

GREEN INFRASTRUCTURE FOR RESILIENT COMMUNITIES

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EPA Region 8 Resources

- ◉ **Climate Adaptation/Sustainable Communities** *Laura Farris*
- ◉ **Disaster Recovery/Resiliency** *Nat Miullo*
- ◉ **Green Infrastructure** *Stacey Eriksen*
- ◉ **WaterSense** *Alysia Tien*
- ◉ **Energy Star** *Alysia Tien*
- ◉ **Green Building/Renewable Energy** *Tim Rehder*

Partnerships

Partnership for Sustainable Communities

<https://www.sustainablecommunities.gov/>

National Drought Resilience Partnership

<http://www.drought.gov/drought/content/ndrp>

EPA/FEMA MOA

http://www.epa.gov/smartgrowth/fema_moa.htm

Urban Waters Federal Partnership

<https://www.epa.gov/urbanwaterspartners>

Green Infrastructure Collaborative

<https://www.epa.gov/green-infrastructure/green-infrastructure-collaborative>

Silver Jackets-USCOE supports state-led teams through Flood Risk Management Program



COMMUNITIES ARE FACING MANY CHALLENGES



Trash and other stormwater pollutants degrade our waters



Excess volume and velocity of stormwater cause flooding & erosion

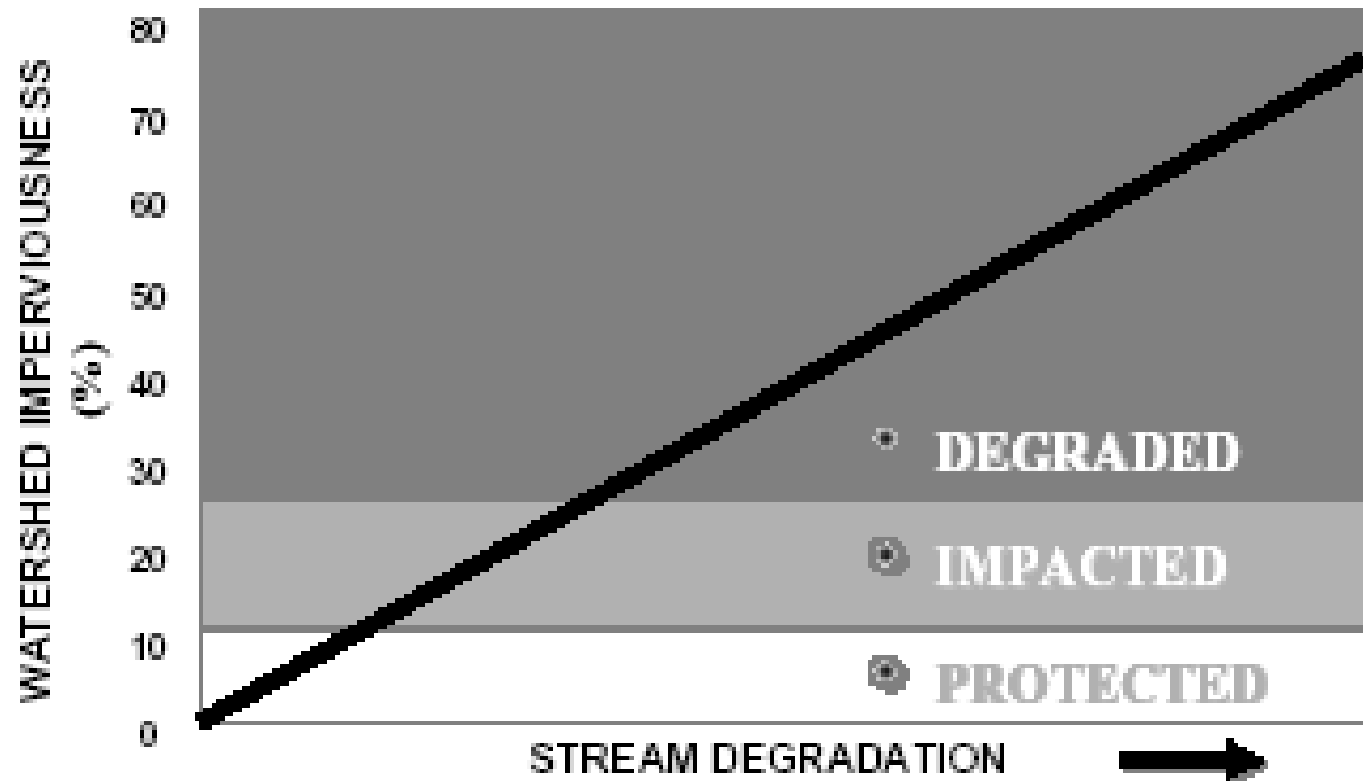


Drought conditions lead to water scarcity and high runoff rates when it eventually does rain



Development often increases impervious cover and stormwater volumes leading to impacts for downstream impacts

Waterway Health and Imperviousness



Enhancing Communities



Climate and Resiliency Tools

- ◉ <https://www.epa.gov/green-infrastructure/building-climate-resiliency-green-infrastructure>
- ◉ https://www.epa.gov/sites/production/files/documents/iowa_climate_adaptation_report.pdf
- ◉ <https://www.epa.gov/sites/production/files/2014-07/documents/flood-resilience-checklist.pdf>
- ◉ https://www.epa.gov/sites/production/files/2015-01/documents/jamestown_flood_restoration_recommendations.pdf
- ◉ <https://www.epa.gov/waterfinancecenter>
- ◉ <http://www.epa.gov/localadaptationtraining>
- ◉ http://www.epa.gov/sites/production/files/2015-10/documents/epa_national_water_program_climate_adaptation_tools_handout.pdf
- ◉ <http://www.epa.gov/climate-change-water-sector/resources-addressing-climate-change-and-water>
- ◉ <http://www2.epa.gov/cre/risk-based-adaptation>
- ◉ <http://www.epa.gov/crwu/assess-water-utility-climate-risks-climate-resilience-evaluation-and-awareness-tool>
- ◉ http://www.epa.gov/sites/production/files/2015-04/documents/updated_adaptation_strategies_guide_for_water_utilities.pdf
- ◉ <http://water.epa.gov/infrastructure/watersecurity/emerplan/upload/epa817b14006.pdf>
- ◉ <http://www.epa.gov/waterutilityresponse/build-flood-resilience-your-water-utility>



WaterSense

<https://www.epa.gov/watersense>



- Promote water efficiency, including landscape irrigation
- Label qualifying products
- Encourage product innovation
- Decrease water use
- Water-Smart Landscapes Guide

Improving the Approach to Stormwater Management

Traditional approach – convey stormwater quickly from site to water body or detention ponds

Approach is not adequately controlling water quality and quantity impacts from discharges from increased development: pollutant loading, stream erosion, increased runoff/reduced infiltration, changes to stream geomorphology and impacts to aquatic habitat

New approach - using Low Impact Development/Green Infrastructure

- View stormwater as a resource
- Manage stormwater on-site
- Reduce pollutant loads to water bodies
- Multi-functional infrastructure



Low Impact Development

- ⦿ A comprehensive land planning design approach for maintaining & enhancing the pre-development hydrologic regime.
- ⦿ Can sustain or restore a watershed's hydrologic and ecological functions.
- ⦿ A sustainable stormwater practice.
- ⦿ Can be applied to new development, redevelopment, or as retrofits to existing development.
- ⦿ A paradigm shift in site design.



Green Infrastructure

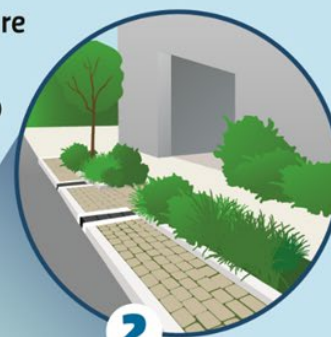
- Systems and practices that use or mimic natural processes to infiltrate, evapotranspire or reuse stormwater or runoff on site.
- Can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements.
- Preservation and restoration of natural landscape features (forests, floodplains and wetlands) are critical components of GI-by protecting these ecologically sensitive areas, water quality will improve while providing wildlife habitat and outdoor recreation opportunities.



Green Infrastructure Builds Resiliency

1 Vegetation-based green infrastructure practices can mitigate carbon pollution.

2 Build green infrastructure like rain gardens and permeable pavement to manage flooding.



2

6

3 Reduce dependence on imported water and save money. Let water soak into the ground to recharge local groundwater supplies.

4 Keep water local. Capture runoff in cisterns and rain barrels to reduce municipal water use.

5 Plant trees and green roofs to mitigate the urban heat island effect.

6 Use living shorelines, buffers, dunes and marsh restoration to reduce the impact of storm surges.



For more information on green infrastructure, see:
www.epa.gov/greeninfrastructure

http://water.epa.gov/infrastructure/greeninfrastructure/climate_res.cfm

Systems Thinking

- Green infrastructure will have a bigger impact when it is holistically integrated with the other infrastructure.
- Multi-benefit infrastructure is more cost effective.

Green Infrastructure

Systems that mimic a natural hydrologic cycle to take stormwater and slow it down, spread it out, and soak it in.



Can be integrated into:

- ✓ Parks, open space, urban forestry
- ✓ Parking lot landscaping requirements
- ✓ Climate adaptation strategies
- ✓ Smart growth/ sustainability/ resilience strategies
- ✓ Flood restoration



Types of Green Infrastructure

- Green Roofs
- Planter Boxes
- Rain Gardens
- Bioswales/Bioretenention Cells
- Vegetated Swales, Tree Trenches
- Ponds
- Porous Pavements
- Green Streets/Complete Streets
- Wetlands, Riparian areas
- Rainwater Harvesting



Value of Green Infrastructure

- Stormwater management
- Climate adaptation
- Urban heat island reduction
- Biodiversity
- Air quality improvements
- Clean water
- Healthy soils
- Recreation
- Quality of life



Additional Benefits

- ◉ Reduced & delayed stormwater runoff volumes
- ◉ Enhanced groundwater recharge
- ◉ Stormwater pollutant reductions
- ◉ Reduced sewer overflow events
- ◉ Increased carbon sequestration
- ◉ Reduced energy demands
- ◉ Additional wildlife habitat & recreational space
- ◉ Improved human health
- ◉ Increased land values
- ◉ Less splash, spray, ponding, noise, and pollutants coming off permeable pavements
- ◉ Can be less expensive than grey infrastructure, especially long term
- ◉ More aesthetically pleasing, quality of life, community amenity
- ◉ Makes communities more resilient



Cost of Green vs Grey

- Denver Housing Authority used both rain gardens and pervious pavements in their Park Ave development. DHA was able to decrease stormwater infrastructure costs from \$850,000 (stormwater vault) to \$350,000 (bioswales and permeable pavements). DHA estimated that they would save \$3,000,000 at it's Mariposa site by using LID/GI over traditional grey infrastructure
- Sun Valley Stormwater Options <https://www.epa.gov/urbanwaterspartners/sun-valley-stormwater-options>
- Communities will spend 2-3 times more in total to implement stormwater BMPs if each land owner goes it alone than if community pooled money and installed BMPs in optimal locations <http://www.epa.gov/ne/topics/water/pdfs/OptimalSWMngtPlanAlternativesUpperCharlesPilotStudy.pdf>
- 12-20% cost savings- Chicago <http://cgl-ltdmap.com/greenforum/?p=93>
- <https://www.epa.gov/nps/urban-runoff-low-impact-development>
- Georgetown Riverview Restoration Project (Duwamish River, Seattle), Markey Manufacturing- Cost to connect to King County stormwater system was more than \$1M. Cost of designing and building 3 swales was \$95K. http://daily.sightline.org/daily_score/archive/2010/03/02/industrial-strength-stormwater-fix
- Calculator <http://greenvalues.cnt.org/>
- Use a systems thinking approach to calculate the complete costs and benefits.



Ways to Get There

Regional stormwater planning

LID/GI BMPs

Stormwater ordinances

Zoning & building codes

Shared parking

Develop requirement for volume reduction

Minimize street setbacks

Bioretention requirements count towards landscaping requirements

Promote tree canopy

Riparian setbacks

Review street width & parking lot requirements

Change water & stormwater pricing structures

GI in the Semi-Arid West

- Denver 15" precipitation
- 300 days of sunshine
- Infrequent intense storms
- Xeriscape-low water native plants
- “Taupe Infrastructure”



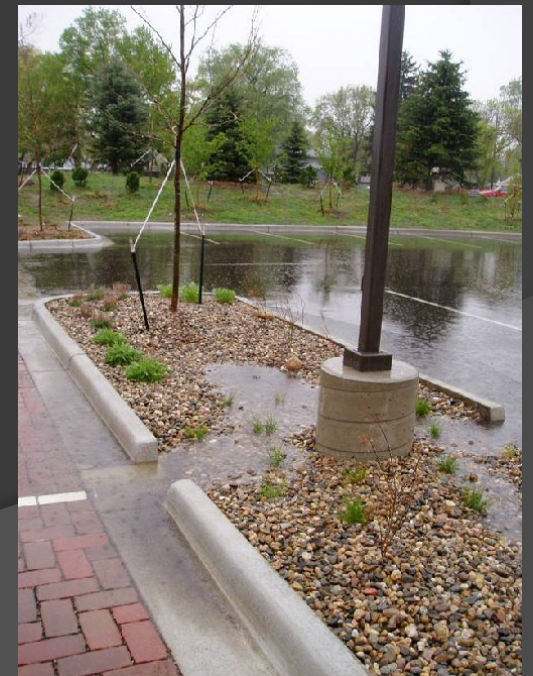
GI in the Semi-Arid West

- No CSOs
- Prior appropriation-someone else owns that water
- Clay soils
- Design and engineering for infiltration
- Site specific design and installation
- Irrigation to get plants established



Barriers to GI in the Semi-Arid West

- Perceived design, construction & maintenance costs
- Mixed messages & lack of connections from different governmental agencies & departments
- Misperception on economics
- Lack of integration into regional & site planning
- Lack of trust in new technologies
- Irrigation to get plants established



Green Roofs

- ◉ <https://www.epa.gov/region-8-green-building/green-roof>
- ◉ https://www.epa.gov/sites/production/files/documents/EPAGreenRoof_factsheet.pdf
- ◉ https://www.epa.gov/sites/production/files/2017-09/documents/denver_case_study_508.pdf
- ◉ https://www.epa.gov/sites/production/files/documents/GreenRoof_PlantingPlan.pdf
- ◉ <https://www.gsa.gov/portal/getMediaData?mediaId=172735>
- ◉ <http://www.greenroofs.com/projects/pview.php?id=495>
- ◉ https://www.researchgate.net/publication/267293773_A_photovoltaic_array_on_a_green_roof_in_Denver_Colorado_improves_resilience_of_green_roof_plants_by_expanding_habitat_heterogeneity
- ◉ https://www.researchgate.net/publication/269101969_Evaluation_of_Green_Roof_Plants_and_Materials_for_Semi-Arid_Climates
- ◉ <https://www.epa.gov/region8/evaluation-green-roof-biological-performance-quality-assurance-plan>
- ◉ <https://www.epa.gov/sites/production/files/documents/GreenRoofsSemiAridWest.pdf>
- ◉ <https://udfcd.org/wp-content/uploads/2014/07/T-04-Green-Roof.pdf>
- ◉ https://www.epa.gov/sites/production/files/documents/design_guidelines_for_green_roofs.pdf
- ◉ <https://www.green-buildings.com/articles/green-roof-or-white-roof/>
- ◉ <https://www.epa.gov/heat-islands>
- ◉ <https://www.epa.gov/sites/production/files/2014-06/documents/greenroofscompendium.pdf>
- ◉ https://www.researchgate.net/publication/274073354_Observations_on_the_survival_of_112_plant_taxa_on_a_green_roof_in_a_semi-arid_climate




Websites and Tools

- ◉ Western examples (CO, UT, MT, WY, ND, SD):
<https://www.epa.gov/region8/green-infrastructure>
- ◉ Barriers analysis in Boulder area
<http://www.keepitcleanpartnership.org/>
- ◉ UDFCD Volume 3 Criteria Manual
<http://udfcd.org/volume-three>
- ◉ Denver Ultra-Urban GI Guidelines
<https://www.denvergov.org/content/denvergov/en/wastewater-management/stormwater-quality/ultra-urban-green-infrastructure.html>
- ◉ Colorado Stormwater Center
<http://stormwatercenter.colostate.edu/>
- ◉ EPA National Green Infrastructure webpage
<http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm>
- ◉ National Stormwater Calculator & Climate Assessment Tool
<http://www.epa.gov/nrmrl/wswrd/wq/models/swc/>
- ◉ Green infrastructure Wizard
<https://cfpub.epa.gov/giwiz/>
- ◉ International Stormwater BMP Database
<http://www.bmpdatabase.org/monitoring-guidance.html>
- ◉ GreenStream Listserv
[Email \[join-greenstream@lists.epa.gov\]\(mailto:join-greenstream@lists.epa.gov\)](mailto:join-greenstream@lists.epa.gov)



GIWiz

 **EPA** United States Environmental Protection Agency


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Green Infrastructure Wizard

 Quick Links


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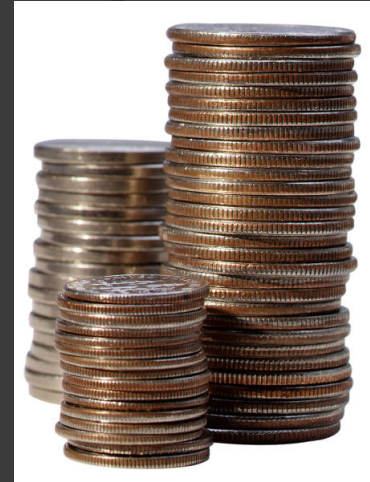


I want to find tools and information that...

Use the Quick Links feature to access green infrastructure tools and resources, customized to a specific objective. Click the button that best matches your needs, and select the corresponding objective to view a tailored list of tools and resources.

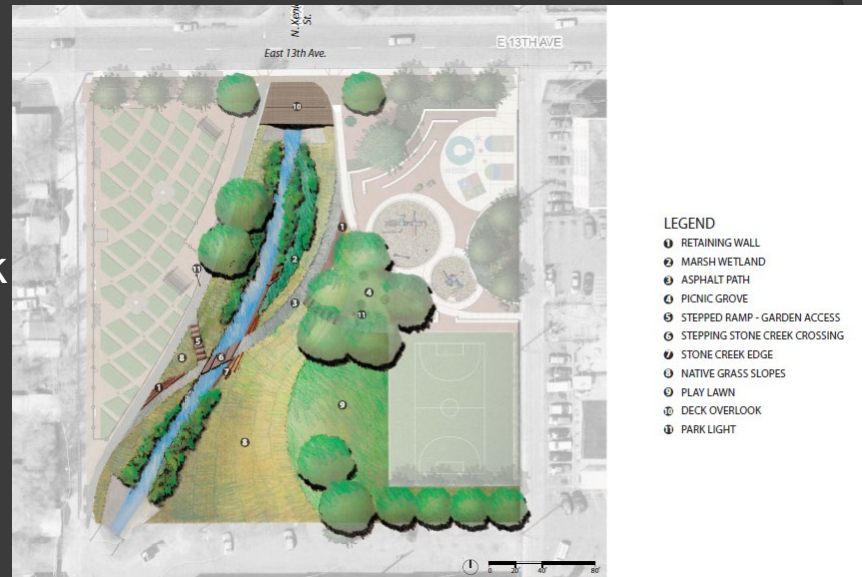
EPA Funding Sources

- Section 319 nonpoint source grants
- Clean Water State Revolving Loan Fund
- Urban Waters Small Grants
- Green infrastructure technical assistance if available
- Brownfields revitalization funding
- Brownfields area-wide planning grants
- Brownfields job-training grants
- Brownfields assessment, revolving loan fund, and cleanup grants
- Greening America's Communities
- Building Blocks Assistance
- Water Infrastructure and Resiliency Finance Center
- Water Infrastructure Finance and Innovation Act (WIFIA)
- NFWF 5 Star and Urban Waters Grants



Green Infrastructure Projects Using EPA Funding

- DHA GI design charrette for S Lincoln
- Westerly Creek GI design
- ULC GI design for 38th & Blake
- S. Platte Brownfields corridor planning
- River North GI design
- Sun Valley & Johnson/Habitat Park design
- Dry Gulch GI Design
- Helene and Pierre Greening America's Capitals
- Denver Ultra-Urban GI Guide
- Sun Valley GI & SW Options
- Greening Valley City ND
- Ft. Peck GI templates
- Heron Pond Open Space
- BuCu West Creative Center

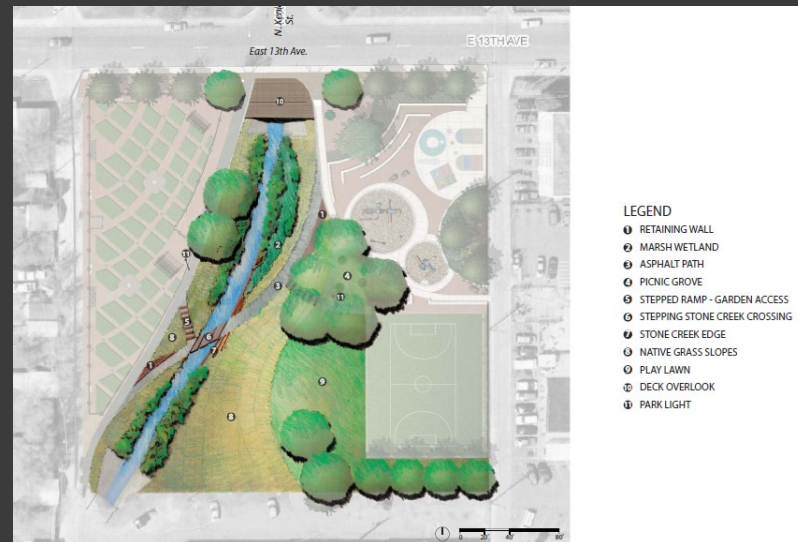


Mariposa/South Lincoln Homes





Westerly Creek, Denver CO





Weir Gulch/Sun Valley, Denver CO



Johnson Habitat Park Denver CO



2012 GREEN INFRASTRUCTURE TECHNICAL ASSISTANCE PROGRAM

Urban Land Conservancy
Denver, Colorado



Denver Housing Authority, Park Avenue Development

Conceptual Green Infrastructure Design for the Blake Street Transit-Oriented Development Site, City of Denver

JUNE 14, 2013

EPA EP-C-11-009

Leveraging Resources and Partnerships: Green Infrastructure Technical Assistance Program

https://www.epa.gov/sites/production/files/2015-10/documents/denver_blakestreet_concept_design.pdf



Figure 5. Existing Site Conditions.

Analyzing the Site

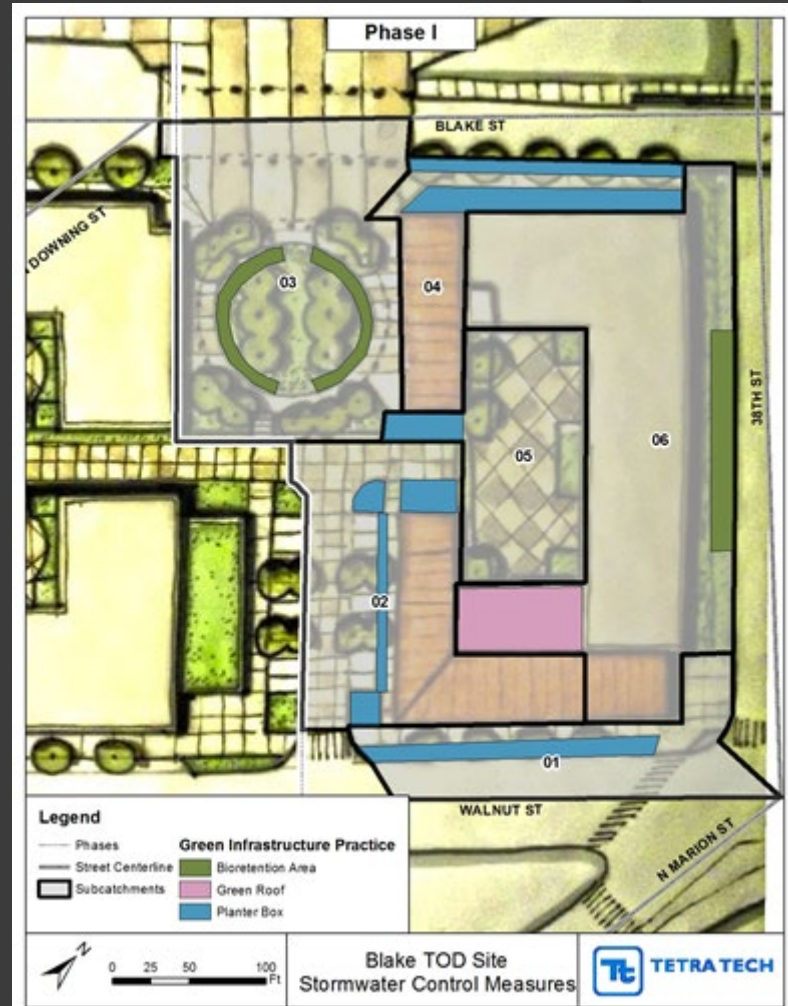
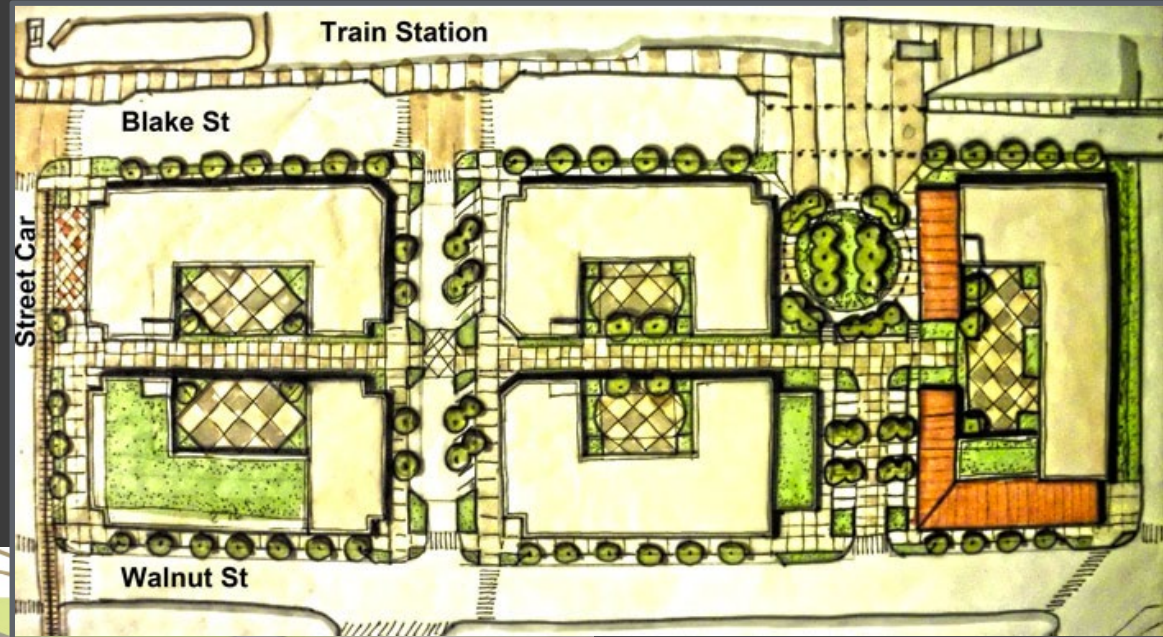


Figure 18. Phase I Stormwater Control Measure Layout.

Designing to the Site

A Broader Area Vision in Three Phases





Toolbox Examples



Phase I Subcatchment Delineations and Runoff Volumes

Subcatchment	Subcatchment Drainage Area (sq ft)	C _{composite}	Required Storage Volume for 1-year, 2-hour Storm (cu ft)	Required Storage Volume for 100-year, 2-hour Storm (cu ft)
01	7,990	0.90	610	1,790
02	13,650	0.85	990	2,880
03	18,900	0.66	1,070	3,120
04	7,170	0.85	520	1,510
05	8,000	0.85	580	1,680
06	25,000	0.66	1,400	4,080

Phase I Green Infrastructure Practice Proposed Location and Sizing.

Subcatchment	Green Infrastructure Practice Type	Location	Width (ft)	Length (ft)	Surface Area (sq ft)	Available Water Storage Volume (cu ft)	Overflow Volume to Under-ground Detention (cu ft)
01	Planter Box ¹	Sidewalk	4.5	189	851	1,800	0
02	Planter Box	Sidewalk	5	95	452 212 264 475	2,896	0
03	Bioretention	Perimeter of circular park	11	261	2,871	3,184	0
04	Planter Box	Sidewalk	4.5 4.5	81 81	729	1,543	0
05	Planter Box	Adjacent to driveway	16	50.4	806	1,707	0
06	Green Roof ² , Bioretention	Open area behind building	17	167	2,839	4,081	0
Total					9,499	15,211	0

¹ If curbside parking is allowed on this block, pedestrian “bridges” will be needed to cross from the curbside parking to the sidewalk.

²Subcatchment 06 is partially treated by a green roof draining to the bioretention area.

O & M Considerations

- ◉ Monitor infiltration and drainage
- ◉ Pruning and mowing
- ◉ Mulching and mulch removal
- ◉ Watering and fertilization
- ◉ Remove and replace dead plants
- ◉ Inlet, outlet, and underdrain inspections
- ◉ Miscellaneous upkeep
- ◉ All at different frequencies

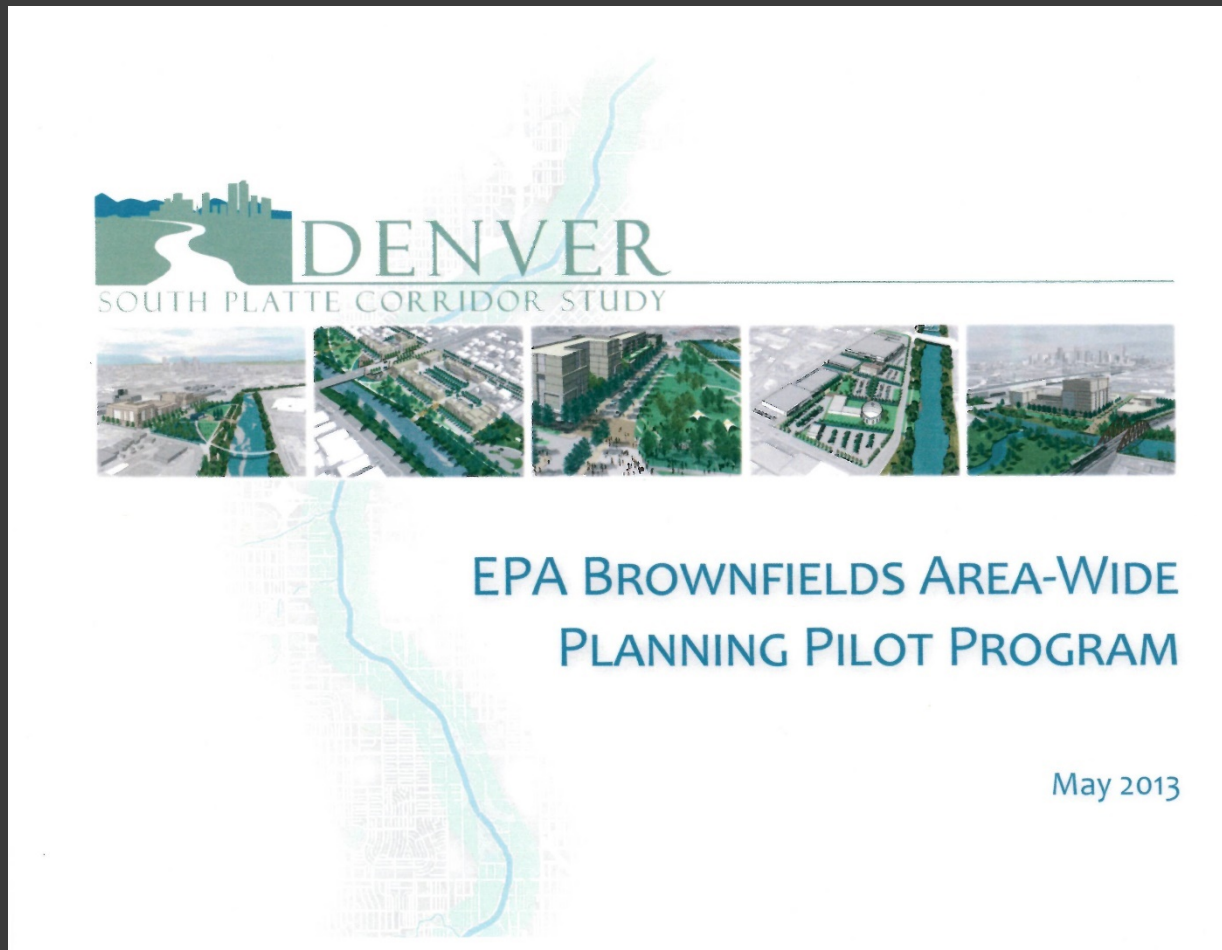


Lessons Learned From Design Charettes

- Holistic approach with GI incorporated into the site design improves design & saves money. Look beyond project boundaries and construction phases.
- Identify all key stakeholders & stormwater plans before developing a solution. Comprehensive gathering leads to a better more implementable design.
- Identify priorities & tradeoffs between water quantity & water quality solutions.
- Define clear goals & metrics of success.
- Collaboration & prioritization among city players is crucial for the successful implementation of solutions. City policies may limit the implementation & effectiveness of some stormwater strategies
- Innovative solutions may require research & testing.
- Environmental conditions may affect GI options, ie brownfields.
- Cost estimates make incorporating recommendations more likely.



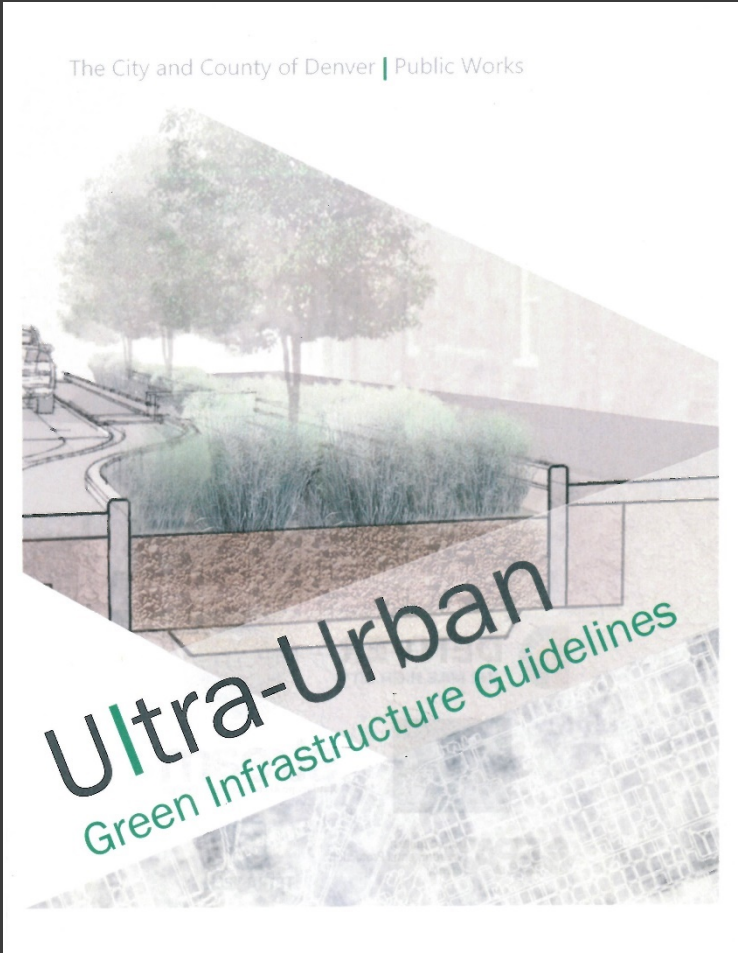
S Platte River Corridor Study



https://www.denvergov.org/content/dam/denvergov/Portals/646/documents/planning/Plans/South_Platte_Corridor_Study.pdf

The City and County of Denver | Public Works

Ultra-Urban
Green Infrastructure Guidelines



Sun Valley GI Options Study

Technical Memorandum
Sun Valley EcoDistrict - Green Infrastructure and Stormwater Management Option 2.5

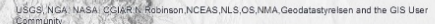
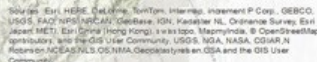
Figure 1. Conceptual Option 2.5



4

<https://www.epa.gov/urbanwaterspartners/sun-valley-stormwater-options>

Description	Capital Cost	Annual Operating Cost	Total NPV Costs (20-YR)
OPTION 2.5 - Integrated Ultra-Urban Green Infrastructure, Off-Site Detention and Water Quality	\$11,492,700	\$425,300	\$18,485,700
OPTION 1 - Conventional Conveyance and Site Retention/Detention	\$11,217,600	\$617,600	\$21,374,300
OPTION 2 - Green Infrastructure with Centralized Site Retention/Detention	\$12,525,400	\$752,700	\$24,902,500
OPTION 3 - Green Infrastructure with De-Centralized Site Retention/Detention	\$15,870,100	\$1,621,300	\$42,530,700

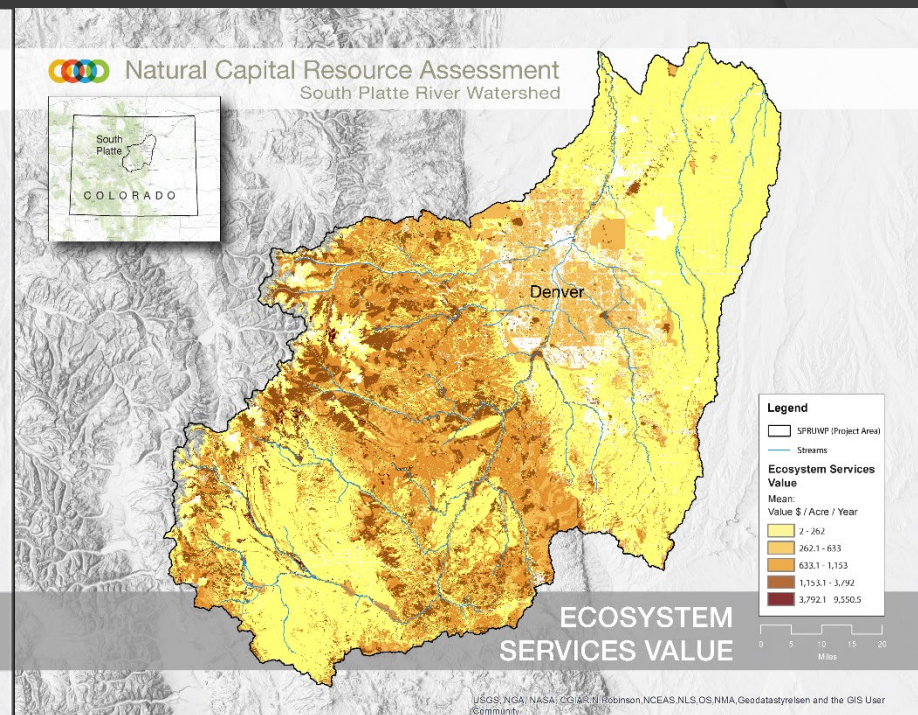
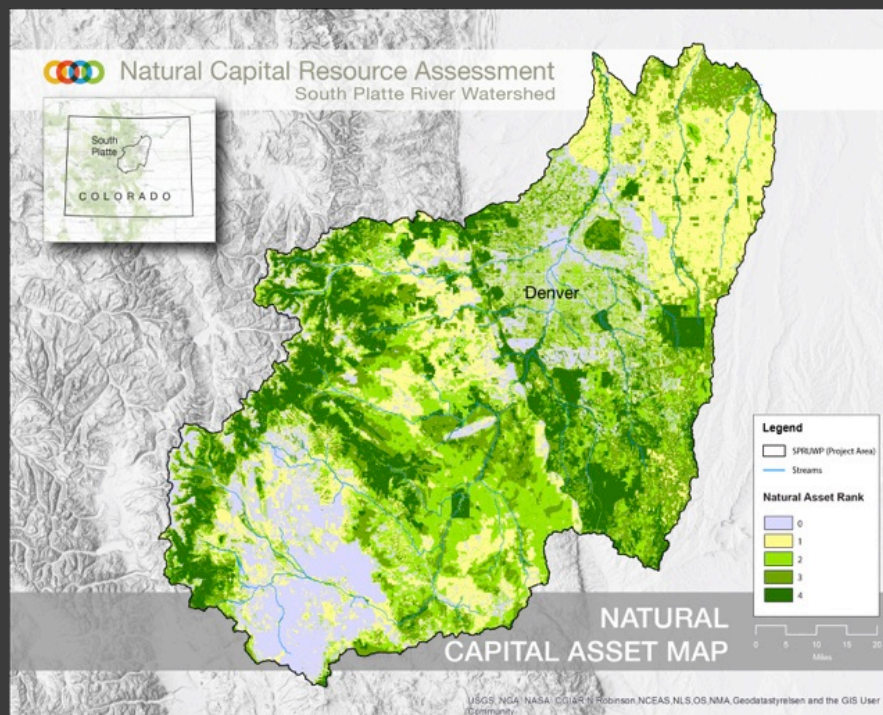


<https://www.epa.gov/urbanwaterspartners/south-platte-natural-capital-project>



Natural Capital Resource Assessment

South Platte River Watershed



<https://pg-cloud.com/NaturalCapital>

Water Quality Assessment Tool

<http://www.exploremetrodenverwaterquality.org/>

The South Platte Urban Waters Partnership is excited to present the updated water quality assessment tool for exploring the health of rivers and streams in the Denver metro area. This online tool combines data from 2009 through 2015 for pollutants including *E. coli*, contaminants of emerging concern, total dissolved and suspended solids, selenium, and nutrients. Use maps, graphs and narratives to explore water quality in the South Platte River basin. Take the tool into the field with the new mobile application and learn how you can protect water quality!





THANK YOU!

Reduce Runoff-
Slow it Down,
Spread it Out,
Soak it in