago, this green roof required no additional structural work on the building
observations: Sedum sp. are the most successful. Cacti are doing well.

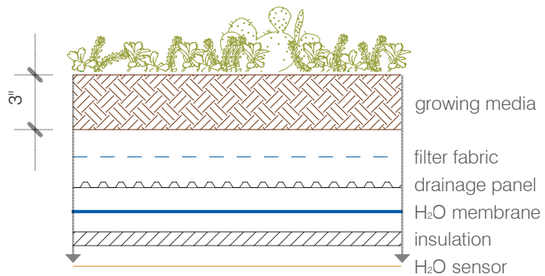

west facing roof


roof surface view


south facing roof


dominant sp. - *Sedum album*


dominant sp. - *Sedum sexangulare*




profile

Lessons Learned:

(1) This green roof has attracted much interest. There is no permanent access to the roof. Access to green roofs for educational purposes should be considered. (2) *Sedum album* and *Sedum sexangulare* have performed best. Roof aspect seems to have an effect upon plant performance. The roof that is facing west has shown the best plant performance. (3) The facilities manager, Stan, felt that a more permanent irrigation system would have been useful. (4) A 1000 gal. cistern holds runoff from the roof, but this cistern is not connected to any system for use. The water from the cistern could be used to irrigate the green roofs. (5) The soils have shown some subsidence or loss to erosion. This should be expected in green roof systems. (6) These roofs have relatively few weeds, which may be a result of the thin, dry growing media.

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green roof

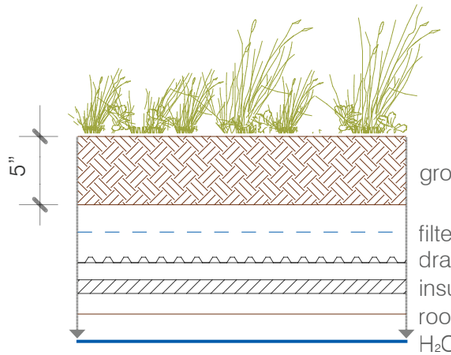
CASE STUDY: Animal Healthcare Facility

Point Defiance Zoo . 5400 N. Pearl Street . Tacoma, WA 98407

Attributes:

designer(s)/builder(s): Bohlin Cywinski Jackson (Arch.), Swift & Co. (L.Arch.), Rana Habitat & Restoration (Green Roof Consultant)
completed: 2005
size: 20,500 sq/ft
cost: $20 sq/ft
type: extensive green roof
exposure/slope/aspect: full sun, concave parabolic, south to north
plants: *Achillea tomentosa, Armeria maritime, Carex inops, Eriphyllum lanatum, Festuca rubra, Festuca idahoensis, Phlox subulata, Saxifrage cepitosa, Sedum oreganum, Sedum album, Sedum spurium, Sisyrinchium, Thymus serphyllum, Triteleia hyacintha.* 5,400 plants out of 18,450 were *Festuca idahoensis*, these plants have deep fine root systems.
irrigation: drip/pop-up irrigation at north (south facing) end only, supplemented with hand watering, in summer 2007 irrigation was added to the south portion of the roof
growing media: 4", 45% mineral component, 15% sand, 40% organics
products/layers: American Hydrotech: Monolithic Membrane 6125®-EV, Hydroflex® RB, Styrofoam® Insulation, LiteTop® Engineered Soil, coconut fiber mat to prevent erosion
maintenance: average of 5 hours per week as of 2007
features: periscope that can be used to view the roof, viewing room(not public), solar panels, skylights

main entrance




plants - 2005 plants - 2007


viewing room and roof access


roof profile


skylight and monitoring equipment


skylights and monitoring equipment

Lessons Learned:

(1) It was believed that irrigating only the the north (south facing) portion of the roof would be sufficient and that water would move through the roof by capillary action and gravity. The roof requires hand watering in addition to this system. (2) Upon completion, the roof featured 13 species. Of the original 13, the remaining visible species composition is mainly clumping grasses. Relying upon minimal irrigation and clumping grasses to provide the recommended 100% vegetal cover may not be sufficient. (3) 1/3 of the plants on the roof are *Festuca idahoensis* which has a deep fine root system and has not performed well in the 5" soil profile. Plants should be chosen to match the soil profile and climatic conditions of the roof. (4) The biodegradable coconut fiber, which was installed to prevent erosion, has presented a persistent obstacle to weeding and replanting.

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green roof

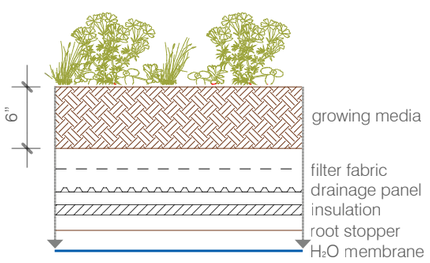
CASE STUDY: Ballard Public Libary

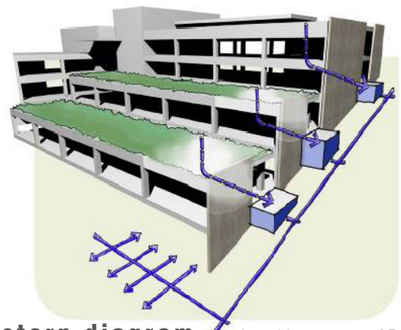
5614 22nd Ave NW . Seattle, WA 98107

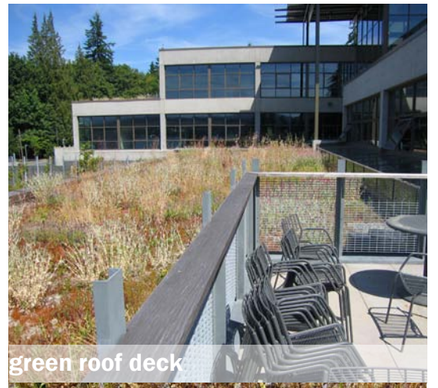
Attributes:

designer(s)/builder(s): SvR Design Company (Civil Eng.), Site Workshop (L.Arch.), Miller Hull Partnership (Arch.)
completed: 2005
size: 11,500 sq/ft green roof, 225,000 gal. cistern capacity
cost: The cisterns & green roofs added 10-15% to the cost of the project. The added cost is offset by money saved on irrigation
type: extensive green roof
exposure/slope/aspect: partial sun/shade, nearly flat, north
plants: *Fragaria chiloensis, Arctostaphylos uva-ursi, Lavandula angustifolia, Lychnis coronaria, Malva sylvestris, Euphorbia sp., Sedum spathufolium, Clarkia sp., Sisyrichum sp., Sidalcea, Gilia sp., Penstemon Sp., Lasthenia sp. Festuca ovina, Carex sp.*
irrigation: drip irrigation for 2-3 yr. establishment period
growing media: 6" proprietary soil mix
products/layers: American Hydrotech
maintenance: unknown
features: Conventional and green roof runoff is captured in cisterns and used for irrigation. Overflow from the cisterns is directed through the landscape to a rain garden (refer to **cistern diagram**). The water captured in the cisterns will lower demand on municipal supplies by 270,000 gallons or about 50% of the irrigation need. After the landscape is established, the cisterns will satisy 100% of the irrigation need. The cisterns function as part of the foundation of the building which helped to integrating costs and reduce the budget. Each of the 4 green roofs feature an accessible deck.


view from green roof deck facing northwest

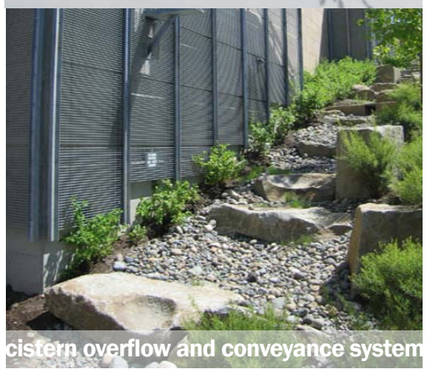



cistern diagram (graphic courtesy of SvR Design Company)


green roof deck


green roof weeds

green roof edge condition


cistern overflow and conveyance system

Lessons Learned:

(1) The cisterns were sized to the amount of water the landscape would need once established. Sizing cisterns based upon future water needs means that the cisterns will not be too large or too small. (2) The cisterns were integrated into the building structure. This resulted in lower costs as compared to cisterns which are separate from structures. (3) Coordinating green roofs with small decks results in spacious, open, outdoor space above ground level. Access to the green roof also contributes to educational opportunities. (4) This roof had a significant quantity of weeds, this may be due to the thick growing profile which is capable of supporting greater diversity than a thin roof.

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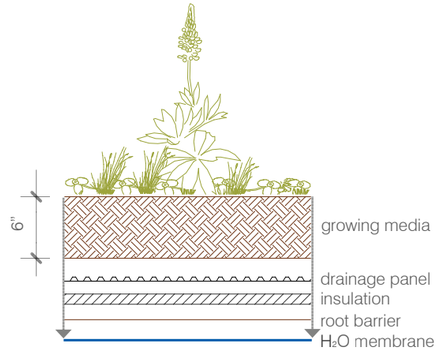
green roof | cistern

CASE STUDY: Kitsap Co. Admin. Bldg.
619 Division Street . Port Orchard, WA 98366

Attributes:

designer(s)/builder(s): Mithun(Arch.)
completed: 2005
size: 8,000 sq/ft
cost: $30 sq/ft
type: extensive green roof
exposure/slope/aspect: full sun, convex parabolic, south to north
plants: *Gaultheria shallon, Polystichum munitum, Arctostaphylos uva-ursi, Allium cernuum, Sisyrinchium douglasii, Lupinus polyphyllus, Fragaria chiloensis.*
1000 plants were replanted 1.5 years after planting due to failure and bird predation. *Allium cernuum*, *Fragaria chiloensis* and *Arctostaphylos uva-ursi* are performing best, *Lupinus* sp. seeded all over and had varying success
irrigation: hand watering only, 6 impact heads were installed in 2007 to make watering more efficient
media: 6", 65% pumice, 25% yard waste compost, 10% sand
products/layers: Coconut fiber mesh, Tremco/Permaquick- PQ 6100 PERMA-GREEN roofing systems™
maintenance: comparable to a forested area of similar size and makeup on the ground.
features: designed to look like PNW forest floor


roof profile




irrigation system image courtesy of M. Martin


***Lupinus* sp.** image courtesy of M. Martin


***Lupinus* sp.** image courtesy of M. Martin


coconut mesh image courtesy of M. Martin


gap in coconut mesh (filled with green) image courtesy of M. Martin

Lessons Learned:

(1) The roof is planted with PNW natives. These plants perform similarly to native plants, except they go into summer dormancy a couple weeks earlier (D. Selk 2007). (2) The self-seeding *Lupinus* sp. has been successful at colonizing the roof and has not required replanting. Self seeding/replicating species may be well suited to providing 100% vegetal cover. (3) Hand watering has proven to be inefficent, and ineffective in saturating the soil (M. Martin 2007). In the PNW, where we can expect summer drought conditions, irrigation should be included. (4) A coconut fiber mesh was used to prevent wind and water erosion, inhibit weed growth and retain moisture. The coconut fiber mesh was effective at reducing erosion and inhibiting weed growth. However, the mesh may have contributed to summer drought conditions on the roof. Much of the water from the sprinklers was absorbed by the coconut fiber mesh and then evaporated without ever reaching the soil (M. Martin 2007).

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CASE STUDY: Zoomazium
Woodland Park Zoo . 5500 Phinney Ave. North . Seattle, WA. 98103

Extensive Green Roofs:

built:
Merrill Hall
Clinton Beach
Medina Residence

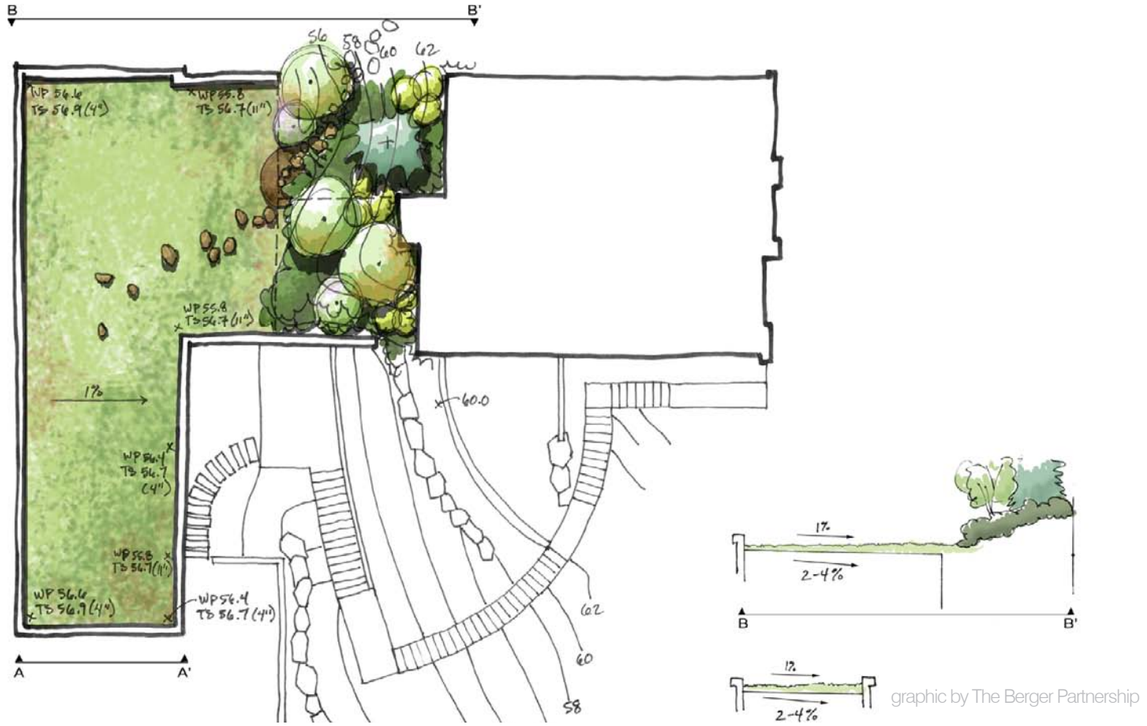
in design/designed:
Colman Center
Stansbury Residence
Smith Residence
SU Lemieux Library
WWU Miller Hall
Whitman Sherwood Center
Lam Residence
Camp Fire Site

designed but not used:
Tacoma Police Station
Magnusson Park Restrooms & Pavilion

Intensive Green Roofs:

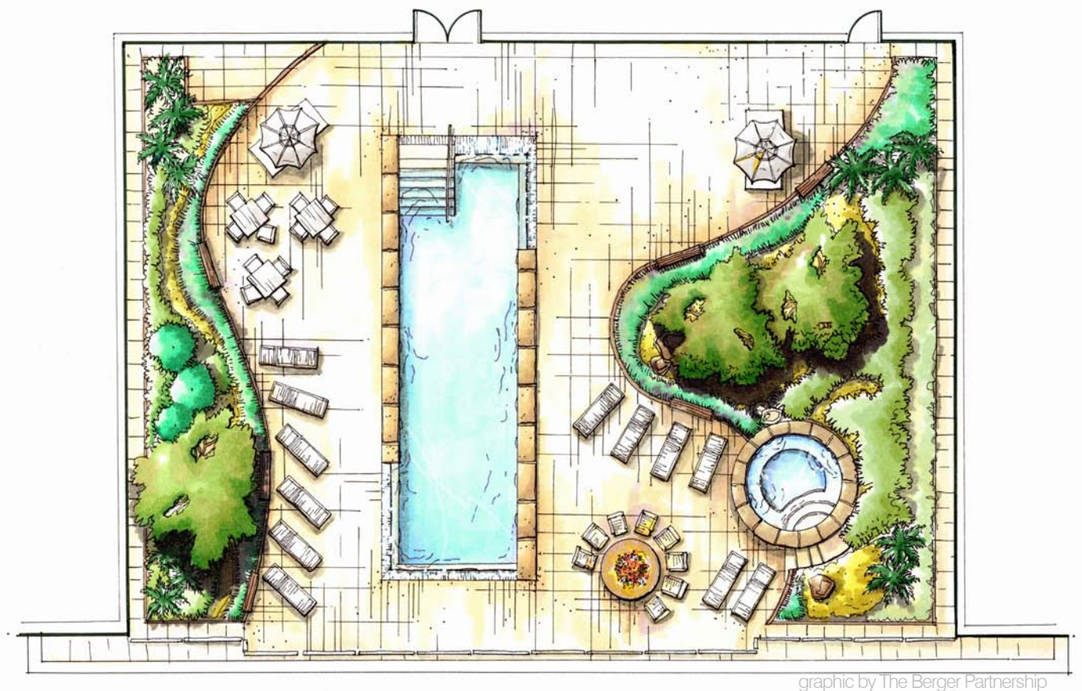
built:
Sunshine Project
Juanita Village
One and Two Union Squares
Cal Anderson Park
1700 7th
The Bristol Apartments
NG Commons
333 Elliot

in design/designed:
Colman Center
Boylston II
40th and Stone Way
Four Seasons Hotel
1 Hotel and Residences
5th and Yesler
635 Elliot
2201 9th Avenue



graphic by The Berger Partnership

Smith Residence



graphic by The Berger Partnership

Four Seasons Hotel

Clinton Beach

Merrill Hall

Sunshine Project

Medina Residence

green roof

The Berger Partnership: Project List

completed projects . designed projects . projects in design . designed but not used

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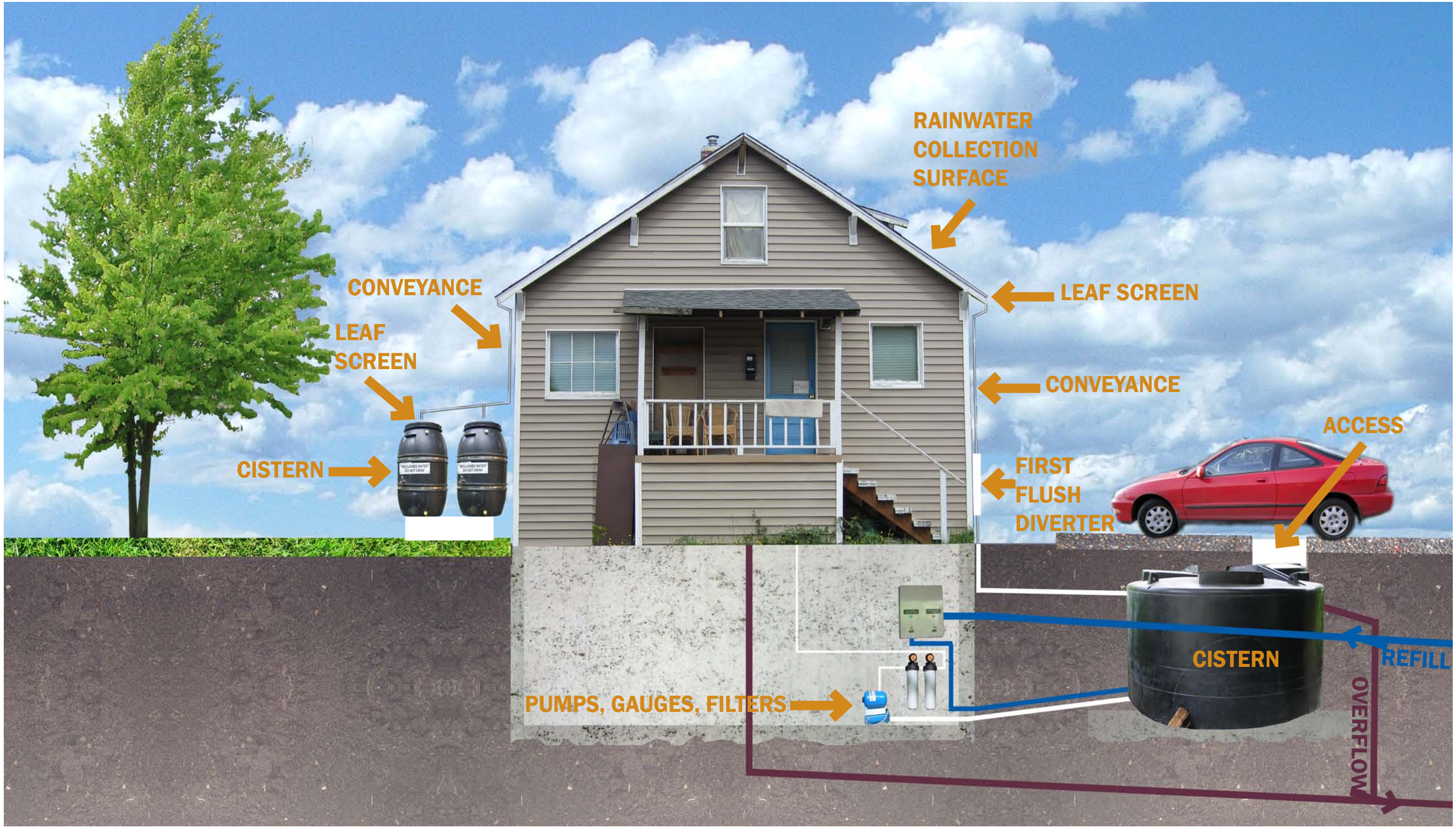

graphic by The Berger Partnership

Rainwater Collection Surface → Leaf Screen → Conveyance → First Flush Diverter → Cistern → Pumps, Gauges, Filters

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Landscape Architecture

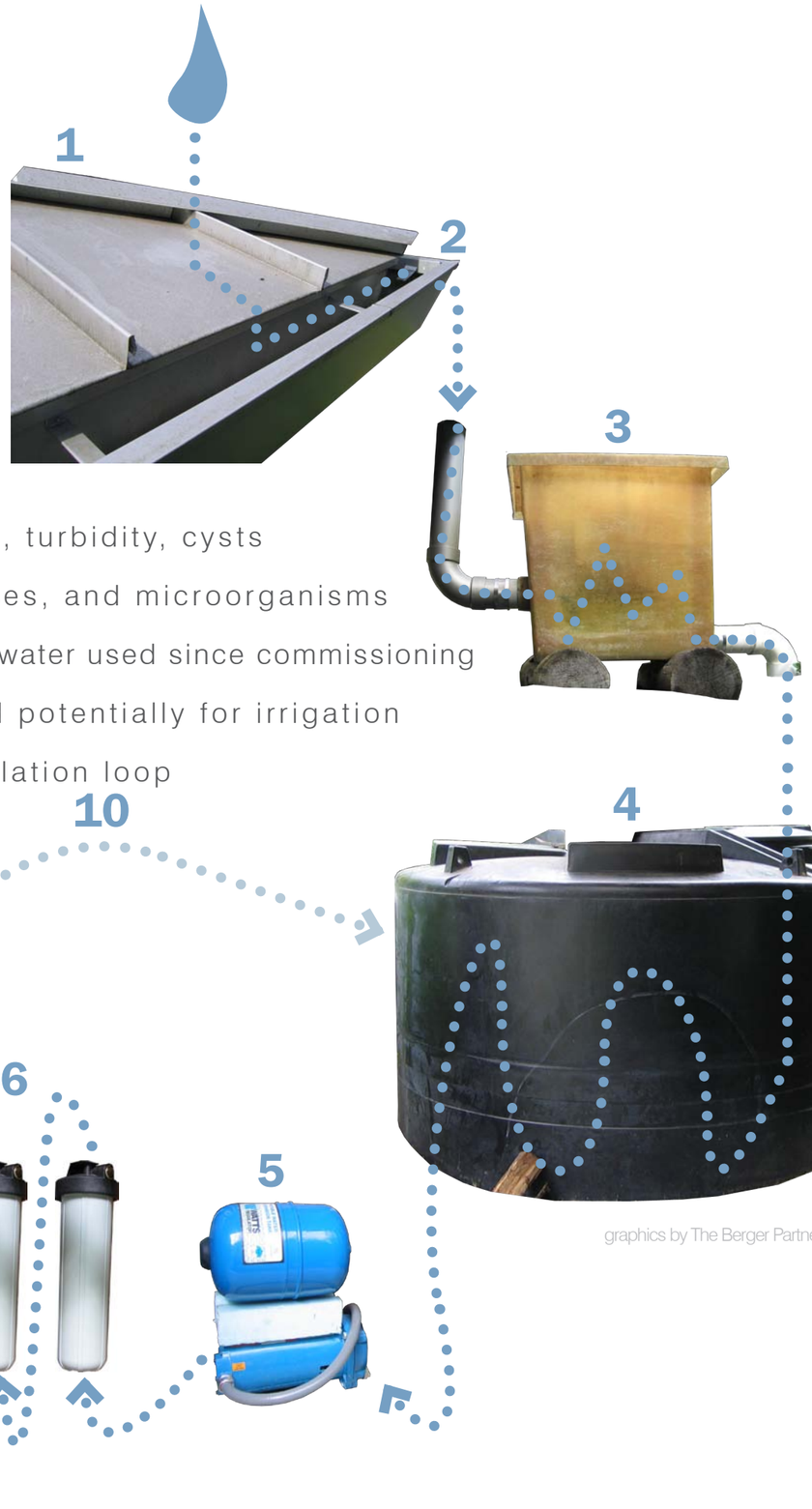
Components: Rainwater Harvesting

rainwater . collection surface . leaf screen . conveyance . first flush diverter . cistern . pumps, gauges, filters . access . overflow . refill

Attributes:

designer(s)/builder(s): Selkirk Miller
Hayashi Architects, Seattle Parks and Recreation,
Herrera Environmental Consultants
completed: 2003
system legend:

1 metal roof
2 gutter/downspout
3 leaf/debris catcher
4 3,500 gal. polyethylene cistern
5 1 horsepower (10 amp.) pump
6 20 and 5 micron filters remove chlorine, turbidity, cysts
7 germicidal UV lamp kills bacteria, viruses, and microorganisms
8 rainwater re-use meter showing gal. of rainwater used since commissioning
9 rainwater is used for toilet flushing and potentially for irrigation
10 rainwater is cycled through this recirculation loop on a daily basis to ensure quality



graphics by The Berger Partnership

Lesson Learned:

Health Department uncertainty regarding water quality resulted in the recirculation loop (10). The recirculation system is now believed to be unnecessary.


cistern


plumbing


inside of leaf/debris catcher


viewing window for rainwater re-use meter

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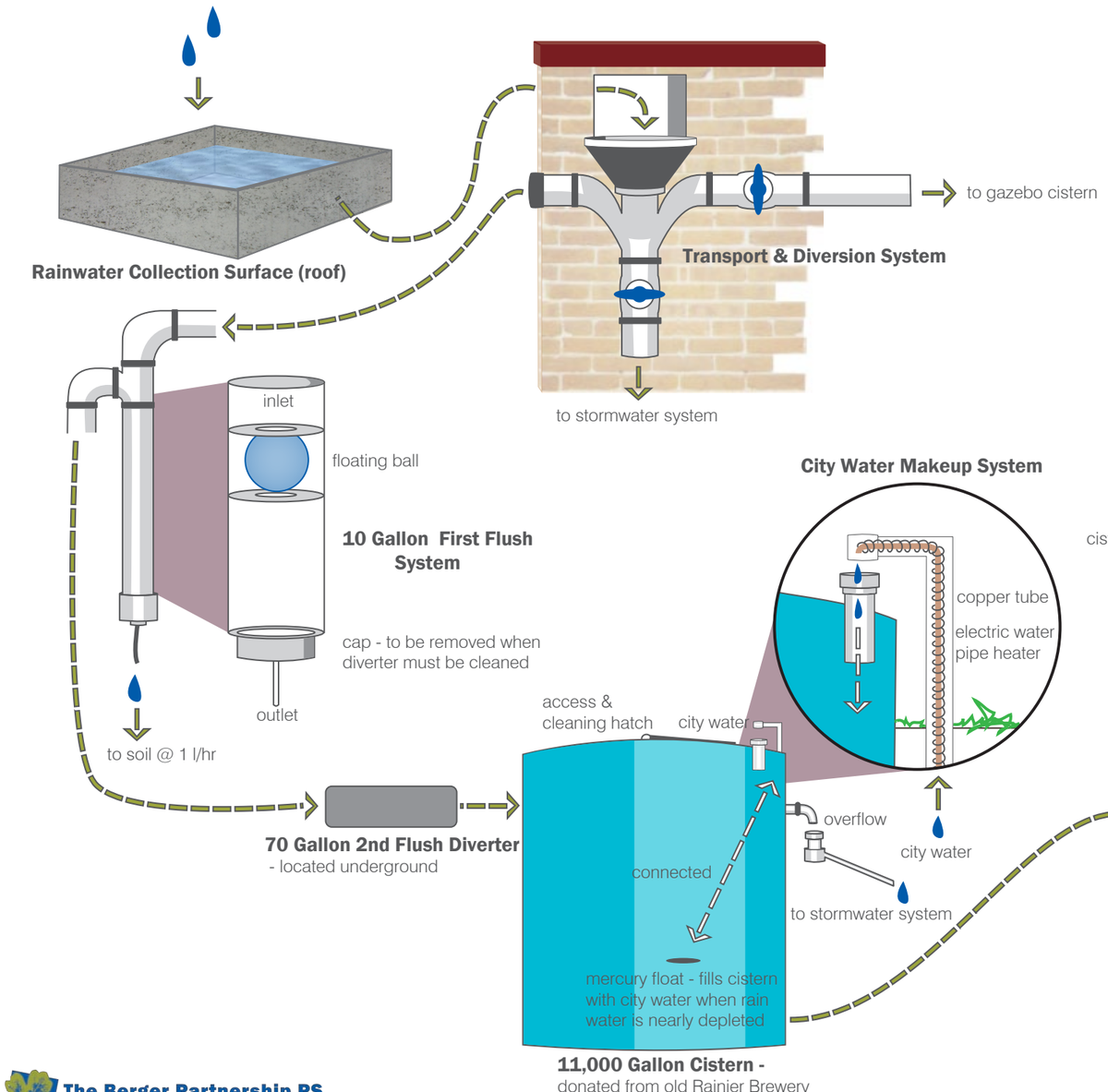
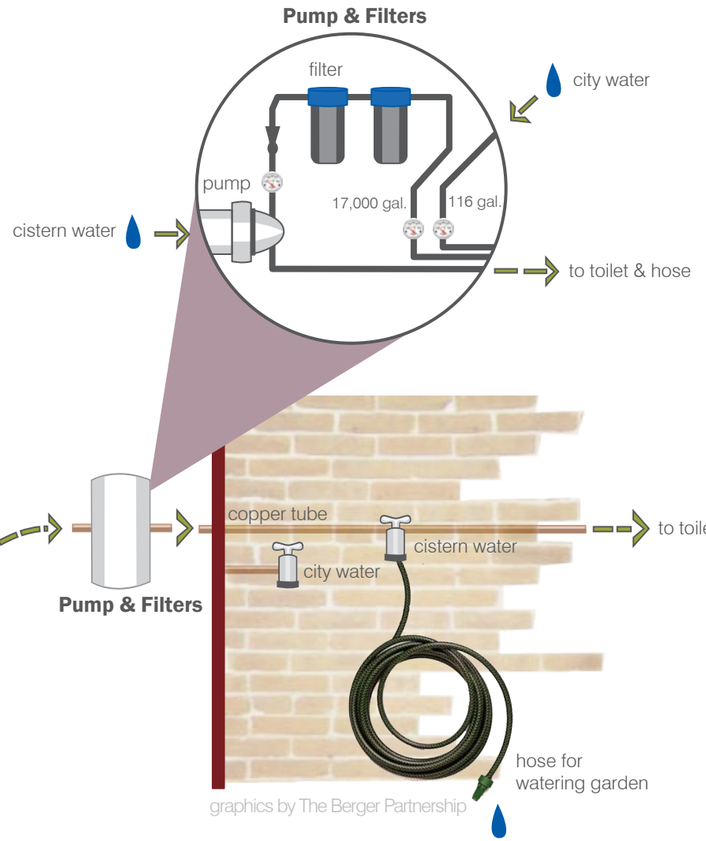
cistern

CASE STUDY: Carkeek Park E.L.C. (environmental learning center)
950 NW Carkeek Park Road . Seattle, WA 98177

Attributes:

designer(s)/builder(s): Cascade People's Center, M. Luksan
completed: 2006
system cost: $25,000. The cistern was donated. Design and construction was performed by volunteers.

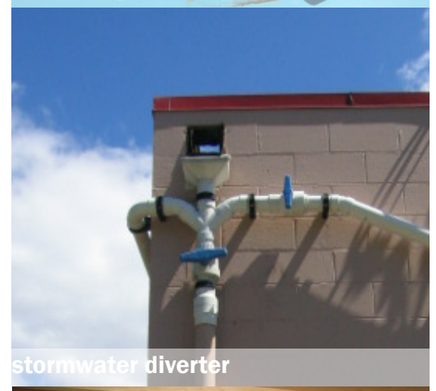




Lessons Learned:

(1) This system has two first flush diverters. First flush diverters may not be necessary in the PNW due to frequent rain events. (2) This system partially refills the cistern with city water when the water level reaches a low point. Partially filling the cistern with city water subtracts from the volume that can be utilized to store rainwater, resulting in inefficiencies.


cistern top and access hatch


stormwater diverter

pump, filters, gauges

cistern water (left) city water (right)

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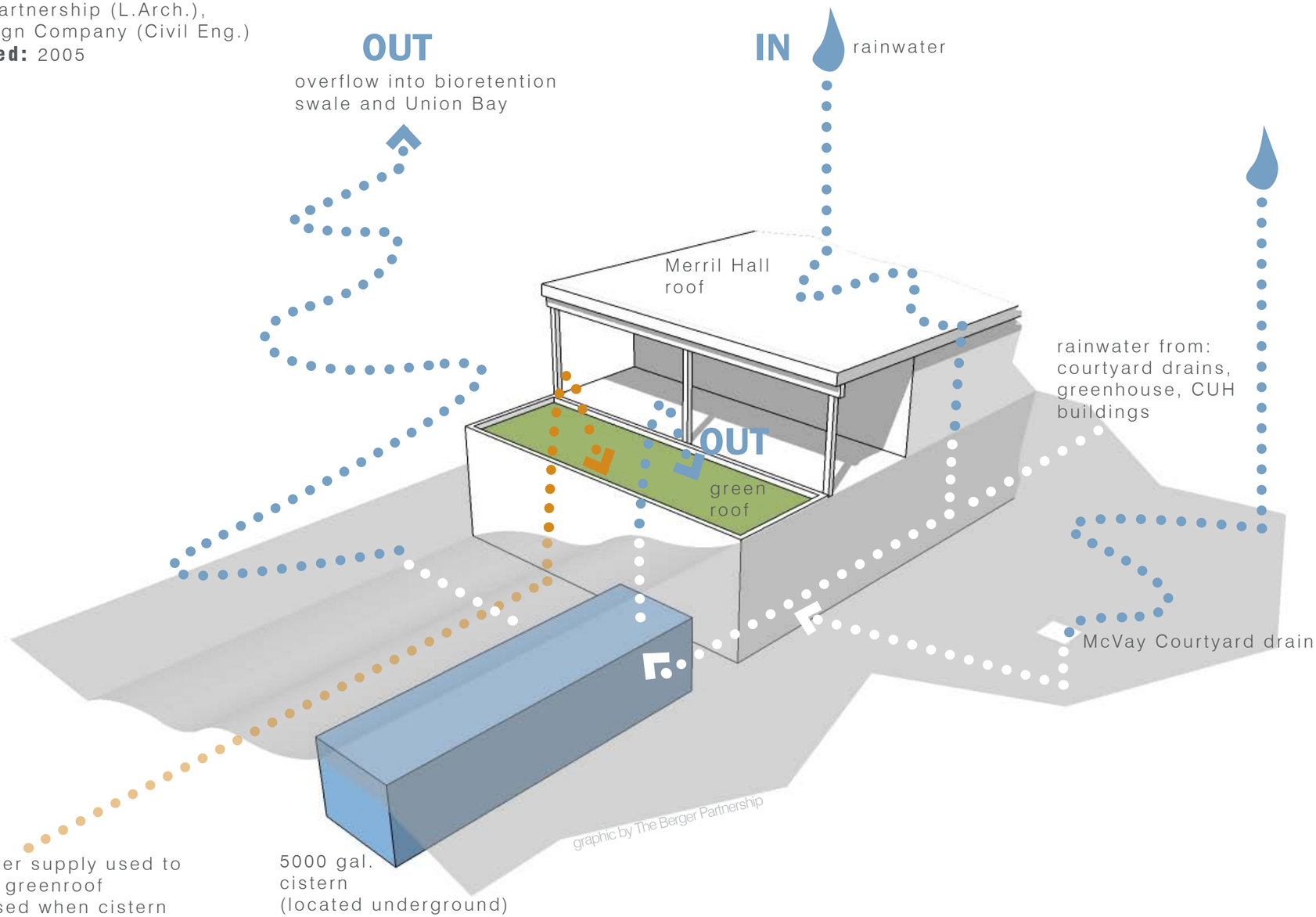
cistern

CASE STUDY: Cascade People's Center

309 Pontius Avenue North . Seattle, WA 98109

Attributes:

designer(s)/builder(s): Miller-Hull Partnership (Arch.), The Berger Partnership (L.Arch.), SvR Design Company (Civil Eng.)
completed: 2005




green roof


Merrill Hall and UBNA


green roof plants


above the cistern

cistern

CASE STUDY: Merrill Hall

3501 NE 41st Street . Seattle, WA 98105

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Rainwater Harvesting:

built:
Merrill Hall
Terrace Park K-8
Islandwood
Bayview Center
Barret Residence
Mullin Residence

in design/designed/designed but not used:
Cedarhurst Elementary
SU Lemieux Library
WWU Miller Hall
Whitman Sherwood Center
Camp Fire Site
Bainbridge Island Residence
Medina Residence
Murray Residence

Cedarhurst Elem. cistern construction

Cistern Concept

Islandwood rainwater conveyance system

Rainwater Harvesting Pond

Islandwood cistern system

The Berger Partnership PS
Landscape Architecture

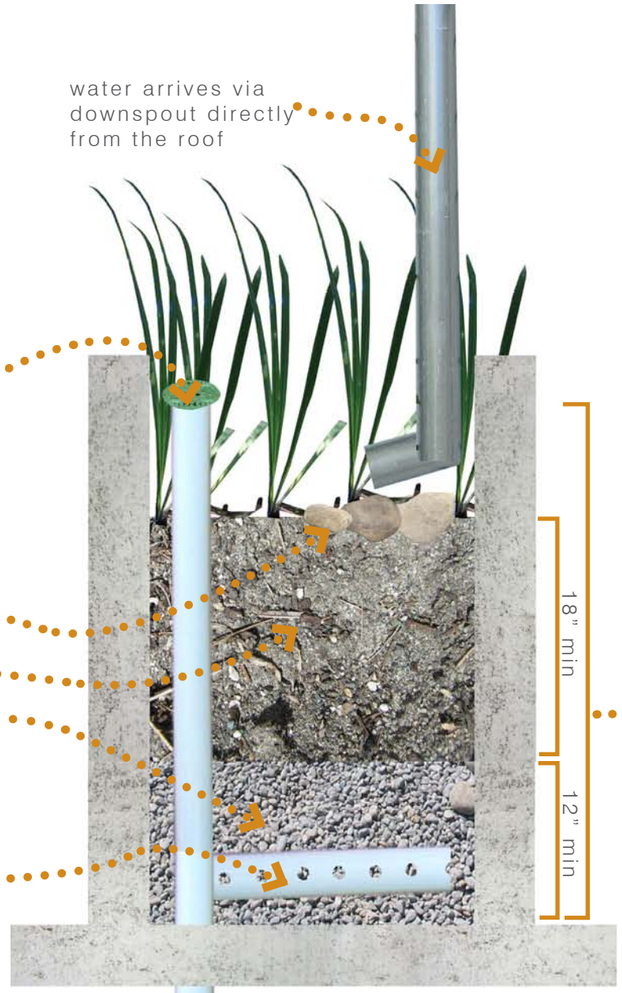
cistern

Project List
completed projects . designed projects . projects in design . designed but not used

The Berger Partnership:

Attributes:

designer(s)/builder(s): Runberg Architecture Group, SvR Design Company (L.Arch. & Civil Eng.)
completed: 2005
plants: grasses, dogwood
irrigation: drip irrigation
media: loamy sand, 3/4" - 1-1/2" pea gravel
maintenance: minimal



graphic by The Berger Partnership


roofline, downspouts


stormwater planter with weeds

stormwater storage area (from top of overflow to bottom of planter)


5 story downspout

stormwater planter

CASE STUDY: Denny Park Apartments

230 8th Ave North . Seattle, WA 98109

Lessons Learned:

(1) This stormwater planter has received little to no maintenance; there are *Acer macrophylum* weed seedlings that are nearly 1 story tall. Stormwater planters will require maintenance similar to landscape plantings. (2) Stormwater planters can be used as stormwater detention facilities. As water filters through the detention system, the additional benefit of pollutant reduction is achieved. (3) Many plants in this stormwater planter are not performing well or have already died. An irrigation system is installed but not used. Stormwater planters may require irrigation during the summer months. (3) The dogwood sp. has performed very well in the absence of irrigation. This plant may be well suited to stormwater planters in Seattle.

The Berger Partnership PS
Landscape Architecture

Attributes:

designer(s)/builder(s): Mithun (Arch.), The Berger Partnership (L.Arch.), 2020 Engineering (System Engineering), RAFN (Contractor)

completed: 2003

size: 1,500 sq/ft

type: Living Machine™ Generation II

living machine plants: hydroponic reactors: *Canna generalis striatus 'Pretoria', Zantedeshia aethiopica, Cyperus gigantus, Hedichium coronarium, Calocasia esculenta, Colocasia esculenta "Euchlora", Alocasia odora, Cyperus papyrus, Scirpus acutus, Salix negra, Salix lucida ssp. Lasiandra, Thalia geniculata* constructed wetland: *Ledum glandulosa, Andromeda polifolia, Bidens cernua, Iris pseudacorus, Equisetum telmateia, Juncus effusus, Glyceria elata*

non-living machine greenhouse plants: *Cornus canadensis, Oxalis oregana, Fragaria sp., Vaccinium sp., Spirea densifolia, Gaultheria shallon, Asarum caudatum, Mahonia nervosa, Polystichum munitum*

animals: snails, fish, frogs, microcrustaceans

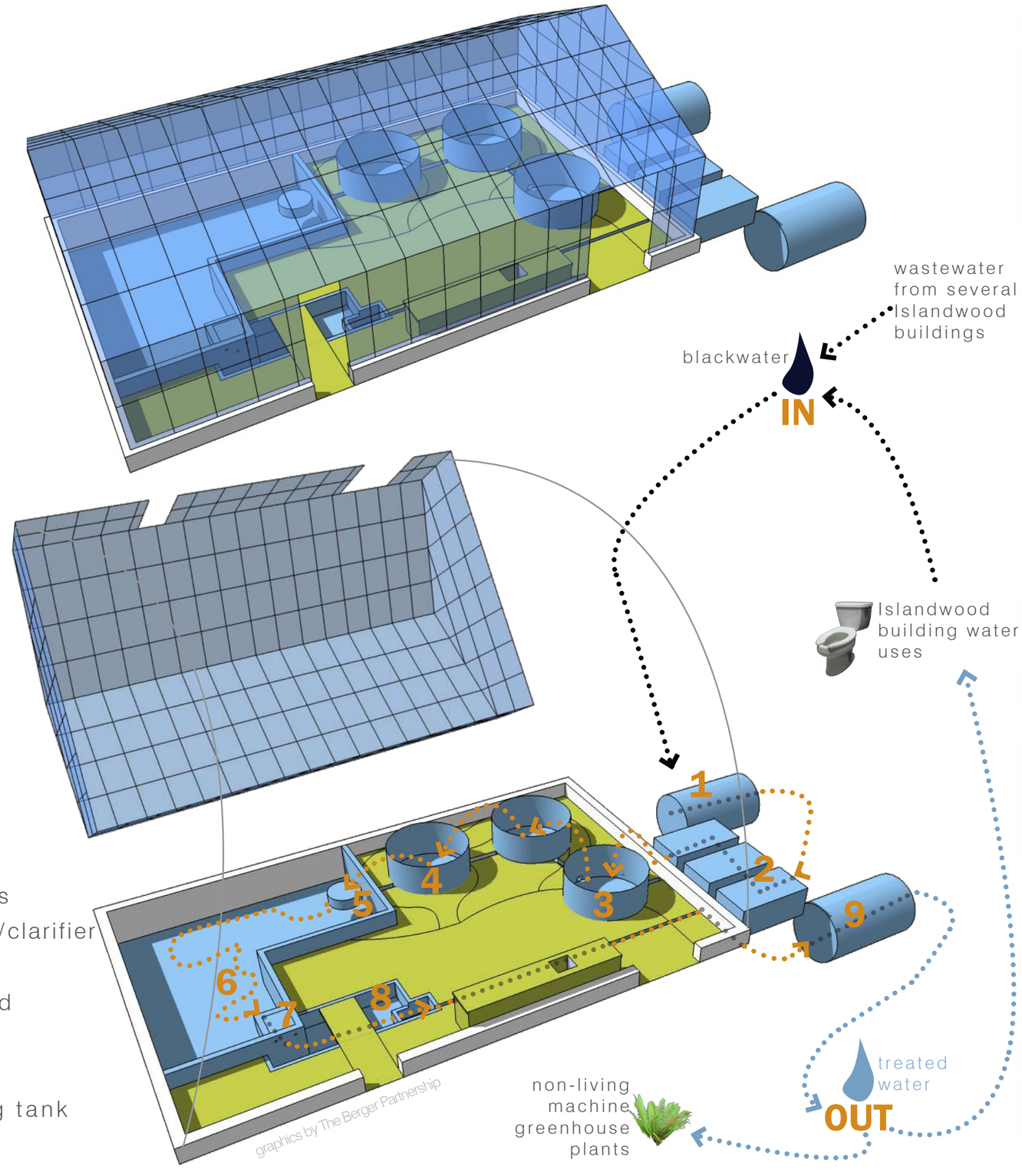
irrigation: living machine plants use black water, non-living machine greenhouse plants are irrigated with a drip system using treated water from the living machine

features: microscope and lab counter, informational signage, treated water can be used to flush toilets that feed back into the system

capacity: can process enough black water to produce 3000 gallons of treated water daily

system key:

1. septic tank
2. filter boxes
3. hydroponic reactors
4. hydroponic reactor/clarifier
5. dosing tank
6. constructed wetland
7. UV treatment
8. pond
9. clean water holding tank



graphics by The Berger Partnership


living machine


clean water spout

water treatment


vegetation

living machine

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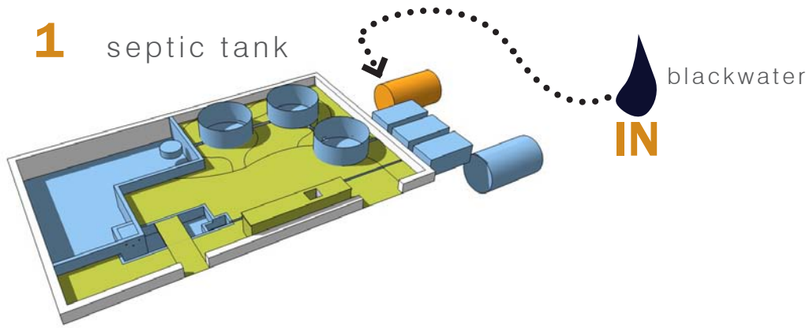
1 septic tank



Attributes:

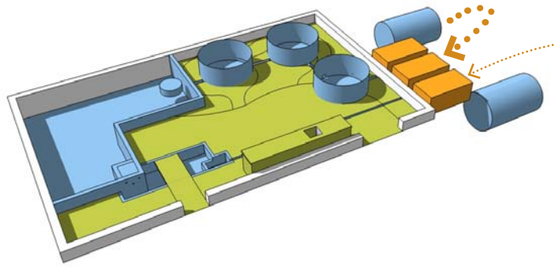
The septic tank is a closed, anaerobic reactor. The tank takes the form of a typical below ground septic tank. Wastewater resides in the tank while anaerobic bacteria break down solids to prepare them for entering the system. Biochemical oxygen demand (BOD) is lowered in the septic tank. BOD is a measure of how much oxygen organisms use in a body of water. The higher the BOD, the more polluted the water. Biosolids will need to be removed from this tank periodically.

Purpose:

Acts as a sedimentation basin to reduce concentrations of BOD and solids.

septic tank lid

2 filter boxes



Attributes:

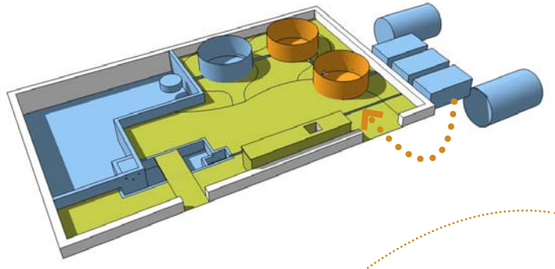
The filter boxes are closed anaerobic reactors. The boxes are located below ground. Bacteria live in the boxes and begin to break down solids in wastewater and reduce BOD. Biosolids will need to be periodically removed.

Purpose:

The filter boxes break down biosolids and reduce wastewater odor before wastewater enters the greenhouse.

filter box lids

3 hydroponic reactors

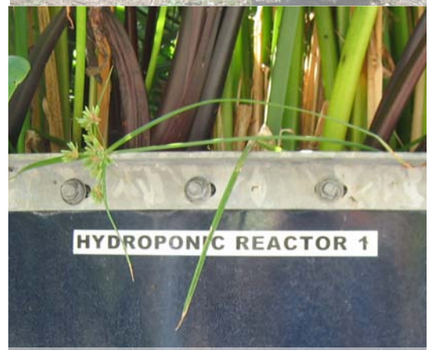


Attributes:

The two hydroponic reactors are large, cylindrical, liquid and biosolid filled containers that are open to the air. The containers have snails, frogs, plants, microcrustaceans and microorganisms such as denitrifying bacteria and floc forming bacteria. Denitrifying bacteria remove nitrogen from the biosolids and floc forming bacteria remove organic materials. These containers are aerated to promote organic growth. The plants perform three functions: (1)provide surface area for microorganisms to colonize and grow (2)perform nutrient uptake (3)provide habitat for organisms to live on.

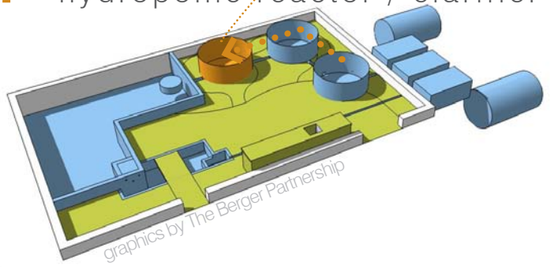
Purpose:

All of the organisms in these reactors live on, and break down organic matter from the wastewater.



hydroponic reactor

4 hydroponic reactor / clarifier



graphics by The Berger Partnership

Attributes:

The hydroponic reactor/clarifier has all of the same attributes as the two hydroponic reactors and has wastewater sorting capabilities. Solids that are not processed enough to enter the constructed wetland are routed back to the filter boxes. Wastewater which has been treated sufficiently to enter the constructed wetland is pumped to the dosing tank.

Purpose:

To ensure that wastewater has been treated adequately prior to entering the constructed wetland.

hydroponic reactor / clarifier

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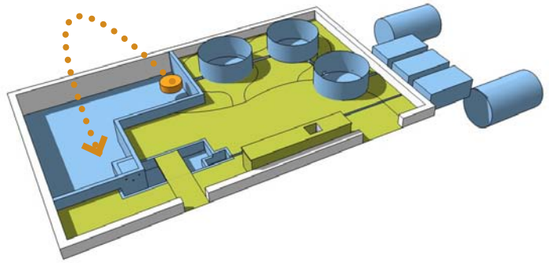
5 dosing tank

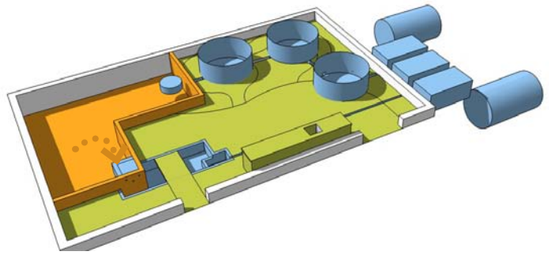


Attributes:
The dosing tank is a small reservoir that periodically flushes measured quantities of wastewater into the wetland.

Purpose:
To regulate the timing and volume of wastewater entering the wetland.

dosing tank

6 constructed wetland

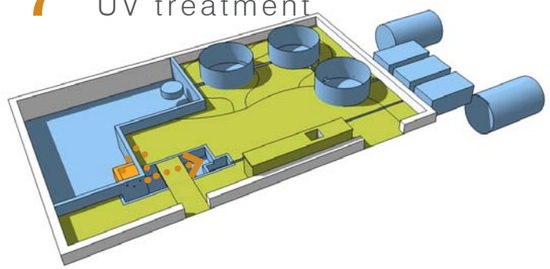


Attributes:
The constructed wetland has a pea gravel media which functions as a filter. Wastewater is circulated through the wetland. The wetland has plants, snails, frogs and microorganisms that break down organic matter. The pea gravel/wastewater wetland is periodically aerated. The aeration is intended to fluidize the biosolids which are trapped at various levels in the media. The biosolids are then removed from the top of the media.

Purpose:
The constructed wetland acts as a coarse downflow filter, trapping waste as gravity pulls wastewater through the media. Water leaving this element is suitable for discharge to surface waters.


constructed wetland

7 UV treatment

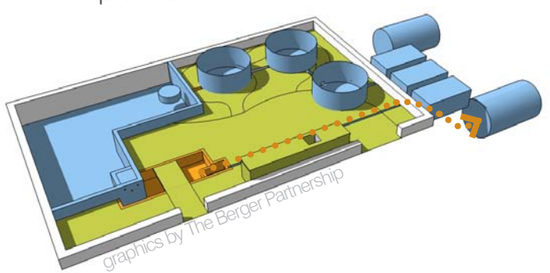


Attributes:
Water from the wetland is subjected to Ultra-violet (UV) treatment for the remaining bacteria in the water.

Purpose:
To ensure water quality.

UV treatment

8 pond



Attributes:
The pond has plants and fish. The water is clear.

Purpose:
To allow visitors and students to interact with the treated water and show the quality of the water that is produced as an end product.


pond

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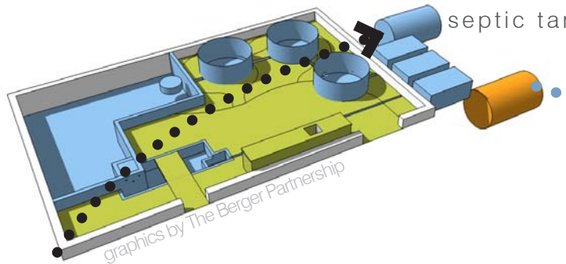
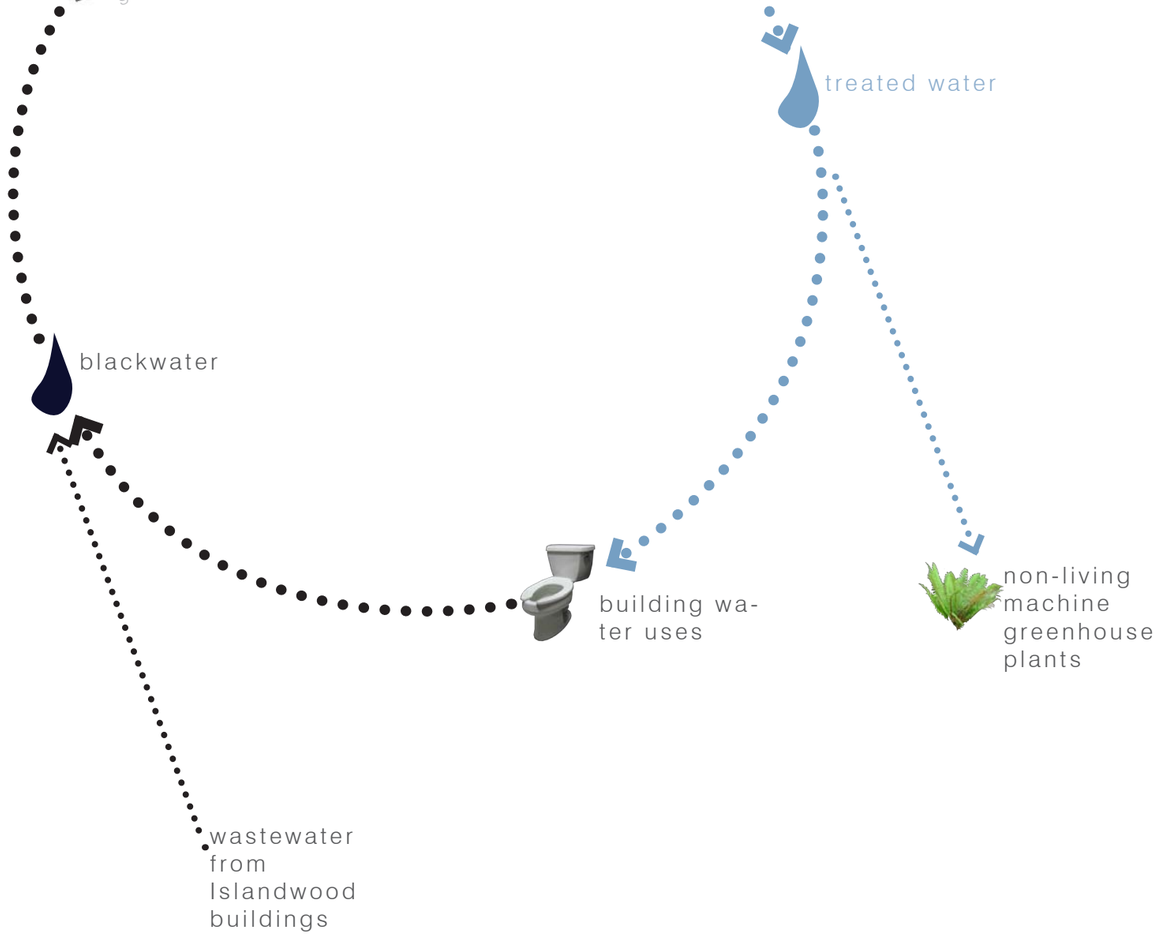
9 clean water holding tank





Attributes:

This tank is located below ground. Water exiting the living machine is stored here. The water can be used to flush toilets and for irrigation of plants in the living machine greenhouse, which are not part of the wastewater treatment process.

Purpose:

To store water to be recycled back into the system.


non-living machine greenhouse plants

living machine

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