2022 Environmental Code Amendments Phase 1

Planning Commission Briefing

August 23, 2022

Objective

- Respond to portion of Resolution 20220609-061 that requires staff to bring forth an ordinance amending Title 25 related to environmental protection.
- Due September 15, 2022
- Key subject areas
  - Stormwater
  - Landscape
  - Water Resource Protection
  - Colorado River Protections
  - Previously identified minor code amendments and other amendments that meet the objectives of the resolution
  - Don't Disincentivize Missing Middle

Progress So Far

- Internal Watershed Protection Dept (WPD) technical staff
- Input from other departments including
  - Development Services Department
  - Austin Water
  - Austin Transportation
  - CoA Project Connect Office
  - Housing and Planning
  - Law

- Environmental Commission Workgroup 7/25/2022
- Environmental Commission Update 8/3/2022
- Codes and Ordinances Joint Committee 8/18/2022

Next Steps

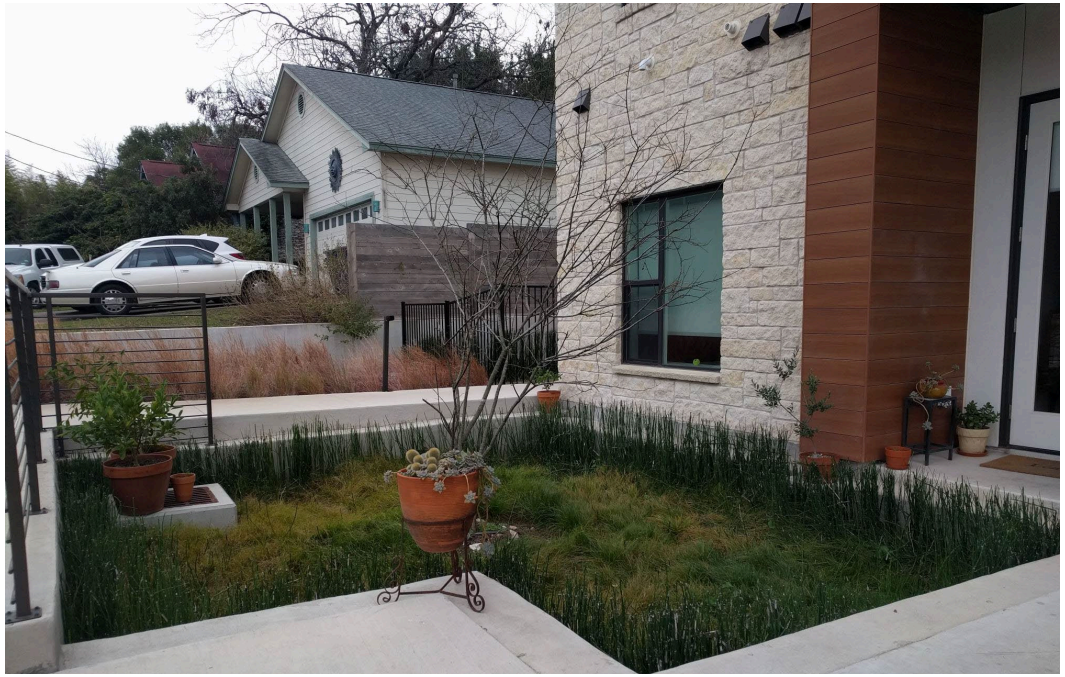
- 9/6/2022 – Zoning and Platting (tentative)
- 9/7/2022 – Environmental Commission
- 9/13/2022 – Planning Commission
- 9/29/2022 – City Council

Phase 2: Greenfield Detention Requirements and Urban Slope Protection

- September & October Commissions
- November City Council

Stormwater

"1. Establish criteria that prioritize when green stormwater methods should be required or incentivized over conventional stormwater controls"



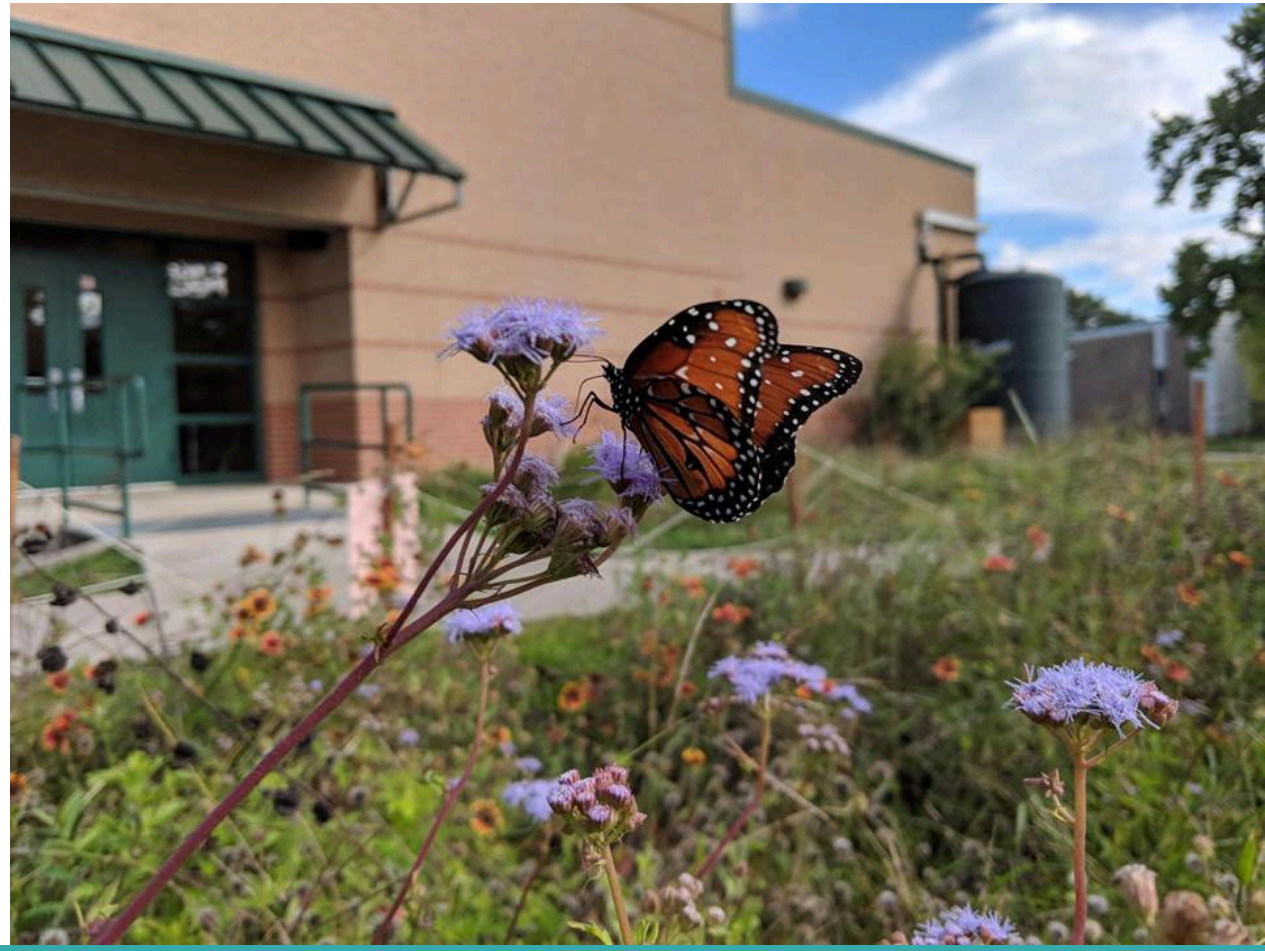
Rain garden

VS

Conventional Stormwater Control
(Sedimentation & Filtration Pond)

Benefits of Green Stormwater Infrastructure (GSI)

- Improved ecosystem services
- Improved stormwater infiltration
- Soil health
- Wildlife habitat
- Heat island mitigation
- Water conservation
- Aesthetic value



GSI Timeline

- 2012: Imagine Austin approved
- 2013: Watershed Protection Ordinance approved
- 2014: Phase 2 of the Watershed Protection Ordinance
  Austin Water Resource Planning Task Force
- 2015: Green Infrastructure Working Group
  WPD CodeNEXT Team
- 2016: Development and approval of draft code language
  Natural & Built Environment Prescription Paper
- 2017: GSI proposal included in CodeNEXT

Cistern at Reilly Elementary

GSI Timeline

Rain garden along Butler Trail

- 2017: Original GSI proposal include in Draft 1 and 2 of CodeNEXT
  Revised GSI proposal developed for inclusion in Draft 3
  Council Resolution for Green Infrastructure/GSI
- 2018: CodeNEXT process ended by City Council
- 2019: Council adopts policy direction to guide LDC Revision
  GSI proposal revised for inclusion in public draft
- 2020: LDC Revision halted after District Court ruling
- 2022: New Council Resolution from City Council (20220609-061)

Stormwater

"1. Establish criteria that prioritize when green stormwater methods should be required or incentivized over conventional stormwater controls"

Draft Recommendation

- Adopt LDC Rewrite 2nd Reading Recommendation
- Code Amendments
  - Require GSI for sites with less than 90% impervious cover
  - Carve outs for sites that treat existing impervious cover with an area greater than 10 acres or for sites that may generate highly contaminated runoff
  - Allow administrative variance with conditions
- Future Environmental Criteria Manual (ECM) amendments to more clearly define GSI
- Consider improvement to sedimentation/filtration pond design standards

Stormwater

"2. Require surface parking lot stormwater to enter pervious parking lot islands, landscaped medians, and perimeter landscapes as a method of water quality and require that pavement be graded to allow runoff to enter planting areas"

Draft Recommendation

- Staff do not recommend requiring all landscape areas to serve as water quality controls for water quality treatment requirements
- Remove requirement that all parking lot landscape areas be protected by a 6" curb (LDC 25-2-1007 Parking Lots)
- Remove stormwater irrigation requirement (LDC 25-2-1008 Irrigation Requirements)
- Require applicants to drain stormwater to landscape areas where possible (LDC 25-8-185 Overland Flow)

Stormwater

"5. Allow cisterns to be sized beyond the required storm capture amount and remove requirement for stormwater release so that they can supply irrigation needs throughout the year"

Draft Recommendation

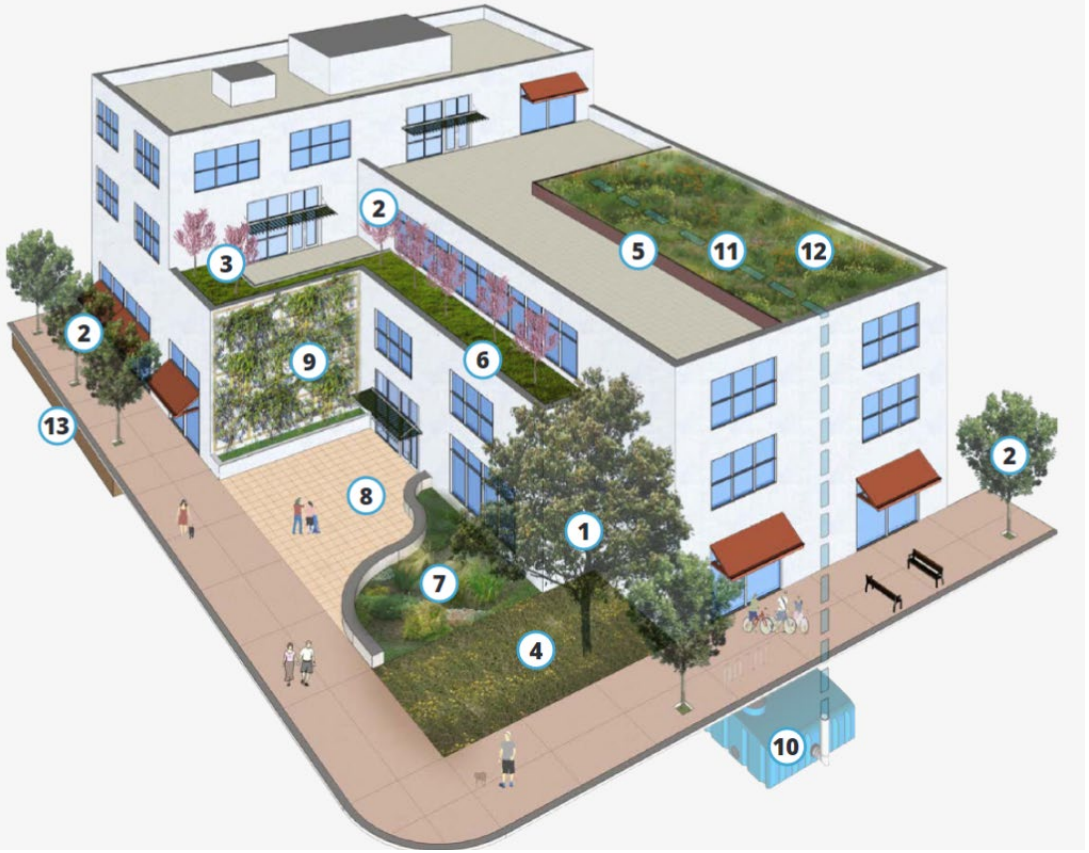
- Land Development Code and Environmental Criteria Manual already allow cisterns to be sized beyond required storm capture amount = no code amendment necessary
- ECM update to continue investigating emerging technology, including smart controls, to determine release requirements for water quality
- Continued close collaboration between Austin Water and WPD staff

What is Functional Green?

"3. Implement Functional Green requirements for properties with more than 80% allowable impervious cover"

Functional Green Landscape is based on the ecosystem service value created by landscape. It is intended to improve ecological balance, replenish native vegetation, and enhance public health, safety, and welfare.

The Functional Green Score measures the total amount of ecosystem services provided by the landscape elements proposed for a development site. Landscape plans are required to reach a total target Functional Green Score based on the assigned value per square foot area of each landscape element in relation to the area of the site.



What is Functional Green?

Required number of points based on site area for high impervious sites.

Landscape elements may include:

- Existing or newly planted trees
- Shrubs, ornamental grasses, perennial forbs, groundcovers
- Turf areas maintained for aesthetic or athletic uses
- Vegetated wall
- Irrigation with alternative water sources
- Vegetated roof
- Rain gardens
- Porous pavement
- Suspended pavement system (for improved urban tree health)
- Pollinator resources
- Publicly accessible green space adjacent to ROW or public sidewalk

Functional Green

"3. Implement Functional Green requirements for properties with more than 80% allowable impervious cover"

Draft Recommendation

- Uphold previous recommendation from LDC rewrite 2nd reading with minor edits
- New Landscape Section in either Zoning or LDC 25-8
- Applies to Central Business District and Downtown Mixed-Use zoning districts and other sites with greater than 80% allowable impervious cover

Water Resource Protection

"7. Prohibit in-channel detention ponds, except for capital projects or private/public partnerships where no other alternative is feasible"

Example of existing in-channel detention pond

Draft Recommendation

- LDC code amendment to 25-8-261(F) which allows in-channel detention and wet ponds

Water Resource Protection

"8. Require projects to relocate replaced or upsized wastewater pipes outside of the inner half of the critical water quality Zone…

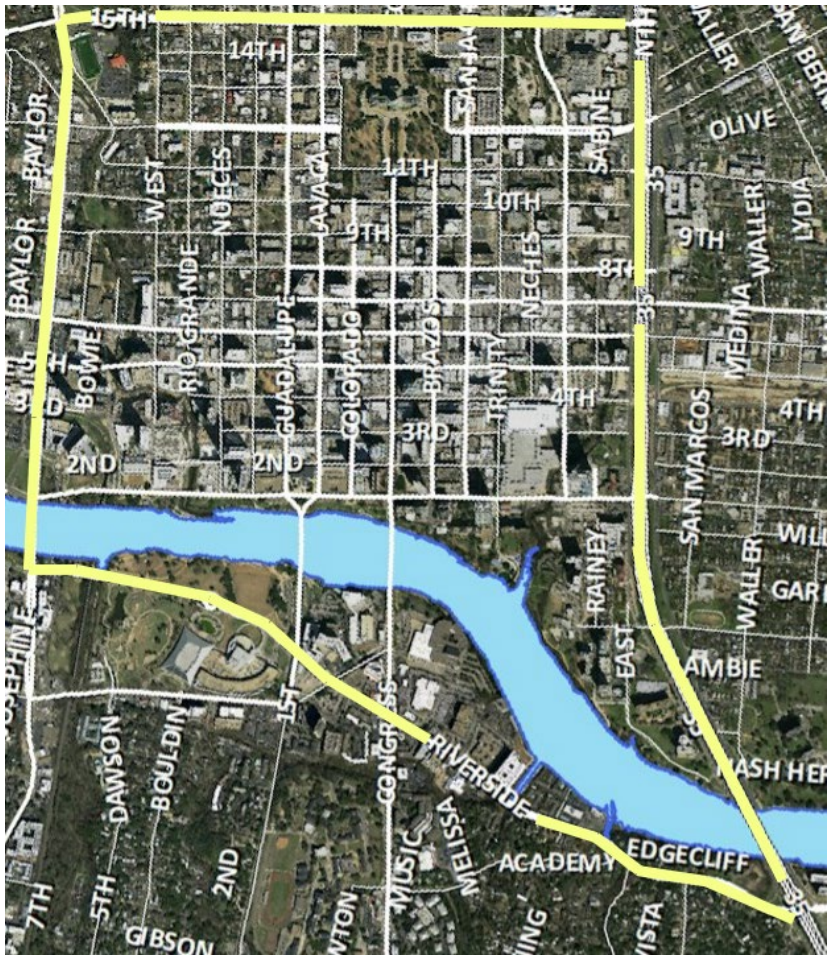
10. Require utility easements to meet the same standards as utility pipes within creeks and creek buffers"

Draft Recommendation

- Code amendment to LDC 25-8-261(D) relating to utility lines in Critical Water Quality Zones
- Code amendment to LDC 25-8-261(E) relating to utility lines running parallel to Critical Water Quality Zones in urban and suburban watersheds

Water Resource Protection

"9. Provide wetland protections and buffers equally along Lady Bird Lake to help stabilize and prevent erosion along the shoreline"



Draft Recommendation

- Code amendment to LDC 25-8-282(A) Wetland Protection
- Retain existing exemptions for wetlands bounded by I-35, Riverside Dr, Barton Springs Rd, Lamar, and 15th Street but carve out the wetlands associated with Lady Bird Lake.

Colorado River Protections

"The City Council directs the City Manager to evaluate the effectiveness of existing Critical Water Quality Zone and Erosion Hazard Zone buffers on the Colorado River downstream of the Longhorn Dam and to propose protections that will provide adequate protections to the river that will ensure a healthy riparian corridor to stabilize the riverbank and protect property from erosion"

Existing LDC requirements include:

- Erosion Hazard Zone analysis within 100' of the Ordinary High Water Mark (OHWM)
- Critical Water Quality Zone (CWQZ) established at 200'-400' feet depending on 100-year floodplain
- No special consideration for stormwater discharge on highly erodible bank of the Colorado River

Colorado River Protections

"The City Council directs the City Manager to evaluate the effectiveness of existing Critical Water Quality Zone and Erosion Hazard Zone buffers on the Colorado River downstream of the Longhorn Dam and to propose protections that will provide adequate protections to the river that will ensure a healthy riparian corridor to stabilize the riverbank and protect property from erosion"

Draft Recommendation

- Code amendment to LDC 25-7-32 Director Authorized to Require Erosion Hazard Zone Analysis – expanded to 400' from Ordinary High Water Mark (OHWM)
- Code amendment to LDC 25-8-92 Critical Water Quality Zones Established to expand CWQZ to 400' from OHWM
- Code amendment to LDC 25-8-261(E) to require new stormwater outfalls to discharge in drainages located upstream of the Colorado River
- Update City of Austin Property Profile viewer to show estimated location of OHWM

Other code amendments

"11. Address current environmental code inconsistencies and other minor code revisions in Chapters 25-7 and 25-8 that staff have previously identified and reviewed as part of the Code Next and the Land Development Code revision process.

The City Council initiates other code amendments, as necessary, to accomplish the goals of this Resolution. The City Council expects that these code amendments will use the previous staff work and, where appropriate, adhere as closely as possible to the language and intent of the ordinances previously drafted and reviewed through the proposed revision of the Land Development Code."

Other code amendments

Draft Recommendation

- Update to correct department names and accountable officials
- Minor reorganization of certain sections
  - Minor revisions to titles to improve readability
  - 25-2 Landscape streetyard tree requirements consolidated with other streetyard landscape requirements
  - 25-8 Division 1 Critical Water Quality Zone Restrictions renamed Waterway and Floodplain
  - 25-8 Floodplain modification criteria moved directly after Critical Water Quality Zone
  - 25-2-1179(B) Bulkhead wave abatement requirements moved to 25-8-261(C)
  - Move lake fill/land capture & lake dredge requirements to 25-8-261(C)
- Minor edits to improve clarity without changing intent
  - Edits to floodplain modification language
  - Edits to roadside ditch exemption
- Exempt rainwater harvesting cisterns from impervious cover calculations

Other code amendments

Draft Recommendation

- Streamline and clarify process for redevelopment exceptions in Urban, Suburban, Water Supply Suburban, and Water Supply Rural watersheds
- Minor edits to Barton Springs Zone redevelopment exception to allow GSI when sedimentation/filtration ponds are currently required
- Update Environmental Resource Inventory requirement to remove certain (WQTZ, EA Contributing Zone, DWPZ) triggers and add requirement for upland ponded areas previously identified in GIS
- Update street crossing requirements to use language consistent with ASMP

Other code amendments

Draft Recommendation

- Allow Critical Environmental Feature (CEF) variances to be approved at staff level except when mechanized pedestrian access (aka trams) is proposed within 500' of Lake Austin
- Allow Stormwater Control Measurs (SCM) retrofits in floodplain and within 50' of a CEF to address existing drainage issues
- Clarify existing subdivision requirements related to CEFs
- Remove code language that explicitly allows wetlands to serve as water quality controls

Other code amendments

Draft Recommendation

- Update cut/fill restrictions to allow cut/fill in excess of 4’ for construction of street or driveway necessary to provide primary access with conditions
- Remove 25-8-367 Relocation of Shoreline Between Tom Miller Dam and Longhorn Dam
- Simplify Endangered Species Notification

Don't Disincentivize Missing Middle

"WHEREAS, small-scale missing middle housing projects (projects ranging from approximately 3 to 12 units) are required to comply with the same water quality, drainage, and site plan requirements as large scale multifamily residential project, while single-family homes are not subject to those requirements, creating an incentive for developers to build single-family homes over missing middle housing to avoid water quality regulations, contributing to urban sprawl and the housing affordability crisis; and

WHEREAS, a large single-family home can actually have more impervious cover than a multi-unit development, and the amount of impervious cover for a project is one of the key factors affecting drainage regardless of project type and should be taken into account when evaluating water quality and drainage requirements for site plans;…

"The initiated ordinances will ensure that, for the same environmental impact as a single-family home, the City does not disincentivize small-scale missing middle housing projects"

Don't Disincentivize Missing Middle

Draft Recommendation

- Clarify which elements apply to single family residential

  (ex: impervious cover definitions, erosion/sedimentation control, waterway protections for lots platted after May 18, 1986, clearing of vegetation, cut, fill, SOS)

- Adopt similar process requirements as proposed in LDC Rewrite

Don't Disincentivize Missing Middle

Draft Recommendation

- Allow up to 11 units (unless more allowable via Affordability Unlocked program) on existing single family lots to qualify as small project site plans
- Same environmental requirements as those that apply to single family residential
- Impervious cover limit of 55%
- Site limit
- Administrative variance option for lots with waterway setbacks that were established after platting

Don't Disincentivize Missing Middle

Draft Recommendation

- Require Small Project Site Plan Applications for qualifying projects
  - Established review process with existing fee structure for partnering departments
  - No notice
  - Faster review time

Analyses (due 2 weeks prior to Council Date)

- Affordability Impact Statement (Housing and Planning)
- Fiscal Impact Statement (WPD Planning & Policy Divisions)
- Cost of Doing Nothing (WPD Planning & Policy Divisions)
- Equity Analysis (WPD Equity Team)*

*not specifically required by Resolution 20220609-061

Next Steps

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Questions?

CHAPTER 25-2. ZONING.

ARTICLE 9. LANDSCAPING

§ 25-2-981 - APPLICABILITY; EXCEPTIONS.

(A) Except as provided in Subsection (B), this article applies in the city's zoning jurisdiction.

(B) Division 2 (*Requirements for a Site Plan*) and Division 3 (*Additional Site Plan Requirements in Hill Country Roadway Corridors*) do not apply to:

(1) property zoned central business district or downtown mixed use district**, except** for **(Functional Green)**;

(2) a lot containing one single-family residence;

(3) a lot containing one duplex residence, unless the residence exceeds 4,000 square feet of gross floor area or has more than six bedrooms;

(4) a two-family residential use;

(5) a secondary apartment special use;

(6) substantial restoration of a building within one year after the building is damaged;

(7) restoration of a building designated as a historic landmark; or

(8) interior or facade remodeling, if the front and side exterior walls of the building remain in the same location.

(C) Developed property, or property with an approved site plan, that is affected by right-of-way condemnation may be developed without compliance with this article, as provided by this subsection.

(1) After condemnation, improvements shown on the remainder of an approved site plan may be constructed, and only the landscaping on the remainder of the approved site plan is required.

(2) Improvements on developed properties that are lost through condemnation may be replaced. Only the area within the limits of construction for the replaced improvements must comply with this article, except an owner is not required to provide more landscaping than was in existence before the condemnation.

Division 2. Requirements for a Site Plan.

§ 25-2-1007 PARKING LOTS.

(A) For each 12 parking spaces in a parking lot that is in a landscape yard, a minimum of 90 square feet of landscaped area are required within the parking lot.

(B) For each 12 parking spaces in a parking lot that is not in a landscape yard, a minimum of 60 square feet of landscaped area are required within the parking lot.

(C) A parking lot must have end islands landscaped with trees in accordance with the Environmental Criteria Manual.

(D) Except as provided in Subsection (E), a parking space may not be located more than 50 feet from a landscaped area, or more than 50 feet from a tree.

(E) In a parking lot that has more than three distinct modules for the parking of vehicles:

(1) a landscaped median at least 10 feet wide and at least the length of the parking module is required for every second parking module for the parking of vehicles;

(2) a tree must be located within 25 feet of each parking space adjacent to a median; and

(3) end islands with trees are required.

(F) A landscaped area that is required by this section:

(1) may consist of non-contiguous portions, and may be in the form of features commonly referred to as medians, peninsulas, and islands;

(2) must be evenly distributed throughout a parking lot, except that the distribution and location of landscaped area may accommodate existing trees or other natural features if the total area requirement is satisfied; ~~**and**~~

(3) may count toward compliance with Section 25-2-1003(A) (*General Requirements*)**; and**

(4) must have an edge-of-pavement treatment that allows overland flow of stormwater runoff across the landscape area except:

(a) for perimeter landscape areas that are not required to drain to a required stormwater control measure; and

(b) for sites located within the Edwards Aquifer Recharge Zone.

§ 25-2-1008 IRRIGATION REQUIREMENTS.

~~(A) An area equal to at least 50% of the total required landscaped area on a project must:~~

~~(1) be undisturbed natural area(s) or undisturbed existing trees with no potable irrigation; or~~

~~(2) be irrigated by stormwater runoff conveyed from impervious surfaces on the site using one or more of the following methods:~~

~~(a) overland flow;~~

~~(b) storm drains;~~

~~(c) downspouts;~~

~~(d) rainwater harvesting;~~

~~(e) retention irrigation; or~~

~~(f) other methods of conveyance as prescribed by rule.~~

~~(B) The drainage area used to irrigate under Subsection (A) must be calculated to provide sufficient water for the landscaped area, as prescribed by rule.~~

~~(C) Unless the landscaped area under Subsection (A) is being designed as a water quality control under Section 25-8-211, the drainage area used to irrigate the landscaped area that is the source of the overland flow:~~

~~(1) may not include impervious areas on which the land use or activities may generate highly contaminated runoff, as prescribed by rule; and~~

~~(2) may not include impervious areas used for parking or driving of vehicles if located within the Edwards Aquifer Recharge Zone as defined in Section 25-8-2~~.

(A~~D~~) No permanent irrigation is required for all or a portion of a required landscaped area that consists of:

(1) undisturbed natural area; or

(2) undisturbed existing trees;

(B~~E~~) ~~In addition to irrigation meeting the requirements of Subsection (A),~~ s~~S~~upplemental irrigation using irrigation methods described in Subsection (C~~F~~) is required:

(1) for the first two growing seasons for all or a portion of a newly planted required landscaped area without permanent irrigation;

(2) permanently for all newly planted trees in a required landscape area; and

(3) as prescribed by rule for all newly planted required landscaping located in medians, islands, or peninsulas.

(C~~F~~) Irrigation required under subsection (B~~E~~) may be provided only by one or more of the methods described below:

(1) an automatic irrigation system;

(2) a hose attachment, if:

(a) the hose attachment is within 100 feet of the landscaped area or plant; and

(b) there is not a road or parking pavement between the hose attachment and the landscaped area or plan; or

(3) a temporary, above ground automatic irrigation system, if the system complies with the water conservation requirements in the Environmental Criteria Manual.

(D~~G~~) An irrigation method must:

(1) provide a moisture level adequate to sustain growth of the plant materials on a permanent basis;

(2) unless fiscal security is provided to the City for the installation of the system, be operational at the time of the final landscape inspection; and

(3) be maintained and kept operational.

(E~~H~~) A site plan must show:

(1) the drainage area(s) used to irrigate under Subsection (A), including notation of the land uses on impervious areas within the drainage area(s);

(2) the nature and location of an irrigation system; and

(3) that there is no disturbance to the critical root zone of an existing tree.

(F~~I~~)The director may grant an administrative variance to the requirements in this Section. An applicant for a variance must demonstrate that:

(1) strict compliance with this Section is infeasible due to unique site conditions including but not limited to topography, size, shape, and location of existing features such as trees or previous development; and

(2) the proposed irrigation plan is the minimal departure from the requirements of this Section.

Functional Green.

(A) Applicability.

(1) This division/article applies

(a) In an Urban watershed, for a site with an impervious cover limit greater than 80% as allowed in Chapter 25-2 (*Zoning*); and

(b) In a watershed other than Urban, for a site with total allowable impervious cover greater than 80% gross site area as per Chapter 25-8 (*Environment*).

(B) The Functional Green score shall be calculated as follows:

(1) Identify all proposed landscape elements, sorted into the categories presented in Table A.

(2) Multiply the square feet, or equivalent square footage where applicable, of each landscape element by the multiplier provided in Table A, according to the following provisions:

(a) If multiple elements listed on Table A occupy the same area (for example, groundcover under a tree), count the full square footage or equivalent square footage of each element.

(b) Landscaping elements in the right-of-way between the lot line and the roadway may be counted.

(c) Elements listed in Table A that are provided to satisfy any other requirements of another City of Austin regulation or rule may be counted.

(d) Ensure that Functional Green landscapes provide a variety of ecosystem services by providing a minimum of 3 different Functional Green Landscape Elements, 2 of which must be living elements; trees and shrubs/ornamental grasses of different sizes may count independently as different elements.

3. Add together all the products calculated under Table A to determine the Functional Green numerator.

4. Divide the Functional Green numerator by the lot area (excluding the ROW area) to determine the Functional Green score.

TABLE No. TBD

	Landscape element	Multiplier
	PLANTED AREA	
A	Existing tree	0.8
B.1	Large, newly planted tree (mature width 40' or greater)	0.6
B.2	Medium, newly planted tree (mature width 20-39')	0.5
B.3	Small, newly planted tree (mature width 10- 19')	0.4
C.1	Large shrubs, ornamental grasses, or perennial forbs	0.3
C.2	Small shrubs, ornamental grasses, or perennial forbs	0.3
D	Groundcover	0.2

E	Turf	0.1
F	Vegetated wall	0.5
	SPECIALIZED MEDIA	
G	Intensive vegetated (green) roof media (depth 12 inches or greater)	0.6
H.1	Extensive vegetated (green) roof media (depth 6-11.9 inches)	0.5
H.2	Rain garden Media	0.3
	ADDITIONAL ELEMENTS	
I	Irrigation with alternative water source	0.2
J	Porous pavement	0.2
K	Suspended pavement system	0.2
	BONUS OPTIONS	
L	Bonus: Pollinator resources	0.1
M	Bonus: Publicly Accessible Green	0.1

(C) Requirements.

A Functional Green Landscape plan is required to:

1. **Meet or exceed the minimum Functional Green Score of 0.3.**
2. **Except for property zoned central business district or downtown mixed use district, comply with landscape requirements for a site plan, per Chapter 25-2, Subchapter C, Article 9 and the Environmental Criterial Manual.**
3. **Provide 100 percent of plant selections, as prescribed by the Environmental Criteria Manual**
4. **Provide 100 percent drought tolerant plants, as prescribed by the Environmental Criteria Manual.**
5. **Add the following note to the landscape plan: "This landscape plan uses the Functional Green scoring system. A site plan revision is required to modify the landscape plan."**

ARTICLE 13. - DOCKS, BULKHEADS, AND SHORELINE ACCESS.

§ 25-2-1179 ENVIRONMENTAL PROTECTION.

(A) In addition to other applicable requirements of this title, a dock, bulkhead, or shoreline access must be designed, constructed, and maintained in accordance with the applicable requirements of this subsection.

~~**(B) A retaining wall, bulkhead, or other erosion protection device must be designed and constructed to minimize wave return and wave action in accordance with the Environmental Criteria Manual.**~~

(**B~~C~~**) A marine fuel facility or service station must comply with the requirements of Chapter 6-2 (*Hazardous Materials*) and shall be designed, maintained, and operated in a manner that prevents the spilling or leaking of fuel or petroleum products into the water.

(**C~~D~~**) The maintenance and repair of watercraft shall be performed in a manner that prevents discharge of fuel, oil, or other pollutants into the water.

(**D~~E~~**) Containers of hazardous materials, fuel, oil, herbicides, insecticides, fertilizers or other pollutants may not be stored on docks extending into or above Lake Austin, Lady Bird Lake, or Lake Walter E. Long.

(**E~~F~~**) Construction of shoreline access structures must minimize disturbance to woody and herbaceous vegetation, preserve the tree canopy, and replace herbaceous ground cover to the extent practicable.

(~~F~~G) A marina or marine fuel service facility or service station must provide adequate fire protection approved by the Fire Chief of the Austin Fire Department in accordance with the Fire Code and National Fire Protection Association standards for marinas and boatyards.

CHAPTER 25-5. SITE PLANS

§ 25-5-3 SMALL PROJECTS.

(A) The director shall determine whether a project is a small project described in this section.

(B) The following are small projects:

(1) construction of a building or parking area if the proposed construction:

(a) does not require a variance from a water quality regulation;

(b) does not exceed 5,000 square feet of impervious cover; and

(c) the construction site does not exceed 10,000 square feet, including the following areas:

(i) construction;

(ii) clearing;

(iii) grading;

(iv) construction equipment access;

(v) driveway reconstruction;

(vi) temporary installations, including portable buildings, construction trailers, storage areas for building materials, spoil disposal areas, erosion and sedimentation controls, and construction entrances;

(vii) landscaping; and

(viii) other areas that the director determines are part of the construction site;

(2) construction of a storm sewer not more than 30 inches in diameter that is entirely in a public right-of-way or an easement;

(3) construction of a utility line not more than eight inches in diameter that is entirely in a public right-of-way;

(4) construction of a left turn lane on a divided arterial street;

(5) construction of street intersection improvements;

(6) widening a public street to provide a deceleration lane if additional right-of-way is not required;

(7) depositing less than two feet of earth fill, if the site is not in a 100 year floodplain and the fill is not to be deposited within the dripline of a protected tree;

(8) construction of a boat dock as an accessory use to a single-family residential use, duplex residential use, two-family residential use, or secondary apartment special use if shoreline modification or dredging of not more than 25 cubic yards is not required; or

(9) construction of a retaining wall, if the wall is less than 100 feet in length and less than eight feet in height, and the back fill does not reclaim a substantial amount of land except land that has eroded because of the failure of an existing retaining wall;

(10) minor development that the director determines is similar to that described in Subsections (B)(1) through (9) of this section;

(11) the replacement of development that is removed as a result of right-of-way condemnation; ~~and~~

(12) the construction of a telecommunications tower described in Subsection 25-2-839(F) or (G) (Telecommunication Towers)**; and**~~.~~

(13) construction of a multi-family residential project of up to 11 units on a platted residential lot, unless an additional number of units is allowed for a qualifying development participating in the Affordability Unlocked Bonus Program (Chapter 25-1, Article 15, Division 4), that:

(a) is not located within in the Barton Springs Zone;

(b) does not exceed 55% impervious cover;

(c) is located on a lot that was originally part of a single family residential subdivision; and

(d) is located on a site of less than half an acre.

(C) Notwithstanding any other provisions in this Section, construction of Shoreline Access, as defined in Section 25-2-1172, that exceeds 50 feet in length and is constructed on slopes exceeding 35% gradient does not constitute a small project.

(D) For a small project, the director may waive a submittal requirement that the director determines is not essential to demonstrate compliance with this title. The director shall maintain a record of submittal requirements that are waived under this subsection.

CHAPTER 25-7. DRAINAGE

§ 25-7-32 DIRECTOR AUTHORIZED TO REQUIRE EROSION HAZARD ZONE ANALYSIS.

(A) The director may require the owner of real property to provide, at the owner's expense and as a condition for development application approval, an analysis to establish the erosion hazard zone if the proposed development is:

(1) within 100 feet of the centerline of a waterway with a drainage area of 64 acres or greater; or

(2) within ~~100~~ **400** feet of the ordinary high water mark of the Colorado River downstream from Longhorn Dam, as defined by Code of Federal Regulations Title 33, Section 328.3 (*Definitions*), unless additional distance is required as determined by the Director; or

(3) located where significant erosion is present **as determined by the director**.

(B) The erosion hazard zone analysis must be in accordance with the Drainage Criteria Manual.

(C) If an erosion hazard zone analysis is required under this section, the City may not accept for review a development application for any portion of the proposed development until the director has received the required erosion hazard zone analysis.

CHAPTER 25-8 SUBCHAPTER A. WATER QUALITY.

§ 25-8-1 DEFINITIONS.

In this subchapter:

(1) BARTON SPRINGS means the springs that comprise the Barton Springs complex associated with Barton Springs Pool, and includes Upper Barton, Old Mill, Eliza, and Parthenia springs.

(2) BLUFF means a vertical change in elevation of more than 40 feet and an average gradient greater than 400 percent.

(3) CANYON RIMROCK means a rock substrate that:

(a) has a gradient that exceeds 60 percent for a vertical distance of at least four feet; and

(b) is exposed for at least 50 feet horizontally along the rim of the canyon.

(4) COMMERCIAL DEVELOPMENT means all development other than open space and residential development.

(5) CLUSTER HOUSING means a residential housing development that maximizes common open space by grouping housing units to minimize individual yards and has a maximum lot area of fifteen thousand (15,000) square feet for detached residential development.

(6) CRITICAL ENVIRONMENTAL FEATURES means features that are of critical importance to the protection of environmental resources, and includes bluffs, canyon rimrocks, caves, faults and fractures, seeps, sinkholes, springs, and wetlands.

(7) DIRECTOR, when used without a qualifier, means the director of the ~~Planning and Development Review~~ **Watershed Protection** Department, or the director's designee.

(8) EROSION HAZARD ZONE means an area where future stream channel erosion is predicted to result in damage to or loss of property, buildings, infrastructure, utilities, or other valued resources.

(9) FAULTS AND FRACTURES means significant fissures or cracks in rock that may permit infiltration of surface water to underground cavities or channels.

(10) FLOODPLAIN MODIFICATION means development that results in any vertical or horizontal change in the cross section of the 100-year floodplain as determined under Section 25-7-6 (*Determination of the 100-Year Floodplain*).
(11) IMPERVIOUS COVER means the total area of any surface that prevents the infiltration of water into the ground, such as roads, parking areas, concrete, and buildings.
(12) MULTI-USE TRAIL means a facility designated for the use of pedestrians, bicycles, and/or other non-motorized users and associated bridges.
(13) OPEN SPACE means a public or private park, multi-use trail, golf cart path, the portions of a golf course left in a natural state, and an area intended for outdoor activities which does not significantly alter the existing natural vegetation, drainage patterns, or increase erosion. OPEN SPACE does not include parking lots.
(14) OWNER includes a lessee.
(15) POINT RECHARGE FEATURE means a cave, sinkhole, fault, joint, or other natural feature that lies over the Edwards Aquifer recharge zone and that may transmit a significant amount of surface water into the subsurface strata.
(16) WATER QUALITY CONTROL means a structure, system, or feature that provides water quality benefits by treating stormwater run-off.
(17) WETLAND means a transitional land between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water, and conforms to the Army Corps of Engineers' definition.

§ 25-8-2 DESCRIPTIONS OF REGULATED AREAS.

(A) This section describes the watersheds, aquifers, and **other** water **quality protection** zones that are regulated by this subchapter. A map of these areas ~~is~~ **shall be** maintained by the Watershed Protection Department and **made** available for **reference** ~~inspection~~ **online and** at the offices of ~~the Planning and Development Review~~ **Development Services** Department.
(B) The director ~~of the Watershed Protection Department~~ shall determine the boundaries of the areas described in Subsection (D).
(C) The director ~~of the Watershed Protection Department~~ may require an applicant to verify the boundary of an area described in Subsection (D). For property within 1,500 feet of an Edwards Aquifer recharge zone boundary, the director of the Watershed Protection Department may require that an applicant provide a certified report from a geologist or hydrologist verifying the boundary location.
(D) In this subchapter:

(1) BARTON SPRINGS ZONE means the Barton Creek watershed and all watersheds that contribute recharge to Barton Springs, including those portions of the Williamson, Slaughter, Onion, Bear and Little Bear Creek watersheds located in the Edwards Aquifer recharge or contributing zones.
(2) BARTON CREEK WATERSHED means the land area that drains to Barton Creek, including Little Barton Creek watershed.
(3) EDWARDS AQUIFER is the water-bearing substrata that includes the stratigraphic rock units known as the Edwards Group and Georgetown Formation.
(4) EDWARDS AQUIFER CONTRIBUTING ZONE means all land generally to the west and upstream of the Edwards Aquifer recharge zone that provides drainage into the Edwards Aquifer recharge zone.
(5) EDWARDS AQUIFER RECHARGE ZONE means all land over the Edwards Aquifer that recharges the aquifer, as determined by the surface exposure of the geologic units comprising the Edwards Aquifer, including the areas overlain with quaternary terrace deposits.
(6) SOUTH EDWARDS AQUIFER RECHARGE ZONE means the portion of the Edwards Aquifer recharge zone that is located south of the Colorado River and north of the Blanco River.
(7) SUBURBAN WATERSHEDS include all watersheds not otherwise classified as urban, water supply suburban, or water supply rural watersheds, and include:

(a) the Brushy, Buttercup, Carson, Cedar, Cottonmouth, Country Club East, Country Club West, Decker, Dry Creek East, Elm Creek, Elm Creek South, Gilleland, Harris Branch, Lake, Lockwood, Maha, Marble, North Fork Dry, Plum, Rattan, Rinard, South Boggy, South Fork Dry, South Brushy, Walnut, and Wilbarger creek watersheds;
(b) the Colorado River watershed downstream of U.S. 183; and
(c) those portions of the Onion, Bear, Little Bear, Slaughter, and Williamson creek watersheds not located in the Edwards Aquifer recharge or contributing zones.

(8) URBAN WATERSHEDS include:

(a) the Blunn, Buttermilk, Boggy, East Bouldin, Fort, Harper Branch, Johnson, Little Walnut, Shoal, Tannehill, Waller, and West Bouldin creek watersheds;
(b) the north side of the Colorado River watershed from Johnson Creek to U.S. 183; and
(c) the south side of the Colorado River watershed from Barton Creek to U.S. 183.

(9) WATER SUPPLY RURAL WATERSHEDS include:

(a) the Lake Travis watershed;
(b) the Lake Austin watershed, excluding the Bull Creek watershed and the area to the south of Bull Creek and the east of Lake Austin; and
(c) the Bear West, Bee, Bohl's Hollow, Cedar Hollow, Coldwater, Commons Ford, Connors, Cuernavaca, Harrison Hollow, Hog Pen, Honey, Little Bee, Panther Hollow, Running Deer, St. Stephens, Steiner, and Turkey Creek watersheds.

(10) WATER SUPPLY SUBURBAN WATERSHEDS include:

(a) the Bull, Eanes, Dry Creek North, Huck's Slough, Taylor Slough North, Taylor Slough South, and West Bull creek watersheds;
(b) the Lady Bird Lake watershed on the south side of Lady Bird Lake from Barton Creek to Tom Miller Dam;
(c) the Lady Bird Lake watershed on the north side of Lady Bird Lake from Johnson Creek to Tom Miller Dam; and
(d) the Lake Austin watershed on the east side of Lake Austin from Tom Miller Dam to Bull Creek.

Division 2. Applicability; Exemptions; Exceptions.

§ 25-8-21 APPLICABILITY.

(A) Except as provided in Subsection~~s~~ **(B) and (C)**, this subchapter applies in the planning jurisdiction.
(B) For a preliminary plan, final plat, or subdivision construction plan in the portion of the city's extraterritorial jurisdiction that is within Travis County:

(1) this subchapter does not apply; and
(2) Title 30 (*Austin/Travis County Subdivision Regulations*) governs.

(C) The following requirements of this subchapter apply to residential construction of one to eleven units;
(1) 25-8-261 Critical Water Quality Zone Restrictions, for a legal tract or a lot platted on or after May 18, 1986, and for development associated with boat docks, shoreline access, or shoreline modifications including bulkheads and bank stabilization;
(2) 25-8-63 Impervious Cover Calculations;
(3) 25-8 Article 2 Waterways Classified; Zones Established for a legal tract or a lot platted on or after May 18, 1986, and for development associated with boat docks, shoreline access, or shoreline modifications including bulkheads and bank stabilization;
(4) 25-8 Article 5 Erosion and Sedimentation Control; Overland Flow;
(5) 25-8-321 Clearing of Vegetation;
(6) 25-8-323 Temporary Storage Areas; Topsoil Protection
(7) 25-8-341 Cut Requirements;

(8) 25-8-342 Fill Requirements;
(9) 25-8-364 Floodplain Modifications for a legal tract or a lot platted on or after May 18, 1986, and for development associated with boat docks, shoreline access, or shoreline modifications including bulkheads and bank stabilization;
(10) 25-8-368 Restrictions on Development Impacting Lake Austin, Lady Bird Lake, and Lake Walter E Long;
(11) Article 13 Save Our Springs

(D) Compliance with municipal regulatory restrictions on a recorded plat or covenant is required, to the extent the director determines that the restrictions are applicable.

§ 25-8-25 REDEVELOPMENT EXCEPTION IN URBAN AND SUBURBAN WATERSHEDS.

(A) This section applies to property located in an urban or suburban watershed that has existing development if:

(1) ~~no unpermitted development occurred on the site after January 1, 1992, and~~ **Any development constructed without a permit after January 1, 1992 will be removed from the site and the area restored to pre-development conditions; and**

(2) ~~the property owner files a site plan application and an election for the property to be governed by this section.~~ **The applicant files a site plan application or concurrent subdivision and site plan applications and elects for the property to be governed by this section.**

~~(B) The requirements of this subchapter do not apply to the subdivision of property if at the time of redevelopment under this section subdivision and site plan applications are filed concurrently.~~

(~~C~~**B**) The requirements of this subchapter do not apply to the redevelopment of the property if the redevelopment:

(1) does not increase the existing amount of impervious cover **on the site**;

(2) removes existing impervious cover from within 50 feet of the centerline of a classified waterway, or 50' from the shoreline of a lake, or 100' from the Ordinary High Water Mark of the Colorado River, and revegetates the area as prescribed in the Environmental Criteria Manual;

(~~2~~**3**) provides the level of water quality treatment prescribed by current regulations for the redeveloped area or an equivalent area on the site;

~~(3) does not generate more than 2,000 vehicle trips a day above the estimated traffic level based on the most recent authorized use on the property;~~

~~(4) is consistent with the neighborhood plan adopted by council, if any;~~

(~~5~~**4**) does not increase non-compliance, if any, with Article 7, Division 1 (*Critical Water Quality Zone Restrictions*), Section 25-8-281 (*Critical Environmental Features*), or Section 25-8-282 (*Wetland Protection*); and

(5) complies with Article 3 (Environmental Resource Inventory; Pollutant Attenuation Plan) and all construction phase environmental standards in effect at the time of construction, including Article 5 (Erosion and Sedimentation Control; Overland Flow); and

(6) does not place redevelopment within the Erosion Hazard Zone, unless protective works are provided as prescribed in the Drainage Criteria Manual.

~~(D) The redevelopment must comply with Section 25-8-121 (*Environmental Resource Inventory Requirement*) and all construction phase environmental requirements in effect at the time of construction, including Chapter 25-8, Article 5 (*Erosion and Sedimentation Control; Overland Flow*).~~

§ 25-8-26 REDEVELOPMENT EXCEPTION IN THE BARTON SPRINGS ZONE.

(A) This section applies to property located in the Barton Springs Zone that has existing commercial development if:

(1) no unpermitted development occurred on the site after January 1, 1992, and
(2) the property owner files a site plan application and an election for the property to be governed by this section.

(B) For property governed by this section, this section supersedes Article 13 (*Save Our Springs Initiative*), to the extent of conflict.

(C) In this section:

(1) ~~**SEDIMENTATION/FILTRATION POND**~~ **STANDARD POND** means water quality controls that comply with Section 25-8-213 (*Water Quality Control Standards*) or are approved under Section 25-8-151 (*Innovative Management Practices*); and

(2) SOS POND means water quality controls that comply with all requirements of Section 25-8-213 (*Water Quality Control Standards*) and the pollutant removal requirements of Section 25-8-514(A) (*Pollution Prevention Required*).

(D) The requirements of this subchapter do not apply to the subdivision of property if at the time of redevelopment under this section subdivision and site plan applications are filed concurrently.

(E) The requirements of this subchapter do not apply to the redevelopment of property if the redevelopment meets all of the following conditions:

(1) The redevelopment may not increase the existing amount of impervious cover on the site.

(2) The redevelopment may not increase non-compliance, if any, with Article 7, Division 1 (*Critical Water Quality Zone Restrictions*), Section 25-8-281 (*Critical Environmental Features*), Section 25-8-282 (*Wetland Protection*), or Section 25-8-482 (*Water Quality Transition Zone*).

(3) The redevelopment must comply with ~~**Section 25-8-121**~~**Article 3** (*Environmental Resource Inventory Requirement*~~**;**~~ ***Pollution Attenuation Plan***) and all construction phase environmental requirements in effect at the time of construction, including Chapter 25-8, Article 5 (*Erosion and Sedimentation Control; Overland Flow*) and Section 25-8-234 (*Fiscal Security in the Barton Springs Zone*).

(4) The water quality controls on the redevelopment site must provide a level of water quality treatment that is equal to or greater than that which was previously provided.

(5) For a commercial or multifamily redevelopment, the owner or operator must obtain a permit under Section 25-8-233 (*Barton Springs Zone Operating Permit*) for both ~~**sedimentation/filtration**~~ **standard** ponds and SOS ponds.

(6) For a site with more than 40 percent net site area impervious cover, the redevelopment must have:

(a) ~~**sedimentation/filtration**~~ **standard** ponds for the entire site; or

(b) SOS ponds for a portion of the site, and ~~**sedimentation/filtration**~~ **standard** ponds for the remainder of the redeveloped site.

(7) For a site with 40 percent or less net site area impervious cover, the redevelopment must have SOS ponds for the entire site.

(8) The property owner must mitigate the effects of the redevelopment, if required by and in accordance with Subsection (H).

(9) Redevelopment may not be located within the Erosion Hazard Zone, unless protective works are provided as prescribed in the Drainage Criteria Manual.

(F) City Council approval of a redevelopment in accordance with Subsection (G) is required if the redevelopment:

(1) includes more than 25 dwelling units;

(2) is located outside the City's zoning jurisdiction;

(3) is proposed on property with an existing industrial or civic use;

(4) is inconsistent with a neighborhood plan; or

(5) will generate more than 2,000 vehicle trips a day above the estimated traffic level based on the most recent authorized use on the property.

(G) City Council shall consider the following factors in determining whether to approve a proposed redevelopment:

(1) benefits of the redevelopment to the community;

(2) whether the proposed mitigation or manner of development offsets the potential environmental impact of the redevelopment;
(3) the effects of offsite infrastructure requirements of the redevelopment; and
(4) compatibility with the City's comprehensive plan.

(H) Redevelopment of property under this section requires the purchase or restriction of mitigation land if the site has a sedimentation/filtration pond.

(1) The combined gross site area impervious cover of the mitigation land and the portion of the redevelopment site treated by sedimentation/filtration ponds may not exceed 20 percent.
(2) The mitigation requirement may be satisfied by:

(a) paying into the Barton Springs Zone Mitigation Fund a non-refundable amount established by ordinance;
(b) transferring to the City in accordance with Paragraph (3) mitigation land approved by the director of the Watershed Protection Department within a watershed that contributes recharge to Barton Springs, either inside or outside the City's jurisdiction;
(c) placing restrictions in accordance with Paragraph (3) on mitigation land approved by the director of the Watershed Protection Department within a watershed that contributes recharge to Barton Springs, either inside or outside the City's jurisdiction; or
(d) a combination of the mitigation methods described in Subparagraphs (a) - (c), if approved by the director of the Watershed Protection Department.

(3) A person redeveloping under this section shall pay all costs of restricting the mitigation land or transferring the mitigation land to the City, including the costs of:

(a) an environmental site assessment without any recommendations for further clean-up, certified to the City not earlier than the 120th day before the closing date transferring land to the City;
(b) a category 1(a) land title survey, certified to the City and the title company not earlier than the 120th day before the closing date transferring land to the City;
(c) a title commitment with copies of all Schedules B and C documents, and an owner's title policy;
(d) a fee simple deed, or, for a restriction, a restrictive covenant approved as to form by the city attorney;
(e) taxes prorated to the closing date;
(f) recording fees; and
(g) charges or fees collected by the title company.

(I) The Watershed Protection Department shall adopt rules to identify criteria for director approval under this section to ensure that the proposed mitigation, manner of development, and water quality controls offset the potential environmental impact of the redevelopment.

§ 25-8-27 REDEVELOPMENT EXCEPTION IN THE WATER SUPPLY RURAL AND WATER SUPPLY SUBURBAN WATERSHEDS.

(A) This section applies to property located in a water supply rural or water supply suburban watershed that has existing commercial development or existing residential development with greater than two dwelling units per lot if:

(1) **any development constructed without a permit after January 1, 1992 will be removed from the site and the area restored to pre-development conditions** ~~**no unpermitted development occurred on the site after January 1, 1992**~~, and
(2) **the applicant files a site plan application or concurrent subdivision and site plan applications and elects for the property to be governed by this section** ~~**the property owner files a site plan application and an election for the property to be governed by this section**~~**.**

(B) In this section, ~~SEDIMENTATION/FILTRATION POND~~ **STANDARD POND** means water quality controls that comply with Section 25-8-213 (*Water Quality Control Standards*) or are approved under Section 25-8-151 (*Innovative Management Practices*).

~~(C) The requirements of this subchapter do not apply to the subdivision of property if at the time of redevelopment under this section subdivision and site plan applications are filed concurrently.~~

(D) The requirements of this subchapter do not apply to the redevelopment of property if the redevelopment meets all of the following conditions:

(1) The redevelopment may not increase the existing amount of impervious cover on the site.

(2) The redevelopment may not increase non-compliance, if any, with Article 7, Division 1 (*Critical Water Quality Zone Restrictions*), Section 25-8-281 (*Critical Environmental Features*), Section 25-8-282 (*Wetland Protection*), Section 25-8-422 (*Water Quality Transition Zone*), or Section 25-8-452 (*Water Quality Transition Zone*).

(2) The redevelopment must remove any existing impervious cover from within 50 feet of the centerline of a classified waterway or 50' from the shoreline of a lake and revegetate the area as prescribed in the Environmental Criteria Manual.

(3) The redevelopment must comply with ~~Section 25-8-121~~**Article 3** (*Environmental Resource Inventory Requirement*~~*;*~~ ***; Pollutant Attenuation Plan*)** and all construction phase environmental requirements in effect at the time of construction, including Chapter 25-8, Article 5 (*Erosion and Sedimentation Control; Overland Flow*).

(4) The water quality controls for the redeveloped areas or an equivalent area on the site must provide a level of water quality treatment that is equal to or greater than that which was previously provided. At a minimum, the site must provide ~~sedimentation/filtration~~ **standard** ponds for the redeveloped area or an equivalent area on the site.

(5) The ~~property owner~~ **applicant** must mitigate the effects of the redevelopment, if required by and in accordance with Subsection (G).

(6) Redevelopment may not be located within the Erosion Hazard Zone, unless protective works are provided as prescribed in the Drainage Criteria Manual.

~~(E) City Council approval of a redevelopment in accordance with Subsection (F) is required if the redevelopment:~~

~~(1) includes more than 25 additional dwelling units;~~
~~(2) is located outside the City's zoning jurisdiction;~~
~~(3) is proposed on property with an existing industrial use;~~
~~(4) is inconsistent with a neighborhood plan; or~~
~~(5) will generate more than 2,000 vehicle trips a day above the estimated traffic level based on the most recent authorized use on the property.~~

~~(F) City Council shall consider the following factors in determining whether to approve a proposed redevelopment:~~

~~(1) benefits of the redevelopment to the community;~~
~~(2) whether the proposed mitigation or manner of development offsets the potential environmental impact of the redevelopment;~~
~~(3) the effects of off-site infrastructure requirements of the redevelopment; and~~
~~(4) compatibility with the City's comprehensive plan.~~

(G) Redevelopment of property under this section requires the purchase or restriction of mitigation land.

(1) The combined impervious cover of the mitigation land and the portion of the redevelopment treated by sedimentation/filtration ponds may not exceed 20 percent of gross site area if in a water supply rural watershed or 40 percent of gross site area if in a water supply suburban watershed.

(2) The mitigation requirement may be satisfied by:

(a) paying into the Water Supply Mitigation Fund a nonrefundable amount established by ordinance;

(b) transferring to the City in accordance with Paragraph (3) mitigation land approved by the director of the Watershed Protection Department within a water supply rural or water supply suburban watershed, either inside or outside the City's jurisdiction;
(c) placing restrictions in accordance with Paragraph (3) on mitigation land approved by the director of the Watershed Protection Department within a water supply rural or water supply suburban watershed, either inside or outside the City's jurisdiction; or
(d) a combination of the mitigation methods described in Subparagraphs (a)—(c), if approved by the director of the Watershed Protection Department.

(3) A**n** **applicant** ~~**person**~~ redeveloping under this section shall pay all costs of restricting the mitigation land or transferring the mitigation land to the City, including the costs of:

(a) an environmental site assessment without any recommendations for further clean-up, certified to the City not earlier than the 120th day before the closing date transferring land to the City;
(b) a category 1(a) land title survey, certified to the City and the title company not earlier than the 120th day before the closing date transferring land to the City;
(c) a title commitment with copies of all Schedule B and C documents, and an owner's title policy;
(d) a fee simple deed, or, for a restriction, a restrictive covenant approved as to form by the City Attorney;
(e) taxes prorated to the closing date;
(f) recording fees; and
(g) charges or fees collected by the title company.

(H) The Watershed Protection Department shall adopt rules to identify criteria for ~~**director**~~ approval under this section to ensure that the proposed mitigation, manner of development, and water quality controls offset the potential environmental impact of the redevelopment.

Division 3. Variances.

§ 25-8-42 ADMINISTRATIVE VARIANCES.

(A) A variance under this section may not vary the requirements of Article 13 (*Save Our Springs Initiative*) ~~**and may not be granted for development of a property if any portion of the property abuts or is within 500 feet of the shoreline of Lake Austin, measured horizontally**~~.

(B) The director of the Watershed Protection Department may grant a variance from a requirement of:

(1) Subsection 25-8-213(C) (Water Quality Control Standards);

(**2**~~**1**~~) Section 25-8-261 (*Critical Water Quality Zone Development*), only if:

(a) necessary to protect public health and safety, or if ~~**it**~~ **the type of development requiring the variance** ~~**would**~~ **directly contributes to** ~~**provide**~~ a significant, demonstrable environmental benefit, as determined by a functional assessment of floodplain health as prescribed by the Environmental Criteria Manual,
(b) necessary to allow an athletic field in existence on October 28, 2013, to be maintained, improved, or replaced,
(c) necessary to allow an athletic field to be located in an area not otherwise allowed under Section 25-8-261(B)(5), or
(d) necessary to allow a hard surfaced trail to be located in an area not otherwise allowed under Section 25-8-261(B)(3);
(e) necessary to allow the specified green stormwater infrastructure to be located in an area not otherwise allowed under Section 25-8-261(H);
(f) except in the Barton Springs Zone, necessary to allow a private driveway or private street to cross a Critical Water Quality Zone if the crossing is necessary to provide primary access to the right-of-way or the crossing is required to comply with public health and safety requirements

(g) necessary to allow residential use of up to 11 units located on an existing single family platted lot

(**~~3~~2**) Section 25-8-261 (*Critical Water Quality Zone Development*), for development within an urban watershed, only if the proposed development:

(a) is located not less than 25 feet from the centerline of a waterway,
(b) is located outside the erosion hazard zone, unless protective works are provided as prescribed in the Drainage Criteria Manual,
(c) does not increase non-compliance, if any, with Article 7, Division 1 (*Critical Water Quality Zone Restrictions*), Section 25-8-281 (*Critical Environmental Features*) or Section 25-8-282 (*Wetland Protection*), and
(d) restores native vegetation and soils if development is removed from the Critical Water Quality Zone;

(**~~4~~3**) Subsection 25-8-262(B) (*Critical Water Quality Zone Street Crossings*), only outside the Barton Springs Zone;
(**~~5~~4**) Section 25-8-281 (*Critical Environmental Features*);
(**~~6~~5**) Section 25-8-322 (*Clearing for a Roadway*);
(**~~7~~6**) Section 25-8-341 (*Cut Requirements*) or Section 25-8-342 (*Fill Requirements*), for **a cut or fill of not more than eight feet:**
(a) in the desired development zone**; ~~and,~~**
(b) for a public primary or secondary educational facility**~~, within the desired development zone or the drinking water protection zone; and~~** or
(c) for residential use residential construction of up to 11 units located on an existing single family platted lot.
(**~~8~~7**) Subsection 25-8-343(A) (*Spoil Disposal*);
(**~~9~~8**) Section 25-8-365 (*Interbasin Diversion*).
(**~~10~~9**) Subsection 25-8-392(B)(61 (Uplands Zone), Subsection 25-8-392(C)(61 (Uplands Zone), Subsection 25-8-423(D) (Uplands Zone), or Subsection 25-8-453(El (Uplands Zone).

(C) It is the applicant's burden to establish that the findings described in this Section have been met.
(D) The director of the Watershed Protection Department may grant a variance described in Subsection (B) only after determining that development in accordance with the variance meets the objective of the requirement for which the variance is requested and:

(1) for property in the Barton Springs Zone, the variance will result in water quality that is at least equal to the water quality achievable without the variance;
(2) for a variance from Section 25-8-213(C), that the proposed water quality control is necessitated by unique site conditions, excluding any potential loss of impervious cover entitlements resulting from full compliance;
(3) for a variance from Section 25-8-261 necessary to allow a private driveway or private street to cross a Critical Water Quality Zone the applicant must demonstrate compliance with the following:
a) The crossing must span the active channel or use open bottom culverts as determined by the ;
b) In suburban watersheds, Critical Water Quality Zone buffer averaging must be applied to the extent feasible in order to minimize the area of the private driveway within the Critical Water Quality Zone impacted by the crossing;
c) The location of the crossing must minimize impacts to critical environmental features, protected and heritage trees, slopes greater than 15%, and must minimize the amount of cut or fill necessary for construction; and
d) The construction is not located in the Barton Springs Zone.
(4) for a variance from 25-8-261 necessary to allow residential construction of up to 11 units located on an existing single family platted lot if:
(1) the modification is the minimum deviation necessary to ensure reasonable use and maintenance of the property for an existing nonconforming structure;

(2) for new development the director determines that:

(i) the usable lot area cannot accommodate the assumed square footage of impervious cover established under 25-8-64 Impervious Cover Assumptions, after accounting for all applicable regulations;

(ii) the total proposed impervious cover does not exceed the assumed square footage of impervious cover established; and

(iii) the development is the minimum deviation necessary to accommodate the development.

(5~~2~~) for a variance from Section 25-8-261(B)(5), that the proposed work on or placement of the athletic field will have no adverse environmental impacts;

(6~~3~~) **for a variance from Section 25-8-261(H), that the green stormwater infrastructure is:**
(a) not required for regulatory compliance with 25-8-211 Water Quality Requirement.
(b) designed to capture runoff from existing, untreated impervious cover; and
(c) proposed in a location that is the minimum necessary departure from the code requirement;

(7~~4~~) for a variance from Section 25-8-281, that the proposed ~~measures~~ **development does not include mechanized shoreline access and the proposed measures** preserve all characteristics of the critical environmental feature;

(8~~5~~) for a variance from Section 25-8-341 or Section 25-8-342 the cut or fill is not located on a slope with a gradient of more than 15 percent or within 100 feet of a classified waterway;

(9~~6~~) **for a variance from Section 25-8-341 or Section 25-8-342 necessary to allow residential construction of up to 11 units located on an existing single family platted lot if:**
(a) for an existing nonconforming structure, the modification is the minimum deviation necessary to ensure reasonable use and maintenance of the property; or
(b) for new development, the director determines that:
(i) the usable lot area cannot accommodate the assumed square footage of impervious cover established under 25-8-64 Impervious Cover Assumptions, after accounting for all applicable regulations;
(ii) the total proposed impervious cover does not exceed the assumed square footage of impervious cover established; and
(iii) the development is the minimum deviation necessary to accommodate the development.

(10~~7~~) for a variance from Section 25-8-343(A), use of the spoil provides a necessary public benefit. Necessary public benefits include:

(a) roadways;
(b) stormwater detention facilities;
(c) public or private park sites; and
(d) building sites that comply with Section 25-8-341 (*Cut Requirements*), Section 25-8-342 (*Fill Requirements*), and Chapter 25-7 (*Drainage*); and

(11~~8~~) for a variance from Section 25-8-365, there are no adverse environmental or drainage impacts.

(12~~9~~) or a variance from Subsection 25-8-392(B)(6), Subsection 25-8-392(C)(6), Subsection 25-8-423(D), or Subsection 25-8-453(E), the variance:

(a) is the minimum deviation needed to provide necessary improvements for a public mobility project in the right-of-way; and

(b) does not create significant adverse environmental impacts.

(E) The Watershed Protection Department director shall prepare written findings to support the grant or denial of a variance request under this section.

Division 4. Impervious Cover Determinations.

§ 25-8-62 NET SITE AREA.

(A) Net site area includes only the portions of a site that lie in an uplands zone and have not been designated for **surface or subsurface** wastewater irrigation.

(B) For land described in Subsection (A), net site area is the aggregate of:

(1) 100 percent of the land with a gradient of 15 percent or less;
(2) 40 percent of the land with a gradient of more than 15 percent and not more than 25 percent; and
(3) 20 percent of the land with a gradient of more than 25 percent and not more than 35 percent.

(C) Net site area does not apply in the urban and suburban watersheds.

§ 25-8-63 IMPERVIOUS COVER CALCULATIONS.

(A) Impervious cover is calculated in accordance with this Section and the Environmental Criteria Manual.

(B) Impervious cover calculations include:

(1) roads;
(2) driveways;
(3) parking areas;
(4) buildings;
(5) concrete;
(6) impermeable construction covering the natural land surface;
(7) for an uncovered wood deck that has drainage spaces between the deck boards and that is located over a pervious surface, 50 percent of the horizontal area of the deck; and
(8) the portion of a site used for the storage of scrap and metal salvage, including auto salvage.

(C) Impervious cover calculations exclude:

(1) sidewalks in a public right-of-way or public easement;
(2) multi-use trails open to the public and located on public land or in a public easement;
(3) water quality controls, excluding subsurface water quality controls;
(4) detention basins, excluding subsurface detention basins;
(5) ground level rainwater harvesting cisterns, excluding subsurface cisterns;
(~~5~~6) drainage swales and conveyances;
(~~6~~7) the water surface area of ground level pools, fountains, and ponds;
(~~7~~8) areas with gravel placed over pervious surfaces that are used only for landscaping or by pedestrians and are not constructed with compacted base;
(~~8~~9) porous pavement designed in accordance with the Environmental Criteria Manual, limited to only pedestrian walkways and multi-use trails, and located outside the Edwards Aquifer Recharge Zone;
(~~9~~10) fire lanes designed as prescribed by the Environmental Criteria Manual, that consist of interlocking pavers, and are restricted from routine vehicle access;
(~~10~~11) an access ramp for an existing single-family and duplex residential unit if:

(a) a person with a disability requires access to a dwelling entrance that meets the requirements of the Residential Code, Section R320.6 (*Visitable dwelling entrance*);
(b) the building official determines that the ramp will not pose a threat to public health and safety;
(c) the ramp:

(i) is no wider than 48 inches, except that any portion of a landing for the ramp required for turns may be no wider than 60 inches; and
(ii) may have a hand railing, but may not have a roof or walls; and

(d) the ramp is located in a manner that utilizes existing impervious cover to the greatest extent possible if:

(i) impervious cover on the property is at or above the maximum amount of impervious cover allowed by this title; or

(ii) if placement of the ramp would result in the property exceeding the maximum amount of impervious cover allowed by this title; and

(~~11~~12) a subsurface portion of a parking structure if the director of the Watershed Protection Department determines that:

(a) the subsurface portion of the structure:

(i) is located within an urban or suburban watershed;

(ii) is below the grade of the land that existed before construction of the structure;

(iii) is covered by soil with a minimum depth of two feet and an average depth of not less than four feet; and

(iv) has an area not greater than fifteen percent of the site;

(b) the structure is not associated with a use regulated by Section 1.2.2 of Subchapter F of Chapter 25-2 (*Residential Design and Compatibility Standards*);

(c) the applicant submits an assessment of the presence and depth of groundwater at the site sufficient to determine whether groundwater will need to be discharged or impounded; and

(d) the applicant submits documentation that the discharge or impoundment of groundwater from the structure, if any, will be managed to avoid adverse effects on public health and safety, the environment, and adjacent property.

(13) For purposes of residential building permit review only, no more than two feet of elevated, projecting elements such as eaves, overhangs, cantilevered portions of structures, balconies, awnings, and bay windows. This exemption does not apply to site plans or the calculation of the drainage charge under Section 15-2-5 (*Impervious Cover Calculation*).

§ 25-8-64 IMPERVIOUS COVER ASSUMPTIONS.

(A) This section applies to impervious cover calculations for duplex or single-family lots.

(B) Except as provided in Subsection (C):

(1) for each lot greater than three acres in size, 10,000 square feet of impervious cover is assumed;

(2) for each lot greater than one acre and not more than three acres in size, 7,000 square feet of impervious cover is assumed;

(3) for each lot greater than 15,000 square feet and not more than one acre in size, 5,000 square feet of impervious cover is assumed;

(4) for each lot greater than 10,000 square feet and not more than 15,000 square feet in size, 3,500 square feet of impervious cover is assumed; and

(5) for each lot not more than 10,000 square feet in size, 2,500 square feet of impervious cover is assumed.

(C) For a lot that is restricted to a lesser amount of impervious cover than prescribed by this section, the lesser amount of impervious cover is assumed. The manner in which the lot is restricted is subject to the approval of the director.

(D) Except as provided in Subsection (C), this section does not restrict impervious cover on an individual lot.

(E) The applicant must demonstrate that all proposed one and two-unit residential lots have usable lot area that can reasonably accommodate the assumed square footage of impervious cover established by Subsection (B). The usable lot area must account for all applicable waterway setbacks, floodplains, steep slopes, critical environmental features, protected trees, on-site sewage facilities, and other relevant code restrictions.

ARTICLE 2. WATERWAYS CLASSIFIED; ZONES ESTABLISHED.

§ 25-8-92 CRITICAL WATER QUALITY ZONES ESTABLISHED.

(A) In the water supply rural watersheds, water supply suburban watersheds, and Barton Springs Zone, a critical water quality zone is established along each waterway classified under Section 25-8-91 (*Waterway Classifications*).

(1) The boundaries of a critical water quality zone coincide with the boundaries of the 100-year flood plain as determined under Section 25-7-6 (Determination of the 100-Year Floodplain), except:

(a) for a minor waterway, the boundaries of the critical water quality zone are located not less than 50 feet and not more than 100 feet from the centerline of the waterway;
(b) for an intermediate waterway, the boundaries of the critical water quality zone are located not less than 100 feet and not more than 200 feet from the centerline of the waterway;
(c) for a major waterway, the boundaries of the critical water quality zone are located not less than 200 feet and not more than 400 feet from the centerline of the waterway; and
(d) for the main channel of Barton Creek, the boundaries of the critical water quality zone are located 400 feet from the centerline of the creek.

(2) Notwithstanding the provisions of Subsections (A)(1)(a), (b), and (c), a critical water quality zone does not apply to a **drainage ditch located parallel and adjacent to ~~previously modified drainage feature serving~~** a railroad or public roadway right-of-way **if the ditch: ~~that does not possess any natural and traditional character and cannot reasonably be restored to a natural condition, as prescribed in the Envionmental Criteria Manual.~~**

(a) was designed and constructed primarily to serve the adjacent railroad or public roadway;
(b) is not a segment or modification of a natural waterway;
(c) does not possess any natural and traditional character; and
(d) cannot reasonably be restored to a natural condition due to existing site constraints.

(B) In the suburban watersheds, a critical water quality zone is established along each waterway classified under Section 25-8-91 (*Waterway Classifications*).

(1) for a minor waterway, the boundaries of the critical water quality zone are located 100 feet from the centerline of the waterway;
(2) for an intermediate waterway, the boundaries of the critical water quality zone are located 200 feet from the centerline of the waterway;
(3) for a major waterway, the boundaries of the critical water quality zone are located 300 feet from the centerline of the waterway;
(4) the critical water quality zone boundaries may be reduced to not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, **~~and~~** 150 feet from the centerline of a major waterway**, and 200 feet from the Ordinary High Water Mark of the Colorado River downstream of the Longhorn Dam** if the overall surface area of the critical water quality zone is the same or greater than the surface area that would be provided without the reduction, as prescribed in the Environmental Criteria Manual; and
(5) notwithstanding the provisions of Subsections (B)(1), (2), and (3), a critical water quality zone does not apply to a **drainage ditch located parallel and adjacent to ~~previously modified drainage feature serving~~** a railroad or public roadway right-of-way **if the ditch: ~~that does not possess any natural and traditional character and cannot reasonably be restored to a natural condition~~.**

(a) was designed and constructed primarily to serve the adjacent railroad or public roadway;
(b) is not a segment or modification of a natural waterway;
(c) does not possess any natural and traditional character; and
(d) cannot reasonably be restored to a natural condition due to existing site constraints.

(C) In an urban watershed, a critical water quality zone is established along each waterway with a drainage area of at least 64 acres. This does not apply in the area bounded by IH-35, Riverside Drive, Barton Springs Road, Lamar Boulevard, and 15th Street.

(1) The boundaries of the critical water quality zone coincide with the boundaries of the 100-year floodplain as determined under Section 25-7-6 (*Determination of the 100-Year Floodplain*), provided that the boundary is not less than 50 feet and not more than 400 feet from the centerline of the waterway.

(2) Notwithstanding the provisions of Subsection (C)(1), a critical water quality zone does not apply ~~to a previously modified drainage feature serving~~ **drainage ditch located parallel and adjacent to** a railroad or public roadway right-of-way **if the ditch:** ~~that does not possess any natural and traditional character and cannot reasonably be restored to a natural condition.~~

(a) was designed and constructed primarily to serve the adjacent railroad or public roadway;
(b) is not a segment or modification of a natural waterway;
(c) does not possess any natural and traditional character; and
(d) cannot reasonably be restored to a natural condition due to existing site constraints.

(D) Critical water quality zones are established to include the inundated areas that constitute Lake Walter E. Long, Lake Austin, Lady Bird Lake, and the Colorado River downstream of Lady Bird Lake.

(E) Critical water quality zones are established along and parallel to the shorelines of Lake Travis, Lake Austin, Lady Bird Lake, and Lake Walter E. Long.

(1) The shoreline boundary of a critical water quality zone:

(a) for Lake Travis, coincides with the 681.0 foot contour line;
(b) for Lake Austin, coincides with the 492.8 foot contour line;
(c) for Lady Bird Lake, coincides with the 429.0 foot contour line; and
(d) for Lake Walter E. Long, coincides with the 554.5 foot contour line.

(2) The width of a critical water quality zone, measured horizontally inland, is:

(a) 100 feet; or
(b) for a detached single-family residential use, 75 feet.

(F) Critical water quality zones are established along and parallel to the shorelines of the Colorado River downstream of Lady Bird Lake.

(1) The shoreline boundary of a critical water quality zone coincides with the river's ordinary high water mark, as defined by Code of Federal Regulations Title 33, Section 328.3 (*Definitions*)~~.~~

(2) **The width of a critical water quality zone, measured horizontally inland, is 400 feet.** ~~**The inland boundary of a critical water quality zone coincides with the boundary of the 100-year floodplain as determined under Section 25-7-6 (*Determination of the 100-Year Floodplain*) except that the width of the critical water quality zone, measured horizontally inland, is not less than 200 feet and not more than 400 feet.**~~

ARTICLE 3. ENVIRONMENTAL RESOURCE INVENTORY; POLLUTANT ATTENUATION PLAN.

§ 25-8-121 ENVIRONMENTAL RESOURCE INVENTORY REQUIREMENT.

(A) An applicant shall file an environmental resource inventory with the director for proposed developmentlocated on a tract:

(1) within the Edwards Aquifer recharge ~~**or contributing**~~ zone;
~~**(2) within the Drinking Water Protection Zone;**~~
~~**(3) containing a water quality transition zone;**~~
(**2**4) containing a critical water quality zone;~~**or**~~
(**3**~~5~~) with a gradient of more than 15 percent**; or**

(4) containing, or within 150 feet of, a potential or verified wetland feature as identified in a map maintained by the Watershed Protection Department and made available for reference online and at the offices of Development Services Department.

(B) An environmental resource inventory must:

(1) identify critical environmental features and propose protection measures for the features;
(2) provide an environmental justification for spoil disposal locations or roadway alignments;
(3) propose methods to achieve overland flow;
(4) describe proposed industrial uses and the pollution abatement program; and
(5) be completed as prescribed by the Environmental Criteria Manual.

(C) An environmental resource inventory must include:

(1) a hydrogeologic report in accordance with Section 25-8-122 (*Hydrogeologic Report*);
(2) a vegetation report in accordance with Section 25-8-123 (*Vegetation Report*); and
(3) a wastewater report in accordance with Section 25-8-124 (*Wastewater Report*).

(D) The director of the Watershed Protection Department may permit an applicant to exclude from an environmental resource inventory information required by this section after determining that the information is unnecessary because of the scope and nature of the proposed development.

ARTICLE 5. EROSION AND SEDIMENTATION CONTROL; OVERLAND FLOW.

§ 25-8-182 DEVELOPMENT COMPLETION.

(A) Development is not completed until:

(1) permanent revegetation is established; and
(2) the **director** ~~**Planning and Development Review Department**~~:

(a) receives the engineer's concurrence letter; and
(b) certifies installation of the vegetation for acceptance.

(B) Development must be completed under Subsection (A) before the City may accept maintenance responsibility for streets, drainage facilities, or utilities, or issue a certificate of occupancy or compliance, unless the City and the applicant enter into an agreement to ensure completion of the revegetation within a named period.

§ 25-8-184 ADDITIONAL EROSION AND SEDIMENTATION CONTROL REQUIREMENTS IN THE BARTON SPRINGS ZONE.

(A) This section provides additional erosion and sedimentation control requirements for development in the Barton Springs Zone.

(B) A temporary erosion and sedimentation control plan and a water quality plan certified by a registered professional engineer and approved by the ~~**Planning and Development Review Department**~~ **director** is required.

(1) The plans must describe the temporary structural controls, site management practices, or other approved methods that will be used to control of off-site sedimentation until permanent revegetation is certified as completed under Section 25-8-182 (*Development Completion*).
(2) The temporary erosion control plan must be phased to be effective at all stages of construction. Each temporary erosion control method must be adjusted, maintained, and repaired as necessary.

(C) The **director** ~~**Planning and Development Review Department**~~ may require a modification of the temporary erosion control plan after determining that the plan does not adequately control off-site sedimentation from the development. Approval by the Planning and Development Review Department and the engineer who certified the plan is required for a major modification of the plan.

(D) The owner shall designate a project manager who is responsible for compliance with the erosion and sedimentation control and water quality plan requirements during development.
(E) The length of time between clearing and final revegetation of development may not exceed 18 months, unless extended by the director.
(F) If an applicant does not comply with the deadline in Subsection (E), or does not adequately maintain the temporary erosion and sedimentation controls, the director shall notify the applicant in writing that the City will repair the controls or revegetate the disturbed area at the applicant's expense unless the work is completed or revegetation is begun not later than the 15th day after the date of the notice.
(G) A person commits an offense if the person allows sediment from a construction site to enter a waterway by failing to maintain erosion controls or failing to follow the approved sequence of construction.

§ 25-8-185 OVERLAND FLOW.

(A) Drainage patterns must be designed to:

(1) prevent erosion;
(2) maintain infiltration and recharge of local seeps**,** ~~**and**~~ springs**, and waterways**;
(3) attenuate the harm of contaminants collected and transported by stormwater; ~~**and**~~
(4) where possible, maintain and restore overland sheet flow, maintain natural drainage features and patterns, and disperse runoff back to sheet flow**; and**
(5) where feasible, direct stormwater to landscape areas including islands, medians, peninsulas, and other similar areas. Exceptions to this requirement include:

(a) impervious areas on which the land use or activities may generate highly contaminated runoff, as prescribed by rule; and

(b) impervious areas used for parking or driving of vehicles if located within the Edwards Aquifer Recharge Zone as defined in Section 25-8-2

(B) The applicant shall design an enclosed storm drain to mitigate potential adverse impacts on water quality by using methods to prevent erosion and dissipate discharges from outlets. Applicant shall locate discharges to maximize overland flow through buffer zones or grass-lined swales wherever practicable.

ARTICLE 6. WATER QUALITY CONTROLS.

§ 25-8-213 WATER QUALITY CONTROL STANDARDS.

(A) A water quality control must be designed in accordance with the Environmental Criteria Manual.

(1) The control must ~~**provide at least the treatment level of a sedimentation/filtration system under**~~ **the achieve the load reduction standards prescribed in the** Environmental Criteria Manual.
(2) An impervious liner is required **for structural water quality controls over the Edwards Aquifer Recharge Zone** ~~**in an area where there is surface runoff to groundwater conductivity**~~. If a liner is required and ~~**controls are located in series**~~ **there are multiple controls in series**, liners are **only required for the first control in the series** ~~**not required for the second or later in the series following sedimentation, extended detention, or sedimentation/filtration**~~.
(3) The control must be accessible for maintenance and inspection as prescribed in the Environmental Criteria Manual.

(B) A water quality control must capture and treat the water draining to the control from the contributing area. The required capture volume is:

(1) the first one-half inch of runoff; and
(2) for each 10 percent increase in impervious cover over 20 percent of gross site area, an additional one-tenth of an inch of runoff.

(C) The required water quality treatment must be provided using green stormwater control measures, as prescribed in the Environmental Criteria Manual.

(D) Notwithstanding Subsection (C), all or part of the required water quality treatment may be provided using other water quality controls for:

(1) areas with land uses or activities that may generate highly contaminated runoff, as described in the Environmental Criteria Manual;

(2) a project that provides water quality treatment for currently untreated, developed off-site areas of at least 10 acres in size; or

(3) sites with greater than 90 percent gross site area impervious cover.

(**E~~C~~**) The location of a water quality control:

(1) must avoid recharge features to the greatest extent possible;
(2) must be shown on the slope map, preliminary plan, site plan, or subdivision construction plan, as applicable; and
(3) in a water supply rural watershed, may not be in the 40 percent buffer zone, unless the control disturbs less than 50% of the buffer, and is located to maximize overland flow and recharge in the undisturbed remainder of the 40 percent buffer zone.

(**F~~D~~**) This subsection provides additional requirements for the Barton Springs Zone.

(1) Approval by the Watershed Protection Department is required for a proposed water quality control that is not described in the Environmental Criteria Manual. The applicant must substantiate the pollutant removal efficiency of the proposed control with published literature or a verifiable engineering study.
(2) Water quality controls must be placed in sequence if necessary to remove the required amount of pollutant. The sequence of controls must be:

(a) based on the Environmental Criteria Manual or generally accepted engineering principles; and
(b) designed to minimize maintenance requirements.

§ 25-8-214 OPTIONAL PAYMENT INSTEAD OF STRUCTURAL CONTROLS IN URBAN WATERSHEDS.

(A) The director of the Watershed Protection Department shall identify and prioritize water quality control facilities for the urban watersheds in an Urban Watersheds Structural Control Plan. The Environmental **~~Board~~** **Commission** shall review the plan **~~in January of each year~~** **annually**.
(B) An Urban Watersheds Structural Control Fund is established for use in the design and construction of water quality control facilities in the urban watersheds.
(C) Instead of providing the water quality controls required under Section 25-8-211 (*Water Quality Control Requirement*), in an urban watershed an applicant may request approval to deposit with the City a nonrefundable cash payment, based on a formula established by the council. The director shall review the request and accept or deny the request based on the standards in the Environmental Criteria Manual.
(D) The director shall deposit a payment made under Subsection (C) in the Urban Watersheds Structural Control Fund.
(E) A Suburban and Water Supply Watersheds Structural Control Fund is established for use in the design and construction of water quality control facilities.
(F) For a public mobility project in the right-of-wav that is located in a suburban, water supply suburban, or water supply rural watershed, an applicant may request approval to deposit a nonrefundable cash payment, based on a formula established by the council, with the City instead of providing the water quality controls required under Section 25-8-211 (Water Quality Control Requirement). The director shall review the request and accept or deny the request based on the standards in the Environmental Criteria Manual.
(G) The director shall deposit a payment made under Subsection (F) in the Suburban and Water Supply Watersheds Structural Control Fund.

Division 2. Maintenance and Inspection.

§ 25-8-232 DEDICATED FUND.

(A) The director of the Finance Department shall establish a dedicated fund to:

(1) monitor water quality controls; and
(2) maintain water quality controls for single-family and duplex residential development.

(B) An applicant shall pay the required fee into the fund:

(1) for development that does not require a site plan, when the applicant posts fiscal security for the subdivision or requests that the director **of the Development Services Department** record the subdivision plat, whichever occurs first; or
(2) for development that requires a site plan, when the site plan is approved.

(C) The director of the Watershed Protection Department shall administer the fund, allocate the fund for appropriate projects, and report annually to the council regarding the status of the fund and the monitoring and maintenance program described in this section.

§ 25-8-233 BARTON SPRINGS ZONE OPERATING PERMIT.

(A) In the Barton Springs Zone, the owner or operator of a commercial or multifamily development is required to obtain an annual operating permit for the required water quality controls.

(B) To obtain an annual operating permit, an applicant must:

(1) provide the **director** ~~**Planning and Development Review Department**~~ with:

(a) a maintenance plan; and
(b) the information necessary to verify that the water quality controls are in proper operating condition; and

(2) pay the required, nonrefundable fee.

(C) The **director** ~~**Planning and Development Review Department**~~ may verify that a water quality control is in proper operating condition by either inspecting the water quality control or accepting a report from a registered engineer.

(D) The **director** ~~**Planning and Development Review Department**~~ shall issue an operating permit after determining that:

(1) the applicant has complied with the requirements of Subsection (B); and
(2) the water quality controls are in proper operating condition.

(E) The **director** ~~**Planning and Development Review Department**~~ shall transfer an operating permit to a new owner or operator if, not later than 30 days after a change in ownership or operation, the new owner or operator:

(1) signs the operating permit;
(2) accepts responsibility for the water quality controls; and
(3) documents the transfer on a form provided by the **director** ~~**Planning and Development Review Department**~~.

ARTICLE 7. REQUIREMENTS IN ALL WATERSHEDS.

Division 1. ~~Critical Water Quality Zone Restrictions~~ Waterway and Floodplain Protection.

§ 25-8-261 CRITICAL WATER QUALITY ZONE DEVELOPMENT.

In all watersheds, development is prohibited in a critical water quality zone except as provided in this Division. Development allowed in the critical water quality zone under this Division shall be revegetated and restored within the limits of construction as prescribed by the Environmental Criteria Manual.

(A) A fence that does not obstruct flood flows is permitted in a critical water quality zone.

(B) Open space is permitted in a critical water quality zone if a program of fertilizer, pesticide, and herbicide use is approved by the Watershed Protection Department, subject to the conditions in this Subsection.

(1) In a water supply rural watershed, water supply suburban, or the Barton Springs Zone, open space is limited to sustainable urban agriculture or a community garden if the requirements in subsection (B)(4) are met, multi-use trails, picnic facilities, and outdoor facilities, excluding stables, corrals for animals and athletic fields.

(2) A park with a council-adopted plan ~~master planned park that is approved by the council~~ may include recreational development other than that described in Subsection (B)(1).

(3) A hard surfaced trail may cross the critical water quality zone pursuant to Section 25-8-262 (*Critical Water Quality Zone Street Crossings*). A hard surfaced trail that does not cross the critical water quality zone may be located within the critical water quality zone only if:

(a) designed in accordance with the Environmental Criteria Manual;

(b) located outside the erosion hazard zone unless protective works are provided as prescribed in the Drainage Criteria Manual;

(c) limited to 12 feet in width plus one-foot compacted sub-grade shoulders, unless a wider trail is designated in a Council-adopted plan;

(d) located not less than 25 feet from the centerline of a waterway if within an urban watershed;

(e) located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, and 150 feet from the centerline of a major waterway if within a watershed other than an urban watershed;

(f) located not less than 50 feet from the shoreline of Lake Travis, Lake Austin, Lady Bird Lake, and Lake Walter E. Long, as defined in Section 25-8-92; and

(g) located not less than ~~100~~ 200 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam.

(4) Open space may include sustainable urban agriculture or a community garden only if:

(a) in an urban watershed and located not less than 25 feet from the centerline of a waterway, or in a watershed other than an urban watershed and located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, and 150 feet from the centerline of a major waterway;

(b) located not less than 50 feet from the shoreline of Lake Travis, Lake Austin, Lady Bird Lake, and Lake Walter E. Long, as defined in Section 25-8-92;

(c) located not less than ~~100~~ 200 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam;

(d) designed in accordance with the Environmental Criteria Manual; and

(e) limited to garden plots and paths, with no storage facilities or other structures over 500 square feet.

(5) In a suburban or urban watershed, open space may include an athletic field only if:

(a) in an urban watershed and located not less than 25 feet from the centerline of a waterway, or in a suburban watershed and located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, and 150 feet from the centerline of a major waterway;
(b) located not less than 50 feet from the shoreline of Lady Bird Lake and Lake Walter E. Long, as defined in Section 25-8-92;
(c) located not less than 100 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam; and
(d) the owner of the athletic field submits to the Watershed Protection Department a maintenance plan to keep the athletic field well vegetated and minimize compaction, as prescribed in the Environmental Criteria Manual.

(C) The requirements of this subsection apply along Lake Travis, Lake Austin, **Lake Walter E Long** or Lady Bird Lake.

(1) A dock, public boat ramp, bulkhead or marina, and necessary access and appurtenances, are permitted in a critical water quality zone subject to compliance with Chapter 25-2, Subchapter C, Article 12 (*Docks, Bulkheads, and Shoreline Access*). For a single-family residential use, necessary access may not exceed the minimum area of land disturbance required to construct a single means of access from the shoreline to a dock.
(2) Disturbed areas must be restored in accordance with the Environmental Criteria Manual and the following requirements:

(a) Within a lakefront critical water quality zone, or an equivalent area within 25 feet of a shoreline, restoration must include:

(i) at least one native shade tree and one native understory tree, per 500 square feet of disturbed area; and
(ii) one native shrub per 150 square feet of disturbed area; and

(b) Remaining disturbed areas must be restored per standard specifications for native restoration.

(3) Within the shoreline setback area defined by Section 25-2-551 (*Lake Austin (LA) District Regulations*) and within the overlay established by Section 25-2-180 (*Lake Austin (LA) Overlay District*), no more than 30 percent of the total number of shade trees of 8 inches or greater, as designated in the Environmental Criteria Manual, may be removed.
(4) Before a building permit may be issued or a site plan released, approval by the Watershed Protection Department is required for chemicals used to treat building materials that will be submerged in water.
(5) Bank erosion above the 100-year-flood plain may be stabilized within a lakefront critical water quality zone if the restoration meets the requirements of Subsection (B) (2) of this section.

(6) A retaining wall, bulkhead, or other erosion protection device must be designed and constructed to minimize wave return and wave action in compliance with the Environmental Criteria Manual. A shoreline modification within the wave action zone with a greater than 45 degree vertical slope for any portion greater than one foot in height is not allowed on or adjacent to the shoreline of a lake, unless the shoreline modification is located within an existing man-made channel.

(7) A retaining wall, bulkhead, or other erosion protection device may not capture or recapture land from a lake unless doing so is required to restore the shoreline to whichever of the following boundaries would encroach the least into the lake:

(a) the shoreline as it existed 10 years prior to the date of application, with documentation as prescribed by the Environmental Criteria Manual; or
(b) the lakeside boundary of the subdivided lot line.

(8) A bulkhead may be replaced in front of an existing bulkhead once, if:

(a) the existing bulkhead was legally constructed; and
(b) construction of the replacement bulkhead does not change the location of the shoreline by more than 6 inches; and
(c) the director determines that there is no reasonable alternative to replacement of the bulkhead in the location of the existing bulkhead.

(9) Dredging is prohibited unless:
(a) the area of dredging is less than 25 cubic yards; and
(b) the dredging is necessary for navigation safety.

(D) A **new utility line or major replacement of an existing** utility line, including a storm drain, **or a utility easement associated with planned infrastructure,** is prohibited in the critical water quality zone, except as provided in subsection (E) or for a necessary crossing. A necessary utility crossing may cross into or through a critical water quality zone only if:

(1) the utility line follows the most direct path into or across the critical water quality zone to minimize disturbance**, unless boring or tunneling is the proposed method of installation for the entire crossing and all bore pits are located outside of the Critical Water Quality Zone**;
(2) the depth of the utility line and location of associated access shafts are not located within an erosion hazard zone, unless protective works are provided as prescribed in the Drainage Criteria Manual;~~and~~
(3) **stormwater outfalls must minimize disturbance to the bank of the Colorado River by locating outfalls in upstream drainages where feasible; and**
(~~4~~**3**) in the Barton Springs Zone, **the crossing** is approved by the director of the Watershed Protection Department.

(E) In the urban and suburban watersheds, a **new utility line or major replacement of an existing** utility line may be located parallel to and within the critical water quality zone if:

(1) in an urban watershed and located not less than 50 feet from the centerline of a waterway, or in a watershed other than urban and located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, and 150 feet from the centerline of a major waterway;
(2) located not less than 50 feet from the shoreline of Lady Bird Lake and Lake Walter E. Long, as defined in Section 25-8-92;
(3) located not less than ~~100~~ **200** feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam;
(4) designed in accordance with the Environmental Criteria Manual;
(5) located outside the erosion hazard zone, unless protective works are provided as prescribed in the Drainage Criteria Manual; and
(6) the project includes either riparian restoration of an area within the critical water quality zone equal in size to the area of disturbance in accordance with the Environmental Criteria Manual, or payment into the Riparian Zone Mitigation Fund of a non-refundable amount established by ordinance.

(F) In-channel detention basins and in-channel wet ponds are allowed in the critical water quality zone only if**:**

(1) proposed as part of a public capital improvement project or public private partnership;
(2) no alternative location is feasible; and
(3) designed in accordance with the Environmental Criteria Manual.

(G) Floodplain modification~~s are~~ **is** prohibited in the critical water quality zone unless **the modification proposed**:

(1) ~~the floodplain modifications proposed are~~ is necessary to address an existing threat to public health and safety, as determined by the director of the Watershed Protection Department;

(2) ~~the floodplain modifications proposed would provide a significant, demonstrable environmental benefit~~, is designed solely to improve floodplain health as determined by a functional assessment of floodplain health as prescribed by the Environmental Criteria Manual; or

(3) ~~the floodplain modifications proposed are~~ is the minimum necessary for development allowed in the critical water quality zone under Section 25-8-261 (*Critical Water Quality Zone Development*), Section 25-8-262 (*Critical Water Quality Zone Mobility Crossings*), or Section 25-8-367 (*Restrictions on Development Impacting Lake Austin, Lady Bird Lake, and Lake Walter E. Long*) as prescribed in the Environmental Criteria Manual.

(H) In the urban and suburban watersheds, vegetative filter strips, rain gardens, biofiltration ponds, areas used for irrigation or infiltration of stormwater, or other controls as prescribed by rule are allowed in the critical water quality zone if:

(1) in an urban watershed and located not less than 50 feet from the centerline of a waterway, or in a watershed other than urban and located no less than 50 feet from the centerline of a minor waterway, no less than 100 feet from the centerline of an intermediate waterway, and no less than 150 feet from the centerline of a major waterway;

(2) located not less than 50 feet from the shoreline of Lady Bird Lake and Lake Walter E. Long, as defined in Section 25-8-92;

(3) located not less than ~~100~~ 200 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam;

(4) located outside the 100-year floodplain; and

(5) located outside the erosion hazard zone, unless protective works are provided as prescribed in the Drainage Criteria Manual.

(I) Development associated with power generation, transmission, or distribution at the Decker Creek Power Station is allowed in the critical water quality zone.

(J) A residential lot that is 5,750 square feet or less in size may not include any portion of a critical water quality zone.

§ 25-8-262 CRITICAL WATER QUALITY ZONE MOBILITY CROSSINGS.

(A) In an urban watershed, an arterial street, collector street, residential street, or rail line may cross a critical water quality zone of any waterway.

(B) This subsection applies in a watershed other than an urban watershed.

(1) A major waterway critical water quality zone may be crossed by ~~an arterial street~~ a Level 3, 4, or 5 street or rail line identified in the Transportation Plan.

(2) An intermediate waterway critical water quality zone may be crossed by ~~an~~ a Level 2, 3, 4, or 5 street ~~arterial street, collector street~~ or rail lineexcept:

(a) a Level 2 ~~collector~~ street crossing must be at least 2,500 feet, measured in creek miles, from a Level 2, ~~collector~~ or Level 3, 4, or 5 street ~~arterial street~~ crossing on the same waterway; or

(b) in a water supply suburban or water supply rural watershed, or the Barton Springs Zone, a Level 2 ~~collector~~ street crossing must be at least one mile, measured in creek miles, from a ~~collector or~~ Level 2, 3, 4, or 5 street ~~arterial street~~ crossing on the same waterway.

(3) A minor waterway critical water quality zone may be crossed by ~~an~~ a Level 2, 3, 4, or 5 street~~arterial street, collector street,~~ or rail line except:

(a) a ~~collector~~ Level 2 street crossing must be at least 900 feet, measured in creek miles, from a ~~collector or~~ Level 2, 3, 4, or 5 street ~~arterial~~ street crossing on the same waterway; or

(b) in a water supply suburban or water supply rural watershed, or the Barton Springs Zone, a **Level 2** ~~**collector**~~ street crossing must be at least 2,000 feet**, measured in creek miles,** from a ~~**collector or**~~ **Level 2, 3, 4, or 5** ~~**arterial**~~ street crossing on the same waterway.

(4) A minor waterway critical water quality zone may be crossed by a ~~**residential**~~ **Level 1** or **2** ~~**commercial**~~ street if necessary to provide access to property that cannot otherwise be safely accessed.

(C) In all watersheds, multi-use trails may cross a critical water quality zone of any waterway **if:**
(1) designed in compliance with the Environmental Criteria Manual; and
(2) the development demonstrates no additional adverse impact from flood or erosion potential.

(D) Notwithstanding subsections (A) and (B) and except in the Barton Springs Zone, a street or driveway may cross the critical water quality zone if the street or driveway is located in a center or corridor as identified on the growth concept map of the Imagine Austin Comprehensive Plan, as adopted by Ordinance No. 20120614-058, and if the proposed crossing:

(1) is necessary to facilitate the development or redevelopment of a designated corridor or center as recommended in the Imagine Austin Comprehensive Plan, Chapter 4 (*Shaping Austin: Building the Complete Community*), growth concept map and related definitions; and

(2) maintains the quality and quantity of recharge if located in a center or corridor designated as a sensitive environmental area in the Edwards Aquifer recharge zone, Edwards Aquifer contributing zone, or the South Edwards Aquifer recharge zone, as determined by the director of the Watershed Protection Department .

§ 25-8-263 FLOODPLAIN MODIFICATION.

(A) ~~**Floodplain modification within a critical water quality zone is prohibited except as allowed under Section 25-8-261 (*Critical Water Quality Zone Development*).**~~ **All floodplain modifications must:**

(1) be designed to accommodate existing and fully-vegetated hydraulic conditions;
(2) apply sound engineering and ecological practices, prevent and reduce degradation of water quality, and demonstrate the stability and integrity of floodplains and waterways, as prescribed in the Environmental Criteria Manual;
(3) restore floodplain health, or provide mitigation if restoration is infeasible, to support natural functions and processes as prescribed in the floodplain modification criteria in the Environmental Criteria Manual; and
(4) comply with the requirements of Chapter 25-7 (*Drainage*), the Drainage Criteria Manual, and the Environmental Criteria Manual.

(B) **Floodplain modification within a critical water quality zone is prohibited except as allowed under Section 25-8-261 (*Critical Water Quality Zone Development*).** ~~**Floodplain modification outside a critical water quality zone is allowed only if the modification proposed:**~~

~~**(1) is necessary to protect public health and safety by addressing an existing threat, as determined by the director of the Watershed Protection Department;**~~

~~**(2) would provide a significant, demonstrable environmental benefit, as determined by a functional assessment of floodplain health as prescribed by the Environmental Criteria Manual;**~~

~~**(3) is located within a floodplain area classified as in fair or poor condition, as determined by a functional assessment of floodplain health, prescribed by the Environmental Criteria Manual; or**~~

~~**(4) is necessary for development allowed under Section 25-8-261 (*Critical Water Quality Development*) or 25-8-262 (*Critical Water Quality Zone Street Crossings*).**~~

(C) ~~**All floodplain modifications must:**~~

~~**(1) be designed to accommodate existing and fully-vegetated conditions;**~~

~~(2) encourage sound engineering and ecological practices, prevent and reduce degradation of water quality, and encourage the stability and integrity of floodplains and waterways, as prescribed in the floodplain modification criteria in the Environmental Criteria Manual;~~

~~(3) restore floodplain health, or provide mitigation if restoration is infeasible, to support natural functions and processes as prescribed in the floodplain modification criteria in the Environmental Criteria Manual; and~~

~~(4) comply with the requirements of Chapter 25-7 (*Drainage*), the Drainage Criteria Manual, and the Environmental Criteria Manual.~~

Floodplain modification outside a critical water quality zone is allowed only if the modification proposed:

(1) is necessary to protect public health and safety by addressing an existing threat, as determined by the director;

(2) is designed solely to improve floodplain health, as determined by a functional assessment of floodplain health as prescribed by the Environmental Criteria Manual;

(3) is located within a floodplain area classified as in fair or poor condition, as determined by a functional assessment of floodplain health, and provides restoration or mitigation in accordance with the ratios and specifications prescribed in the Environmental Criteria Manual.; or

(4) is the minimum modification necessary for development allowed under Section 25-8-261 (*Critical Water Quality Development*) or 25-8-262 (*Critical Water Quality Zone Mobility Crossings*).

(D) If **on-site restoration, as prescribed in the Environmental Criteria Manual, is infeasible and** mitigation is required under this Section, it may be satisfied by:

(1) paying into the Riparian Zone Mitigation Fund a nonrefundable amount established by ordinance;

(2) transferring in fee simple or placing restrictions on mitigation land approved by the director ~~of the Watershed Protection Department~~ and meeting the following conditions:

(a) located within the same watershed classification;

(b) in accordance with the procedures in Section 25-8-26 (*Redevelopment Exception in the Barton Springs Zone*), Subsection (H) (3);

(c) dedicated to or restricted for the benefit of the City or another entity approved by the director and which the City or other approved entity accepts;

(d) an amount proportionate to the amount of area within the existing floodplain that is proposed to be modified, as prescribed in the Environmental Criteria Manual; or

(3) a combination of the mitigation methods described in Subparagraphs (1) and (2), if approved by the director ~~of the Watershed Protection Department~~.

Division 2. Protection for Special Features.

§ 25-8-281 CRITICAL ENVIRONMENTAL FEATURES.

(A) Drainage patterns for proposed development must be designed to protect critical environmental features from the effects of runoff from developed areas, and to maintain the catchment areas of recharge features in a natural state. Special controls must be used where necessary to avoid the effects of erosion, or sedimentation, or high rates of flow.

(B) A residential lot may not include a critical environmental feature **or** ~~be located within 50 feet of a critical environmental feature~~ **a critical environmental feature buffer zone and may not be located within 50 feet of a critical environmental feature**.

(C) This subsection prescribes the requirements for critical environmental feature buffer zones.

(1) A buffer zone is established around each critical environmental feature described in this subchapter.

(a) Except as provided in Subsection (C)(1)(b), the width of the buffer zone is 150 feet from the edge of the critical environmental feature.

(b) For a point recharge feature, the buffer zone coincides with the topographically defined catchment basin, except that the width of the buffer zone from the edge of the critical environmental feature is:

(i) not less than 150 feet;
(ii) not more than 300 feet; and
(iii) calculated in accordance with the Environmental Criteria Manual.

(2) Within a buffer zone described in this subsection:

(a) the natural vegetative cover must be retained to the maximum extent practicable;
(b) construction is prohibited; and
(c) wastewater disposal or irrigation is prohibited.

(3) If located at least 50 feet from the edge of the critical environmental feature, the prohibition of Subsection (C)(2)(b) does not apply to:

(a) ~~a yard or~~ a hiking trail; ~~or~~
(b) a recharge basin approved under Section 25-8-213 (*Water Quality Control Standards*) that discharges to a point recharge feature~~.~~; or
(c) an innovative runoff management practice approved under Section 25-8-151 (*Innovative Management Practices*) **that is designed to address the standards of this section, enhance the recharge of groundwater and the discharge of springs, and maintain the function of critical environmental features**.

(4) Perimeter fencing with not less than one access gate must be installed at the outer edge of the buffer zone for all point recharge features. The fencing must comply with the Standard Specifications Manual.
(5) The owner must maintain the buffer zone in accordance with standards in the Environmental Criteria Manual to preserve the water quality function of the buffer.
(6) All critical environmental feature locations and required setbacks must be shown on preliminary subdivision plans, site plans, and other permits as determined by the director.
(7) All critical environmental feature locations must be shown on final plats.

(D) When voids in the rock substrate are uncovered during development, the following protocol must be followed:

(1) construction in the area of the void must cease while the applicant conducts a preliminary investigation of the void as prescribed by the Environmental Criteria Manual.
(2) The applicant shall contact a City of Austin Environmental Inspector to schedule further investigation by the City of the void as prescribed by the Environmental Criteria Manual if the preliminary investigation indicates that the void:

(a) is at least one square foot in total area;
(b) blows air from within the substrate;
(c) consistently receives water during any rain event; or
(d) potentially transmits groundwater.

(3) Construction may only proceed after mitigation measures are reviewed and approved by the Watershed Protection Department.

§ 25-8-282 WETLAND PROTECTION.

(A) Wetlands must be protected in all watersheds, except ~~in~~ **for wetlands located within** the **area** bounded by Interstate 35, Riverside Drive, Barton Springs Road, Lamar Boulevard, and 15th **Street that are not associated with the critical water quality zone of Lady Bird Lake**.
(B) Protection methods for wetlands include:

(1) appropriate setbacks that preserve the wetlands or wetland functions;
(2) wetland mitigation, including wetland replacement; **or**

(3) wetland restoration or enhancement~~; or~~

~~(4) use of a wetlands for water quality controls~~.

(C) The director ~~of the Watershed Protection Department~~ may approve **the proposed protection methods.:**

~~(1) the removal and replacement of a wetland; or~~

~~(2) the elimination of setbacks from a wetland that is proposed to be used as a water quality control.~~

Division 4. Clearing.

§ 25-8-323 TEMPORARY STORAGE AREAS; TOPSOIL PROTECTION.

(A) The site plan or subdivision construction plan must designate the areas to be cleared for temporary storage of spoils or construction equipment. Areas cleared for temporary storage must be located and restored in accordance with the Environmental Criteria Manual.

(B) During and after site grading operations, the topsoil must be protected and vegetation left in place to the maximum extent practicable**;**

(C) For areas on the site that are to remain pervious post-development, any soils that are compacted during site grading and construction operations must be decompacted in compliance with the Environmental Criteria Manual and the Standard Specifications Manual.

Division 5. Cut, Fill, and Spoil.

§ 25-8-341 CUT REQUIREMENTS.

(A) Cuts on a tract of land may not exceed four feet of depth, except:

(1) in an urban watershed;

(2) in a roadway right-of-way or rail line right-of-way;

(3) for construction of a building foundation or swimming pool, excluding the surrounding pool deck;

(4) for construction of a water quality control or detention facility and appurtenances for conveyance such as swales, drainage ditches, and diversion berms, if:

(a) the design and location of the facility within the site minimize the amount of cut over four feet;

(b) the cut is the minimum necessary for the appropriate functioning of the facility; and

(c) the cut is not located on a slope with a gradient of more than 15 percent or within 100 feet of a classified waterway;

(5) for utility construction or a wastewater drain field, if the area is restored to natural grade;

(6) in a state-permitted sanitary landfill or a sand or gravel excavation located in the extraterritorial jurisdiction, if:

(a) the cut is not in a critical water quality zone;

(b) the cut does not alter a 100-year floodplain;

(c) the landfill or excavation has an erosion and restoration plan approved by the City; and

(d) all other applicable City Code provisions are met~~.~~ **;**

(7) for any cut associated with construction of a multi-use trail, if:

(a) the cut is not located on a slope with a gradient of more than 15 percent or within 100 feet of a classified waterway;

(b) the cut is limited to no more than eight feet in depth;

(c) the cut is located in a public right-of-way or public easement; and

(d) the trail is designed in accordance with the Environmental Criteria Manual~~.~~**; and**

(8) for construction of a street or driveway necessary to provide primary access if:

(a) the construction complies with Division 3 (*Construction on Slopes*) of this article;

(b) the cut is not within a critical water quality zone;

(c) the cut is limited to no more than eight feet in depth;

(d) the cut over four feet is the minimum amount necessary to comply with safety access requirements and the horizontal and vertical curve requirements of the Transportation Criteria Manual; and
(e) there is no other feasible alternative for the street or driveway location.

§ 25-8-342 FILL REQUIREMENTS.

(A) Fill on a tract of land may not exceed four feet of depth, except:

(1) in an urban watershed;
(2) in a roadway right-of-way or rail line right-of-way;
(3) under a foundation with sides perpendicular to the ground, or with pier and beam construction;
(4) for construction of a water quality control or detention facility and appurtenances for conveyance such as swales, drainage ditches, and diversion berms, if:

(a) the design and location of the facility within the site minimize the amount of fill over four feet;
(b) the fill is the minimum necessary for the appropriate functioning of the facility; and
(c) the fill is not located on a slope with a gradient of more than 15 percent or within 100 feet of a classified waterway;

(5) for utility construction or a wastewater drain field;
(6) in a state-permitted sanitary landfill located in the extraterritorial jurisdiction, if:

(a) the fill is derived from the landfill operation;
(b) the fill is not placed in a critical water quality zone or a 100-year floodplain;
(c) the landfill operation has an erosion and restoration plan approved by the City; and
(d) all other applicable City Code provisions are met; ~~or~~

(7) for fill associated with construction of a multi-use trail, if:

(a) the fill is not located on a slope with a gradient of more than 15 percent or within 100 feet of a classified waterway;
(b) the fill is limited to no more than eight feet in depth;
(c) the fill is located in a public right-of-way or public easement; and
(d) the trail is designed in accordance with the Environmental Criteria Manual~~.~~**; or**

(8) for construction of a street or driveway necessary to provide primary access if:
(a) the construction complies with Division 3 (*Construction on Slopes*) of this article;
(b) the fill is not in a critical water quality zone;
(c) the fill is limited to no more than eight feet in depth;
(d) the fill over four feet is the minimum amount necessary to comply with safety access requirements and the horizontal and vertical curve requirements of the Transportation Criteria Manual; and
(e) there is no other feasible alternative for driveway location.

(B) A fill area must be restored and stabilized.
(C) Fill for a roadway must be contained within the roadway clearing width described in Section 25-8-322 (*Clearing For A Roadway*).

Division 6. Other Restrictions.

~~**§ 25-8-364 FLOODPLAIN MODIFICATION.**~~

~~**(A) Floodplain modification within a critical water quality zone is prohibited except as allowed under Section 25-8-261 (*Critical Water Quality Zone Development*).**~~
~~**(B) Floodplain modification outside a critical water quality zone is allowed only if the modification proposed:**~~

~~**(1) is necessary to protect public health and safety by addressing an existing threat, as determined by the director of the Watershed Protection Department;**~~

~~(2) would provide a significant, demonstrable environmental benefit, as determined by a functional assessment of floodplain health as prescribed by the Environmental Criteria Manual;~~
~~(3) is located within a floodplain area classified as in fair or poor condition, as determined by a functional assessment of floodplain health, prescribed by the Environmental Criteria Manual; or~~
~~(4) is necessary for development allowed under Section 25-8-261 (*Critical Water Quality Development*) or 25-8-262 (*Critical Water Quality Zone Street Crossings*).~~

~~(C) All floodplain modifications must:~~

~~(1) be designed to accommodate existing and fully vegetated conditions;~~
~~(2) encourage sound engineering and ecological practices, prevent and reduce degradation of water quality, and encourage the stability and integrity of floodplains and waterways, as prescribed in the floodplain modification criteria in the Environmental Criteria Manual;~~
~~(3) restore floodplain health, or provide mitigation if restoration is infeasible, to support natural functions and processes as prescribed in the floodplain modification criteria in the Environmental Criteria Manual; and~~
~~(4) comply with the requirements of Chapter 25-7 (*Drainage*), the Drainage Criteria Manual, and the Environmental Criteria Manual.~~

~~(D) If mitigation is required under this Section, it may be satisfied by:~~

~~(1) paying into the Riparian Zone Mitigation Fund a nonrefundable amount established by ordinance;~~
~~(2) transferring in fee simple or placing restrictions on mitigation land approved by the director of the Watershed Protection Department and meeting the following conditions:~~

~~(a) located within the same watershed classification;~~
~~(b) in accordance with the procedures in Section 25-8-26 (*Redevelopment Exception in the Barton Springs Zone*), Subsection (H) (3);~~
~~(c) dedicated to or restricted for the benefit of the City or another entity approved by the Watershed Protection Department director and which the City or other approved entity accepts;~~
~~(d) an amount proportionate to the amount of area within the existing floodplain that is proposed to be modified, as prescribed in the Environmental Criteria Manual; or~~

~~(3) a combination of the mitigation methods described in Subparagraphs (1) and (2), if approved by the director of the Watershed Protection Department.~~

~~**Division 7. Shoreline Relocation and Lakefill.**~~

~~**§ 25-8-367 RELOCATION OF SHORELINE BETWEEN TOM MILLER DAM AND LONGHORN DAM.**~~

~~(A) This section applies:~~

~~(1) along the Colorado River;~~
~~(2) between Tom Miller Dam and Longhorn Dam; and~~
~~(3) below a contour elevation of 435 feet above mean sea level.~~

~~(B) City council approval is required to relocate existing earth material in the area described in Subsection (A).~~
~~(C) A person may request approval under this section by filing an application with the council that includes a plan showing the proposed layout of the relocation and a legal description of the property.~~
~~(D) The applicant must demonstrate to the council that:~~

~~(1) approving the application will not:~~

~~(a) endanger a water supply, water supply system, storm or sanitary sewer facility, or other public utility facility;~~
~~(b) create a hazard to navigation or swimming;~~

~~(c) create a hazard to the safety, maintenance and operation of a dam, bridge, or other structure not owned by the applicant; and~~

~~(d) materially and adversely affect the use and enjoyment of other property on the Colorado River between the Tom Miller Dam and Longhorn Dam; and~~

~~(2) if similar applications were granted for all similarly situated properties, the water storage or flood capacity of the Colorado River basin would not be materially reduced.~~

~~§ 25-8-368 RESTRICTIONS ON DEVELOPMENT IMPACTING LAKE AUSTIN, LADY BIRD LAKE, AND LAKE WALTER E. LONG.~~

~~(A) The requirements of this section apply to development on or adjacent to Lake Austin, Lady Bird Lake, or Lake Walter E. Long.~~

~~(B) Except as otherwise provided by this section, placing fill or dredging in a lake is prohibited.~~

~~(C) A retaining wall, bulkhead, or other erosion protection device may not capture or recapture land from a lake unless doing so is required to restore the shoreline to whichever of the following boundaries would encroach the least into the lake:~~

~~(1) the shoreline as it existed 10 years prior to the date of application, with documentation as prescribed by the Environmental Criteria Manual; or~~

~~(2) the lakeside boundary of the subdivided lot line.~~

~~(D) A bulkhead may be replaced in front of an existing bulkhead once, if:~~

~~(1) the existing bulkhead was legally constructed; and~~

~~(2) construction of the replacement bulkhead does not change the location of the shoreline by more than 6 inches; and~~

~~(3) the director of the Watershed Protection Department determines that there is no reasonable alternative to replacement of the bulkhead in the location of the existing bulkhead.~~

~~(E) The director may approve less than 25 cubic yards of dredging in a lake if the dredging is necessary for navigation safety.~~

CHAPTER 25-8 SUBCHAPTER B. *ARTICLE 2.* ~~***ENDANGERED SPECIES.***~~***Threatened or Endangered Species Notification***

§ 25-8-691 **THREATENED OR ENDANGERED SPECIES NOTIFICATION****APPLICABILITY.**

(A) **This section applies in areas of the planning jurisdiction that may contain habitat for federally listed threatened or endangered species identified in the map maintained by the City online or available for inspection in the office of the Development Services Department.** ~~**Except as provided in Subsection (B), this article applies to development in the areas of the planning jurisdiction described in Sections 25-8-693 (*Birds And Plants*), 25-8-694 (*Cave Species*), and 25-8-695 (*Salamander Species*).**~~

(B) On submission of an application for a subdivision or site plan in an area described in Subsection (A), the applicant must give notice of the application to the appropriate authority, including:

(1) United States Fish and Wildlife Service;

(2) Balcones Canyonlands Conservation Plan Coordinating Committee Secretary; and

(3) Travis or Williamson County, as applicable depending on project location.

(C) The notice must include a statement that the development could cause the loss of threatened or endangered species habitat.

~~**This article does not apply to development of:**~~

~~(1) a subdivision for which a preliminary plan or final plat was approved before August 27, 1989;~~

~~(2) a site for which a site plan or site development permit was approved before August 27, 1989; or~~

~~(3) a tract of land containing not more than ten acres, if the tract:~~

~~(a) is legally platted; or~~

~~(b) existed in its current configuration when it became subject to City subdivision regulations.~~

~~**§ 25-8-692 THREATENED OR ENDANGERED SPECIES.**~~
~~In this article, "threatened or endangered species" means:~~
~~(1) black-capped vireo;~~
~~(2) golden-cheeked warbler;~~
~~(3) Tooth Cave pseudoscorpion;~~
~~(4) Tooth Cave spider;~~
~~(5) Bee Creek Cave harvestman;~~
~~(6) Tooth Cave ground beetle;~~
~~(7) Kretschmarr Cave mold beetle;~~
~~(8) Jollyville Plateau salamander;~~
~~(9) a species included in the Balcones Canyonland Conservation Plan; or~~
~~(10) a species classified as threatened or endangered by the United States Fish and Wildlife Service.~~
~~Source: Section 13-7-73; Ord. 990225-70; Ord. 031211-11; Ord. No. 20170615-102 , Pt. 30, 6-15-17.~~
~~**§ 25-8-693 BIRDS AND PLANTS.**~~
~~For an endangered bird or plant species, the requirements of Section 25-8-696 (Notice) apply west of a line bounded by U. S. 183 North at the City's extraterritorial boundary limit, then southeast to Loop 1, then south along Loop 1 to U.S. 290 West, then west on U. S. 290 to R.M. 1826, and then south to the City's extraterritorial boundary limit.~~
~~Source: Section 13-7-72(a)(1), and (b); Ord. 990225-70; Ord. 031211-11; Ord. 20131017-046.~~
~~**§ 25-8-694 CAVE SPECIES.**~~
~~For an endangered cave species, the requirements of Section 25-8-696 (*Notice*) apply in the Edwards Aquifer Recharge Zone as defined by Section 25-8-2 (*Description of Regulated Areas*).~~
~~Source: Section 13-7-72(a)(2) and (b); Ord. 990225-70; Ord. 031211-11; Ord. 20131017-046.~~
~~**§ 25-8-695 SALAMANDER SPECIES.**~~
~~For a threatened or endangered salamander species, the requirements of Section 25-8-696 (*Notice*) apply in the areas included in the salamander habitat map maintained by the Watershed Protection Department.~~

~~Source: Ord. 20131017-046; Ord. No. 20170615-102 , Pt. 31, 6-15-17.~~
~~**§ 25-8-696 NOTICE.**~~

~~(A) On submission of an application for subdivision or site plan approval in an area described in Section 25-8-693 (*Birds and Plants*), 25-8-694 (*Cave Species*), or 25-8-695 (*Salamander Species*)Subsection (A), the applicant shall give notice of the application to the appropriate authority, including:~~

~~(1) United States Fish and Wildlife Service;~~
~~(2) Texas Parks and Wildlife Department;~~
~~(3) Balcones Canyonlands Conservation Plan Coordinating Committee Secretary; and~~
~~(4) Travis or Williamson County, as applicable.~~

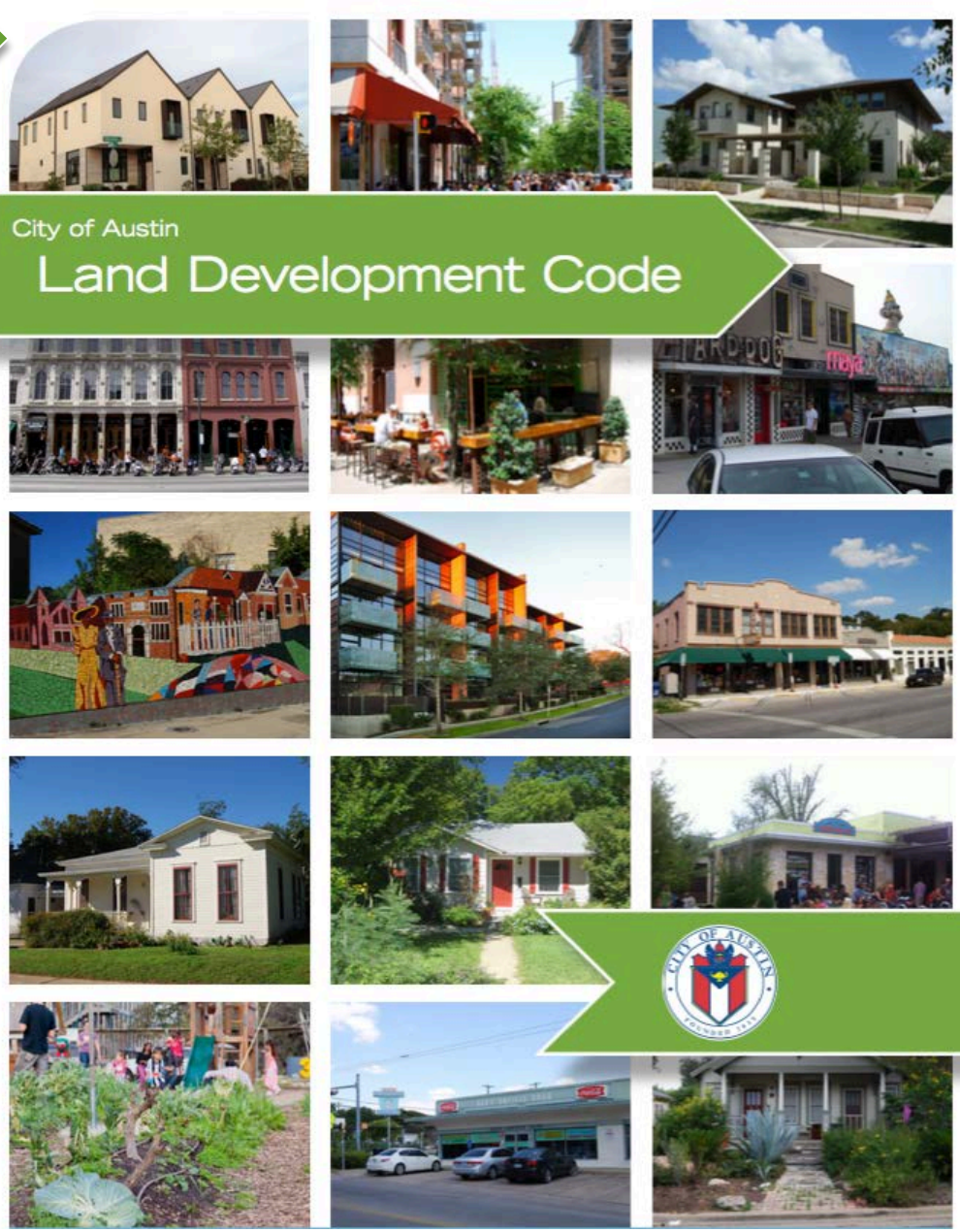
~~(B) The notice must include a statement that the development could cause the loss of threatened or endangered species habitat.~~

Functional Green
Studies, Analyses, Rationale
August 18, 2022

A compilation of the papers produced by the CodeNEXT consultant team

Amy Belaire, PhD
Ed MacMullan, ECONorthwest
Heather Venhaus, Regenerative Environmenta Design

Functional Green



Meeting purpose = Share progress

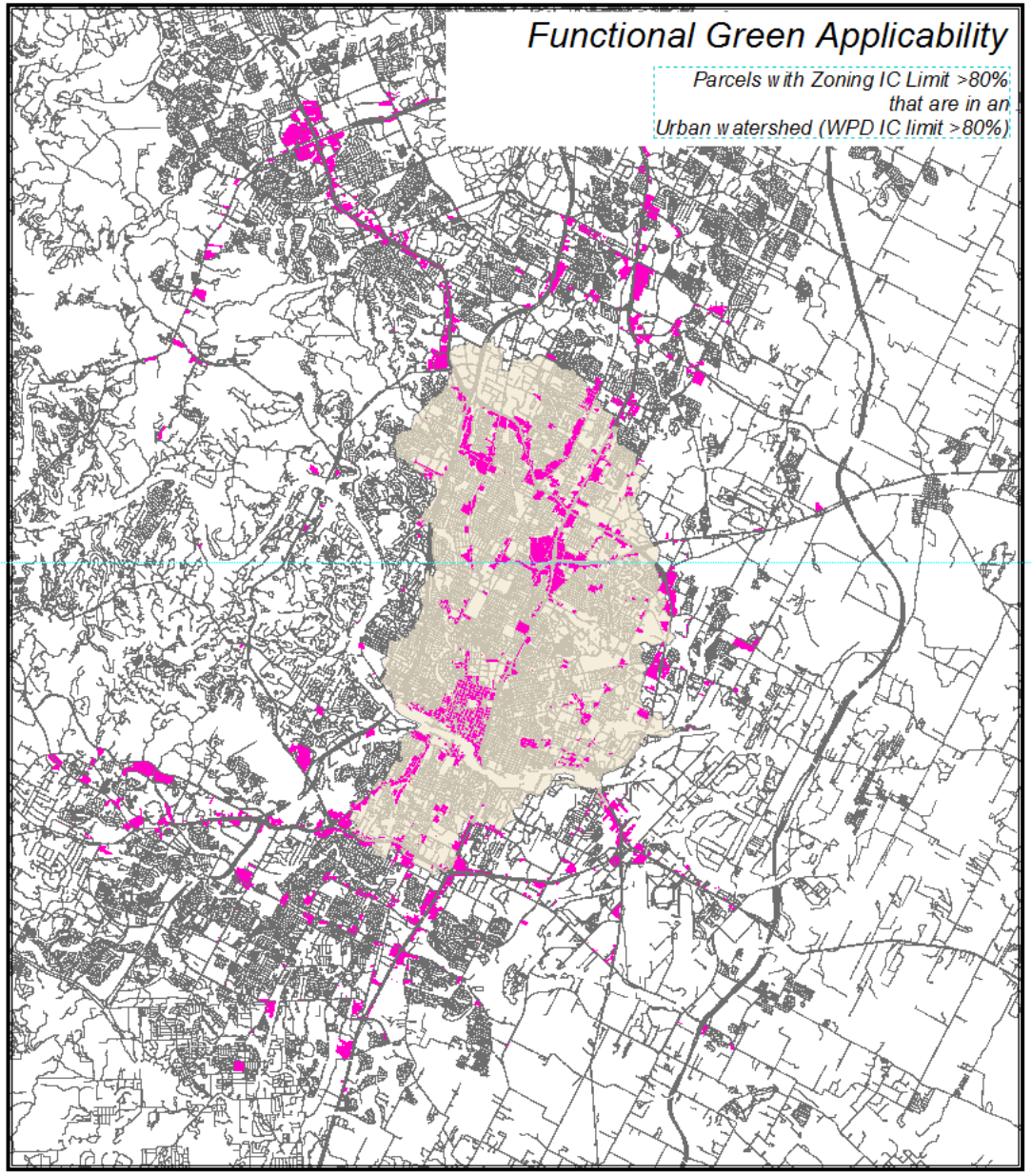
- Case study findings. Case study scores are relative to each other. This information informs the target score and tests the landscape element weights. Landscape elements will continue to be tested with the proof of concept work.
- Landscape element overview
- Next steps & Timeline
- Question & Answer
- Set date for follow up meeting after staff has time to discuss internally.
  - 12/15 - 1 to 5
  - 12/14 – all day

What are the goals of Functional Green?

1) **Integrate nature** into parcels where building cover or other impervious surfaces limit what the standard landscape code can accomplish.

1) Develop a **planning tool** that is **flexible and provides ecological benefits** comparable to those required in the standard landscape code.

1) Provide a **program** that is **straight forward** and **easy to implement and review**.


Functional Green Applicability
Parcels with Zoning IC Limit >80%
that are in an
Urban watershed (WPD IC limit >80%)
Legend
Parcels with Zoning IC Limit >80%
Urban Watersheds - WPD IC Limit >80%
0
5
10
Miles
N

Functional Green Development Process

- Identified the primary ecosystem services
  - Microclimate regulation and mitigation of urban heat island effects
  - Carbon storage and sequestration
  - Air pollutant removal
  - Stormwater retention and runoff reduction
  - Water filtration
  - Biodiversity benefits
  - Human health and well-being benefits

- Identified the landscape elements most likely to occur in dense urban landscapes
  - Trees
  - Planting beds
  - Green roofs
  - Rain gardens
  - Vegetated walls
  - Porous paving
  - Cisterns
  - Bonus points (pollinator friendly gardens, reduce potable water use etc…)

Functional Green Development Process

- **Literature review** which includes research from **120 published studies**

  Reviewed data on each of the landscape elements for (1) biophysical benefits, (2) economic values, (3) beneficiaries (4) costs of implementation

- **Technical and economic analysis of landscape elements**
  - Range of the likely biophysical benefits and economic costs and benefits
  - Estimated performance

Landscape element	References
Trees	Loughner et al. 2012, Shashua-Bar et al. 2009, Davis et al. 2016, and Wang & Akbari 2016, Nowak et al. 2013, Nowak & Dywer 2007, Davies et al. 2011, Nowak et al. 2016, iTree Design v 6.0, Mullaney et al. 2015, Livesley et al. 2014, Sanders 1986, Ikin et al. 2012, Strohbach et al. 2013, Belaire et al. 2014, Gomez-Baggethun et al. 2013, Kuo & Sullivan 2001, Tarran 2009, Interagency Working Group 2016, American Forests 2002, Wolf 2007, Martin Maggio and Appel 1989, Donovan and Butry 2011, Wolf 2015
Green roofs	Alexandri & Jones 2008, Susca et al. 2011, Santamouris 2014, Meek et al. 2014, Getter et al. 2009, Whittinghill et al. 2014, Yang et al. 2008, Currie et al. 2008, Carter et al. 2007, Simmons et al. 2013, Glass 2007, Berndtsson et al. 2010, Harper et al. 2015, Morgan et al. 2013, Rowe et al. 2011, Ahiablame et al. 2012, Colla et al. 2009, Tonietto et al. 2011, Madre et al. 2013, Braaker et al. 2014, Van Renterghem & Botteldooren 2009, Oberndorfer 2007, EPA 2000, Blackhurst et al. 2010, Interagency Working Group 2016, American Forests 2002, Wolf 2015, GSA 2011
Rain gardens	Perring et al. 2016, Davis et al. 2016, Bouchard et al. 2013, Davies et al. 2011, Perring et al. 2013, DeBusk & Wynn 2011, Li et al. 2009, Brown et al. 2013, Jennings 2016, Geosyntec 2016, Glick et al. 2016, Hunt et al. 2008, International BMP Database 2014, Richter et al. 2015, Limouzin et al. 2011, Kazemi et al. 2009, Kazemi et al. 2011, Walsh et al. 2015, Sandifer et al. 2015, Hamel et al. 2013, Interagency Working Group 2016, Wolf 2015, American Forests 2002
Vegetated walls	Alexandri & Jones 2008, Mazzali et al. 2013, Perez et al. 2011, Cameron et al. 2014, Chen et al. 2013, Davies et al. 2011, Currie et al. 2008, Pugh et al. 2012, Madre et al. 2015, Chiquet et al. 2013, Azkorra et al. 2015, Perini 2013, Hassan 2015, Wolf 2015, Nowak et al. 2016, Interagency Working Group 2016, Wolf 2015, American Forests 2002
Porous pavements	Santamouris 2013, Qin 2015, Kevern et al. 2009, Stempihar et al. 2013, Collins et al. 2008, Dreelin et al. 2006, Hunt et al. 2008, Ball and Rankin 2010, Geosyntec 2016, International Stormwater BMP Database 2014, Richter et al. 2015, Ahiablame et al. 2012, Bean et al. 2007, American Forests 2002, Century West Engineering (no date)
Cisterns	Geosyntec 2016, Glick et al. 2016, Walsh et al. 2015, American Forests 2002

Functional Green Development Process

Research provided a **rating for each landscape element based on its ecological and economic performance**. The ratings indicate the performance of each landscape **element relative to the others**.

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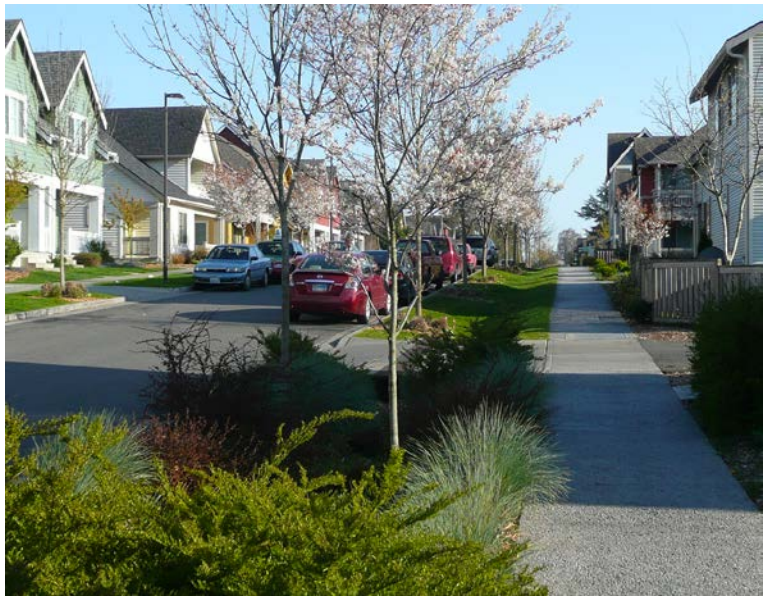


Functional Green Development Process

Multi-Criteria Decision Analysis - allowed us to summarize across the 9 criteria we evaluated – including ecosystem services and economic considerations – and arrive at one value that represents performance across all 9 criteria.

Landscape elements	Scenario 1 Rating	Scenario 2 Rating	Scenario 3 Rating	Scenario 4 Rating	AVERAGE RATING
Existing tree	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Newly planted tree	★★★	★★★	★★★★	★★★	★★★
Green roof	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Rain garden	★★★★	★★★	★★★★	★★★★	★★★★
Vegetated wall	★★	★★	★★★	★★	★★
Planting beds	★	★	★★	★	★
Porous pavement	★	★	★	★	★
Cistern	★	★	★	★	★

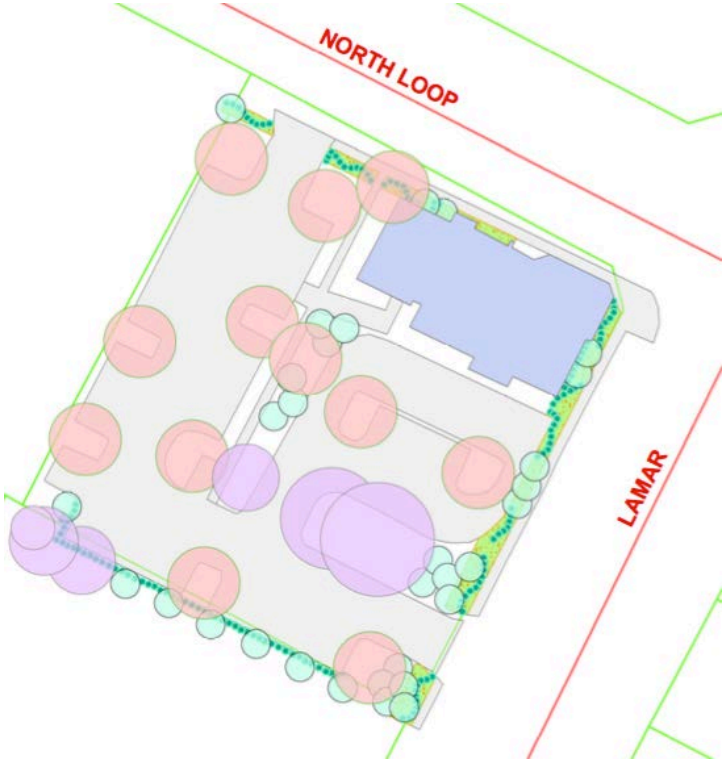
*Bonus points: All rated equally – one star

Functional Green multiplier for each landscape element is based on its ecological and economic performance. The multiplier indicates the performance of each **landscape element relative to the others**.

Landscape elements	Multiplier
Vegetation	
Existing trees	0.8
Newly planted trees	0.4-0.6
Shrubs, ornamental grasses and large perennials	0.3
Ground cover	0.2
Turf grass	0.1
Specialized media	
Green roof media - extensive	0.5
Green roof media - intensive	0.6
Rain garden media	0.3
Additional elements	
Porous pavement	0.4
Vegetated walls	0.5
Cistern	0.3
Bonus options	
bonus: native or adapted drought tolerant vegetation	0.1
bonus: alternative water irrigation	0.1
bonus: pollinator resources	0.1
bonus: enhanced soil systems	0.1

Functional Green Development Process

Test **landscape elements multiplier** and parcel **target score** based on **City of Austin standard landscape code** case studies and **other projects over 81% impervious cover**



Landscape	Project	Address	Size acres	IC
Standard Landscape Code	Balcones Ranch Apartments	13145 N US 183 HIGHWAY, 78729	12.17 ac/53,292 sf	55% existing, 70% allowed
Standard Landscape Code	Villas of 55th	502 W 55th Street 78751	0.28 ac	59%, 65% allowed
Standard Landscape Code	Glazer's Distributors Expansion	8119 Exchange Drive, 78754	13.5 ac	72%, 80% allowed
Standard Landscape Code	Taco Cabana	5242 N LAMAR BOULEVARD, 78756	0.87 ac	72%, 95% allowed
Standard Landscape Code	The Groves at Lamar	3607 South Lamar Boulevard	2.3 acres	77%
As designed	Highland Greystar	Highland mall	3.2	83%
As built	Rainey		1.6	86%
As built	AMLI	5350 Burnet	2.4	87%
As built	San Gabriel	South lamar	0.33 ac	90%
As built	SC Hotel	1603 S Congress Ave	0.95 ac	95%
As built	5th & Colorado	downtown	0.7	100%
As built	Seven Rio	615 W 7th St, Austin, TX 78701	0.8	100%

Balcones Ranch Apartments (1)
13145 N US 183 HIGHWAY

Size: 12.17 acres
IC: 55%
Score: 0.23
Standard Landscape Code

Landscape elements:
Existing trees (88,083)
Newly planted trees (56,549)
Shrubs (9686)
Groundcover (11,230)
Turf (50,060)
Rain garden (25,305)
Cistern (7,842)
Native plants (88,083)

Assumptions:
1. Detention pond counted as rain garden
2. Sand filter counted as cistern
3. Turf in medians and rain garden

Balcones Ranch Apartments (2)
13145 N US 183 HIGHWAY

Size: 12.17 acres
IC: 55%
Score: 0.22
Standard Landscape Code

Landscape elements:
Existing trees (88,083)
Newly planted trees (56,549)
Shrubs (9686)
Groundcover (11,230)
Turf (50,060)
Native plants (88,083)

Assumptions
1. **Stormwater treated in detention pond and sand filter.**
2. **Detention pond, median and peninsulas covered with turf**

Villas of 55th
502 w 55th Street

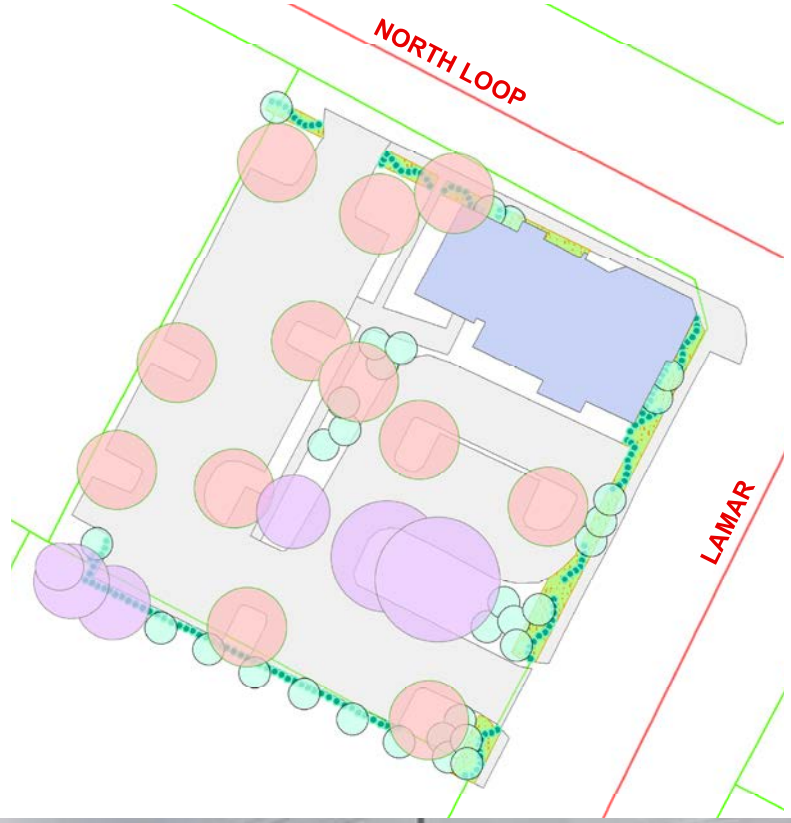
Size: 0.28
IC: 59%
Score: 0.44
Standard landscape code

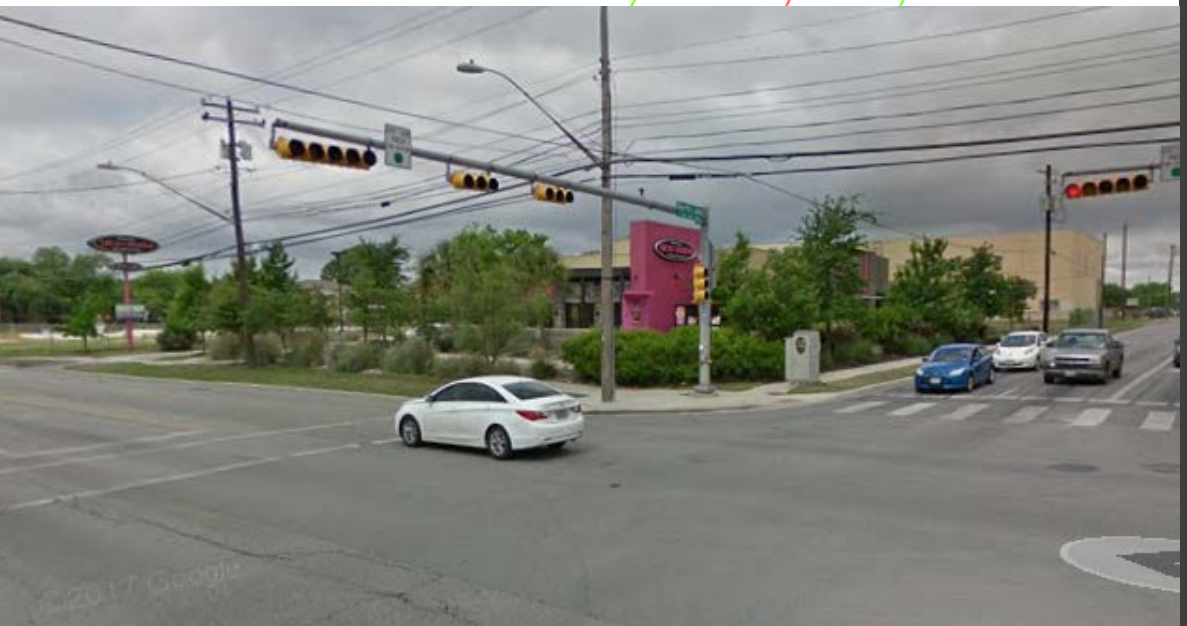
Landscape elements
Existing trees (1,257)
Planted trees (7,775)
Shrubs (813)
Groundcover (417)
Turf (5,424)
Native plants (1,257)

Villas of 55th
502 w 55th Street

Size: 0.28
IC: 59%
Score: 0.44
Standard landscape code

Landscape elements
Existing trees (1,257)
Planted trees (7,775)
Shrubs (813)
Groundcover (417)
Turf (5,424)
Native plants (1,257)

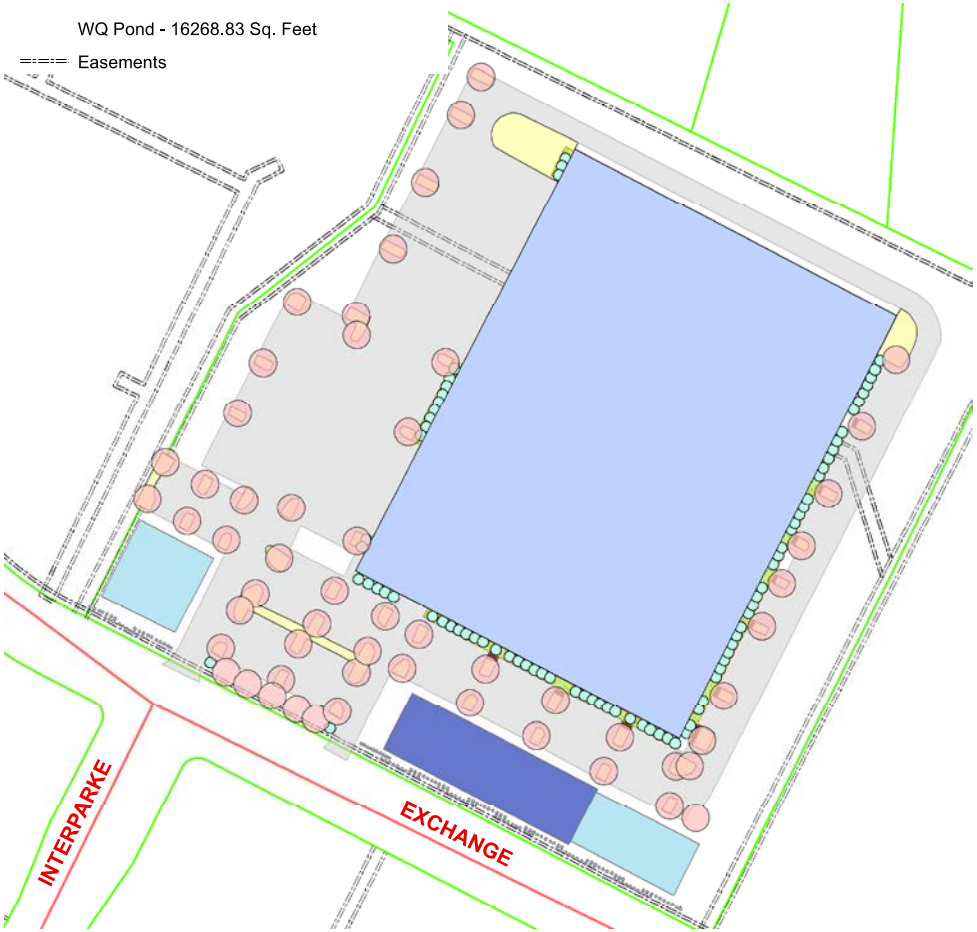




Taco Cabana
5242 N LAMAR BOULEVARD

Size: 0.87 acre
IC: 72%
Score: 0.34
Standard Landscape Code

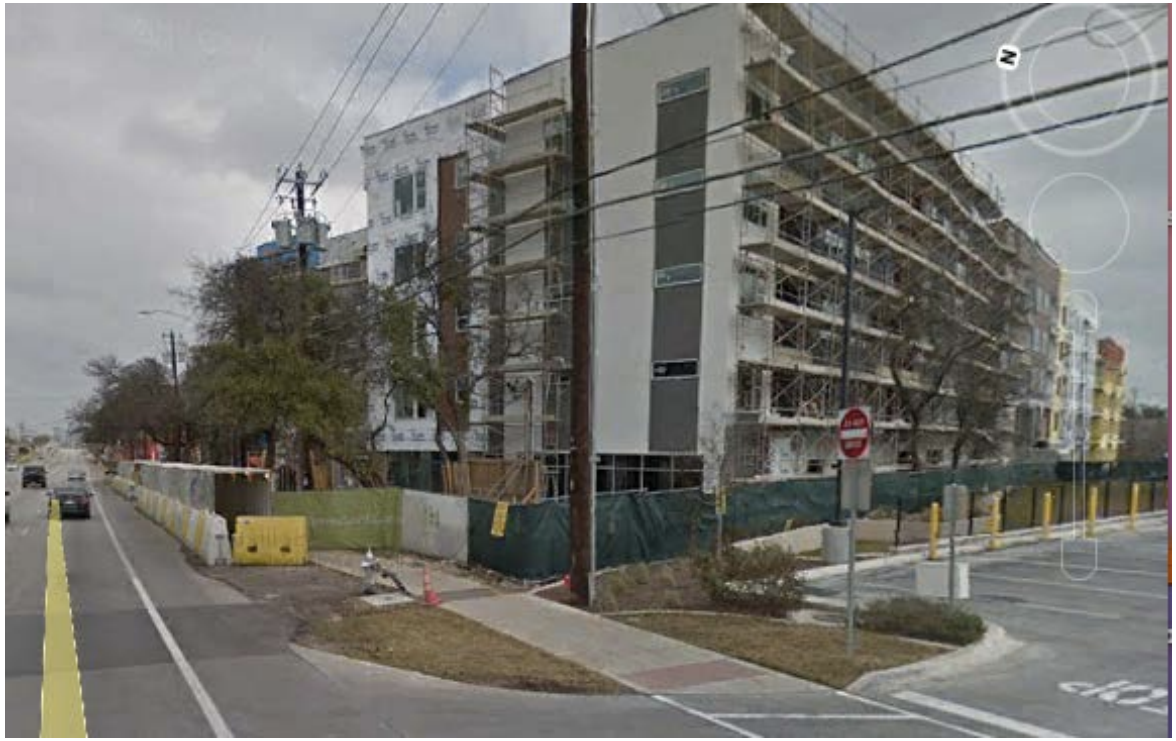
Landscape elements
Existing trees (5,281)
Planted trees (16,258)
Shrubs (1,059)
Groundcover (1,934)
Native plants (5,281)



Glazer's Distribution
8119 Exchange Drive

Size: 13.5 acres
IC: 72%
Score: 0.06
Standard Landscape Code

Landscape elements
Newly planted trees (53,721)
Shrubs (8,909)
Groundcover (7,920)
Rain garden (7,700)
Turf (58,834)
Native plants (53,721)



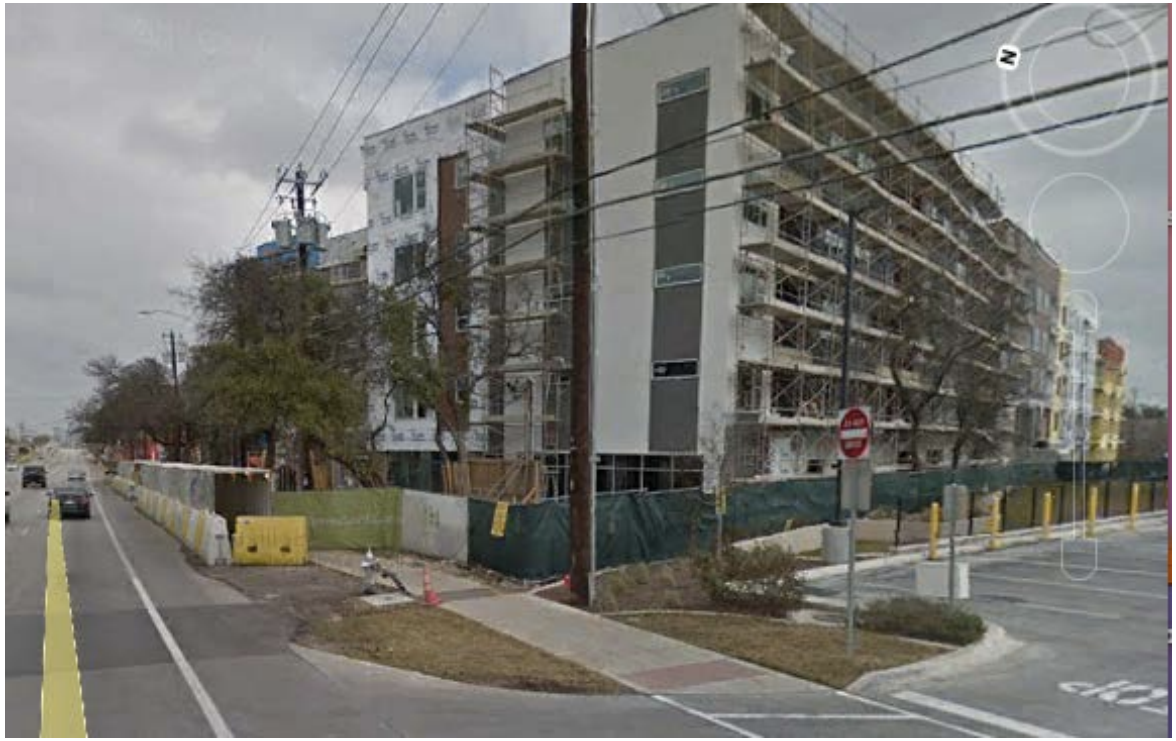
The Groves at Lamar (1)

3607 South Lamar Boulevard

Size: 2.3 acres
IC: 77%
Score: 0.29
Standard landscape code

Landscape elements
Existing trees (12,566)
Planted trees (31,671)
Shrubs (1,650)
Groundcover (512)
Turf (10,770)
Cistern (12,555)
Native plants (8,792)

Assumptions:
15’ easement
Compatibility buffer
Reduced building footprint



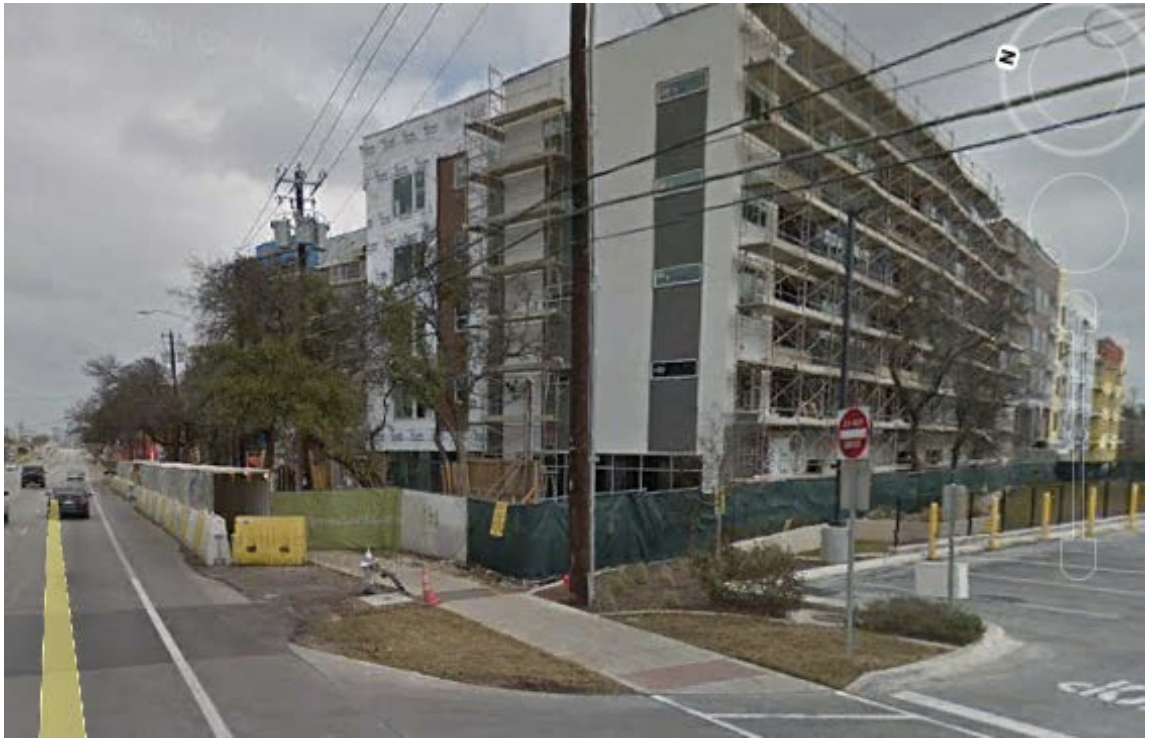
The Groves at Lamar (2)

3607 South Lamar Boulevard

Size: 2.3 acres
IC: 77%
Score: 0.26
Standard landscape code

Landscape elements
Existing trees (8,796)
Planted trees (31,318)
Shrubs (1,395)
Groundcover (256)
Turf (10,770)
Cistern (12,555)
Native plants (8,792)

Assumptions:
Without 15’ easement
Compatibility buffer
Reduced building footprint

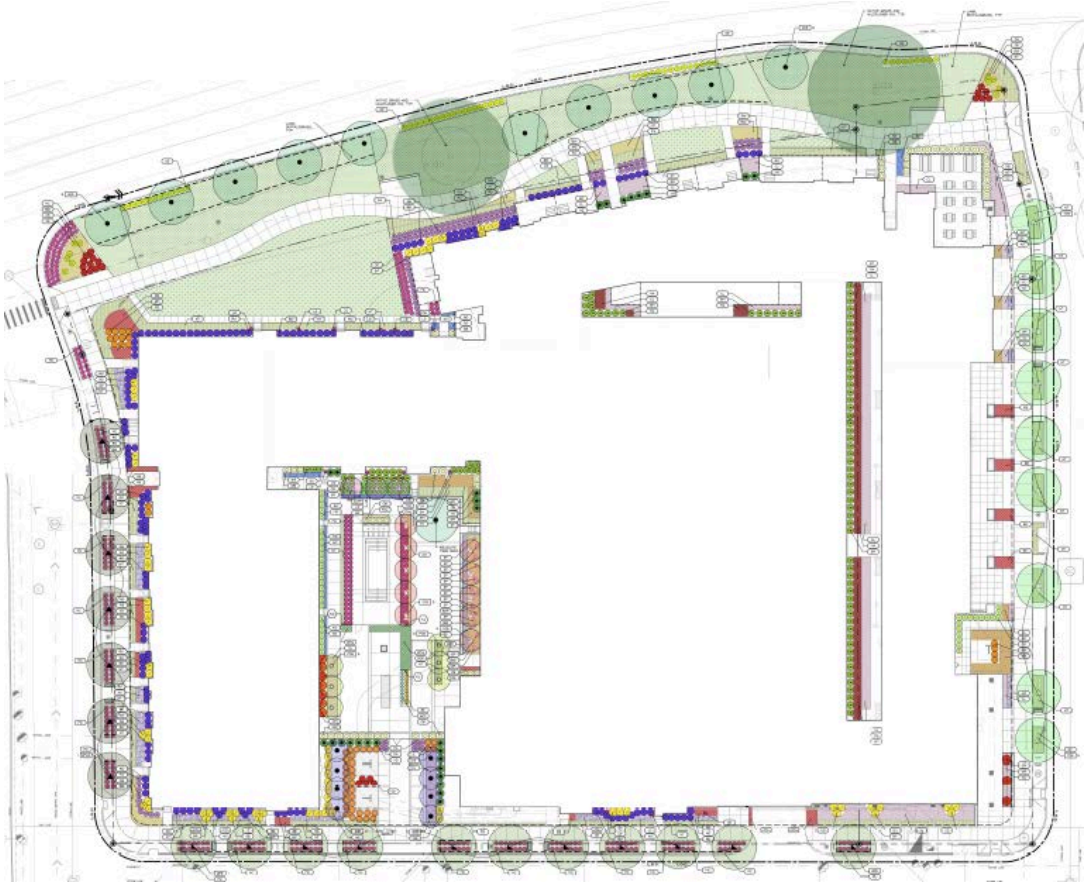


The Groves at Lamar (3)
3607 South Lamar Boulevard

Size: 2.3 acres
IC: 77%
Score: 0.13
Standard landscape code

Landscape elements
Existing trees (12,566)
Planted trees (353)
Shrubs (512)
Groundcover (512)
Turf (512)
Cistern (12,555)
Native plants (12,560)

Assumptions:
15’ easement
No compatibility buffer
Building footprint as is



Highland Greystar
Highland Mall Redevelopment

Size: 3.23
IC: 83%
Score: 0.30
Existing landscape (planned)

Landscape elements
Existing trees (2,513)
Planted trees (42,804)
Shrubs (7,408)
Turf (13,270)
Native plants (45,317)

Note: stormwater is handled off site in a regional detention pond making this similar to payment in lieu case studies

Rainey
Rainey Street

Size: 1.6 acres
IC: 86%
Score: 0.28
Existing landscape

Landscape elements
Existing trees (2,513)
Planted trees (23,287)
Shrubs (1,108)
Groundcover (4,167)
Native plants (20,106)

AMLI
5350 Burnet

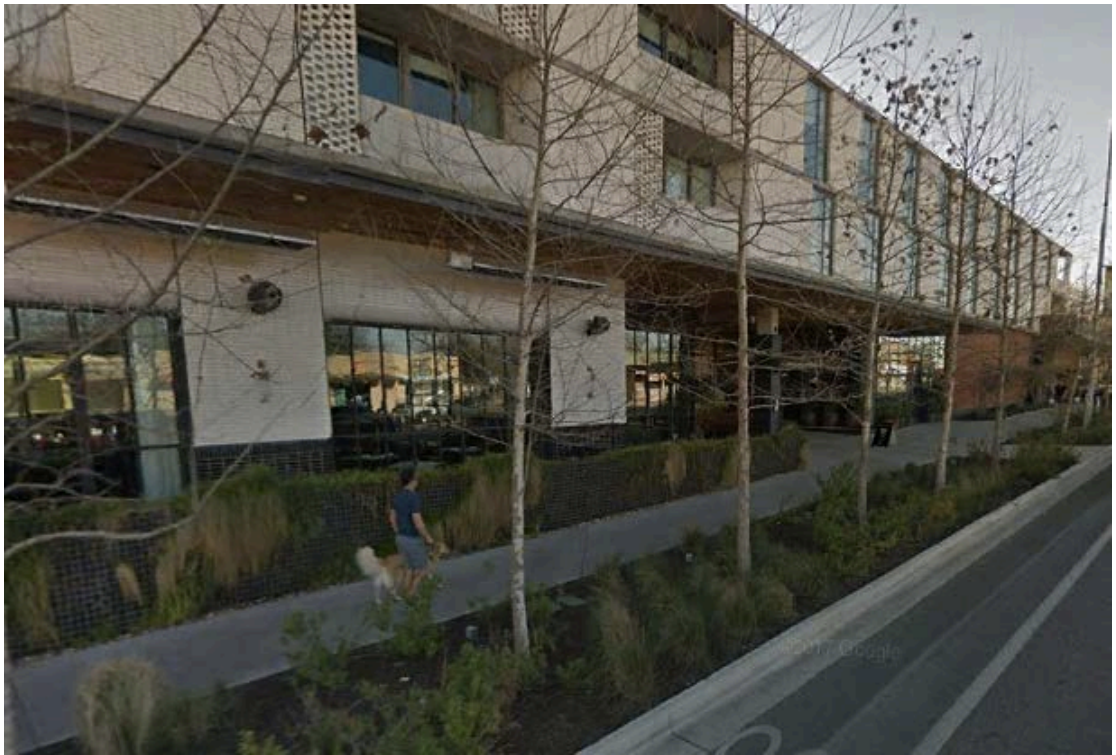
Size: 2.4 acres
IC: 87%
Score: 0.13
Existing landscape

Landscape elements
Planted trees (18,476)
Shrubs (2,600)
Groundcover (2,000)
Turf (2,000)
Rain garden (1000)
Native plants (18,476)

San Gabriel
San Gabriel & 25th

Size: 0.33 acre
IC: 90%
Score: 0.22
Existing landscape

Landscape elements
Planted trees (4,948)
Shrubs (261)
Ground cover (261)
Native plants (4,948)



South Congress Hotel
1603 S Congress Ave.

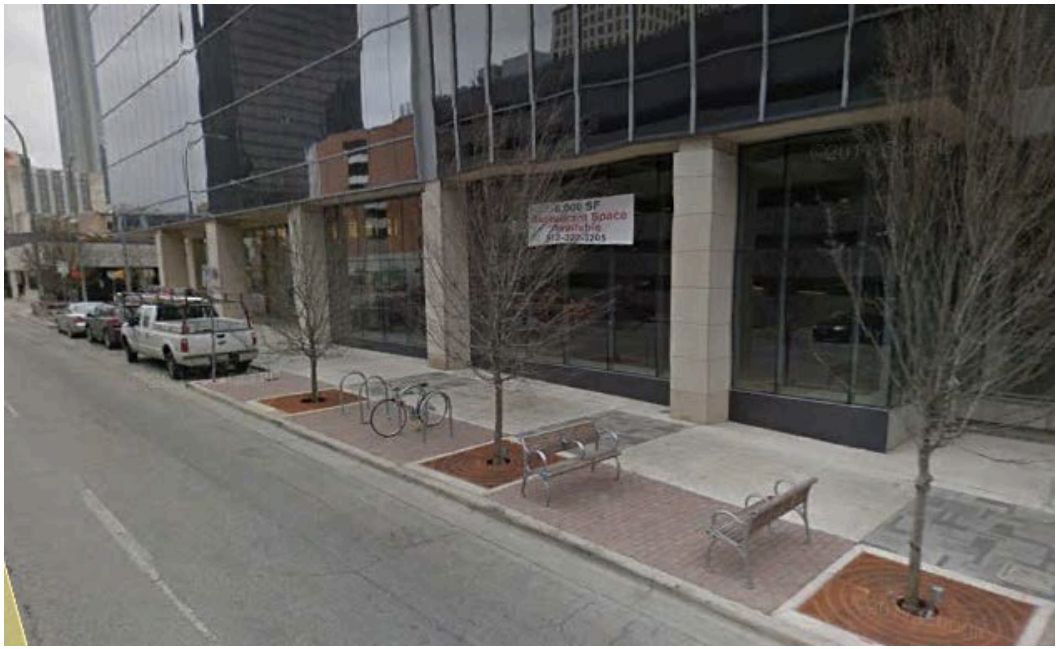
Size: 0.95 acre
IC: 95%
Score: 0.33
Existing landscape

Landscape elements
Planted trees (19,792)
Green wall (2,343)
Shrubs (4,991)
Groundcover (539)
Native plants (9,879)

South Congress Hotel
1603 S Congress Ave.

Size: 0.95 acre
IC: 95%
Score: 0.33
Existing landscape

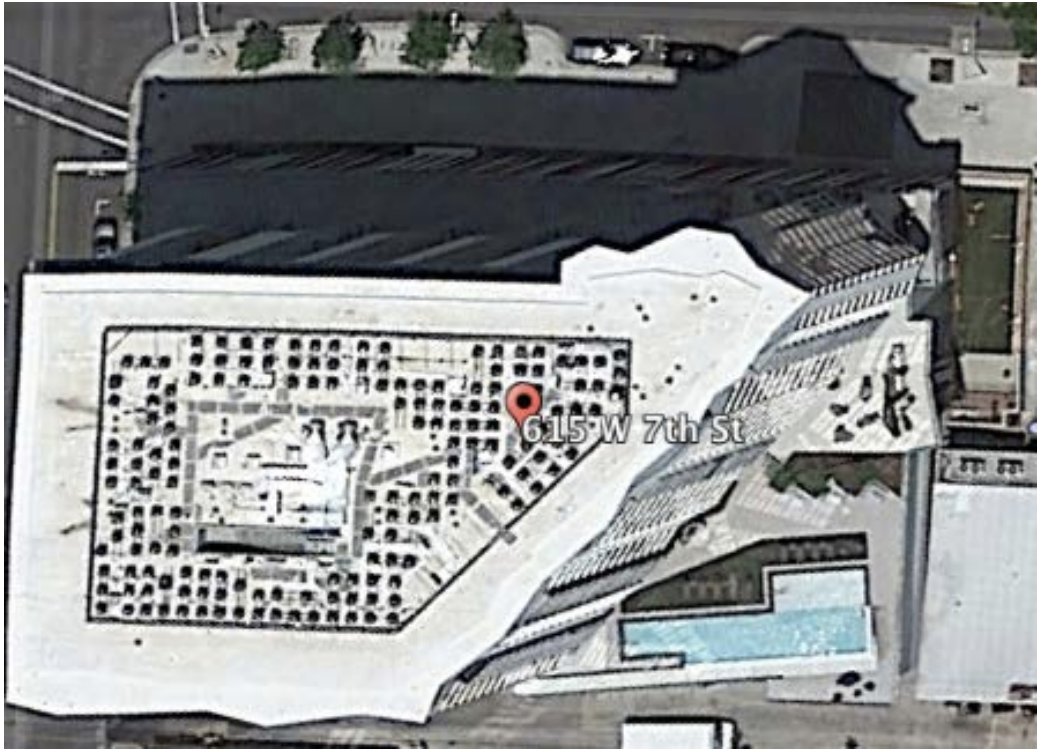
Landscape elements
Planted trees (19,792)
Green wall (2,343)
Shrubs (4,991)
Groundcover (539)
Native plants (9,879)

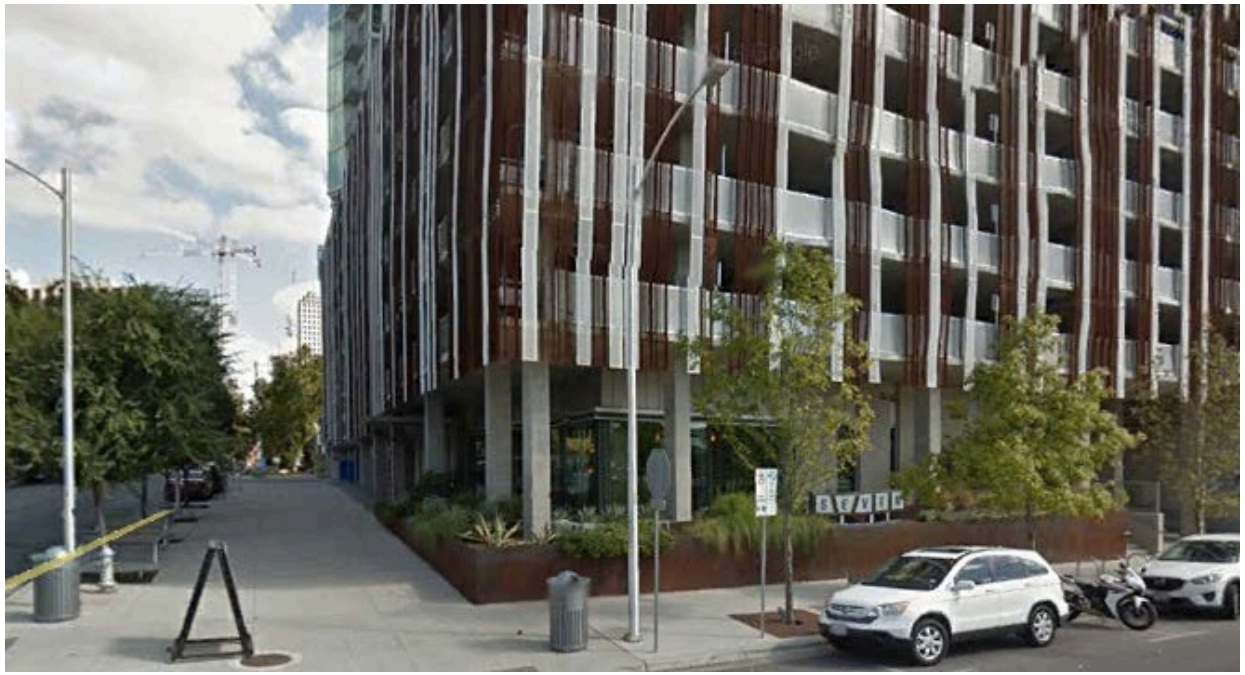


5th & Colorado Downtown

Size: 0.66
IC: 100%
Score: 0.16
Existing landscape

Landscape elements
Planted trees (6,362)
Native plants (6,362)





Seven Rio
615 W 7th Street

Size: 0.75 acre
IC: 100%
Score: 0.18
Existing landscape

Landscape elements
Planted trees (5,655)
Shrubs (820)
Groundcover (820)
Native plants (5,662)

Landscape	Project	Address	Size acres	IC	Score
Standard Landscape Code	Balcones Ranch Apartments	13145 N US 183 HIGHWAY, 78729	12.17 ac/53,292 sf	55% existing, 70% allowed	0.22-0.23
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Standard Landscape Code	Glazer's Distributors Expansion	8119 Exchange Drive, 78754	13.5 ac	72%, 80% allowed	0.06
Standard Landscape Code	Taco Cabana	5242 N LAMAR BOULEVARD, 78756	0.87 ac	72%, 95% allowed	0.34
Standard Landscape Code	The Groves at Lamar	3607 South Lamar Boulevard	2.3 acres	77%	0.13 - 0.29
As designed	Highland Greystar	Highland mall	3.2	83%	0.25
As built	Rainey		1.6	86%	0.28
As built	AMLI	5350 Burnet	2.4	87%	0.13
As built	San Gabriel	South lamar	0.33 ac	90%	0.22
As built	SC Hotel	1603 S Congress Ave	0.95 ac	95%	0.33
As built	5th & Colorado	downtown	0.7	100%	0.13
As built	Seven Rio	615 W 7th St, Austin, TX 78701	0.8	100%	0.12

Functional Green Next Steps

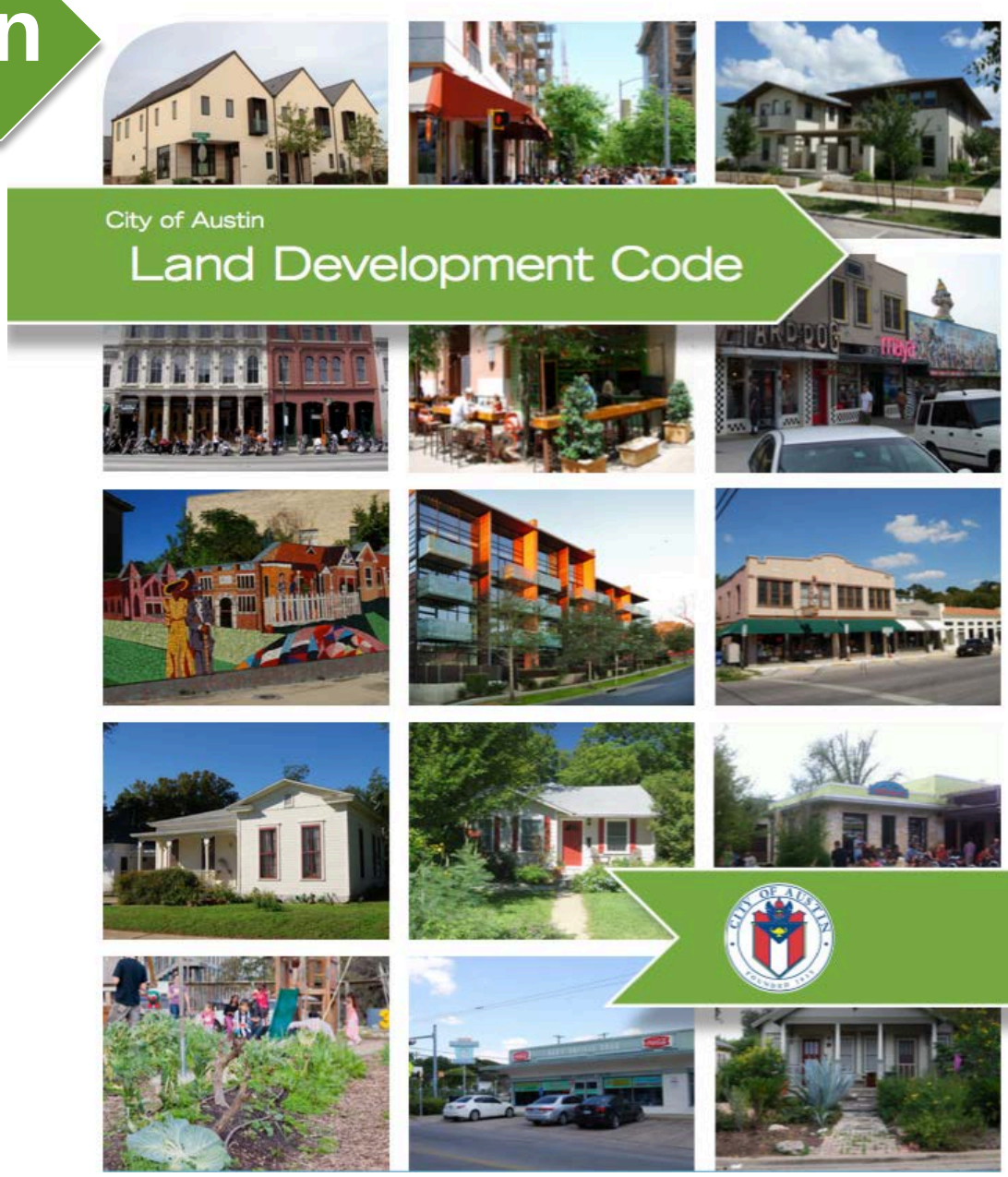
- Follow up meeting to discuss feedback 12/13 or 12/14
- Functional Green development cost for various building types
- Meet with COA Landscape and Watershed staff to discuss economic findings and preliminary proof of concept studies
- Proof of concept studies – continue to test landscape element weights and target score
- Meet with COA Landscape and Watershed staff to provide update and discuss draft materials for February release of draft
- 2/5/17 – Send Functional Green materials to printer

Questions for staff to address prior to next meeting

- Preliminary thoughts about a target score
- Review definitions, measurements and code requirements (excel file)
- Address questions in excel file
- Compile staff comments/questions and send to consultants in advance

Landscape elements	Multiplier	Definition	Measurement	Understanding of code requirements and applications	COA Questions/Comments
Vegetation					
Existing trees	**0.8**	Any tree existing on-site prior to construction of the project under review. In order to receive credit, existing trees must be protected during construction as per COA requirements. Invasive tree species as identified by the COA can not be counted towards existing vegetation credits.	Credit is given for the square foot area of the tree canopy. See COA ECM Appendix F - Descriptive Categories of Tree Species - Mature Width. To determine the area a project may claim per tree, locate tree species in Appendix F and reference the mature width. Count tree in the appopriate Functional Green category. Additional square foot area can be claimed if a project can verify that the existing canopy is larger than shown in Appendix F.	Tree preservation will follow same rules for FG as for all sites: no penalty for removing invasives; preservation = 1. a minimum of 50% of the critical root zone must be preserved at natural grade, with natural ground cover; 2. cut or fill is limited to 4 inches from the 1/2 critical root zone to the 1/4 critical root zone; and 3. no cut or fill is permitted within the 1/4 critical root zone. 4. removal of more than 25% of the canopy constitutes tree removal	
Newly planted trees					
Large trees	**0.6**	Newly planted tree with a mature width of 40 feet or greater. See COA ECM Appendix F - Descriptive Categories of Tree Species - Mature Width.	Credit is given for the square foot area of the tree canopy. See COA ECM Appendix F - Descriptive Categories of Tree Species - Mature Width. To determine the area a project may claim per tree, locate tree species in Appendix F and reference the mature width. Count tree in the appopriate Functional	All streets will be required to have street trees. In all commercial non-transect zones and Core Transit Corridors street trees will be required in the planting zone at an average spacing not greater than 30' o.c. Director shall adopt a list of acceptable trees. Tree list can be found in the ECM Appendix F https://library.municode.com/TX/Austin/codes/environmental_criteria_manual	
Medium trees	**0.5**	Newly planted tree with a mature width between 20 - 39 feet. See COA ECM Appendix F - Descriptive Categories of Tree Species - Mature Width.	Credit is given for the square foot area of the tree canopy. See COA ECM Appendix F - Descriptive Categories of Tree Species - Mature Width. To determine the area a project may claim per tree, locate tree species in Appendix F and reference the mature width. Count tree in the appopriate Functional	All streets will be required to have street trees. In all commercial non-transect zones and Core Transit Corridors street trees will be required in the planting zone at an average spacing not greater than 30' o.c. Director shall adopt a list of acceptable trees. Tree list can be found in the ECM Appendix F https://library.municode.com/TX/Austin/codes/environmental_criteria_manual	
Ornamental trees	**0.4**	Newly planted tree with a mature width between 10 - 19 feet. See COA ECM Appendix F - Descriptive Categories of Tree Species - Mature Width.	Credit is given for the square foot area of the tree canopy. See COA ECM Appendix F - Descriptive Categories of Tree Species - Mature Width. To determine the area a project may claim per tree, locate tree species in Appendix F and reference the mature width. Count tree in the appopriate Functional	All streets will be required to have street trees. In all commercial non-transect zones and Core Transit Corridors street trees will be required in the planting zone at an average spacing not greater than 30' o.c. Director shall adopt a list of acceptable trees. Tree list can be found in the ECM Appendix F https://library.municode.com/TX/Austin/codes/environmental_criteria_manual	
Shrubs, ornamental grasses and large perennials	**0.3**	Shrubs are woody vegetation over 2 feet in height. To achieve credit for ornamental grasses and perennials in FG, plants must have a mature height of at least 2 feet and be evergreen or have year round structure. Perennials not meeting this description will count towards ground cover.	Credit is given for the square foot area of shrub, ornamental grass or large perennial.		
Ground cover	**0.2**	Low spreading vegetation typically less than 24 inches in height.	Credit is given for the square foot area of groundcover.		
Turf grass	**0.1**	turf grass grown from seed or sod	Credit is given for the square foot area of turf.		

Functional Green



Functional Green Development Process

- **Intensive literature review**
  - We summarized **peer-reviewed literature and local reports for the Austin area whenever possible**; we also included **additional studies conducted in locations with climates similar to Austin's (humid subtropical)** when they were available. In cases where little published research exists, we relied on best available data regardless of location or climate.
  - We reviewed **studies of performance for individual landscape elements in the field and lab as well as modeling studies.**

- **Findings were summarized to to provide an estimate of the range of likely benefits.**
  - Results are **summarized on a per-unit or per-area basis**, and where modeling studies are available results are reported for implementation at broader spatial scales. **Identified and reported common metrics** wherever possible to allow comparison.

ECONorthwest
ECONOMICS • FINANCE • PLANNING

DATE: January 12, 2017
TO: Austin City Staff
FROM: Heather Venhaus, Regenerative Environmental Design
Amy Belaire, PhD
Ed MacMullan and Sarah Reich, ECONorthwest
SUBJECT: Results of Task 7B—Landscape Elements and Ecosystem Services Literature Review

1 Introduction

Ecosystem services have become a mainstream concept to describe how natural resources and processes interact with and benefit human society. In 2005, the Millennium Ecosystem Assessment (MA), a pivotal work involving over 1,300 scientists, formalized a definition and classification of ecosystem services that is still widely recognized and used. The MA defined ecosystem services concisely as, "the benefits people obtain from ecosystems" (MA 2005, page v). In 2015, the US EPA developed the "National Ecosystem Services Classification System" (NESCS). NESCS provides a framework to help identify and describe the human welfare impacts of changes in the supply of ecosystem services. (US EPA, 2015)

Our analysis focuses on the ecosystem services and their associated economic values of a range of landscape elements that could be incorporated in urban sites. These alternatives include: planting street trees; installing green roofs; planting rain gardens and other bioretention structures; installing green façades on buildings; substituting porous pavement for asphalt or cement roadways; and collecting rainwater via cisterns or similar catchment systems. These landscape elements, collectively known by a variety of names including "low impact development," and "green infrastructure," provide ecosystem services important to municipalities, property owners and residents in urban areas. They provide the following ecosystem services that are particularly relevant in urban landscapes and have been prioritized by the City of Austin:

- Reducing stormwater volumes by infiltrating it into the ground or releasing it over time into a city's stormwater pipes and other "grey" stormwater infrastructure.
- Filtering stormwater onsite and improving downstream water quality.
- Reducing downstream flooding.
- Improving air quality with vegetation that sequesters carbon, removes particulate matter, and captures other air-borne contaminants.
- Moderating air temperatures and mitigating urban heat island effects.
- Providing habitat value and resources for biodiversity.
- Providing visual amenities.

Economists value these benefits a number of ways. The *avoided-cost* method estimates benefit values based on the amount and cost of municipal services avoided because of the landscape

elements in place. An example is the volume of stormwater kept out of a jurisdiction's system of stormwater pipes and treatment facilities, and the associated cost savings of not having to process this volume of stormwater. *Hedonic analyses* estimate the impacts of landscape components on nearby property values. These analyses control for property-specific attributes, e.g., number of bedrooms, size of lot, school district, etc. and estimate the resulting impact on property values from landscape components, e.g., street trees. *Contingent valuation* studies estimate people's willingness to pay to protect landscape attributes. For example, this type of study could estimate the value that residents place on the habitat benefits provided by a city's green roofs.

The state of the science of ecosystem services is such that the available data are typically insufficient to allow quantifying and valuing all ecosystem services from all green infrastructure applications. While the body of relevant literature and data continues growing, much work remains to fill quantification and valuation gaps. Another point to consider is that the supply of ecosystem services and their associated economic values from green infrastructure can be very site specific. That is, local soils, landscape and climate conditions influence the supply of ecosystem services. These conditions, plus local cost of services, property values, etc., can influence ecosystem service values. For this reason, care must be taken when considering using supply and value estimates from past studies conducted elsewhere.

The purpose of this literature review is to summarize estimates of the supply and value of ecosystem services provided by six key landscape elements expected to be included in the City of Austin's Functional Green program. This review focuses on the relationship between the landscape elements and the magnitude and quality of ecosystem goods and services that flow from the landscape. For each of the landscape elements, we review relevant ecosystem services literature from four perspectives: (1) biophysical benefits, (2) economic values, (3) beneficiaries, and (4) costs of implementation. Whenever possible, we refer to studies conducted in the Austin area or in locations with similar climate conditions (humid subtropical climate zones as classified by Koppen Climate Classification System). In cases where Austin-specific data are not available, we report results from studies conducted elsewhere. In some cases, the available data do not allow quantification or valuation of an ecosystem service, so we describe supply and value qualitatively.

2 Trees

2.1 Biophysical Benefits

Extensive research has been conducted on the environmental and social benefits of trees in urban landscapes. In Austin, Texas, a comprehensive study of over 200 field plots provided input data for the U.S. Forest Service's iTree Eco modeling software in 2014 (Nowak et al. 2016). The field data collection and modeling effort allowed for a range of ecosystem services to be quantified in biophysical and economic terms for Austin's trees. Trees within developed land uses account for approximately 40 percent of Austin's urban forest, suggesting that the benefits

of trees can be integrated throughout the urban mosaic and provide extensive benefits to citizens across the city.

More broadly, previous research in urban landscapes indicates that urban trees are the most powerful generators of ecosystem services within highly developed environments as key providers of regulating, supporting, provisioning, and cultural services (Nowak and Dywer 2007, Mullaney et al. 2015). Urban trees provide a broad range of biophysical benefits, including regulating microclimate, capturing air pollutants, sequestering and storing carbon, reducing stormwater runoff, and providing resources for biodiversity. Most of these benefits are correlated with the leaf area of the trees; larger trees and those with greater leaf area provide greater benefits than smaller trees or trees with less leaf area (Nowak et al. 2016). In Austin, trees with particularly high leaf area that may be included in streetscapes include live oaks and cedar elms.

As microclimate regulators, trees provide shade by acting as structural shields from solar radiation (blocking 70 to 90 percent of incoming solar radiation on sunny days, Heisler 1986); they also provide cooling benefits on sunny days through evapotranspiration, which can disperse to provide an overall cooling effect at a broader spatial scale. Research in a humid subtropical climate (Maryland, USA) examined the collective effects of street trees on urban heat island effects and found that tree cover adjacent to urban roads can decrease surface air temperatures by 7° F (4.1K), road-surface temperatures by 27° F, and building wall temperatures by 16° F (Loughner et al. 2012). In Austin, the cooling benefits of trees have been quantified in terms of the projected energy savings that buildings could save on air conditioning costs due to tree location, size, and proximity to building walls and roofs, with a net savings of $18.9 million annually for residential buildings (Nowak et al. 2016). These energy savings also result in substantial avoided greenhouse gas emissions from power plants. The cooling effects of urban trees can also lead to reduced formation of ground-level ozone, an air pollutant linked with serious respiratory health effects (Nowak and Dywer 2007).

Trees also play a direct role in urban air quality, by storing and sequestering carbon, capturing gaseous air pollutants through leaf stomata, and intercepting particles on plant surfaces (Nowak and Dywer 2007). Collectively, Austin's existing tree canopy contributes to the annual removal of 1,120 tons of O_3, 86 tons of NO_2, 24 tons of $PM_{2.5}$, and 23 tons of SO_2 (Nowak et al. 2016). Some trees can emit volatile organic compounds (VOCs), which are precursors to O_3 and CO formation; however, this process is temperature dependent, and the cooling effects of trees are expected to outweigh the effects of VOC emission (Nowak and Dywer 2007). Furthermore, trees take in carbon from the atmosphere as they grow, with one large healthy tree sequestering about 93 kg C per year (Nowak and Dywer 2007). Austin's trees collectively store approximately 1.9 million tons of carbon in their biomass, with an annual net sequestration rate of 67,000 tons of C per year (Nowak et al. 2016). In urban areas, the vast majority of the carbon pool is stored in trees rather than herbaceous plants or smaller woody vegetation (Davies et al. 2011).

Trees also contribute to stormwater management goals in urban areas by intercepting rainwater and promoting infiltration and water storage in soil, which in turn leads to reduced peak flow and runoff volumes. An individual tree is estimated to reduce stormwater runoff volume by 113-400 cubic feet each year (Mullaney et al. 2015). Calculations performed by City of Austin staff suggest that the stormwater management benefits of trees (specifically interception of rainwater) are relatively low compared to the retention benefits of other green infrastructure such as rain gardens. The collective stormwater benefits of trees in Austin was estimated at 65 million cubic feet of "avoided runoff" each year (Nowak et al. 2016).

Trees benefit biodiversity by providing habitat resources and enhancing habitat connectivity across urban landscapes (Strohbach et al. 2013, Ikin et al. 2013, Belaire et al. 2014). Research also demonstrates that trees can contribute to noise reduction in urban areas (reviewed in Gomez-Baggethun and Barton 2013) and a variety of social benefits, including reduced crime (Kuo and Sullivan 2001) and improved road safety for drivers and pedestrians (reviewed in Tarran 2009).

2.2 Economic Benefits

The economic benefits of trees derive from their biophysical effects. For several of these effects, there is a strong body of literature assigning a dollar value to trees, including benefits arising from trees' positive impact on air quality, local climate regulation, carbon uptake, and property values.

2.2.1 Value of Air Pollutant Removal and Emissions Avoidance

Trees reduce air pollution by taking up and filtering pollutants already in the air, and by regulating local climate conditions, which can reduce energy use and associated air pollution. Economists measure the value of air quality improvements in several ways. The iTree Eco Modeling Software described above, and used in the Nowak et al. (2016) study of the value of trees in Austin, uses an approach that quantifies the avoided costs associated with pollutants' effects on human health: as pollutant concentrations decrease, the costs associated with pollution-induced health conditions, such as premature death, respiratory conditions, and absenteeism due to illness also decrease. The iTree model integrates data from U.S. EPA's BenMAP tool, which estimates the health impacts and economic value of changes in air quality. This modeling process accounts for local population density and age characteristics where air quality benefits occur, because the value of diminished air pollution is greater where there are more people to benefit. Also, benefits are greater among older and younger populations, which are typically more vulnerable to air pollution. Table 1 shows the values from iTree for rural and urban areas in Austin, showing the differences in value based on the population differences in different parts of the city.

Table 1. Value of Air Pollutant Removal (Dollars per Pound in 2015 Dollars)

	Values for the City of Austin (Nowak et al. 2016)	Values for a Rural Site in Austin	Values for an Urban Site in Austin[1]
Nitrogen Dioxide (NO_2)	$0.14	$0.06	$0.15
Sulfur Dioxide (SO_2)	$0.04	$0.02	$0.04
Small Particulate Matter	$22.68	$12.00	$29.72

Sources: iTree
Notes: [1] This site is typical of the downtown area where Austin's Functional Green program is focused.

2.2.2 Value of Carbon Emissions Avoidance and Carbon Sequestration

Trees provide benefits for global climate regulation by sequestering carbon and by regulating local climate conditions, which can reduce energy consumption by reducing building heating and cooling demand. The amount of carbon sequestration varies by species and age of the tree. The amount of carbon emissions avoided by reducing energy demand depends on local climate conditions and on the placement of trees relative to buildings.

Trees in Austin store (taking into account decomposition) approximately 67,000 tons of carbon each year, valued at about $8.5 million per year (Nowak et al. 2016, calculated based on reported information for value of gross carbon sequestered each year). Trees also offset energy demand (see below), which reduces carbon emissions from fossil-fuel-based power sources, valued at almost $5 million (Nowak et al. 2016). This equates to about $35 per ton of CO_2 offset or sequestered, which is based on the U.S. Council on Environmental Quality and the EPA's recommendations for valuing the social cost of carbon. The EPA's guidance on valuing carbon sequestration and avoided carbon dioxide emissions recommends using a value between approximately $12 and $65 per metric ton of CO_2 for emissions avoided or carbon dioxide equivalent sequestered in 2015 (Interagency Working Group 2016; dollars converted to 2015 based on the CPI; range depends on the discount rate used to adjust future damages). This value accounts for the social cost of carbon emitted today, accounting for costs of effects associated with that unit of carbon that accrue over time. The value of a metric ton of carbon dioxide equivalent sequestered (or carbon dioxide emissions avoided) in the future (by 2050) increases to between $30 and $110, to account for the cumulative and increasing damages attributable to climate change (Interagency Working Group 2016; dollars converted to 2015 based on the CPI).

2.2.3 Energy Costs

Homes and other buildings with appropriately located trees may cost less to heat and cool. The amount of avoided energy costs depends on the location of the trees relative to the structure, the local climate, and the efficiency of the building itself. Multi-story and multi-family residential buildings experience fewer benefits than single-family residential buildings, because they are less influenced by shade effects of trees and more by climate conditions (McPherson and Simpson 2003). Even in areas dominated by multi-story buildings, a high density of urban trees helps reduce energy demand by reducing the urban heat-island effect, lowering ambient air temperature. Nowak et al. (2016) suggests that interactions between trees and buildings reduces the City of Austin's residents' energy costs by almost $19 million each year. This also reflects the offsetting effect that trees may increase heating demands during the winter, because

they (especially evergreen species) provide shade when sun exposure would otherwise offset heating expenses. This offsetting effect is smaller for multi-story buildings, because they are less influenced by the shading effects (McPherson and Simpson 2003).

2.2.4 Property Values

Trees offer many amenities that contribute to property values. A review of studies comparing areas with street trees to areas without across the country found that street trees can add between 2 and 10 percent (potentially up to 15 percent for mature trees in high-income neighborhoods) to property values (Wolf 2007). A mature tree canopy throughout a neighborhood can add between 6 and 9 percent to the homes in the neighborhood. There has been comparatively little research on the influence of trees on the value of multi-family and rental dwellings, but limited research has found that in Portland, Oregon, street trees increase rents (Donovan and Butry 2011). Trees enhance the value of commercial property, by increasing the street appeal to potential consumers and potentially increasing sales, and by increasing rental rates and reducing turnover for commercial offices (Laverne and Winson-Geidman 2003; Wolf 2007). A study of property values in Austin found, using two different methods, that street trees contribute between 13 and 19 percent of the value of residential property (Martin, Maggio, and Appel 1989).

2.2.5 Stormwater Runoff Costs

Trees capture and absorb stormwater, which has the potential to generate several economic benefits. These include lower risk of flooding and associated damage, reduced storm/sewer overflow events and potentially improved water quality, and reduced capacity of stormwater management infrastructure in areas with trees, especially combined with bioretention. These benefits all have the potential to yield avoided costs and economic benefits for property owners and the city's taxpayers. Nowak et al. (2016) calculates that Austin's trees capture 65 million cubic feet of stormwater runoff each year. Putting a dollar value on that reduced runoff city-wide is challenging, but examples from elsewhere suggest trees can provide very large benefits. In Washington, D.C., the existing 46 percent tree canopy reduces the need for stormwater retention structures by 949 million cubic feet, saving the District $4.7 billion every 20 years (American Forests 2002). Using a national average of $2 per cubic foot of storage, Austin's trees would provide approximately $130 million in stormwater retention benefits every 20 years (American Forests 2002).

2.2.6 Other Benefits

In addition to these benefits, the literature describes qualitatively additional economic values associated with trees, including health benefits, and benefits associated with increased biodiversity. A recent article attempted to value urban green spaces at the national level, evaluating studies associated with six social and health conditions that show improvement and reduced treatment costs when correlated with access to green spaces: newborn health, ADHD, school performance, crime, Alzheimer's disease, and cardiovascular health. The potential cost savings associated with improvements in these conditions ranges from $2.7 to $6.7 billion per year (Wolf 2015). Some of these benefits are likely at least partially captured by the valuation

methods used for the benefits described above (e.g., property values and avoided costs of air pollution), but the quantified benefits almost certainly underestimate the total economic value generated by trees.

2.3 Beneficiaries

Trees generate public and private benefits. Private property owners with trees enjoy heating and cooling savings, increased property value, and enjoyment of the amenities trees provide. Private property owners adjacent to property with tree canopy may also enjoy these benefits without bearing the cost of the investment. Renters in buildings that benefit from trees may enjoy reduced energy costs, but may also pay higher rents that offset the cost savings. The public may enjoy benefits arising from the environmental effects of trees, including mental and physical health improvements from better air quality and enhanced amenities, moderated temperatures from reduced urban heat island effect, and enjoyment of increased biodiversity.

2.4 Costs of Implementation

The cost of trees includes planting, pruning and maintenance, tree and stump removal at the end of a tree's life, pest and disease control, irrigation, and other costs (e.g., infrastructure opportunity costs, liability costs, litter and waste disposal costs, and for public trees, inspection and administration costs) (McPherson 2006). Regional surveys of tree costs as reported by urban arborists and municipal foresters in the Piedmont (North Carolina to Texas) and Interior West (Texas west) are shown in Table 2. Austin sits on the border of these regions, so likely would experience costs somewhere within this range.

Table 2. Costs of Trees (2015$)

	Piedmont Region[a]	Interior West Region[b]
Planting (One-time)	$587	$97-$457
Pruning (Per tree per year, depending on size and age)	$0.07-$5.50	$4-$515
Removal (Per inch of diameter)	$41-$260	$25-$40
Pest and Disease Control (Per tree per year)	$23	N/A
Irrigation (Per year for first 5 years)	N/A	$1.14-$4.57

Sources: [a] Vargas et. al. 2007; [b] McPherson et al. 2006

3 Green roofs

3.1 Biophysical Benefits

Green roofs cover building rooftops with a vegetated surface and substrate, taking the form of an "intensive" or "extensive" design. Intensive green roofs are often designed with diverse vegetation types, including trees, whereas extensive green roofs are often planted with dense, low-growing vegetation in shallower substrates (Oberndorfer et al. 2007, Ahiablame et al. 2012). Green roofs can be one means of increasing vegetation cover in urban landscapes, compensating for the vegetation that was removed during construction. The biophysical benefits of green roofs center on improved stormwater management, reduced temperatures of buildings and broader urban heat islands, and enhanced habitat resources and connectivity for

biodiversity. Aesthetic appeal and functional space for urban residents are also possible, depending on design and characteristics (Oberndorfer et al. 2007).

The stormwater management benefits of green roofs have been explored in a wide variety of climates and contexts. Research indicates that green roofs can retain 20-100 percent of rainfall, but this is highly dependent on the amount of rainfall and the existing water holding capacity of the roof during a given storm (reviewed in Ahiablame et al. 2012). In general, green infrastructure such as green roofs, bioretention, and porous pavements experience saturation and therefore provide little benefit in large storms and flash flood events. Studies in Austin and in locations with similar humid subtropical climates (Cfa) demonstrate that green roofs can retain 44-48 percent of rainfall volume during large (e.g., 3-inch) storms and 86-88 percent during smaller (e.g., <1-inch) storms (Carter et al. 2007, Simmons et al. 2013). One study in Maryland, USA found that per-storm retention rates varied depending on storm size, but 74 percent of the total rainfall volume over 10 months was retained by the green roof (Glass 2007). The effects of green roofs on water quality, however, are less clear, with studies showing mixed results for green roofs in removing nutrients and metals from stormwater (Ahiablame et al. 2012). However, one review suggests that as green roofs get older, their performance improves in terms of reducing pollutant loads (Rowe 2011).

Studies conducted at multiple spatial scales suggest that green roofs can contribute substantially to reducing urban heat island effects by increasing the albedo of existing rooftops and increasing the amount of vegetation that provides shade and cooling benefits of evapotranspiration. A modeling study of cities across the globe, including one city in a humid subtropical climate (Hong Kong), found that the maximum roof surface temperature difference for a green roof (compared to a non-vegetated roof) was 45° F cooler on a hot summer day (Alexandri and Jones 2008). Models also indicate that green roofs can reduce average ambient temperatures by up to 2.7-5.4° F when applied more broadly across an urban landscape (Meek et al. 2014, Santamouris 2014). It is important to note that the green roofs on taller buildings may contribute negligible benefits for mitigating broader urban heat island effects (Santamouris 2014). However, the cooling benefits for underlying buildings can translate to reduced air conditioning needs, leading to energy savings and reduced greenhouse gas emissions at power plants as a result (Rowe 2011).

Additional biophysical benefits provided by green roofs include reduction of noise and air pollution in urban streetscapes (Van Renterghem and Botteldooren 2009, Rowe 2011). Green roofs are capable of removing air pollutants from the atmosphere and acting as a carbon sink, depending on plant characteristics and design (Currie et al. 2008, Pugh et al. 2012, Rowe 2011). In addition, the cooling benefits of green roofs may contribute to reduced formation of ground-level ozone (Rowe 2011).

Research in recent years has demonstrated that green roofs support a surprising diversity of invertebrate species, including native pollinators and specialist species (Colla et al. 2009, Tonietto et al. 2011, Madre et al. 2013). Moreover, green roofs can be important "stepping stones" between urban habitat patches and contribute to functional connectivity for some

species (Braaker et al. 2014). Several studies have shown that invertebrates respond to green roof habitat regardless of the broader landscape context, which suggests that even small green roofs in highly urbanized surroundings can provide important habitat value for biodiversity (Madre et al. 2013, Tonietto et al. 2011).

3.2 Economic Benefits

Green roofs provide building owners with private costs savings and increased property values. They also provide a variety of public benefits, some of which are quantifiable and some are not, especially at the scale of an individual green roof. In general, in areas that experience droughts, maintenance costs for vegetation can increase due to additional water requirements and the potential replacement of vegetation.

3.2.1 Building Cost Savings

Green roof experts suggest that the lifespan of a roof can double under a green roof, reducing maintenance costs over conventional roofs and leading to a potential $25 per square foot savings. Additional savings to the building owner may come from incentives or development credits offered by the City. In the City of Austin, Green Roofs qualify for meeting development requirements and may qualify a development for a density bonus in the downtown area (City of Austin 2014).

3.2.2 Energy Costs

The insulating effect of the green roof depends on the characteristics of the building it sits on, and the climate where the building is located. In the absence of specific building data, green roof experts suggest the insulative properties of a green roof provide approximately the equivalent of an inch of conventional insulating materials, which typically cost approximately $3 per square foot. Based on these cost savings in addition to reduced periodic repair costs, the building owner may enjoy a cost savings of $32 per square foot over a conventional roof (Breuning No Date). The relative energy savings benefit is greatest for one- and two-story buildings. Multi-story buildings experience energy efficiency improvements only on the few stories below the green roof: floors greater than four stories below the green roof are not impacted (Blackhurst et al. 2010).

3.2.3 Property Values

Green buildings and green roofs have been shown to increase property values. One analysis showed the real estate effect nationally at $13 per square foot of green roof (GSA 2011). Buildings that have views of a green roof experience increases in value as well. A study in New York City found that apartment rents in buildings with green roofs were about 16 percent higher on average than buildings without green roofs (Ichihara and Cohen 2010). Data from national surveys by the U.S. Green Building Council found that green buildings in general realize 5.7 percent more rent than conventional buildings (GSA 2011).

3.2.4 Stormwater Runoff

Modeling results suggest that most green roofs reduce annual stormwater runoff volume. This reduces the stormwater management costs to the City, and may reduce the need for future conventional stormwater infrastructure investments. An individual green roof may not have a measurable effect on public stormwater investment requirements, however more widespread adoption has been shown to produce substantial public savings. In Washington, D.C., a 10 percent increase in green roof coverage could reduce the infrastructure costs in the District's Long-Term Control Plan (LTCP) by $10 million (Deutsch et al 2005). In Detroit, a 10 percent increase in green roof coverage could reduce the LTCP costs by $114 million (Deutsch et al 2005).

3.2.5 Air Quality

Green roofs also provide public economic benefits by improving air quality. The most commonly measured pollutant reductions are nitrogen-oxides and particulate matter. The GSA (2011) calculated that the economic benefit of reducing these pollutants is negligible to almost $0.60 per square foot of green roof. For an individual green roof, this does not add up to a huge benefit, but at a larger scale, the economic benefits become more meaningful.

3.2.6 Health and Well-Being

The improvements in human health and well-being that arise from access and views of greenspaces apply to greenroofs. A green roof that is within view of office space may improve worker productivity: one study found that workers who have a view of vegetation out their window are almost 3 percent more productive (GSA 2011). College students working in a computer lab with plants were 12 percent more productive, demonstrating faster reaction times and lower stress (Lohr et al. 1996). Benefits in the form of less stress, better mental health, and faster recovery times have also been documented for younger students, health care workers, and patients in hospitals. All of these health and well-being effects have economic implications, though they are not easy to quantify. Lower absenteeism has the potential to save employers millions per year, and the effects of reduced stress may contribute to lower health care costs nationally, and higher quality of life (Wolf 2014).

3.3 Beneficiaries

Building owners enjoy cost savings and increased property value, rental rates, and potentially increased worker productivity after installing a green roof. Renters in a building with a greenroof may experience reduced energy costs, depending on site-specific conditions, but higher rental rates may offset this benefit. The public enjoys reduced stormwater management costs, especially if green roof installation is widespread. The public may also enjoy benefits related to air quality improvement and urban heat island mitigation, and enhanced biodiversity if green roof implementation is widespread in an urban area. These public benefits are more limited with isolated green roof applications.

3.4 Costs of Implementation

Installation costs of an extensive green roof may be between around $10 and $30 per square foot more expensive than conventional roofs (Breuning No Date; GSA 2011; Center for Neighborhood Technology No Date), but typically the extra cost for extensive roofs is on the lower end of this range. Over its lifetime, a greenroof will require maintenance of around $15 per square foot (Breuning No Date): annual maintenance is typically higher than a conventional roof by $0.21 to $0.31 per square foot (GSA 2011). The Center for Neighborhood Technology (No Date) suggests maintenance costs for green roofs range from 2 cents per square foot to around 40 cents. The maintenance cost is influenced by roof design and local climate. Table 3 summarizes the construction and maintenance costs, as compiled by the Center for Neighborhood Technology.

Table 3: Costs for Bioretention and Rain Garden Structures (2016$)

	Construction Costs/Sq. Ft.	Maintenance Costs/Sq. Ft.	Useful Lifespan (Years)	
Low	$8.75	$0.020	Long	50
Medium	$15.75	$0.025	Mid	40
High	$31.80	$0.421	Short	25

Source: (Center for Neighborhood Technology, No date)

4 Bioretention, Biofiltration Systems, and Rain Gardens

4.1 Biophysical Benefits

Bioretention, biofiltration systems, and rain gardens are typically small depressions that retain and treat stormwater runoff with plants and soils. Generally, the terms "bioretention cells" and "rain gardens" describe stormwater management systems that are designed to function similarly to natural landscapes by capturing runoff and promoting infiltration/filtration via vegetated systems planted in a variety of media types (Ahiablame et al. 2012). Bioretention cells and rain gardens may or may not be designed with an underdrain, depending on underlying soil conditions. The City of Austin's definition of a "biofiltration" system requires a two-step process, in which runoff is first directed to a sedimentation basin for pre-treatment and then directed through a cell with a biologically active system of plants rooted in a filter medium (City of Austin 2016, Section C). The majority of research conducted thus far has focused on bioretention systems without pre-treatment sedimentation basins. The biophysical benefits provided by these types of system include reduced urban runoff, improved water quality, microclimate regulation, reduced air pollution and noise, and support for urban biodiversity.

Bioretention systems perform particularly well in reducing runoff volumes and peak flow rates and can capture the entire inflow volume, especially in small events. In general, green infrastructure such as green roofs, bioretention, and porous pavements experience saturation and therefore provide little benefit in large storms and flash flood events. A 7-month field study in a humid subtropical climate (Virginia, USA) documented a cumulative volume reduction of 97 percent during the study period; on a per-storm basis, the median volume reduction was 100 percent, with only 5 of 28 storm events producing outflow (DeBusk and

Wynn 2011). Six bioretention cells monitored in Maryland and North Carolina, USA (both humid subtropical climates) for more than 10 months also performed well, with median runoff volume reduction ranging from 40-99 percent across the six sites (Li et al. 2009). A nationwide modeling study with 3-year continuous simulations for real precipitation patterns demonstrated that individual rain gardens in Texas could reduce total runoff volumes by 65 percent (Jennings 2016).

The reduction in runoff volumes also translates into reduction of peak flow rates, with one study in North Carolina, USA documenting a mean peak flow reduction of 99 percent over a two-year time span (Hunt et al. 2008). Modeling studies demonstrate that when bioretention systems and/or rain gardens are implemented broadly across a watershed, they can cumulatively contribute to increased groundwater recharge, increased stream baseflow rates, and reduced number of erosive events in urban streams, which can in turn lead to improved stream ecological health (Hamel et al. 2013, Glick et al. 2016). The in-stream ecological effects of catchment-scale implementation of green infrastructure have been monitored in an innovative Australian study, although no change in ecological indicators has been observed thus far (Walsh et al. 2015).

The performance of bioretention systems in removing pollutants from urban runoff has also been relatively well documented. A lab study conducted with synthetic and real stormwater in Austin, Texas demonstrated that vegetated systems in biofiltration media removed all nutrients (especially total phosphorus, >80 percent removed), metals (>95 percent removed for copper, lead, and zinc), and total suspended solids (>85 percent removed) (Limouzin et al. 2011). A separate study in Austin, Texas indicated that effluent from biofiltration systems had concentrations of total suspended solids, zinc, and *E. coli* that were significantly lower than those of runoff from undeveloped land in Austin (Richter 2015). In general, these results agree with data reported from other studies, with bioretention systems in a variety of settings showing consistently high removal rates for total suspended solids, some nutrients, and metals (although removal rates are dependent upon design characteristics) (reviewed in Ahiablame et al. 2012). Recent studies have also demonstrated bioretention systems can effectively remove *E. coli* over the long-term (70-97 percent removal, in lab experiments conducted by Zhang et al. 2011).

As with other small vegetated areas in urban landscapes, rain gardens and bioretention systems can also store and sequester carbon, mitigate urban heat island effects, reduce noise pollution, and support urban biodiversity. Even small areas of herbaceous cover can store 0.14 kg carbon per square meter (Davies et al. 2011), which can increase substantially as the system ages (i.e., 3.34 kg carbon per square meter after 21 years; Bouchard et al. 2013). In addition, small vegetated areas contribute to overall cooling effects through transpiration (Perring et al. 2013, Davis et al. 2016) and can reduce noise levels in urban areas (Bolund and Hunhammar 1999). Furthermore, a series of studies in Melbourne, Australia demonstrated that bioretention systems support high biodiversity invertebrate species, with greater species richness in bioretention basins than in nearby urban green spaces (Kazemi et al. 2009, Kazemi et al. 2011).

4.2 Economic Benefits

4.2.1 Stormwater

The City of Austin charges property owners a Drainage Utility Fee (DUF) for managing stormwater. The DUF includes a base rate applied to the square footage of a property's impervious area, modified by an adjustment factor. The median household charge is approximately $12 per month (Pantalion, 2016). Biofiltration controls can help reduce stormwater volumes that flow into the City of Austin's stormwater infrastructure, and help property owners qualify for MDC discounts. Monthly discounts range from $0.22 for a 55-gallon reduction in stormwater volume, up to $8.05 per month for reductions of 3,000 gallons or more. These discounts reflect reduced costs to the City of Austin of managing and treating stormwater (Pantalion, 2016). Bioretention and realted storwmater controls help reduce runoff volumes, which can help reduce stormwater management costs.

4.2.2 Carbon Sequestration and Air quality

Bioretention areas that include significant vegetation, including grasses, shrubs, and trees produce environmental benefits ranging from air quality improvements to carbon sequestration. These benefits would be valued using the economic values and methods described above for trees. Shrubs and grasses and other smaller vegetation has smaller effects on these ecosystem services than do trees, so biofiltration that does not include trees would produce a smaller magnitude of these benefits.

4.3 Beneficiaries

Bioretention structures and rain gardens generate benefits for a range of stakeholders. City of Austin stormwater managers benefit through reduced volumes of stormwater managed and processed. Reducing stormwater volumes can also help reduce demand for stormwater services as the city's population grows, thus extending the capacity of the city's stormwater infrastructure further out into the future. Combined, these benefits can reduce operating costs. Property owners benefit through reduced MDC costs. Property owners also incur the costs of implementing the green infrastructure controls, which we address in the next subsection. Residents of multi-family and other rental properties may or may not benefit from reduced MDC costs, depending on their agreements with property owners regarding utility payments. In cases where property owners, not tenants, pay stormwater utility fees, owners may or may not pass reduced MDC costs on to tenants. To the extent that stormwater controls help reduce flooding, they can also help reduce downstream flood risks, damage and costs. These benefits accrue to downstream property owners and to the City of Austin through reduced emergency management and response costs. The carbon sequestration benefits accrue to society at large.

4.4 Cost of Implementation

Costs of implementing bioretention and rain garden stormwater controls can be very site specific depending on local soil, vegetation, and climate conditions. Tables 4A and 4B summarize the instillation and maintenance and management cost information reported in the

literature. The "Low" construction costs apply to smaller scale and self-installed controls. In Table 4A, instillation costs for biofiltration and rain gardens reported as cost per cubic foot of stormwater retention volume. Costs for vegetative filter strip reported per square foot of instillation. O&M costs reports as annual average costs per instillation. Costs in Table 4B report per square foot of instillation.

Table 4A: City of Austin Costs for Bioretention and Rain Garden Structures (2016$)

	Low Cost	Average Cost	High Cost	Annual O&M/Instillation
Biofiltration ($/CF)	$5.14	$11.33	$18.05	$3,000
Rain Garden ($/CF)	$8.21	$24.25	61.79	$1,700
Vegetative Filter Strip ($/SF)	$1.98	$3.11	$4.80	$3,076

Source: City of Austin staff, Personal Communication, January 17, 2017.

Table 4B: Nationwide Range of Costs for Bioretention and Rain Garden Structures (2016$)

	Construction Costs/Sq. Ft.	Maintenance Costs/Sq. Ft.	Useful Lifespan (Years)	
Low	$5.943	$0.380	**Long**	50
Medium	$7.805	$0.488	**Mid**	30
High	$18.522	$0.747	**Short**	25

Source; (Center for Neighborhood Technology, No date)

A subdivision in Austin included four bioretention areas as a substitute for the sedimentation-filtration pond that would have otherwise been required. In addition to providing the ecosystem services benefits and values described above, installing the bioretention structures cost approximately $185,000 less. On a per-lot basis, the bioretention option cost approximately $450, compared to approximately $1,700 for the sedimentation-filtration option. (US EPA, 2005)

5 Green Façade

5.1 Biophysical Benefits

The term "green façade" or "green wall" describes built vertical surfaces that support vegetation. Green façades may be "direct," with vegetation growing directly on a wall itself, or "double-skin," which support plants with engineered structures such as cables and create an insulating layer of air between plants and building (Hunter et al. 2012, Perini et al. 2011). In both cases, the plants are rooted in soil at the ground level or in planter boxes. "Living walls," on the other hand, include encased growing medium within a support structure that is anchored on the building surface (i.e., plants need not be rooted in substrate at the base of the wall) (Perini et al. 2011). The biophysical benefits of green façades center on microclimate regulation, noise reduction, and air pollutant capture.

Vegetation adjacent to building walls can contribute substantially to urban microclimates by screening solar radiation before it reaches the building, increasing albedo (reflective capacity), and cooling the surrounding air as plants transpire (Hunter et al. 2012). The cooling benefits can be especially pronounced for green façade designs that maintain an insulating layer between the building surface and vegetation. Studies in humid subtropical climates indicate that

building surface temperatures behind vegetated walls can be 21-36° F cooler than non-vegetated walls on hot sunny days (Alexandri and Jones 2008, Chen et al. 2013, Mazzali et al. 2013), which in turn leads to reduced energy loads for building climate control. Furthermore, the temperature effects can extend to the adjacent street "canyons," reducing air temperatures by around 7° F (Alexandri and Jones 2008). The cooling benefits vary with individual plant species characteristics, including physiology and leaf area (Cameron et al. 2014).

Vegetated walls can also provide air quality benefits in urban landscapes, including capture of particulate matter and uptake of O_3, NO_2, and SO_2 (Currie et al. 2008, Pugh et al. 2012). The cooling benefits they provide can also reduce formation of ground-level O_3. The vegetation in green façades also reduce noise pollution and act as sound insulation tools for buildings (Azkorra et al. 2015).

In addition, vegetated walls can be designed specifically to provide foraging or nesting resources for local wildlife species (Francis 2011). They show promise for supporting arthropod species (i.e., beetles and spiders) and urban bird species (i.e., house sparrows and European starlings) (Chiquet et a. 2013, Madre et al. 2015).

5.2 Economic Benefits

The economic benefits of green walls have not been studied as extensively as green roofs. They provide similar types of benefits, but from the literature available to date, the magnitude of benefits appears to be smaller, and costs higher. However, for taller buildings, some studies have suggested that green walls be used in conjunction with or instead of green roofs to produce maximum economic benefits. For example, the GSA found that "Simultaneous use of green roofs and green walls is significantly more effective than the use of green roofs alone in reducing surface and ambient air temperatures in urban canyons and over rooftops." (GSA 2011 pg. 34)

Green walls generate both public and private benefits. Economic benefits to the building owner arise from the insulating and protective properties of the wall system: the vegetation can reduce energy demand for heating and cooling and increases the lifespan of the exterior façade, increasing the time between required maintenance. Green walls also provide aesthetic benefits that may increase the property value or rent a building owner may charge. The performance and associated economic benefits of green walls depends in part on choosing vegetation appropriate for the local climate conditions. Using vegetation not suited to the climate may increase costs associated with additional maintenance and irrigation.

Much of the economic research on green wall systems comes from Europe. One study looked at the benefits and costs of several theoretical green wall installations in Genoa, Italy (Perini 2013). This study found the green wall could increase property value by 2 to 5 percent, with the highest increase for buildings located in the periphery of the city. Energy savings in the Mediterranean climate where the hypothetical building would be located resulted from reduced air conditioning. Maximum benefit depended on the existing insulation of the building, with all

concrete-walls benefiting the most (up to 65.8 percent), and walls with polystyrene insulation already in place benefiting the least (1.4 to 2.6 percent energy use reduction). The green wall systems also increased the lifespan of the building façade (plaster) from 35 years to 50 years. The study examined the literature on social benefits (e.g., air quality improvement, urban heat island effect, and biodiversity) but found limited data to support the quantification of benefits on a single-building scale. Overall, the study found that green wall systems with the lowest installation cost (green walls versus living walls) had a positive rate of return to the building owner, but in no scenario, did the living wall system produce positive net benefits because of its ongoing maintenance costs.

Another benefit-cost analysis of a living wall system on a school in Dubai found that the system produced a yearly cooling savings of 18 percent, and an increased rental rate (Haggag and Hassan 2015). However, with these quantified benefits, the payback period for the building owner would be 17 years under current energy prices. This study did not consider other private benefits, such as increased longevity of the building façade or public benefits, such as air quality improvement.

The public benefits discussed but not quantified in the economic literature include reduced urban heat island effect, improved exterior air quality (green walls installed indoors can improve interior air quality as well), aesthetic improvements, biodiversity, and noise reduction (Green Roofs for Healthy Cities 2008). Stormwater capture is rarely mentioned as a benefit of green walls, but some specifically designed examples do exist (see e.g., City of Portland 2014).

5.3 Beneficiaries

Building owners and occupants are the primary beneficiary of green walls, with some aesthetic benefit accruing to pedestrians and adjacent property owners in view of the green wall installation. Most of the public benefits associated with individual green walls are too small to make a noticeable difference in factors such as the urban heat island and air quality. However, the incremental improvement of individual installations could add up if green walls are more widely adopted, leading to measurable public benefits.

5.4 Costs of Implementation

Green wall systems vary in installation costs, depending on their design. Livings walls are typically more expensive to install and maintain than green façades using ground-level plantings. Installation costs can range from approximately $80 to $150 per square foot for livings walls (Liang 2014). Maintenance costs for living walls can range from $7 to $15 per square foot. Installation for green facades can range from $25 to $40 per square foot or more, which includes installation of the climbing structure, substrate, plants, and irrigation systems (Architek No Date; State of Victoria 2014; Perini and Rosasco 2013). Annual maintenance costs for green façades are not widely documented in the literature, but are typically cited as minimal ($0.25 to $1 per square foot, Perini and Rosasco 2013). Typical activities, such as pruning, plant replacement if necessary, and debris clearing are often covered in landscape budgets. Other activities, such as structural inspection, occur infrequently, if at all. Maintenance costs are

higher for green wall systems in climates that require irrigation, because water charges would accrue and the irrigation system would need additional annual maintenance and repair. These are still fairly new systems, and engineering challenges in installation and maintenance remain for many applications. Costs may decline as green walls gain wider acceptance, as was the case for green roofs (Rizer 2014).

6 Porous pavement

6.1 Biophysical Benefits

Porous pavement promotes retention of stormwater by allowing water to permeate the surface layer and infiltrate into underlying substrate, which can in turn reduce pollutants and recharge groundwater. A variety of porous pavement systems exist, including permeable interlocking concrete pavers, concrete grid pavers, open-jointed block pavement, and porous asphalt. In some types of porous pavement, vegetation can grow between paving units and promote cooling through evapotranspiration.

Research on stormwater management performance indicates that porous pavements substantially reduce runoff volume and peak flow rates. Studies from humid subtropical climates in North Carolina, Florida, and Georgia, USA have demonstrated that porous pavement can reduce runoff volumes by more than 90 percent and can eliminate runoff entirely for small storms (Rushton 2001, Collins et al. 2008, Dreelin et al. 2006, Bean et al. 2007, Ball and Rankin 2010). In general, green infrastructure such as green roofs, bioretention, and porous pavements experience saturation and therefore provide little benefit in large storms and flash flood events. A modeling study for an Austin watershed demonstrated that incorporating porous pavement as part of a broader green infrastructure implementation plan could lead to reduced runoff volumes, reduced peak flow rates, increased groundwater recharge, and reduced pollutant loads, although the relative contribution of porous pavement was minor compared to other green infrastructure types (Geosyntec 2016).

The benefits for water quality vary between studies, indicating that performance depends on a variety of factors related to design and precipitation. The International Stormwater BMP Database 2014 statistical summary report indicates that porous pavements are associated with statistically significant reductions in total suspended solids, total phosphorus, and some metals (copper, lead, nickel, and zinc).

Porous pavements can also provide cooling benefits, but results from previous studies have been inconclusive. In general, porous pavements can have a cooling effect when the retained water evaporates; however, when the water is depleted, the pavement surface can be hotter than conventional pavements (Santamouris 2013). In addition, porous pavements generally have a lower albedo than impermeable types. Results from studies in Arizona, South Carolina, and Iowa, USA demonstrate that porous pavements can reach higher daytime surface temperatures than other pavements, but they also cool to lower temperatures overnight (Caslon et al. 2009, Haselbach 2009, Kevern et al. 2009).

6.2 Economic Benefits

Porous pavement generates economic benefits primarily through the stormwater retention effect, reducing the need for other types of stormwater infrastructure. These benefits are described in more detail for Austin under the Bioretention section above.

Depending on the type of material used, the porous material may cost less to install, resulting in a reduced cost of development (Century West Engineering No Date). The cost savings comes from several sources. First, on street and parking lot applications, porous pavement may eliminate the need for standard curbs, gutters, storm drains, piping, and retention basis. Second, because extensive stormwater infrastructure is not required, less land is needed to manage the stormwater (i.e., detention basis are not required) so it may be put to other uses (ConcreteNetwork.com 2017).

Porous pavement applications that would not typically require stormwater management infrastructure (i.e., sidewalks, pedestrian areas) would not likely result in similar cost savings to developers. The economic benefit for these areas would primarily be in the form of reduced public stormwater infrastructure costs and reduced flooding, as described above.

6.3 Beneficiaries

For porous pavement installed on private property, the property owner would enjoy any cost savings that materializes from choosing porous pavement over conventional pavement, primarily the cost savings that comes from reduced drainage system requirements. The public (i.e., taxpayers) would enjoy the benefits of reduced public stormwater infrastructure, if a porous pavement installation reduced the need for stormwater retention on public property.

6.4 Costs of Implementation

Tables 5 shows the costs of instillation and O&M for porous pavement in City of Austin.

Table 5: City of Austin Cost of Porous Pavement Installations

	Low Cost ($/SF)	Average Cost ($/SF)	High Cost ($/SF)	Annual Average O&M ($/Instillation)
Porous Pavement	$6.34	$9.88	$18.55	$678

Source: City of Austin staff, Personal Communication, January 17, 2017.

Porous materials are even more cost competitive in larger applications and for areas where conventional alternatives would require stormwater retention infrastructure.

7 Cisterns

7.1 Biophysical Benefits

A cistern is an above- or below-ground tank that collects and stores rainwater for reuse. The biophysical benefits of cisterns include reducing stormwater volume and peak flow rates, which can in turn contribute to improved ecological health of urban streams. In addition, the water collected in a cistern can be reused for landscape purposes, which reduces the need for potable

water in irrigation. Two Austin-based modeling studies included cisterns as part of broader green infrastructure implementation scenarios and demonstrated that cisterns could play a substantial role in reducing peak flow rates and total runoff volumes in Austin watersheds (Glick et al. 2016, Geosyntec 2016). In most urban landscapes, a multi-pronged strategy of stormwater harvesting (e.g., with cisterns) combined with infiltration (e.g., with biofiltration) will be required to achieve stormwater targets and improve urban stream health (Askari et al. 2015, Burns et al. 2015). The stormwater management benefits of cisterns can be an important strategy to reduce the "flashiness" of flow in urban streams and lead to improvements in stream health, including reduced flooding, reduced erosion, and improved aquatic life. Cisterns would need to be emptied prior to large storage events to provide additional storage.

7.2 Economic Benefits

Cisterns provide economic benefits through stormwater capture and reuse. When stormwater is captured in cisterns, the risk of flooding and economic damage from flood events decreases. Since they serve to capture and hold water, less stormwater retention infrastructure may be required. However, for this latter benefit to be realized, the tanks must be reliably maintained and used (e.g., after a rainfall event they must be drained and ready to capture the next rainfall event). The other economic benefit cisterns provide is water supply, which can be used for non-potable applications, such as lawn watering, or in some cases can be coupled with treatment to supply a wider range of uses.

The economic benefits that cisterns generate related to reduced flood damage or avoided retention infrastructure costs depend on how widely cisterns are adopted and how much stormwater they are capable of capturing. These benefits materialize at a meaningful level when cistern use is widespread or targeted in areas where flooding is a problem.

Passive rainwater harvesting systems, such as rain barrels, provide limited opportunities for significant runoff reduction due to relative small volumes and unpredictable operational readiness when a storm occurs (EPA 2013). This dramatically limits the economic benefits that cities can realize in the form of reduced retention infrastructure: primary stormwater capture infrastructure must still be built. Moreover, passive capture systems typically satisfy only a small fraction of the water demand of a typically homeowner, even for landscape irrigation.

Active cistern systems are larger volume systems (between 1,000 and 100,000 gallons) that capture and provide water supply. These are more appropriately scaled to multi-family dwelling units. They can range from simple, gravity-fed systems that provide untreated water for landscaping purposes to complex systems with treatment and pressure to supply a distribution system, for potable or gray-water use. The latter systems can supply a wider range of uses (EPA 2013). If the primary goal for cistern use is stormwater capture, the system must have a reliable source of demand, so that it can be drained prior to a storm. Some systems connect to backup stormwater management controls, such as a rain garden or the stormwater system itself, and empty stored water at low-flow periods to ensure adequate storage capacity

for the next rainfall event. Automated monitoring systems are available to control the cistern capacity and time releases to weather events.

Optimal cistern sizing takes into consideration the local climate and water demand. A study of cisterns in Austin found that the maximum tank size to capture all available runoff in an average year in Austin would be 7,000 gallons. A tank this size would provide 46 percent of the typical water demand from a household in Austin (Kim 2011).

The economic benefits in water savings from these active systems would accrue slowly: the annual savings in water purchases of a system of this scale is in the low-hundreds of dollars per year. When a cheap, reliable source of water is available from the public water provider, cisterns do not compete economically. However, when water reliability becomes an issue, cisterns provide their owners with assurance that water will be available. This reliability factor has an economic value, which depends on the cost of obtaining alternative supplies of water and the individual's willingness to accept different levels of reliability from the public system.

7.3 Beneficiaries

Cistern owners enjoy private benefits in the form of reduced water purchases and potentially increased water reliability if public water shortages occur. The public may enjoy benefits to the extent that cisterns reduce the peak flow of stormwater events, reducing the risk of flood damage for public and private property owners, and potentially reducing the investment required in stormwater retention infrastructure on public property.

7.4 Costs of Implementation

A small-scale rain barrel system that might be purchased from a hardware store and self-installed runs between $2 and $3 per gallon (City-Data 2010; EPA 2013). Active cistern systems are much more expensive. Large cisterns typically cost between $1.50 and $3.00 per gallon of storage. The rest of the system can vary significantly in cost, depending on the pumps, treatment systems, and distribution systems selected. The additional cost is typically between $2.00 and $5.00 per gallon but could be much more. The 7,000-gallon system specified by Kim (2011) for Austin costs between $7,500 and $12,000 (2016$). Operation and maintenance also varies depending on the system, ranging from virtually no maintenance at all for a simple rain barrel, to around $800 per year for routine maintenance and $350 per year for infrequent maintenance activities.

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Regenerative Environmental Design

Date: January 18, 2017

To: Austin City Staff

From: Heather Venhaus, RED

Amy Belaire, PhD

Ed MacMullan and Sarah Reich, ECONorthwest

Subject: Results of Task 7C: Existing Program Analysis

1.0. Introduction

This report summarizes the key findings from an analysis of existing programs that are similar to City of Austin's Functional Green program. Six programs from Europe and the United States were evaluated. Each of these programs requires urban developments to incorporate landscape elements that enhance ecological function of cities; however, the details of each program vary from city to city. This analysis was conducted by reviewing relevant literature and interviewing key personnel associated with each program. A comparison chart of the programs can be found in Appendix A. In the report below, we discuss details of each program individually, including how the program was developed, which landscape elements are included, and how development scores are calculated. Furthermore, we summarize the "lessons learned" from the existing programs around the world and highlight important recommendations for the City of Austin in its process of developing a similar program.

1.1 Overview of existing programs: the basics

A Biotope Area Factor, also known as a Green Space Factor or Green Area Ratio, is an environmental metric and planning tool for urban green space. The metric was developed to increase the ecological performance and vegetated area of urban environments. Biotope Area Factor (BAF)

has been in use in Europe since the 1990's and represents the ratio between ecologically effective surface area and the total project area. To calculate the performance rating, the total area of each landscape element is determined and then multiplied by an established factor. The value of each landscape element is summed and then divided by the total area of the site.

$$BAF = \frac{(\text{area A} \times \text{factor A}) + (\text{area B} \times \text{factor B}) + (\text{area C} \times \text{factor C})}{\text{total site area}}$$

The factors assigned to the different landscape elements vary based upon their relative environmental performance and aesthetic value. Landscape elements that address certain ecosystem services identified as a priority are typically given higher factors.

Minimum BAF target scores vary depending on building type and location. Target scores represent the minimum percentage of a site that must provide ecosystem services. The goal is to set realistic minimum levels that can be achieved on most projects while also increasing the ecosystem service benefits provided. In general, target project scores are determined through comparison studies of existing landscape code and BAF requirements, experimental design case studies that explore the green potential of sites, and the goals of city planners. Pilot phases are conducted to test and refine as needed. BAF plan review is typically part of the building permit application process. After a project has been approved, property owners are typically not required to resubmit plans for approval when landscape changes occur. However, property owners are expected to continually maintain landscapes in a manner that support BAF objectives.

1.2. BAF research gaps & leadership opportunity

Reports and guidance documents related to the BAF tools reviewed in this report note the environmental benefits of the landscape elements (e.g., vegetated walls provide high transpiration efficiency, high binding of dust and high significance as a habitat for animals). However, none of the programs provide literature reviews of the science that informed decisions or discuss the process that was used to determine the value of the landscape elements to the owner and community at large. Supporting documentation for these tools also lacks details regarding the estimated performance and post-occupancy monitoring of the BAF projects. The City of Austin is taking a leadership role by documenting the scientific evidence for ecosystem service benefits that influence the proposed weights of the landscape elements in Functional Green. Additional opportunities exist to contribute to the continued improvement of BAF tools by providing methods to estimate performance and gathering post-occupancy information. This data will be necessary to document ecosystem service benefits provided to the community and to enable the continual improvement of Functional Green.

2.0 Berlin, Germany Biotope Area Factor (BAF)

The first Biotope Area Factor was developed by the City of Berlin in response to strong public desire to reduce environmental impacts and to provide green space in dense urban areas (Berlin, 2016). It has been in use since 1997 and is the inspiration for similar programs around the world.

The BAF is applied in select parts of Berlin to all forms of urban development with target factors ranging from 0.6 for new residential units, public facilities and day care complexes to 0.3 for commercial sites, schools and technical infrastructure (Berlin, 2016). Whereas it is

the intent of the program to build more ecologically robust sites, Berlin administrators routinely reduce minimum target factors in situations where target fulfillment results in exceptional costs or in cases involving special status properties such as historic buildings, schools or transits hubs (Kelley 2011).

Landscape element weights or multiplication factors were based on the perceived ecological effectiveness of each element in regards to the following areas: 1) improvement of the microclimate and air quality, 2) soil function, 3) efficiency of water management and 4) an increase in plant and animal habitat (Becker Giseke Mohren Richard 1990).

One unique component of Berlin's BAF is the score of 1 given to all vegetated surfaces regardless of the plant type. Some consider this a weakness of the program due to the variation in ecosystem service benefits provided by different vegetation types (for example, trees vs. lawns). However, one potential benefit of this strategy is that a uniform point value for all vegetated areas greatly simplifies project calculations. Point values increase for vegetated ground surfaces with deeper soils and connection to subsoils. Roof area that is not green roof can be also gain points if the stormwater drains to a vegetated surface that provides infiltration (Berlin, 2016).

Post-occupancy monitoring of the BAF has been virtually non-existent (Keeley 2011), however over the course of the last 20 years the Berlin City Planning Department has observed widespread acceptance of the program. Germany's federal laws serve as a strong legal foundation for BAF aiding in its adoption. In addition to the support of the German people, the success of the BAF can be contributed to three primary factors (Keeley 2011):

- Clarity of the requirements and permitting process

- Flexibility in design choices
- Dual compliance, where BAF meets other city requirements and can lead to reduced fees such as stormwater

3.0 Malmö, Sweden Green Space Factor (GSF)

The city of Malmö adapted Berlin's BAF for the redevelopment of Western Harbour, a 395-acre environmentally sustainable urban district designed to showcase the most innovative strategies for construction and design. The first completed stage of the development was the neighborhood Bo01, which had a minimal target score of 0.5. Evaluation and monitoring of Bo01 concluded that most of the development achieved the target score. This prompted an increase in the minimal target to 0.6 for the remainder of the development. Reviewers noted that built projects with lower than planned scores were typically the result of the failure to replace dead vegetation resulting in a less vegetation (Kruuse 2011). The GSF differs from Berlin's BAF in the weights assigned to different vegetation types and in the potential to layer landscape elements to achieve a greater score. In addition, the program added the concept of Green Points to improve the overall quality of the landscape. A list of 35 Green Points are given to developers who must implement 10 of them. Options include items such as bird and bat boxes, nectar rich gardens that provide a variety of food for butterflies ("butterfly restaurant"), no-mow lawns, frog habitat, greywater reuse and the cultivation of food crops. A full list of the Green Points can be found in Appendix B.

4.0 Seattle Green Factor (SGF)

Seattle was the first city in the United States to implement a biotope area factor. In 2006, Seattle revised the code standards for urban village commercial zones and adopted the Seattle Green Factor. The SGF is intended to increase the quality and quantity of urban

landscaping. SGF requirements have been extended to other portions of the city, with targets of 0.3 for commercial, neighborhood and industrial commercial, 0.5 for midrise and highrise multifamily residential, and 0.6 for lowrise multifamily residential (Seattle, 2016). Steve Moddemeyer, principal author of the Seattle Green Factor, describes the code as a logical trade-off, requiring developers to be more responsible for their impacts in exchange for height restriction relief (S. Moddemeyer, personal communication, Dec. 9, 2016).

4.1 Landscape elements in SGF

Seattle's Green Factor scoring encourages the layering of vegetation with planting areas earning more for the addition of understory. At least 25% of all plantings must be drought-tolerant. Due to the cost savings compared to other landscape elements, project teams pursuing SGF typically begin by adding vegetation to the greatest extent possible (D. LaClergue, personal communication Nov. 29, 2016).

Biofiltration facilities are given credit for the entire area including the sides and bottom of the feature. The value of permeable paving varies with the depth of the soil or gravel reservoir. A cap has been placed on the number of points that can be received from only one landscape element to encourage a variety of design solutions.

As of 2010, there were approximately 200 projects that achieved SGF. Seventy-five percent of these included green walls, 50% included green roofs, 50% included permeable paving, and every project has at least one of the three (ASLA, 2016). Green roofs and permeable paving are frequently applied due to joint benefits, which also meet stormwater management code requirements. Vegetated walls are also common due to the limited area of urban sites. Water features and food cultivation are the landscape elements used least often. This is thought to be due

to the high maintenance requirements of edible landscapes and that 50% of the annual flow for water features must be derived from harvested rainwater (D. LaClergue, personal communication Nov. 29, 2016).

One significant difference that sets the SGF apart from the Malmö and Berlin metrics is the addition of bonus points. Bonus points are given for drought-tolerant or native plants, landscape areas where at least 50% of annual irrigation needs are met through the use of harvested rainwater, landscaping visible to passersby from adjacent public rights-of-way or public open spaces, and food cultivation.

The public right-of-way is not counted in parcel size calculations; however, landscape improvements in rights-of-way contiguous with the parcel may be counted (Seattle, 2016). In addition, a landscape professional must prepare a Landscape Management Plan that includes direction for soils, irrigation, pest control, water features, and vegetation.

4.2 Score factors in SGF

Landscape elements in SGF were weighted according to relative aesthetic and functional values, as determined by the SGF development team which included local site designers, city staff, and land planners (S. Moddemeyer, personal communication, Dec. 9, 2016). A Seattle Green Factor Score Sheet has been provided in Appendix C. SGF came out of the tradition of aesthetic development standards and is not performance driven like other Seattle regulations (D. LaClergue, personal communication Nov. 29, 2016). The program requires extensive collaboration between various city departments due to planting options in both rights-of-way and on private property as well as the implementation of stormwater BMPs.

4.3 Target scores in SGF

The minimum score for new development was determined through a series of case studies conducted by local design firms using existing projects (both typical and high performance) built under conventional City of Seattle standards. The firms also evaluated which additional landscape elements could be reasonably added to the sites. Existing commercial projects achieved scores between 0.05 and 0.15. A minimum score of 0.3 was then set as a reasonable target for commercial projects to provide greater results. It was estimated that the SGF would increase total building costs by roughly 0.5% (S. Moddemeyer, personal communication, Dec. 9, 2016).

4.4 Program success

Overall, the SGF landscapes are thought to be more attractive and better integrated into site programs than conventional landscapes. SGF has encouraged landscape design as part of the initial stages of site planning resulting in more collaboration between design professionals (D. LaClergue, personal communication Nov. 29, 2016). The adoption of the SGF has been relatively smooth because it has been integrated with other zoning changes where the benefits to developers outweigh the Green Factor costs. Success has also been due to extensive collaboration with and education opportunities for design professionals to help communicate requirements to clients and the general public (S. Moddemeyer, personal communication, Dec. 9, 2016).

5.0 Stockholm Biotope Area Factor

A biotope area factor for Stockholm Royal Seaport, an industrial redevelopment site, was developed to identify ecosystem services, to encourage the strengthening of local ecosystems, and to create climate-adapted courtyards with high social values (Block and Bokalders 2016).

Development of the 583-acre environmentally sustainable neighborhood began in 2010.

The planning tool is based on Malmö's GSF; however, refinements were made to include more detailed landscape options that support biodiversity, climate adaptation, and the social use of green space. Points can be awarded for landscape elements such as "butterfly restaurants" (pollinator gardens), fruit-bearing vegetation, beetle and bird feeders, shared roof terraces, and grass areas suitable for games and playing (Block and Bokalders 2016). The result is a greater variety of design outcomes but a potentially more complicated assessment tool. A scoring sheet showing the full range of landscape elements has been included in the Appendix D.

6.0 Washington DC Green Area Ratio (GAR)

Washington, DC, initiated a Green Area Ratio program in 2013. The GAR was created to promote greater livability, ecological function, and climate adaptation in the urban environment. The program primarily focuses on elements that benefit air and water quality and reduce the urban heat island. Washington, DC, is a quickly-developing city with strict stormwater requirements. The GAR reinforces other areas of development code and is a horticultural overlay to existing stormwater regulations (S. Gyor personal interview Dec. 2, 2016).

All new buildings that require a Certificate of Occupancy must meet the appropriate Green Area Ratio based on zoning district. Minimum targets range from 0.1 – 0.4. The program excludes single-family residences, water treatment facilities, and some historic sites. Sites can qualify for a reduced GAR score via special exception if sustainability goals are met through means outside the scope of the program (Cidlowski et al. 2013).

6.1 Landscape elements in GAR

Similar to Seattle, the GAR encourages deeper soils and the layering of vegetation. The City provides recommended specifications for soils and plan submittals require detailed soil testing and installation information. The most commonly applied landscape element is the green roof. City staff note that green roofs are given a high ranking even though they are only visible to a small percentage of the population. To increase the number of green roofs that are visually accessible to the public, the program could provide bonus points for green roofs that are visible to the public. The second most used landscape elements are ground plane plantings and increased soil volume. Many developers take the 24" soil depth option that was developed to encourage trees (S. Gyor personal interview Dec. 2, 2016). No credit is given for trees in rights-of-way. The least commonly used landscape element is green walls due to high installation costs and the limited GAR scoring benefits. The tool is being updated to include the vertical wall area in addition to the base planting (S. Gyor personal interview Dec. 2, 2016). Biofiltration facilities square footage includes the pretreatment area and filter bed. Side slopes are not included in the calculations. Only one-third of the overall Green Area Ratio score can be derived from permeable paving and structural soils.

A bonus multiplier is given for native plant species, food cultivation, and harvested stormwater irrigation. To receive the harvested rainwater irrigation credit, a minimum of 50% of the annual usage must be supplied by stormwater. Water features must receive 50% of their annual flow from harvested rainwater and must hold water a minimum of 6 months of the year. To achieve the food cultivation bonus, the areas credited must continue to grow food Spring through Fall. Animal cultivation is not allowed. City staff noted the need to better define native plants and to allow the use of cultivars (S. Gyor personal interview Dec. 2, 2016). A landscape maintenance plan signed by a

Certified Landscape Expert is submitted with the plan set and must include activities and schedules for each landscape element. The City provides recommended maintenance activities and timelines for each landscape element that can be amended by the Landscape Expert.

The GAR is unique in that it provides credit for renewable energy using PV and solar thermal systems. This option was included because it provides a benefit to the city and is relatively easy for developers to implement (S. Gyor personal interview Dec. 2, 2016). Other programs do not include renewable energy. This is thought to be due to the fact that the BAF is typically part of a city's landscape code and incentives for renewable energy exist in other areas. In addition, allowing credit for renewable energy will reduce the overall area of other landscape elements. A Green Area Ratio Score Sheet has been included in Appendix E.

6.2 Program rollout of GAR

Overall, the program has been a success due in part to the significant comment period and public workshop meetings that allowed input from designers and developers. Social media and blogs were also successful at communicating the simplicity and flexibility of the tool. City staff noted that it is common for projects that are not eligible for exemption to seek exemption (S. Gyor personal interview Dec. 2, 2016). The *Green Area Ratio Guidebook*, which was released with the regulations, has been essential in helping project teams understand the program and clarify requirements. The submittal process was intentionally designed for ease of review and can be handled entirely on-line. City inspectors would like to see more pre-development and pre-construction meetings with applicants to ensure the feasibility of their plans. It is also recommended that inspectors be part of the review process and that site

inspections occur throughout the construction process, not just at the end of the project.

7.0 North West England Green Infrastructure Toolkit

This guidance tool was adapted from Malmö's Green Space Factor and supports green infrastructure objectives. It is included in this report because of its unique approach to establishing target requirements that reflect the existing conditions of the site. Projects with pre-existing structures or hardscape must score at least 0.2 points higher than the existing site conditions. Sites without pre-existing structures have a requirement of 0.6. Flexibility in scoring was given to reflect additional difficulty that may exist for projects with existing urban forms (Kruuse 2011). This type of scoring may be useful to Functional Green and projects that are not complete redevelopments of the site.

8.0 Recommendations and follow up questions:

1. Recommendations related to landscape elements, weighting, and target score
    a. Provide a bonus credit for landscape elements that are physically or visually accessible to the general public to extend benefits to the larger community.
    b. Target goals must be reasonable for most developments. Target conditions that stress high performance will improve environmental conditions; however; if the targets are too onerous, they can discourage dense development and push construction to less desirable areas where Functional Green is not required.
    c. Consider assigning additional weight to landscape strategies that provide human enjoyment benefits and encourage

pedestrian traffic, such as shaded places to play, walk, eat or rest.

d. Limit the portion of a target score that can be met with a single strategy such as permeable paving and green walls.
e. When considering landscape element weighting options, it is important to note that larger multipliers/values can result in a reduced area coverage of that landscape element. In other words, high ranking values intuitively decrease the overall size of that landscape element. Low ranking values encourage more square footage of a landscape element (S. Moddemeyer, personal communication, Dec. 9, 2016).
f. There are always landscape elements to be added or improved upon. Provide for the ability for the program to be easily adjusted over time (S. Gyor personal interview Dec. 2, 2016).

3. Recommendations for implementing and administering the program
    a. Conduct a pilot project phase to test assumptions and make adjustments where needed.
    b. Performance standards are difficult to administer and typically require more highly-trained administrative staff. Map how different city departments work together. Determine communication, responsibility, and decision channels in advance. Provide additional education to review staff and field inspectors (D. LaClergue, personal communication Nov. 29, 2016 and Gyor).
    c. Functional Green should balance the economic costs with the gains of increased building density and square footage.
    d. On-going maintenance that ensures continued attainment of original performance goals is a problem for all the BAF tools. Shoup (1996) recommends additional triggers for compliance

review such as the re-review upon the sale of property or of an issuance of building permits. In addition, a Landscape Maintenance Plan submitted to the owner should be required.

e. Explore the potential to use energy conservation dollars within the city to enhance urban green and reuse. If you can get a small reduction in energy use, the city's utility can incentivize specific strategies (S. Moddemeyer, personal communication, Dec. 9, 2016).

f. Provide opportunities for pre-design and pre-construction meetings with the city to ensure compliance. Provide inspections throughout construction not just at the end of the project. Inspectors should be part of the review process (S. Gyor personal interview Dec. 2, 2016). Can additional reviews be incentivized by an expedited process?

3. Recommendations related to outreach and education about the program

   a. Highlight where compliance meets other City requirements, such as stormwater, in public education materials and talks.

   b. Educational materials such as guidebooks are essential to early adoption and ease of communication. These tools should be released at the same time as Functional Green.

   c. Communicate benefits to the various stakeholder groups including developers.

   d. Recommend looking at Sustainable Sites Initiative (SITES) and similar programs to illustrate how Functional Green can help developers meet other goals. Communicate to design teams and owners how the BAF can support project certification (D. LaClergue, personal communication Nov. 29, 2016).

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Appendix

Appendix A: Program comparison

Landscape Elements	Berlin BAF	Malmo GSF	North west England Green Infrastructure Toolkit	Seattle GF	Stockholm BAF *	Washington GAR
Target	0.6 for new residential, public facilities and day care complexes, 0.3 commercial and schools	0.6 - Redevelopment of Western Harbour, an urban district meant to showcase environmentally sustainable practices.	0.6 for vacant plot development, a +0.2 difference from pre-developed phase for renovations.	0.3 for commercial, neighborhood and industrial commercial, 0.5 midrise and highrise multifamily residential, and 0.6 for lowrise multifamily residential	0.6 - Royal Urban Seaport , environmentally sustainable neighborhood	0.1 - 0.4. New buildings that require a Certificate of Occupancy must meet the appropriate target based on the zoning district
Year established	1997	2001	2011	2006	2010	2013
Bioretention facility	0.2	0.2	0	1	0.1 - 2.0	0.4
Drought tolerant or native plants	0	0	0	0.1	0	0.1
Food cultivation	0	0	0	0.1	0	0.1
Green roof	0.7	0.6	0.7	0.4 - 0.7	0.1 - 0.4	0.6 - 0.8
Harvested rainwater	0	0	0	0.2	0	0.1
Landscape visibility to passerbys	0	0	0	0.1	0	0
Ground cover	1			0.1	2	0.2
Permeable paving	0.3-0.5	0.2 - 0.4	0.2-0.4	0.2 - 0.5	0.05 - 0.3	0.4 -0.5
Tree preservation	1	0	0	0.8	0.2 - 3	0.7 - 0.8
Renewable energy generation	0	0	0	0	0	0.5
Sealed surface	0	0	0	0	0	0
Shrubs or perennials	1	0.2	0.3	0.3	0.1 - 0.4	0.3
Soil depth < 24"		0		0.1	0	0.3
Soil depth > 24"	0.5 - 0.7	0	0.4 - 1	0.6	0	0.6
Structural soils	0	0	0	0.2	0	0.4
Tree large	1	2	0.4	0.4	2.4	0.6
Tree medium	1	1.5	0.4	0.3 - 0.4	2.5	0.6
Tree small	1	1	0.4	0.3	1	0.5
Vegetated walls	0.5	0.7	0.6	0.7	0.4	0.6
Water feature	0	1	1	0.7	0	0.2

*** The Stockholm Biotope Area Factor is difficult to compare to the other programs because the landscape element options are significantly different. The program places an unique emphasis biodiversity, climate adaptation and the social use of green space. See Appendix D for more details.**

Appendix B: Green Points

- A bird box for every apartment
- A biotope for specified insects in the courtyard (water striders and other aquatic insects in the pond)
- Bat boxes in the courtyard
- No surfaces in the courtyard are sealed, and all surfaces are permeable to water
- All non-paved surfaces within the courtyard have sufficient soil depth and quality for growing vegetables
- The courtyard includes a rustic garden with different sections
- All walls, where possible, are covered with climbing plants
- There is 1 square metre of pond area for every 5 square metres of hard-surface area in the courtyard
- The vegetation in the courtyard is selected to be nectar rich and provide a variety of food for butterflies (a so-called 'butterfly restaurant')
- No more than five trees or shrubs of the same species
- The biotopes within the courtyard are all designed to be moist
- The biotopes within the courtyard are all designed to be dry
- The biotopes within the courtyard are all designed to be semi-natural
- All stormwater flows for at least 10 metres on the surface of the ground before it is diverted into pipes
- The courtyard is green, but there are no mown lawns
- All rainwater from buildings and hard surfaces in the courtyard is collected and used for irrigation
- All plants have some household use
- There are frog habitats within the courtyard as well as space for frogs to hibernate
- In the courtyard, there is at least 5 square metres of conservatory or greenhouse for each apartment
- There is food for birds throughout the year within the courtyard
- There are at least two different old-crop varieties of fruits and berries for every 100 square metres of courtyard
- The facades of the buildings have swallow nesting facilities
- The whole courtyard is used for the cultivation of vegetables, fruit and berries
- The developers liaise with ecological experts
- Greywater is treated in the courtyard and re-used
- All biodegradable household and garden waste is composted
- Only recycled construction materials are used in the courtyard
- Each apartment has at least 2 square metres of built-in growing plots or flower boxes on the balcony

Appendix B: Green Points continued

- At least half the courtyard area consists of water
- The courtyard has a certain colour (and texture) as the theme
- All the trees and bushes in the courtyard bear fruit and berries
- The courtyard has trimmed and shaped plants as its theme
- A section of the courtyard is left for natural succession (that is, to naturally grow and regenerate)
- There should be at least 50 flowering Swedish wild herbs within the courtyard
- All the buildings have green roofs

Appendix C: Seattle Green Factor Score Sheet

Revised 12/28/10

Green Factor Score Sheet

SEATTLE × green factor

Project title:

		enter sq ft of parcel			
	Parcel size *(enter this value first)* *	5,000		SCORE	-
	Landscape Elements**	**Totals from GF worksheet**		**Factor**	**Total**
A	**Landscaped areas (select one of the following for each area)**				
1	Landscaped areas with a soil depth of less than 24"		enter sq ft 0	0.1	-
2	Landscaped areas with a soil depth of 24" or greater		enter sq ft 0	0.6	-
3	Bioretention facilities		enter sq ft 0	1.0	-
B	**Plantings (credit for plants in landscaped areas from Section A)**				
1	Mulch, ground covers, or other plants less than 2' tall at maturity		enter sq ft 0	0.1	-
2	Shrubs or perennials 2'+ at maturity - calculated at 12 sq ft per plant (typically planted no closer than 18" on center)	enter number of plants 0	0	0.3	-
3	Tree canopy for "small trees" or equivalent (canopy spread 8' to 15') - calculated at 75 sq ft per tree	enter number of plants 0	0	0.3	-
4	Tree canopy for "small/medium trees" or equivalent (canopy spread 16' to 20') - calculated at 150 sq ft per tree	enter number of plants 0	0	0.3	-
5	Tree canopy for "medium/large trees" or equivalent (canopy spread of 21' to 25') - calculated at 250 sq ft per tree	enter number of plants 0	0	0.4	-
6	Tree canopy for "large trees" or equivalent (canopy spread of 26' to 30') - calculated at 350 sq ft per tree	enter number of plants 0	0	0.4	-
7	Tree canopy for preservation of large existing trees with trunks 6"+ in diameter - calculated at 20 sq ft per inch diameter	enter inches DBH 0	0	0.8	-
C	**Green roofs**				
1	Over at least 2" and less than 4" of growth medium		enter sq ft 0	0.4	-
2	Over at least 4" of growth medium		enter sq ft 0	0.7	-
D	**Vegetated walls**		enter sq ft 0	0.7	-
E	**Approved water features**		enter sq ft 0	0.7	-
F	**Permeable paving**				
1	Permeable paving over at least 6" and less than 24" of soil or gravel		enter sq ft 0	0.2	-
2	Permeable paving over at least 24" of soil or gravel		enter sq ft 0	0.5	-
G	**Structural soil systems**		enter sq ft 0	0.2	-
		sub-total of sq ft =	*0*		
H	**Bonuses**				
1	Drought-tolerant or native plant species		enter sq ft 0	0.1	-
2	Landscaped areas where at least 50% of annual irrigation needs are met through the use of harvested rainwater		enter sq ft 0	0.2	-
3	Landscaping visible to passersby from adjacent public right of way or public open spaces		enter sq ft 0	0.1	-
4	Landscaping in food cultivation		enter sq ft 0	0.1	-
				Green Factor numerator =	-

**** Do not count public rights-of-way in parcel size calculation.***

***** You may count landscape improvements in rights-of-way contiguous with the parcel. All landscaping on private and public property must comply with the Landscape Standards Director's Rule (DR 6-2009)***

Appendix D: Stockholm Biotope Area Factor Score Sheet

SURFACE:	FACTOR:	NUMBER:	AREA:	FACTOR * AREA:
Sub-factors greenery				
Unsupported ground greenery	2.0	-	0	0
Plant bed (>800 mm)	1.2	-	0	0
Plant bed (600-800 mm)	0.4	-	0	0
Plant bed (200-600 mm)	0.2	-	0	0
Green roof (> 300 mm)	0.4	-	0	0
Green roof (50 - 300 mm)	0.1	-	0	0
Greenery on walls	0.4	-	0	0
Balcony boxes	0.3	-	0	0
Supplementary factors greenery/biodiversity				
Diversity in the field layer	0.7	-	0	0
Natural species selection	0.5	-	0	0
Diversity on thin sedum roofs	0.1	-	0	0
Integrated balcony boxes with climbing plants	0.3	-	0	0
Butterfly restaurants	1.0	-	0	0
Bushes, general	0.2	-	0	0
Berry bushes	0.4	-	0	0
Large trees (trunk >30 cm)	2.4	0	0	0
Medium large trees (trunk 20-30 cm)	1.5	0	0	0
Small trees (trunk 16-20 cm)	1.0	0	0	0
Oak (Quercus robur)	3.0	0	0	0
Fruit trees	0.4	0	0	0
Fauna depots	2.0	0	0	0
Beetle feeders	2.0	0	0	0
Bird feeders	2	0	0	0
Supplementary factors greenery/recreation and social value				
Grass area usable for ball games and playing	1.2	-	0	0
Gardening areas in yards	0.5	-	0	0
Balconies and terraces prepared for growing	0.5	-	0	0
Shared roof terraces	0.2	-	0	0
Visible green roofs	0.1	-	0	0
Floral arrangements	0.2	-	0	0
Experiential value of bushes	0.1	-	0	0
Berry bushes with edible fruit, etc.	0.2	-	0	0
Trees, experiential value	0.5	0	0	0
Fruit trees and blooming trees	0.2	0	0	0
Pergolas, paths surrounded by leaves and other greenery	0.3	-	0	0
Bird feeders, experiential value	0.2	0	0	0
Supplementary factors greenery/climate - heat islands				
Trees with leafy shade over play areas, etc.	0.5	0	0	0
Pergolas, green corridors etc = shade from leaf cover	0.5	-	0	0
Green roofs, ground greenery - evening out of temp.	0.1	-	0	0
Sub-factors water				
Water surface, permanent	1.0	-	0	0
get through	0.3	-	0	0
Gravel and sand	0.2	-	0	0
Concrete slabs with joints	0.05	-	0	0

Appendix D: Stockholm continued

Supplementary factors water/biodiversity				
Biologically accessible permanent water	4.0	-	0	0
Dry areas with plants that temporarily fill with rainwater	2.0	-	0	0
Delay of rainwater in ponds etc.	0.2	-	0	0
Delay of rainwater in underground percolation systems	0.1	-	0	0
Runoff from impermeable surfaces to surfaces with plants	0.1	-	0	0
Supplementary factors water/recreational and social values				
Water surfaces	1.0	-	0	0
Biologically accessible water - experiential value	1.0	-	0	0
Fountains, circulations systems, etc.	0.3	0	0	0
Supplementary factors water/climate - heat islands				
Water collection during dry periods	0.5	-	0	0
Collected rainwater for watering - climate impact	0.05	-	0	0
Fountains etc. - cooling effect	0.3	0	0	0
Total (eco-effective area):				0
Total land area			0	
Achieved factor:				**0.00**

Balance sheet:	**Max amount:**	**Amount achieved:**	**:**
B = Biodiversity	**30**		
S = Social value	**27**		
K = Climate adaptation	**18**		

Appendix E: Washington D.C. Green Area Ratio Score Sheet

Green Area Ratio Scoresheet

Address

Other / BZA Order

Lot size *(enter this value first)* *

Ward	Lot	Square	Zoning District

enter sq ft of lot: 0

multipli

SCORE: #DIV/0!

	Landscape Elements	Square Ft.	Factor	Total
A	**Landscaped areas (select one of the following for each area)**			
1	Landscaped areas with a soil depth of less than 24"	enter sq ft: 0	0.3	-
2	Landscaped areas with a soil depth of 24" or greater	enter sq ft: 0	0.6	-
3	Bioretention facilities	enter sq ft: 0	0.4	-
B	**Plantings (credit for plants in landscaped areas from Section A)**			
1	Groundcovers, or other plants less than 2' tall at maturity	enter sq ft: 0	0.2	-
2	Plants, not including grasses, 2' or taller at maturity - calculated at 9 sq ft per plant (typically planted no closer than 18" on center)	enter number of plants: 0 → 0	0.3	-
3	Tree canopy for all trees 2.5" to 6" diameter or equivalent - calculated at 50 sq ft per tree	enter number of trees: 0 → 0	0.5	-
4	Tree canopy for new trees 6" diameter or larger or equivalent - calculated at 250 sq ft per tree	enter number of trees: 0 → 0	0.6	-
5	Tree canopy for preservation of existing tree 6" to 12" diameter or larger or equivalent - calculated at 250 sq ft per tree	enter number of trees: 0 → 0	0.7	-
6	Tree canopy for preservation of existing tree 12" to 18" diameter or larger or equivalent - calculated at 600 sq ft per tree	enter number of trees: 0 → 0	0.7	-
7	Tree canopy for preservation of all existing trees 18" to 24" dia. or equivalent - calculated at 1300 sq ft per tree	enter number of trees: 0 → 0	0.7	-
8	Tree canopy for preservation of all existing trees 24" diameter or larger or equivalent - calculated at 2000 sq ft per tree	enter number of trees: 0 → 0	0.8	-
9	Vegetated wall, plantings on a vertical surface	enter sq ft: 0	0.6	-

Appendix E: Washington D.C. continued

C	**Vegetated or "green" roofs**			
1	Over at least 2" and less than 8" of growth medium	*enter sq ft* 0	0.6	-
2	Over at least 8" of growth medium	*enter sq ft* 0	0.8	-
D	**Permeable Paving*** **			
1	Permeable paving over at least 6" and less than 24" of soil or gravel	*enter sq ft* 0	0.4	-
2	Permeable paving over at least 24" of soil or gravel	*enter sq ft* 0	0.5	-
E	**Other**			
1	Enhanced tree growth systems***	*enter sq ft* 0	0.4	-
2	Renewable energy generation	*enter sq ft* 0	0.5	-
3	Approved water features	*enter sq ft* 0	0.2	-
		sub-total of sq ft = 0		
H	**Bonuses**			
1	Native plant species	*enter sq ft* 0	0.1	-
2	Landscaping in food cultivation	*enter sq ft* 0	0.1	-
3	Harvested stormwater irrigation	*enter sq ft* 0	0.1	-
			Green Area Ratio numerator =	-

****** Permeable paving and structural soil together may not qualify for more than one third of the Green Area Ratio score.***

Total square footage of all permeable paving and enhanced tree growth -

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DATE: February 15, 2017
TO: Austin City Staff
FROM: Heather Venhaus, Regenerative Environmental Design
Amy Belaire, PhD
Ed MacMullan and Sarah Reich, ECONorthwest
SUBJECT: RESULTS OF TASK 7E—TECHNICAL AND ECONOMIC ANALYSIS OF LANDSCAPE ELEMENTS

1 Introduction

This analysis focuses on six landscape elements that provide ecosystem services in urban landscapes: trees, green roofs, bioretention systems, vegetated walls, porous pavements, and cisterns. We evaluate these landscape elements for their *technical performance* (i.e., biophysical benefits) and associated *economic costs/benefits*.

For the technical review of biophysical benefits, we relied on the results of the literature review (Task 7B) and additional studies on each landscape element. We summarized peer-reviewed literature and local reports for the Austin area whenever possible; we also included additional studies conducted in locations with climates similar to Austin's (humid subtropical) when they were available. In cases where little published research exists, we relied on best available data regardless of location or climate. Technical performance was categorized into several key ecosystem service types prioritized by the City of Austin: (1) microclimate regulation and mitigation of urban heat island effects, (2) carbon storage and sequestration, (3) air pollutant removal, (4) stormwater retention and runoff reduction, (5) water filtration, and (6) biodiversity benefits. In addition, benefits to human well-being are summarized where data are available. Under each of these ecosystem service types, the relevant literature was summarized to provide an estimate of the range of likely benefits. We reviewed studies of performance for individual landscape elements in the field and lab as well as modeling studies that evaluated potential performance if landscape elements were broadly applied across an urban landscape. In the review below, results for biophysical performance are summarized on a per-unit or per-area basis, and, where modeling studies are available, results are reported for implementation at broader spatial scales. Although different studies often report different metrics for performance, we attempted to identify and report common metrics whenever possible to allow for comparison between different landscape elements.

The economic analysis of the costs and benefits of landscape elements also relied on the results of the literature review (Task 7B) and interviews with City of Austin staff. Our analysis also identified the factors that influence the magnitude of economic benefits. The degree to which we were able to quantify economic benefits varied by landscape element. For some landscape elements and some benefits, data were available to identify per-unit values specific to the City of Austin. In some cases, per-unit values were not available for the City of Austin, but were available for other, similar geographies or as a national average. In cases where data on per-unit economic values were not available, we described the value qualitatively, focusing on the mechanism of economic effect, direction and magnitude of change, and other factors that may

influence the value. We estimated costs similarly, relying on primary estimates from the City of Austin's experience installing and maintaining the landscape elements where possible. If data were not available from the City of Austin, we relied on cost estimates from the literature. All dollar values are reported in 2015 equivalent dollars.

We summarize the results of the analysis by landscape element below. First we describe the results of the technical analysis, then follow with the results of the economic analysis.

2 Trees

2.1 Technical Analysis

Trees are known to provide a variety of ecosystem services in urban landscapes, including: (1) regulating microclimate and mitigating urban heat island effects, (2) sequestering and storing carbon, (3) capturing air pollutants, (4) intercepting rainwater to reduce stormwater runoff volumes, and (5) providing resources for urban biodiversity. Most of these benefits are correlated with the leaf area of the trees; larger trees and those with greater leaf area provide greater benefits than smaller trees or trees with less leaf area. Therefore, existing trees most likely provide more ecosystem services than newly planted trees. The range of benefits that trees would likely provide in the Austin urban ecosystem are summarized from relevant peer-reviewed literature and reports in Table 1 below.

Table 1. Range of Estimated Biophysical Benefits for Trees in Austin, Texas

Ecosystem Service Type	Range of Estimated Biophysical Benefits in Austin, Texas	References
Microclimate regulation and mitigation of urban heat island effects	2.2-7.0° F reduction in surface air temperatures (for areas underneath and adjacent to street tree canopy)	Loughner et al. 2012, Shashua-Bar et al. 2009, Davis et al. 2016, and Wang & Akbari 2016
Carbon storage and sequestration	Storage: 7.7-28.9 kg C/m^2 Sequestration (on a per-tree basis): 11-64 kg C/year for small trees[1]; 93-305 kg C/year for larger trees; average 0.28 kg C/m^2 tree cover per year	Nowak et al. 2013, Nowak & Dywer 2007, Davies et al. 2011, Nowak et al. 2016, iTree Design v 6.0
Air pollutant removal	6.6–12.0 g of air pollutants removed per m^2 of tree canopy, depending on location, size and type of tree On a per-tree basis: 2.0-13.3 g CO per tree, 12.2-63.4 g NO_2 per tree, 56.0-93.3 g O_3 per tree, 23.4-83.3 g PM_{10} per tree, and 7.1-34.6 g SO_2 per tree	Nowak & Dywer 2007 (including per-tree calculations derived from Tables 1 and 2)
Stormwater retention and runoff reduction	On a per-tree basis: 11-44 ft^3/year for small trees; 113-400 ft^3/year for large trees At broader scales: canopy coverage of 30% could reduce existing runoff volume by 12-13%	iTree Design v 6.0, Mullaney et al. 2015, Livesley et al. 2014, Sanders 1986
Water filtration	Can lead to reduced total pollutant loads due to some reduction of runoff volume.	
Biodiversity	Increased biodiversity observed in areas of greater tree coverage	Ikin et al. 2012, Strohbach et al. 2013, Belaire et al. 2014
Human well-being	Potential contribution to noise reduction, reduced crime, improved road safety, and other social benefits	Gomez-Baggethun et al. 2013, Kuo & Sullivan 2001, Tarran 2009

2.2 Economic Analysis

2.2.1 Economic Benefits

The economic benefits of ecosystem services provided by trees can depend on several site-specific factors. These include:

- The type and size of tree will influence the supply of ecosystem services and related economic benefits.
- The location of the tree onsite will influence benefits associated with energy use and cooling.
- The height of adjacent buildings will influence the extent to which street trees impact energy use and cooling demands.
- Access and visibility of trees influences property values and human well-being benefits.

Table 2 shows the estimated values of the economic benefits we identified for street trees.

[1] Small trees defined as 2-5 inch diameter live oak or elm species

Table 2. Range of Estimated Values of Economic Benefits of Street Trees in Austin, Texas

Economic Benefit	Range of Values of Economic Benefits for Austin, Texas	References
Energy Costs	Site-specific, depending on location of trees relative to building, baseline energy demand, and energy costs.	
Carbon Sequestration	$44-$239 per metric ton of Carbon	Interagency Working Group 2016
Nitrogen Dioxide Removal	$0.13-$0.33 per kg	Nowak et al. 2016
Sulfur Dioxide Removal	$0.04-$0.09 per kg	Nowak et al. 2016
Small Particulate Matter	$26.45-$66.14 per kg	Nowak et al. 2016
Avoided Stormwater Runoff Costs to City of Austin	$2 per cubic foot of stormwater diverted from system	American Forests 2002
Impacts on Property Values	Up to 13-19% increase for single-family residential. Higher rents; Longer leaseholder retention and lower turnover for commercial and multi-family rentals.	Wolf 2007, Martin Maggio and Appel 1989, Donovan and Butry 2011
Avoided Costs of Ecological and Species Habitat Management	Unquantifiable, but likely positive. Higher value for positive effects on habitat for sensitive species	
Avoided Health Care Costs, Improved Human Well-being	Unquantifiable, but positive relationships have been measured at a national scale, attributing benefits of access to green space to reduced healthcare costs and improved quality of life arising from improved newborn health; reduced incidence of ADHD; improved school performance; reduced crime; and improved cardiovascular health.	Wolf 2015

Economic Costs

The cost of street trees includes planting, pruning and maintenance. The total cost of a street tree during its life will vary depending on factors such as species, placement relative to other infrastructure, and climate. Costs vary geographically based on climate and prevalence of pests and diseases. Regional surveys of tree costs as reported by urban arborists and municipal foresters in the Piedmont (North Carolina to Texas) and Interior West (Texas west) are reported in Table 3. Austin sits on the border of these regions, so it would likely would experience costs somewhere within this range.

Depending on where street trees are located on a site they may or may not incur opportunity costs[2] for developers of occupying land that would otherwise be taken up by a building. For example, planting trees within required sidewalk right-of-ways many not incur opportunity costs for developers. Extensive plantings of trees on interior parts of the site may lessen developable area and potentially result in opportunity costs for the developer.

[2] Opportunity cost means the benefit or profit from one option that must be given up to achieve something else. In this context, the opportunity cost of installing required stormwater controls on land that otherwise would have been developed is the benefit (e.g., profit or rent) that could have been enjoyed from the development.

Table 3. Costs of Street Trees

	Piedmont Region[1]	Interior West Region
Planting (One-time)	$587	$97-$457
Pruning (Per tree per year, depending on size and age)	$0.07-$5.50	$4-$515
Pest and Disease Control (Per tree per year)	$23	N/A
Irrigation (Per year for first 5 years)	N/A	$1.14-$4.57
Removal (One-time, per inch of diameter)	$41-$260	$25-$40

Source: [1] Vargas et al. 2007; [2] McPherson et al. 2006.

3 Green Roofs

3.1 Technical Analysis

Green roofs, which can be either intensive or extensive in design, provide an option to increase vegetation cover in urban landscapes, compensating for the plants and soils that were removed during construction. The primary biophysical benefits of green roofs provide include: (1) regulating temperature and mitigating urban heat island effects, (2) sequestering and storing carbon, (3) retaining stormwater and reducing runoff volume, and (4) providing habitat and enhancing connectivity for biodiversity. In addition, there is some evidence that green roofs can capture and filter pollutants from water and air. The biophysical benefits that green roofs could likely provide in Austin are summarized from relevant peer-reviewed literature in Table 4 below.

Table 4. Range of Estimated Biophysical Benefits for Green Roofs in Austin, Texas

Ecosystem Service Type	Range of Estimated Biophysical Benefits in Austin, Texas	References
Microclimate regulation and mitigation of urban heat island effects	On a per-roof basis: maximum temperature reduction of 45-54° F for roof surface temperatures (compared to non-vegetated roofs) At broader scales: 1.6-5.4° F reduction in ambient air temperatures with widespread green roof implementation	Alexandri & Jones 2008, Susca et al. 2011, Santamouris 2014, Meek et al. 2014
Carbon storage and sequestration	Storage: 0-67.7 kg C/m^2 depending on plant type, substrate, and age of roof	Getter et al. 2009, Whittinghill et al. 2014
Air pollutant removal	Per unit area: 85 kg of pollutants removed per hectare of green roof per year (8.5 g/m^2), with 0.65-1.01 g SO_2/m^2, 2.33-3.57 g NO_2/m^2, 1.12-2.16 g PM_{10}/m^2, 4.49-7.17 g O_3/m^2 At broader scales: Up to 2046 metric tons of pollutants removed per year for widespread green roof implementation	Yang et al. 2008, Currie et al. 2008
Stormwater retention and runoff reduction	On a per-roof basis: 44-88% of rainfall volume retained per storm and 43-78% of rainfall volume retained annually At broader scales: 15-45% reduction in runoff volumes with widespread implementation	Carter et al. 2007, Simmons et al. 2013, Glass 2007, Berndtsson et al. 2010, Harper et al. 2015, Morgan et al. 2013, Meek et al. 2014
Water filtration	Mixed results for water quality. Although total concentrations may be higher in effluent, the total loads are lower due to high runoff volume retention.	Rowe et al. 2011, Ahiablame et al. 2012
Biodiversity	Green roofs can provide habitat for a relatively high diversity of invertebrate species, including native pollinators, and increase functional connectivity for these species	Colla et al. 2009, Tonietto et al. 2011, Madre et al. 2013, Braaker et al. 2014
Human well-being	Potential to reduce noise pollution and provide green views to building occupants	Van Renterghem & Botteldooren 2009, Oberndorfer 2007

3.2 Economic Analysis

3.2.1 Economic Benefits

The economic benefits of ecosystem services provided by green roofs can depend on several site-specific factors. These include:

- The type of green roof, intensive or extensive. Intensive roofs have thicker growing medium and can support more complex vegetation types that also provide more ecosystem service values compared with an extensive roof. Extensive roofs have less growing medium and can typically support less complex vegetation types, relative to an intensive roof.
- The number of floors in a building influences the impacts of heating and cooling benefits of a green roof on total energy use. Typically, heating and cooling benefits are limited to one or two floors directly beneath the green roof.
- The extent to which green roofs are visible from adjacent structures, and are accessible to building occupants, will increase the amenity benefits of the roof.

Table 5 shows the estimated values of the economic benefits we identified for green roofs.

Table 5. Range of Estimated Values of Economic Benefits of Green Roofs in Austin, Texas

Economic Benefit	Range of Values of Economic Benefits for Austin, Texas	References
Building Cost Savings	May extend the life of the roof underlayment by 20 years or more.	EPA 2000
Development Cost Savings	Developers may use green roofs to meet certain development requirements or earn a density bonus credit.	City of Austin No Date
Energy Savings	Expected reduction in energy demand and cost. Magnitude dependent on existing energy efficiency of the building and properties of the green roof. Buildings that are already well-insulated likely will experience more limited energy benefits. Energy savings are greatest for the first floor below the roof, with decreasing benefits up to four stories below the roof.	Blackhurst et al. 2010
Carbon Sequestration	$44-$239 per metric ton of Carbon	Interagency Working Group 2016
Nitrogen Dioxide Removal	$0.13-$0.33 per kg	Nowak et al. 2016
Small Particulate Matter	$0.04-$0.09 per kg	Nowak et al. 2016
Avoided Stormwater Runoff Costs to City of Austin	$2 per cubic foot of stormwater diverted from system	American Forests 2002
Avoided Stormwater Runoff Fee Assessed to Property Owners	Up to a 72% reduction in the monthly drainage charge assessed by the City of Austin. Actual savings depends on site-specific factors.	
Impacts on Property Values	Up to 6% increase in rental rates, which may increase property values	GSA 2011
Avoided Costs of Ecological and Species Habitat Management	Unquantifiable, but likely positive. Higher value for positive effects on habitat for sensitive species	
Avoided Health Care Costs, Improved Human Well-being	Unquantifiable, but likely positive if green roof is within view or accessible. Positive relationships have been measured at a national scale, attributing benefits of access to green space to reduced healthcare costs and improved quality of life arising from improved newborn health; reduced incidence of ADHD; improved school performance; reduced crime; and improved cardiovascular health.	Wolf 2015

3.2.2 Economic Costs

The type of green roof—extensive or intensive—influences both the installation costs as well as the maintenance costs. Table 6 shows the range of costs associated with green roofs. Because green roofs do not occupy space that would otherwise be taken up by site developments, they do not cause opportunity costs for developers.

Table 6. Costs of Green Roofs

	Construction Costs/Sq. Ft.[1]		Annual Maintenance Costs/Sq. Ft.[2]	
	Low	High	Low	High
Extensive	$7.38	$342.55	$0.02	$0.40
Intensive	$16.86	$550.19	$0.02	$0.40

Source: [1] Grey et al. 2013; [2] Center for Neighborhood Technology, No Date.

4 Bioretention, Biofiltration Systems, and Rain Gardens

4.1 Technical Analysis

The terms bioretention cells, rain gardens, and biofiltration systems describe small depressions that retain stormwater and promote infiltration/filtration via vegetated systems. They are designed to function similarly to natural systems and typically provide the following ecosystem services: (1) retaining stormwater and reducing runoff volumes, (2) filtering pollutants from stormwater, and (3) providing habitat for biodiversity and potentially supporting enhanced ecological conditions in nearby streams. In addition, these types of landscape elements can provide some carbon storage and sequestration services as well as minor cooling effects. The range of biophysical benefits that rain gardens, bioretention, and biofiltration systems could likely provide in Austin are summarized from peer-reviewed literature and local reports in Table 7.

Table 7. Range of Estimated Biophysical Benefits for Bioretention, Biofiltration Systems, and Rain Gardens in Austin, Texas

Ecosystem Service Type	Range of Estimated Biophysical Benefits in Austin, Texas	References
Microclimate regulation and mitigation of urban heat island effects	Some potential for minor cooling effects (as with any small vegetated area)	Perring et al. 2016, Davis et al. 2016
Carbon storage and sequestration	Storage: 0-3.34 kg C/m^2 Sequestration: 0.05-0.09 kg C/m^2 per year	Bouchard et al. 2013, Davies et al. 2011
Air pollutant removal	No estimates in literature; however, the cooling effects of vegetation can contribute to reduced ozone formation	Perring et al. 2013
Stormwater retention and runoff reduction	On a per-site basis: 40-100% of rainfall volume retained per storm and 58-97% of rainfall volume retained annually. At broader spatial scales: Substantial reduction in runoff volumes and peak flow with widespread implementation	DeBusk & Wynn 2011, Li et al. 2009, Brown et al. 2013, Jennings 2016, Geosyntec 2016, Glick et al. 2016, Hunt et al. 2008
Water filtration	Concentration reduction: significant reduction in total suspended solids (mg/L) likely (85-95% removal) Pollutant load reduction: 30-50% reduction in load for total suspended solids, total phosphorus, total nitrogen, fecal coliform, and total zinc with widespread implementation (conservative estimate)	Geosyntec 2016, International BMP Database 2014, Richter et al. 2015, Limouzin et al. 2011
Biodiversity	Bioretention systems and rain gardens support similar or greater diversity of invertebrates than nearby green spaces. With widespread implementation, they can also contribute to improved ecological health and aquatic life in urban streams.	Kazemi et al. 2009, Kazemi et al. 2011, Glick et al. 2016, Hamel et al. 2013, Walsh et al. 2015
Human well-being	Some potential to provide residents with increased exposure to nature and associated health benefits (as with other vegetated areas)	Sandifer et al. 2015

4.2 Economic Analysis

4.2.1 Economic Benefits

The economic benefits of ecosystem services provided by bioretention, biofiltration systems and rain gardens can depend on a number of site-specific factors. These include:

- The extent of area covered by these landscape factors influences the supply of ecosystem service values.
- The vegetation mix will influence the supply of ecosystem service values.

Table 8 shows the estimated values of the economic benefits we identified for bioretention, biofiltration systems and rain gardens.

Table 8. Range of Estimated Values of Economic Benefits of Bioretention, Biofiltration Systems, and Rain Gardens in Austin, Texas

Economic Benefit	Range of Values of Economic Benefits for Austin, Texas	References
Energy Costs	Unlikely to have significant effect; however, installations with trees, water features, or in areas with considerable influence on a building may generate minor energy cost savings, especially if density of installations is high in an otherwise hardscape-dominated area.	
Carbon Sequestration	$44-$239 per metric ton of Carbon	Interagency Working Group 2016
Avoided Stormwater Runoff Costs to City of Austin	$2 per cubic foot of stormwater diverted from system	American Forests 2002
Avoided Stormwater Runoff Fee Assessed to Property Owners	Up to a 72% reduction in the monthly drainage charge assessed by the City of Austin. Actual savings depends on site-specific factors.	
Impacts on Property and Amenity Values	Evidence of increase in property value is limited, with some studies showing potential negative effect and others positive. Expected benefit associated with well-maintained installations that add curb appeal beyond typical landscaping.	
Avoided Costs of Ecological and Species Habitat Management	Unquantifiable, but likely positive. Higher value for positive effects on habitat for sensitive species	
Avoided Health Care Costs, Improved Human Well-being	Unquantifiable, but positive relationships have been measured at a national scale, attributing benefits of access to green space to reduced healthcare costs and improved quality of life arising from improved newborn health; reduced incidence of ADHD; improved school performance; reduced crime; and improved cardiovascular health.	Wolf 2015

4.2.2 Economic Costs

Costs of implementing bioretention and rain garden stormwater controls can be very site specific depending on local soil, vegetation, and climate conditions. We report construction and operations and maintenance (O&M) costs below in Table 9. To the extent that bioretention, biofiltration systems and rain gardens reduce a site's developable space, they will generate opportunity costs for developers.

Table 9. Costs of Bioretention, Biofiltration Systems, and Rain Gardens

	Construction Costs/Cubic Foot[1]		Annual Maintenance Costs/Sq. Ft.[2]	
	Low	High	Low	High
Biofiltration, Construction Cost Per Cubic Foot of Water Quality Volume	$5.14	$18.05	$0.38	$0.747
Rain Garden, Construction Cost Per Cubic Foot of Water Quality Volume	$8.21	$61.79	$0.38	$0.747
Vegetative Filter Strip, Construction Cost Per Square Foot of Installation	$1.98	$4.80	$0.38	$0.747

Source: [1]City of Austin; [2] Center for Neighborhood Technology, No Date.

5 Vegetated Walls

5.1 Technical Analysis

Vertical surfaces that support vegetation are often called "green walls" or "green facades." This type of landscape element can take several different design forms, including direct green walls in which vegetation grows directly on a wall surface; "double-skin" designs that leave some air space between plants and building wall surface; and "living walls" that include encased growing medium within a support structure anchored to a wall surface. The primary benefits of vegetated walls relate to their role in microclimate regulation, but they may also provide additional ecosystem services such as capturing air pollutants, reducing noise levels, and providing resources for biodiversity. The biophysical benefits that vegetated walls could provide in Austin are summarized from peer-reviewed literature in Table 10 below.

Table 10. Range of Estimated Biophysical Benefits for Vegetated Walls in Austin, Texas

Ecosystem Service Type	Range of Estimated Biophysical Benefits in Austin, Texas	References
Microclimate regulation and mitigation of urban heat island effects	On a per-wall basis: maximum temperature reduction of 16-36° F for wall surface temperatures (compared to non-vegetated walls) At broader scales: 5.4-7.2° F reduction in ambient air temperatures with widespread vegetated wall implementation	Alexandri & Jones 2008, Mazzali et al. 2013, Perez et al. 2011, Cameron et al. 2014, Chen et al. 2013
Carbon storage and sequestration	Likely storage of < 1.0 kg C/m^2 for non-woody vegetation and 6.7 – 16.03 kg C/ m^2 for woody vegetation	Davies et al. 2011
Air pollutant removal	At broad scales: Up to 3,300 kg pollutants removed per year (and concentration reductions of 6-62% possible) with widespread implementation. Annual removal estimates per pollutant include 620 kg NO_2, 1090 kg O_3, 1370 kg PM_{10}, and 230 kg SO_2.	Currie et al. 2008, Pugh et al. 2012
Stormwater retention and runoff reduction	No estimates in the literature; very little contribution to stormwater retention expected	
Water filtration	No estimates in the literature; very little benefit to water filtration expected	
Biodiversity	Vegetated walls can provide some resources for invertebrates and urban birds	Madre et al. 2015, Chiquet et al. 2013
Human well-being	Can reduce noise pollution, provide sound insulation for buildings, and provide green views to residents	Azkorra et al. 2015

5.2 Economic Analysis

5.2.1 Economic Benefits

The economic benefits of ecosystem services provided by vegetated walls or green facades can depend on a number of site-specific factors. These include:

- The type of vegetated wall, direct type with vegetation rooted in the soil at ground level, or living-wall type, with escalating growing medium up the wall.
- The aspect the wall faces, with more energy-demand effects for plantings on south and west facing sides.
- The height of the building. Buildings with many stories will likely see less cooling benefits as a percentage of total cooling costs relative to buildings with fewer stories.
- The area of coverage, with greater extent of vegetation providing more benefits.

Table 11 shows the estimated values of the economic benefits we identified for bioretention, biofiltration systems and rain gardens.

Table 11. Range of Estimated Values of Economic Benefits of Vegetated Walls in Austin, Texas

Economic Benefit	Range of Values of Economic Benefits for Austin, Texas	References
Building Cost Savings	Depends on façade material, but may reduce maintenance requirements and extend the life of the building façade.	Perini 2013
Energy Costs	Expected reduction in energy demand and cost, largely dependent on existing insulation quality. Buildings that are already well-insulated likely will experience more limited energy benefits.	Hassan 2015
Carbon Sequestration	$44-$239 per metric ton of Carbon	Interagency Working Group 2016
Nitrogen Dioxide Removal	$0.13-$0.33 per kg	Nowak et al. 2016
Sulfur Dioxide Removal	$0.04-$0.09 per kg	Nowak et al. 2016
Small Particulate Matter	$26.45-$66.14 per kg	American Forests 2002
Impacts on Property and Amenity Values	Likely positive, for the same reason green roofs and street trees provide benefits. May affect the value of the building it's installed on, as well as adjacent buildings with views of the green façade.	
Avoided Costs of Ecological and Species Habitat Management	Unquantifiable, but likely insignificant, because habitat provided by vegetated walls is typically not suitable for sensitive species, and does not offer habitat types that are considered scarce, even in an urban environment.	
Avoided Health Care Costs, Improved Human Well-being	Unquantifiable, but positive relationships have been measured at a national scale, attributing benefits of access to green space to reduced healthcare costs and improved quality of life arising from improved newborn health; reduced incidence of ADHD; improved school performance; reduced crime; and improved cardiovascular health.	Wolf 2015

5.2.2 Economic Costs

Green wall systems vary in installation costs, depending on their design. Livings walls are typically more expensive to install and maintain than green façades using ground-level plantings. Given their close proximity to buildings, it is unlikely that most vegetated walls or green façade projects would limit site development and so would not cause opportunity costs for developers. Table 12 includes construction and maintenance costs for vegetated walls.

Table 12. Costs of Vegetated Walls

	Construction Costs/Sq. Ft.		Annual Maintenance Costs/Sq. Ft.	
	Low	High	Low	High
Living Walls	$80	$150	$7	$15
Green Facades	$25	$40	$0.25	$1

Sources: Liang 2014, Architek No Date; State of Victoria 2014; Perini and Rosasco 2013

6 Porous Pavement

6.1 Technical Analysis

Porous pavement systems retain stormwater, allowing it to permeate the surface layer and infiltrate into underlying substrate. Several different types of porous pavement systems exist, some of which allow vegetation to grow between paving units. The biophysical benefits of porous pavement are centered on runoff reduction and filtration of water pollutants. In addition, this landscape element may also contribute to urban landscape temperature regulation and provide some benefits to biodiversity. The biophysical benefits that porous pavements could likely provide in Austin are summarized from peer-reviewed literature and local reports in Table 13 below.

Table 13. Range of Estimated Biophysical Benefits for Porous Pavement in Austin, Texas

Ecosystem Service Type	Range of Estimated Biophysical Benefits in Austin, Texas	References
Microclimate regulation and mitigation of urban heat island effects	Mixed results for cooling capabilities of porous pavements in similar climates, although new-generation materials appear to have greater thermal performance.	Santamouris 2013, Qin 2015, Kevern et al. 2009, Stempihar et al. 2013
Carbon storage and sequestration	No estimates in the literature; very little carbon storage and sequestration expected	
Air pollutant removal	Unlikely to have air quality benefits; however, cooling effects could reduce formation of ozone	
Stormwater retention and runoff reduction	On a per-site basis: 74-100% of rainfall volume retained per storm At broader spatial scales: Some reduction in runoff volumes and peak flow	Collins et al. 2008, Dreelin et al. 2006, Hunt et al. 2008, Ball and Rankin 2010, Geosyntec 2016
Water filtration	Concentration reduction: significant reduction in total suspended solids (58-94%), metals (20-99%), and total phosphorus (10-78%) (mg/L) likely Pollutant load reduction: Total pollutant loads are likely low due to high runoff volume retention. 3.4 kg/ha/year estimated for total nitrogen and 0.4 kg/ha/year estimated for total phosphorus in one study (Bean et al. 2007)	International Stormwater BMP Database 2014, Richter et al. 2015, Ahiablame et al. 2012, Bean et al. 2007
Biodiversity	With widespread implementation, they can contribute to increased groundwater recharge and improved ecological health and aquatic life in urban streams.	

6.2 Economic Analysis

6.2.1 Economic Benefits

The economic benefits of ecosystem services provided by porous pavement depend primarily on the extent of site coverage. Porous pavement generates economic benefits primarily through the stormwater retention effect, reducing the need for other types of stormwater infrastructure, or reducing the risk of economic costs associated with flooding events.

Table 14. Range of Estimated Values of Economic Benefits of Porous Pavement in Austin, Texas

Economic Benefit	Range of Values of Economic Benefits for Austin, Texas	References
Building Cost Savings	May reduce cost of private stormwater management infrastructure required, such as curbs and gutters and catchment basins.	Century West Engineering No Date
Avoided Stormwater Runoff Costs to City of Austin	$2 per cubic foot of stormwater diverted from system	American Forests 2002
Avoided Stormwater Runoff Fee Assessed to Property Owners	Up to a 72% reduction in the monthly drainage charge assessed by the City of Austin. Actual savings depends on site-specific factors, and demonstration that installation meets design criteria.	
Avoided Costs of Ecological and Species Habitat Management	Unquantifiable, but likely positive. Higher value for positive effects on habitat for sensitive species	

6.2.2 Economic Costs

The cost of porous pavement varies depending on the system used. We list cost ranges for construction and O&M in Table 15. Porous pavement is usually used instead of a conventional

pavement system wherever hardscape is required in a development. For this reason, it is unlikely to generate opportunity costs for developers, and may increase the overall developable space because traditional curbs and gutters and stormwater management ponds are not required.

Table 15. Costs of Porous Pavement

	Construction Costs/Sq. Ft.[1]		Annual Maintenance Costs/Sq. Ft.	
	Low	High	Low	High
Porous Pavement	$6.34	$18.55	$0.01	$0.23

Source: [1] City of Austin; [2] Center for Neighborhood Technology, No Date.

7 Cisterns

7.1 Technical Analysis

Cisterns are above- or below-ground tanks that retain and store rainwater for reuse. Although they are not a vegetation- or soil-based landscape element, they do provide biophysical benefits in urban systems and can reduce potable water usage for landscape irrigation needs. Their primary benefits center on stormwater retention. Several researchers highlight stormwater harvesting via cisterns as a critical complement to infiltration-based techniques (e.g., rain gardens) to achieve urban stormwater management goals and improve urban stream ecology. The benefits of cisterns for Austin are summarized from peer-reviewed literature and local reports in Table 16 below.

Table 16. Range of Estimated Biophysical Benefits for Cisterns in Austin, Texas

Ecosystem Service Type	Range of Estimated Biophysical Benefits in Austin, Texas	References
Microclimate regulation and mitigation of urban heat island effects	Unlikely to contribute to microclimate regulation or urban heat island effects	
Carbon storage and sequestration	Unlikely to contribute to carbon storage and sequestration; however, water reuse is associated with reduced carbon emissions	
Air pollutant removal	Unlikely to have air quality benefits; however, water reuse is associated with reduced emissions at power plants	
Stormwater retention and runoff reduction	Some reduction in runoff volumes and peak flow with widespread implementation	Geosyntec 2016, Glick et al. 2016
Water filtration	Can lead to reduced total pollutant loads due to high runoff volume retention.	
Biodiversity	With widespread implementation, they can reduce erosive events and peak flow, which can in turn lead to improved ecological health and aquatic life in urban streams.	Geosyntec 2016, Glick et al. 2016, Walsh et al. 2015

7.2 Economic Analysis

7.2.1 Economic Benefits

The economic benefits of ecosystem services provided by cisterns and rainwater harvesting depend on the following factors.

- Size of system and the volume of stormwater captured.
- The type of system. "Smart" systems empty out after a rain event so that they have capacity for the next storm system.
- Types of water re-use supported. Systems that capture and release stormwater provide fewer benefits than those that use captured rainwater for on-site applications.

Table 17. Range of Estimated Values of Economic Benefits of Cisterns in Austin, Texas

Economic Benefit	Range of Values of Economic Benefits for Austin, Texas	References
Reduced Water Purchases and Use of Potable Water	Reusing harvested rainwater onsite can reduce use of potable water and offset water purchased from other sources.	
Increased Water Reliability	During times of shortage, cisterns can reduce the timing and duration of water shortages by augmenting primary water supplies.	
Avoided Stormwater Runoff Costs to City of Austin	$2 per cubic foot of stormwater diverted from system	American Forests 2002
Avoided Stormwater Runoff Fee Assessed to Property Owners	Site-specific, depending on percent reduction in impervious area.	
Avoided Costs of Ecological and Species Habitat Management	Unquantifiable, but likely positive. Higher value for positive effects on habitat for sensitive species	

7.2.2 Economic Costs

Cisterns and rain barrel systems vary in installation costs, depending on their design. To the extent that installing cisterns and rain barrels takes up space that would otherwise be occupied by development, they generate opportunity costs for developers. Cisterns installed below ground may not generate opportunity costs, depending on development demands for below ground space.

Table 18. Costs of Cisterns

	Construction Costs/Cubic Foot[1]		Annual Maintenance Costs/Installation[2]	
	Low	High	Low	High
Cistern Construction Cost Per Cubic Foot of Water Quality Volume	$24.68	$59.84	$350	$

Sources: [1]City of Austin, [2] Kim 2011 and City of Austin

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DATE: May 8, 2017
TO: Austin City Staff
FROM: Amy Belaire, PhD, Ed MacMullan, ECONorthwest, and Heather Venhaus, Regenerative Environmental Design
SUBJECT: Draft Task 7H – Determining the Value of Landscape Elements

I. INTRODUCTION

Functional Green is an environmental planning tool that aims to integrate nature and ecosystem services into new built environments. Ecosystem services are defined as "the benefits people obtain from ecosystems," such as clean air and water, carbon storage and sequestration, and microclimate regulation (Millennium Ecosystem Assessment 2005). To aid in the development of Functional Green, the consultant team has conducted a thorough literature review and analysis of the ecosystem services and economic benefits and costs associated with a range of landscape elements that can be incorporated into dense urban areas. These landscape elements include trees (both existing and newly planted), green roofs, vegetated walls, planting beds, cisterns, porous pavements, and rain gardens.

The review and analysis that has been conducted provides an in-depth understanding of each landscape element's likely performance – in both biophysical and economic terms – in the Austin ecosystem. This information provides a solid analytical foundation for the scoring of landscape elements based on their performance, which in turn facilitates developing a performance-based weighted rating for each element. With this approach, the City of Austin provides a landscape rating process based on science, transparency, and analytical rigor.

The primary goal of this report is to provide recommendations on preliminary ratings for the landscape elements that will likely be included in Functional Green. In the sections below, we describe the biophysical and economic criteria that informed the evaluation of landscape elements and provide details about the Multi-Criteria Decision Analysis process we used to calculate the preliminary ratings. It is important to recognize that this is the first step in a multi-step process; developing the final landscape element ratings will involve working through a series of case studies in which the ratings can be implemented and tested for development projects in Austin. The results of the case studies will inform future modifications to the preliminary ratings for the landscape elements.

II. OVERVIEW OF METHODS FOR CALCULATING LANDSCAPE ELEMENT RATINGS

To determine the preliminary ratings for the landscape elements, the consultant team used a Multi-Criteria Decision Analysis (MCDA)[1] approach. The decision-making analysis framework is commonly used to structure and solve problems dealing with multiple and diverse criteria. The primary steps in our approach include the following:

- STEP 1: Determine a score for each landscape element based on its ecological and economic performance. These scores indicate the performance of each

[1] For a recently published discussion on MCDA for ecosystem services valuation, please see: Saarikoski, H.,

landscape element relative to the others. Scores were assigned to each landscape element based on its performance in nine different biophysical and economic criteria. In other words, each landscape element received nine performance scores, one for each of the criteria evaluated.

- STEP 2: Assign a weighted value to each of the nine biophysical and economic criteria for which the landscape elements were evaluated. The objective of this step is to represent a diverse range of preferences with respect to ecosystem services and economic outcomes. We refer to these as the criteria weights and evaluated several different weighting scenarios.
- STEP 3: Multiply the performance scores by the criteria weights to arrive at adjusted scores, and sum across all criteria to get a final score for the landscape elements. We refer to these results as the preliminary ratings for the landscape elements.

At this time, the ratings for the landscape elements are represented with symbols rather than numeric values. This is because numeric values are somewhat meaningless until target scores are identified for the parcels using Functional Green. We also recognize that the ratings will likely be adjusted at a later date after case studies are conducted, at which point numeric values will be more applicable.

III. STEP 1: DETERMINE THE BIOPHYSICAL AND ECONOMIC PERFORMANCE SCORES OF EACH LANDSCAPE ELEMENT

Criteria for performance evaluation

The analysis included nine primary criteria to evaluate each landscape element that the Functional Green program will likely include[2]. Six criteria are ecosystem services that the City of Austin identified as high priorities. An additional three criteria have significance to property development and use. The six ecosystem services are:

1. Microclimate regulation and mitigation of urban heat island effects
2. Carbon storage and sequestration
3. Air pollutant removal
4. Stormwater retention and runoff reduction
5. Water filtration
6. Biodiversity benefits

In addition to these ecosystem services, several additional criteria were included in the analysis to reflect property development and use considerations. Landscape elements in highly developed environments can improve human health and well-being. For example, views of and access to green spaces (e.g., green roofs) can help reduce stress and improve mental productivity. In addition, the economics literature describes the beneficial impacts that landscape elements can have on property values. To the extent that property markets perceive a landscape element as an amenity, increased demand and sale prices will reflect this. Lastly, landscape elements can also occupy space that would otherwise be developed. This can have implications for the financial returns to developers. Therefore, the three property development and use considerations in Functional Green are:

7. Human health and well-being
8. Effects on property values
9. Effects on developable area

[2] See summary memos for Tasks 7B and 7E for more information on these criteria.

Scoring landscape element performance
The performance scores for each of the criteria above were informed by work conducted under Tasks 7B and 7E, which summarized peer-reviewed literature and local reports for the Austin area. The consultants also included additional studies conducted in locations with climates similar to Austin's (humid subtropical) when they were available. In cases where little published research exists, consultants relied on best available data regardless of location or climate. Common metrics were used whenever possible to assess performance and allow for comparisons between the different landscape elements.

The landscape elements were scored against each other in terms of their expected relative performance for each of the nine criteria listed above. In the ratings, the consultants used a scoring system in which "A" means that the element is expected to perform well (in the top 20%) in comparison to the other elements evaluated. "B" means the performance of this element is in the mid-range when compared to the other elements evaluated (in the range of 50-70% performance). "C" means this element is on the low end of benefits when compared to the other elements evaluated (in the range of 20-40%), and "D" was assigned when minimal or no benefits were expected. In addition, a +/- was used as needed to differentiate between landscape elements in terms of their performance. The performance scores for the nine criteria are summarized in Table 1 below (additional details about the scores are included in Appendix A.)

Table 1. Scores for landscape elements based on their relative performance with respect to nine criteria. See Appendix A for more details about the scores.

	Criteria for evaluating the landscape elements								
	1. Microclimate regulation	2. Carbon storage & sequestration	3. Air pollutant removal	4. Stormwater retention	5. Water filtration	6. Biodiversity benefits	7. Property value	8. Human well-being	9. Developable area
Existing tree	A	A	A	B+	C+	A	A	A	C
Newly planted tree	B	B	B	C+	C	B	B+	A-	B
Green roof	A-	B	B+	A	B	A	A-	B	A+
Rain garden	C+	C+	C	A	A	A	B	B	B
Vegetated wall	B+	C+	B	D	D	C	B	B	A+
Planting beds	C+	C	C	C	C-	C+	C	B	B
Porous pavement	C	D	D	A	A	D	C	D	A
Cistern	D	C-	C-	A	C	D	C	D	C+

A = high performance, in 80-100% range
B = mid-range performance, in 50-70% range
C = low performance, in 20-40% range
D = very low performance, in the bottom 1%

IV. STEP 2: ASSIGN WEIGHTED VALUES TO THE CRITERIA AND MULTIPLY BY PERFORMANCE SCORES

After the landscape elements were scored based on their relative performance in each of the nine criteria, the consultants evaluated different scenarios in which the criteria were assigned weighted values according to a range of possible preferences (under the constraint that the weights must sum to 1). The weighted values assigned to the nine criteria under the different scenarios are summarized in Table 2. The four scenarios include the following:

- **Scenario 1** - All nine criteria have equal weight.
- **Scenario 2** - The six ecosystem services were given higher weight than the three development and use considerations. This scenario represents a preference for landscape elements that provide strong ecosystem services with less weight given to economic constraints.
- **Scenario 3** - The three development and use considerations were given higher weight than the six ecosystem services. This scenario represents a preference for landscape elements that provide strong development and use benefits with less weight given to ecosystem services.
- **Scenario 4** - The nine criteria were assigned weights according to the number and scale of stakeholders affected.

Table 2. Weighted values for the nine criteria by which the landscape elements were evaluated. Four different scenarios were used to represent a range of possible preferences.

Criteria for evaluating the landscape elements	Scenario 1 Values	Scenario 2 Values	Scenario 3 Values	Scenario 4 Values
1. Microclimate regulation	0.11	0.16	0.06	0.15
2. Carbon storage and sequestration	0.11	0.16	0.06	0.10
3. Air pollutant removal	0.11	0.16	0.06	0.15
4. Stormwater retention	0.11	0.10	0.06	0.15
5. Water filtration	0.11	0.10	0.06	0.10
6. Biodiversity benefits	0.11	0.16	0.06	0.15
7. Property values	0.11	0.05	0.22	0.05
8. Human health & well-being	0.11	0.05	0.21	0.10
9. Developable area	0.11	0.05	0.21	0.05
TOTAL (weights are constrained to sum to 1 in each scenario)	1.00	1.00	1.00	1.00

For each of the four scenarios described above, the performance scores (Table 1) were multiplied by the values of the weighted criteria (Table 2) to arrive at adjusted scores.

V. STEP 3: SUM ACROSS ALL CRITERIA TO CALCULATE PRELIMINARY RATINGS FOR LANDSCAPE ELEMENTS

After we calculated adjusted scores in Step 2, we summed across all criteria. This resulted in preliminary ratings for each landscape element. We use a rating system of 1-5 stars in Table 3 below to illustrate the preliminary ratings under each scenario we tested. The right-most column in Table 3 shows the average rating across all four scenarios.

Table 3. Preliminary ratings for landscape elements across four weighted scenarios

Landscape elements	Scenario 1 Rating	Scenario 2 Rating	Scenario 3 Rating	Scenario 4 Rating	AVERAGE RATING
Existing tree	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Newly planted tree	★★★	★★★	★★★★	★★★	★★★
Green roof	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Rain garden	★★★★	★★★	★★★★	★★★★	★★★★
Vegetated wall	★★	★★	★★★	★★	★★
Planting beds	★	★	★★	★	★
Porous pavement	★	★	★	★	★
Cistern	★	★	★	★	★

The preliminary ratings for each landscape element stayed relatively consistent, regardless of the scenario. This suggests that the ratings shift very little, even when a broad variety of preferences are taken into account with respect to ecosystem services and economic considerations.

VI. BONUS POINTS

In addition to the eight landscape elements, the consultants envision options for bonus points, which will provide additional points above those of already-credited landscape elements in the Functional Green tool. All bonus points would be rated equally and would have a low rating (one star). Potential bonus point options include:

- Native plants
- Pollinator gardens
- Low water use landscapes
- Alternative water use landscapes

APPENDIX A

Table A: Microclimate regulation and mitigation of urban heat island effects

Landscape elements	Microclimate perfomance (biophysical)	Microclimate perfomance (economic)	Score
Exising tree	2.2-7.0° F reduction in surface air temperatures for areas underneath and adjacent to street tree canopy	Reduced energy costs.	A
Newly planted tree	Smaller canopy area results in less shade and transpiration than larger existing trees	Reduced energy costs. Benefits start at close to zero and increase over time.	B
Green roof	1.6-5.4° F reduction in ambient air temperatures with widespread green roofs; 45-54° F reduction in roof surface temperatures	Reduced energy costs.	A-
Raingarden	Some potential for minor cooling effects (as with any small vegetated area).	Installations with trees, water features, or in areas with considerable influence on a building may generate minor energy savings.	C+
Vegetated wall	5.4-7.2° F reduction in ambient air temperatures with widespread green walls; 16-36° F reduction in wall surface temperatures.	Expected reduction in energy demand and cost, largely dependent on existing insulation quality. Building that are already well-insulated likely will experience more limited energy benefits.	B+
Planting beds or boxes	Some potential for minor cooling effects (as with any small vegetated area)	Estimated to have minimal benefits.	C+
Porous paving	Mixed results for cooling capabilities of porous pavements in similar climates, although new-generation materials appear to have greater thermal performance.	Minimal economic benefits.	C
Cistern	Unlikely to contribute to microclimate regulation or urban heat island effects.	Minimal economic benefits.	D

Table B: Carbon storage & sequestration

	Carbon storage & sequestration (biophysical)	Carbon storage & sequestration (economic)	Score
Existing tree	Storage: 7.7 - 28.9 kg C/m^2 tree cover Sequestration: 93 - 305 kg C/year for larger trees	$44-$239/metric ton of carbon stored or sequestered	A
Newly planted tree	Storage: 7.7 - 28.9 kg C/m^2 tree cover Sequestration: 11 - 64 kg C/year for small trees	Same as above but benefits will start at close to zero and increase over time.	B
Green roof	Storage: 0 - 67.7 kg C/m^2 depending on plant type, substrate, and age of roof.	$44-$239/metric ton of carbon stored or sequestered	B
Rain garden	Storage: 0 - 3.34 kg C/m^2 Sequestration: 0.05-0.09 kg C/m^2 per year	$44-$239/metric ton of carbon stored or sequestered	C+
Vegetated wall	Storage: < 1.0 kg C/m^2 for non-woody and 6.7 – 16.0 kg C/ m^2 for woody vegetation.	$44-$239/metric ton of carbon stored or sequestered	C+
Planting beds or boxes	Estimated to be less than a newly planted tree	Estimated to be less than a newly planted tree	C
Porous paving	No estimates in the literature; very little carbon storage and sequestration expected.	Minimal economic benefits.	D
Cistern	Unlikely to contribute to carbon storage and sequestration; however, water reuse is associated with reduced carbon emissions	Minimal economic benefits.	D

Table C: Air pollutant removal

	Air Quality (biophysical)	Air Quality (economic)	Score
Existing tree	Up to 12.0 g of air pollutants removed per m^2 of tree canopy, depending on location, size and type of tree	$0.13-$0.33/kg NO2 $0.04-$0.09/kg SO2 $26.45-$66.14/kg Particulate Matter	A
Newly planted tree	Smaller trees with reduced leaf area capture fewer air pollutants than larger trees	$0.13-$0.33/kg NO2 $0.04-$0.09/kg SO2 $26.45-$66.14/kg Particulate Matter but benefits will start at close to zero and increase over time.	B
Green roof	Up to 8.5 g of pollutants removed per m2 of green roof per year.	$0.13-$0.33/kg NO2 $0.04-$0.09/kg SO2 $26.45-$66.14/kg Particulate Matter	B+
Rain garden	No estimates in the literature; however, cooling effects of vegetation can lead to reduced ozone formation.	Minimal economic benefits.	C
Vegetated wall	Cooling effects can lead to reduced ozone formation; up to 3,300 kg pollutants removed per year with widespread green walls.	$0.13-$0.33/kg NO2 $0.04-$0.09/kg SO2 $26.45-$66.14/kg Particulate Matter	B
Planting beds or boxes		Minimal economic benefits.	C
Porous paving	Unlikely to have air quality benefits; however, cooling effects could reduce formation of ozone.	Minimal economic benefits.	D
Cistern	Unlikely to have air quality benefits; however, water reuse is associated with reduced emissions at power plants	Minimal economic benefits.	C-

Table D: Stormwater retention and runoff reduction

	Water retention (biophysical)	Water retention (economic)	Score
Existing tree	113-400 ft3/year for large trees	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure	B+
Newly planted tree	11-44 ft3/year for small trees	Benefits will start at close to zero and increase over time.	C+
Green roof	44-88% of rainfall volume retained per storm and 43-78% of rainfall volume retained annually per roof.	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure.	A
Rain garden	40-100% of rainfall volume retained per storm and 58-97% of rainfall volume retained annually per garden.	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure	A
Vegetated wall	No estimates in the literature; very little contribution to stormwater retention expected.	Minimal economic benefits	D
Planting beds or boxes	Estimated to be less than a newly planted tree.	Estimated to be less than a newly planted tree.	C
Porous paving	74-100% of rainfall volume retained per storm.	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure. Up to 72% reduction in monthly drainage charge.	A
Cistern	High stormwater retention possible with large capacity and “smart” systems.	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure. Up to 72% reduction in monthly drainage charge.	A

Table E: Water filtration

	Water filtration (biophysical)	Water filtration (economic)	Score
Existing tree	Tree canopy can lead to reduced total pollutant loads due to some reduction of runoff volume via canopy interception	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure	C+
Newly planted tree	Smaller trees with reduced canopy coverage will have reduced rainwater interception rates.	Same as above but benefits will start at close to zero and increase over time.	C
Green roof	Mixed results for water quality. Although total concentrations may be higher in effluent, the total loads are lower due to high runoff volume retention.	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure.	B
Rain garden	Reduced concentration of total suspended solids likely (85-95% removal).	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure.	A
Vegetated wall	No estimates in the literature; very little benefit to water quality expected.	Minimal economic benefits	D
Planting beds or boxes	Estimated to be equal to or less than newly planted tree	Minimal economic benefits	C-
Porous paving	Reduced concentrations of total suspended solids (58-94%), metals (20-99%), and total phosphorus (10-78%) likely.	$2 per cubic foot of stormwater diverted from City of Austin stormwater infrastructure. Up to 72% reduction in monthly drainage charge.	A
Cistern	No direct filtration, but some water quality benefits possible due to reduction in runoff volume.	Minimal economic benefits.	C

Table F: Biodiversity benefits

	Biodiversity (biophysical)	Biodiversity (economic)	Score
Existing tree	Increased biodiversity observed in areas of greater tree coverage.	Avoided costs of ecological and species habitat management or replacement.	A
Newly planted tree	Increased biodiversity observed in areas of greater tree coverage.	Avoided costs of ecological and species habitat management or replacement but benefits will start at close to zero and increase over time.	B
Green roof	Can provide habitat for diversity of invertebrates (including native pollinators) and increase functional connectivity.	Provides habitat for insect and bird species.	A
Rain garden	Can support diversity of invertebrates and contribute to improved stream health with widespread implementation.	Avoided costs of ecological and species habitat management or replacement.	A
Vegetated wall	Vegetated walls can provide some resources for invertebrates and urban birds.	Likely insignificant because habitat provided by vegetated walls is typically not suitable for sensitive species, and does not offer habitat types that are considered scarce, even in an urban environment.	C
Planting beds or boxes	Can provide habitat for invertebrates (including native pollinators).	Provides habitat for insect species.	C+
Porous paving	Limited research but improved ecological health and aquatic life in urban streams may occur with widespread implementation.	No economic benefits.	D
Cistern	Limited research but improved ecological health and aquatic life in urban streams may occur with widespread use.	No economic benefits.	D

Table G: Property Value

	Property Values (biophysical)	Property Values (economic)	Score
Existing tree	N/A	Up top 13%-19% increase for single-family residential. Higher rents; longer leaseholder retention and lower turnover for commercial and multi-family rentals.	A
Newly planted tree	N/A	Same as above but benefits will start at close to zero and increase over time.	B+
Green roof	N/A	Up to 6% increase in rental rates, which can increase property values for rental properties.	A-
Rain garden	N/A	Expected benefits associated with well maintained installations that add curb appeal beyond typical landscaping.	B
Vegetated wall	N/A	Likely positive, for the same reason green roofs and street trees provide benefits. May affect the value of the building it's installed on, as well as adjacent buildings with views of the green façade.	B
Planting beds or boxes	N/A	Minimal economic benefits.	C
Porous paving	N/A	Minimal economic benefits.	C
Cistern	N/A	Minimal economic benefits.	C

Table H: Human health and well-being

	Human Well-Being (biophysical)	Human Well-Being (economic)	Score
Existing tree	N/A	Positive relationship between access to greenspaces and reduced healthcare costs and improve quality of life.	A
Newly planted tree	N/A	Positive relationship between access to greenspaces and reduced healthcare costs and improve quality of life.	A-
Green roof	N/A	Positive relationship between access to greenspaces and reduced healthcare costs and improve quality of life.	B
Rain garden	N/A	Positive relationship between access to greenspaces and reduced healthcare costs and improve quality of life.	B
Vegetated wall	N/A	Positive relationship between access to greenspaces and reduced healthcare costs and improve quality of life.	B
Planting beds or boxes	N/A	Positive relationship between access to greenspaces and reduced healthcare costs and improve quality of life.	B
Porous paving	N/A	No economic benefits	D
Cistern	N/A	No economic benefits	D

Table I: Developable area

	Developable (biophysical)	Developable (economic)	Score
Existing tree	N/A	Trees take up space at ground level that could otherwise be occupied by developed site/building.	C
Newly planted tree	N/A	Trees take up space at ground level that could otherwise be occupied by developed site/building.	B
Green roof	N/A	No impact on developable area at ground level.	A+
Rain garden	N/A	Rain gardens take up developable space at ground level.	B
Vegetated wall	N/A	Little to no impact on developable area at ground level	A+
Planting beds or boxes	N/A	Planting beds take up space at the ground level that could otherwise be occupied by development.	B
Porous paving	N/A	Little to no impact on developable area at ground level.	A
Cistern	N/A	Cisterns take up space at ground level	C+

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
Chapter 25-2, Zoning - Article 9, Landscaping					
1	25-2-981 Applicability; Exceptions	Policy	Existing landscaping requirements do not apply to lots zoned Central Business District (CBD) or Downtown Mixed Use (DMU).	Require that lots zoned CBD or DMU meet the new Functional Green requirements (described below).	Additional ecosystem services brought to downtown projects.
2	25-2-1007 Parking Lots	Policy	Parking lot islands are typically surrounded by a 6" curb that prevents stormwater from flowing into the landscape area.	Require parking lot islands to have an edge-of-pavement treatment that allows overland flow of stormwater into the landscape area. Allow exceptions for areas that are not required to drain to a stormwater control and sites located in the Edwards Aquifer Recharge Zone.	Increases beneficial use of stormwater and reduces irrigation needs by directing stormwater into areas that are typically required to provide on-site irrigation.
3	25-2-1008 Irrigation Requirements	Policy	The existing requirement to irrigate 50% of the required landscape area with stormwater has proven problematic and difficult to implement.	Remove existing irrigation requirements and replace with simplified requirement to remove barriers to overland flow into parking lot islands (described above).	Simplified design requirements and reduced cost.
4	Functional Green	Policy	Sites with high impervious cover have few landscape requirements and therefore provide minimal ecosystem services.	Create a new approach to landscape requirements to provide ecosystem services in highly urbanized locations.	Landscape requirements are calibrated to provide ecosystem services in highly urbanized locations.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
Chapter 25-2, Zoning - Article 13, Docks, Bulkheads, and Shoreline Access					
5	25-2-1179 Environmental Protection	Clarification	Bulkhead wave abatement requirements are currently located in the zoning chapter of the Land Development Code, which is inappropriate.	Move bulkhead construction requirements to Chapter 25-8, Subchapter A, Water Quality.	Improves review process and clarifies intent of regulations.
Chapter 25-5, Site Plans					
6	25-5-3 Small Projects	Policy	Small-scale multifamily residential projects must go through a longer, more expensive permitting process than single-family residential projects with the same percent impervious cover.	Allow multifamily residential projects with up to 11 units, or more if allowed under a qualifying Affordability Unlocked project, to follow the Small Project site plan process if they meet certain conditions.	Fewer review fees, faster review times, and no neighborhood notice requirement for qualifying small-scale multifamily residential projects.
Chapter 25-7, Drainage					
7	25-7-32 Director Authorized to Require Erosion Hazard Zone Analysis	Policy & Clarification	The current requirement to analyze the erosion hazard zone within 100' of the Colorado River downstream of Longhorn Dam is not sufficiently protective given the erodibility of the river bank.	Require erosion hazard zone analysis for development within 400' of the Colorado River downstream of Longhorn Dam. Clarify the WPD director's role in determining additional areas where an erosion hazard zone analysis must be performed.	Protects public infrastructure and private development from being damaged or destroyed by erosion.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
Chapter 25-8, Environment					
8	25-8-1 Definitions	Clarification	Code sections that refer to the director of Planning and Development Review do not accurately reflect the role of the Environmental Officer, who is housed in the Watershed Protection Department (WPD) and works on behalf of the Director of WPD.	Change the default director reference from the Planning and Development Review Department to the Watershed Protection Department.	Reflects the Environmental Officer's role and current alignment within the Watershed Protection Department.
9	25-8-2 Description of Regulated Areas	Clarification	Existing language is not clear and does not reflect current status of online resources available to the public.	Clarify language to reflect where the public can find reference maps and reflect the change to the definition of director.	Clarity.
10	25-8-21 Applicability	Policy	Although many environmental regulations technically apply to single-family residential construction, they have not been consistently applied during the building permit process. Small-scale multifamily residential projects are subject to more regulations than single-family residential projects with similar impacts.	Clarify which environmental regulations apply to single-family residential construction and apply only those regulations to qualifying small-scale multifamily projects.	Staff will be able to provide clear guidance to residential owners and homebuilders regarding applicability of environmental regulations to their projects. Small-scale multifamily projects will be subject to the same requirements as single-family residential projects with similar impacts.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
11	25-8-25 Redevelopment Exception in Urban and Suburban Watersheds	Policy & Clarifications	Current redevelopment exception standards are too restrictive regarding unpermitted development and too permissive regarding existing disturbance adjacent to waterways. Requirements related to vehicle trips and land use create barriers to projects that would otherwise be allowed by zoning.	Align language with the LDC Revision proposal. Require unpermitted development to be removed. Require existing impervious cover within a certain distance of a protected waterway to be removed and the area restored. Remove the vehicle trip limit and reference to a neighborhood plan. Reorganize and clarify language.	More projects would be able to use the redevelopment exception, which would result in improved water quality. Removing impervious cover immediately adjacent to a waterway would improve riparian habitat and water quality. Reorganization and wording changes improve clarity.
12	25-8-26 Redevelopment Exception in the Barton Springs Zone	Clarification	Current code uses the term "sedimentation/filtration pond" to refer to any water quality control that complies with Section 25-8-213.	Change the defined term from "sedimentation/filtration pond" to "standard pond" to clarify that green stormwater infrastructure can meet this requirement.	Clarity.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
13	25-8-27 Redevelopment Exception in the Water Supply Rural and Water Supply Suburban Watersheds	Policy & Clarifications	Current redevelopment exception standards are too restrictive regarding unpermitted development and too permissive regarding existing disturbance adjacent to waterways. Requirements related to dwelling units, vehicle trips, and land use create barriers to projects that would otherwise be allowed by zoning.	Align language with the LDC Revision proposal. Require unpermitted development to be removed. Require existing impervious cover within a certain distance of a protected waterway to be removed and the area restored. Remove requirement for Council approval based on dwelling units, vehicle trips, and land use.	More projects could use the redevelopment exception, which would result in improved water quality. Removing impervious cover immediately adjacent to a waterway would improve riparian habitat and water quality. Reorganization and wording changes improve clarity.
14	25-8-42 Administrative Variances	Policy & Minor Edits	The code sections allowed to be varied administratively by staff need to be updated for clarity and to reflect other proposed amendments.	Allow administrative variances for properties along Lake Austin. Allow administrative variances to allow a development to use conventional water quality ponds; to allow green stormwater infrastructure in the critical water quality zone (CWQZ); to allow driveways and private streets to cross a CWQZ; to allow residential construction in the CWQZ; and to allow cut or fill up to 8' for residential construction. Provide applicable conditions that must be met in order for staff to grant the proposed administrative variances.	Streamlines the review process and allows reasonable development that minimizes environmental impacts.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
15	25-8-62 Net Site Area	Clarification	Existing language is not clear.	Clarify that net site area excludes areas designated for surface or subsurface wastewater irrigation.	Clarifies existing policy.
16	25-8-63 Impervious Cover Calculations	Minor Edits	Rainwater harvesting cisterns are considered impervious cover. Calculation of impervious cover does not align with residential review processes.	Remove rainwater harvesting cisterns from impervious cover calculations. Clarify when eaves, overhangs, balconies, etc. are considered impervious cover for residential building permits.	Removes disincentive to install rainwater harvesting cisterns. Improves consistencies between review departments.
17	25-8-64 Impervious Cover Assumptions	Clarification	Current code does not clearly require an applicant to demonstrate the buildability of subdivided lots.	Align language with the LDC Revision proposal. Require subdivision applicants to submit a buildability exhibit.	Protects future homebuilders by ensuring that platted lots can be developed in compliance with environmental regulations.
18	25-8-92 Critical Water Quality Zones Established	Policy & Clarification	The width of the critical water quality zone (CWQZ) setback along the Colorado River is not sufficiently protective. Existing language that exempts roadside ditches from CWQZs is not clear.	Increase the width of the CWQZ along the Colorado River downstream of Longhorn Dam from 200-400' to 400'. Clarify language that exempts roadside ditches from CWQZ requirements.	Provides greater protection of the Colorado River downstream of the Longhorn dam. Provides greater clarity regarding the intent of the roadside ditch exemption.
19	25-8-121 Environmental Resource Inventory Requirement	Minor Edits	The current environmental resource inventory (ERI) triggers do not accurately reflect whether Critical Environmental Features (CEFs) are likely to be present on a property.	Remove requirement to prepare ERIs in areas where CEFs are not more likely to be encountered, and require ERIs when they are.	Removes ERI waiver requirement for certain properties and clarifies the need for an ERI when CEFs are more likely to be present.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
20	25-8-182 Development Completion	Clarification	Reference to Planning and Development Review Department does not accurately reflect the current process.	Update reference to the Watershed Protection Department.	Reflects the Environmental Officer's current alignment within the Watershed Protection Department and the change to the definition of director.
21	25-8-184 Additional Erosion and Sedimentation Control Requirements in the Barton Springs Zone	Clarification	Reference to Planning and Development Review Department does not accurately reflect the current process.	Update reference to the Watershed Protection Department.	Reflects the Environmental Officer's current alignment within the Watershed Protection Department and the change to the definition of director.
22	25-8-185 Overland Flow	Policy & Clarification	The intent of the overland flow section is to maintain infiltration and recharge of all waterbodies, not just seeps and springs. Overland flow should be directed to landscaped areas where possible in order to increase infiltration and reduce the need for irrigation of landscape areas.	Require stormwater to be directed to landscape areas when feasible. Update existing requirement to maintain infiltration and recharge to include waterways.	Increases infiltration, recharge, and beneficial use of stormwater. Clarifies the intent behind the need to maintain overland flow.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
23	25-8-213 Water Quality Control Standards	Policy & Clarification	Development is allowed but generally not required to use green stormwater infrastructure (GSI) to provide water quality treatment.	Require most development to use GSI (e.g., rain gardens, biofiltration, and other green controls prescribed in the ECM) to provide required water quality treatment. Allow exceptions for highly polluting land uses, regional ponds, and sites with more than 90% impervious cover. Clarify existing load reduction standards and liner requirements.	Increases infiltration, recharge, and beneficial use of stormwater. Provides additional ecosystem services and enhanced aesthetic benefits of stormwater control measures so that they can more seamlessly tie into open space areas available to end users.
24	25-8-214 Optional Payment Instead of Structural Controls in Urban Watersheds	Clarification	Language is outdated.	Change Environmental Board to Environmental Commission and update language to match current process.	Clarity.
25	25-8-232 Dedicated Fund	Clarification	Language does not reflect the new definition of director (used without a qualifier).	Add reference to Development Services Department.	Clarity.
26	25-8-233 Barton Springs Zone Operating Permit	Clarification	Reference to Planning and Development Review Department does not accurately reflect the current process.	Update reference to the Watershed Protection Department.	Reflects the Environmental Officer's current alignment within the Watershed Protection Department and the change to the definition of director.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
27	25-8-261(B), (C), (E), (G), and (H) Critical Water Quality Zone Development	Minor Edits & Clarifications	Lakefront development requirements are not included in the critical water quality zone (CWQZ) code section. The Colorado River is not sufficiently protected. Existing language regarding floodplain modification is not clear.	Consolidate environmental protections that specifically apply to the lakes into the CWQZ section. Include Lake Walter E. Long in code related to lakes. Update the minimum distance some types of development must be from the Colorado River to 200' instead of 100' to reflect the wider CWQZ proposed in Section 25-8-92. Clarify floodplain modification requirements.	Improves clarity and organization. Provides greater protection of the Colorado River downstream of Longhorn Dam.
28	25-8-261(D) and (F) Critical Water Quality Zone Development	Clarification & Policy	Existing requirements related to utilities are not clear. Allowing in-channel detention ponds and wet ponds creates significant disturbance to a creek and existing requirements are not sufficiently protective.	Clarify that requirements for utility lines also apply to utility easements and major replacements of an existing line. Allow additional flexibility if a utility line is installed with boring or tunneling, as currently described in the Environmental Criteria Manual. Require that stormwater outfalls minimize disturbance to the bank of the Colorado River. Only allow in-channel detention basins and in-channel wet ponds proposed as part of a public project or public-private partnership.	Improves clarity and provides greater protection for creeks and the Colorado River.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
29	25-8-364 Floodplain Modification *(New section: 25-8-263)*	Clarification	Floodplain modification requirements are often confusing.	Relocate the floodplain modification section to follow critical water quality zone requirements, as proposed in the LDC Revision. Rename the division for clarity. Reorganize and reword floodplain modification requirements for clarity.	Clarity.
30	25-8-262 Critical Water Quality Zone Mobility Crossings	Clarification	Existing language does not reflect the new street classifications in the Austin Strategic Mobility Plan (ASMP). Trail crossing requirements are not clear.	Update street classifications to reflect the ASMP. Clarify that multi-use trails must comply with the ECM and existing no adverse impact standards.	Clarity.
31	25-8-281 Critical Environmental Features	Minor Edits & Clarifications	Critical environmental feature (CEF) buffers are not adequately protected on residential lots. Requirements for innovative runoff management practices are not clear. Subdivision requirements are not clear.	Clarify that residential lots may not include a CEF buffer. Clarify what types of innovative runoff management practices are allowed within 50' of a CEF. Clarify when CEF and buffer locations must be shown on development applications.	Improves protection for CEFs and clarity for applicants and staff.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
32	25-8-282 Wetland Protection	Policy & Minor Edit	Wetlands associated with the shores of Lady Bird Lake are not protected in the downtown area. There are no existing design criteria that would allow a wetland to be used as a water quality control.	Protect all wetlands along the shores of Lady Bird Lake, including in the downtown area. Clarify that a wetland cannot be used as a water quality control. Clarify review and approval authority.	Improves water quality of Lady Bird Lake. Clarity.
33	25-8-323 Temporary Storage Areas; Topsoil Protection	Policy	Soils compacted by construction activity do not provide sufficient infiltration of stormwater.	Decompaction requirements added to code requirements. Require areas that are intended to remain pervious to be protected during construction or decompacted after construction.	Improves infiltration of stormwater by ensuring that pervious areas are functioning as intended.
34	25-8-341 Cut Requirements	Minor Edits	Driveways that are allowed to cross slopes pursuant to 25-8-301 typically also require cut over 4'.	Allow cut up to 8' for construction of a street or driveway necessary to provide primary access if the cut is the minimum necessary to comply with safety requirements.	Improves consistency among code requirements. Streamlines the application process by eliminating a common variance request.
35	25-8-342 Fill Requirements	Minor Edits	Driveways that are allowed to cross slopes pursuant to 25-8-301 typically also require fill over 4'.	Allow fill up to 8' for construction of a street or driveway necessary to provide primary access if the fill is the minimum necessary to comply with safety requirements.	Improves consistency among code requirements. Streamlines the application process by eliminating a common variance request.

	Code Section	Type of Change	Current Status/Concern	Proposed Improvement	Benefits
36	25-8-367 Relocation of Shoreline Between Tom Miller Dam and Longhorn Dam	Minor Edits	This section was written to protect drinking water supply, dam operations, and recreation on Lady Bird Lake and is not related to water quality protection. It is no longer necessary.	Remove section.	Removes unnecessary requirements and increases permitting efficiency for some projects.
37	25-8-368 Restrictions on Development Impacting Lake Austin, Lady Bird Lake, and Walter E. Long	Clarification	The location of these requirements is confusing and difficult to find.	Move this section to be adjacent to the critical water quality zone requirements for lakefront development.	Clarity.
38	Chapter 25-8, Subchapter B, Article 2 Endangered Species	Clarification	The endangered species notification requirements are confusing and inefficient.	Streamline and clarify when an applicant must notify other jurisdictions about potential impacts to endangered species habitat.	Clarity.

RESOLUTION NO. 20220609-061

WHEREAS, protecting our environment is the foundation for sustaining our planet, community, and economy; and

WHEREAS, the City of Austin's "State of Our Environment: 2020 Annual Report," showed that creeks in the Desired Development Zone scored on average 10 points lower than those in the Drinking Water Protection Zone; and

WHEREAS, the Drinking Water Protection Zone designation located on the west side of Austin has restricted development through regulations creating positive environmental outcomes, while the Desired Development Zone, located in Central and East Austin, has more permissive regulations that have resulted in some negative outcomes; and

WHEREAS, properties located in the Desired Development Zone have more permissive development regulations with regard to the size of creek buffers, impervious cover limits, cut and fill, and construction on slopes; and

WHEREAS, extensive empirical literature links exposure to nature with better health, and creeks provide city-wide opportunities to experience nature; and

WHEREAS, current code allows for structures such as in-channel detention basins and concrete wastewater manholes to be placed in creeks, which can cause erosion and other severe, often long-lasting consequences that can be expensive to reverse; and

WHEREAS, the City is faced with the existing and growing threat of industrial discharges that can negatively impact creeks and communities located primarily on the east side of the City of Austin; and

WHEREAS, there has been a steady increase in the amount of land area in Austin covered by impervious surfaces and a corresponding steady decrease in the amount of pervious land area capable of absorbing rainfall; and

WHEREAS, one result of the historically high rates of development is a rise in the amount of runoff that flows off-site from developed properties and into older, undersized stormwater drain systems, creeks, rivers, and lakes, contributing to increases in flooding severity, damage to private property, loss of life, and water pollution; and

WHEREAS, currently City Code allows redeveloped sites to use existing impervious cover as a baseline for drainage calculations, resulting in increased runoff and contributing to flooding and erosive flows downstream; and

WHEREAS, increasing density reduces sprawl and thereby reduces traffic congestion, pollution, and development of open spaces and agricultural; and

WHEREAS, a U.S. Geological Survey study found that using green stormwater infrastructure for water quality provided enhanced mitigation of peak flows and run-off volumes compared to large, detention-based stormwater control practices; and

WHEREAS, the Watershed Protection Department "Master Plan" [sic] of 2016 notes that green stormwater infrastructure controls such as rain gardens, porous pavement, and rainwater harvesting help retain water in the soil before it has a chance to run off into storm drains and creeks thus restoring, to the greatest extent possible, natural hydrologic processes; and

WHEREAS, managing stormwater in this manner can provide multiple benefits to a watershed; and

WHEREAS, using green stormwater infrastructure practices such as bioswales, rain gardens, and permeable pavement can reduce stormwater pollution while also reducing the burden and demand on existing infrastructure by capturing rainfall onsite; and

WHEREAS, onsite infiltration is key to reducing the amount of stormwater flowing to the storm sewers, and using parking lot islands for rainfall capture would allow a code-required element to serve multiple purposes; and

WHEREAS, buildings, roads, and parking lots absorb and retain heat causing a "heat island effect" that can pose serious problems for our health and environment; and

WHEREAS, employing strategies to create cool spaces in areas with high impervious cover helps to mitigate the heat island effect and to cool the urban core; and

WHEREAS, current City Code landscape requirements are based on the land within a commercial property not covered by a building, leaving projects with 80% or more impervious cover with few requirements for greenspace; and

WHEREAS, rainwater harvesting and storage offer the potential for significant cumulative benefits across watersheds, including reducing the burden on and thus extending the utility life of existing stormwater infrastructure, improving water quality, and extending our potable water supply; and

WHEREAS, current City Code provisions require cisterns used for water quality to release harvested water after 72 hours to prepare for the next storm event, though calculations for a successful non-potable rainwater irrigation system rely on keeping all rain captured to be able to have water for dryer months; and

WHEREAS, wetlands help to stabilize the shoreline against heavy rains and floods; and

WHEREAS, current City Code provisions do not protect wetlands bounded by Interstate 35, Riverside Drive, Barton Springs Road, Lamar Boulevard, and 15th Street, though Lady Bird Lake experiences extreme periodic flooding; and

WHEREAS, Resolution No. 20170615-071 directed the City Manager to assess the City's progress toward achieving the vision, goals, policies, and actions relating to green infrastructure, as defined in the Imagine Austin Comprehensive Plan, and to evaluate opportunities to further expand the City's green infrastructure-related programs and projects; and

WHEREAS, City staff's recommended updates and clarifications to portions of Chapters 25-7 (*Drainage*) and 25-8 (*Environment*) that relate to watershed protection did not move forward due to termination of the Land Development Code revision process; and

WHEREAS, staff across several departments spent considerable effort developing draft ordinances for Planning Commission and Council consideration to further the City's goals of substantially increasing infiltration of stormwater on-site, including ordinances in the last proposed revision of the Land Development Code such as:

1. requiring green infrastructure in urban settings where traditional landscape requirements are not possible ("Functional Green" 23-3D-3110);

2. requiring surface parking lots to include tree islands, landscaped medians, and perimeter landscapes and require that pavement be graded to allow runoff to enter planting areas (23-3D-3050, 3060 and 3070);

3. removing an exception to flood mitigation requirements for redevelopments that are not increasing impervious cover (23-9E-3010); and

4. requiring all subdivisions and site plans in Urban Watersheds meet steep slope protections (23-4D-8030); and

WHEREAS, small-scale missing middle housing projects (projects ranging from approximately 3 to 12 units) are required to comply with the same water quality, drainage, and site plan requirements as large scale multifamily residential project, while single-family homes are not subject to those requirements, creating an incentive for developers to build single-family homes over missing middle housing to avoid water quality regulations, contributing to urban sprawl and the housing affordability crisis; and

WHEREAS, a large single-family home can actually have more impervious cover than a multi-unit development, and the amount of impervious cover for a project is one of the key factors affecting drainage regardless of project type and should be taken into account when evaluating water quality and drainage requirements for site plans; and

WHEREAS, such procedures may create an incentive for developers to build single family homes instead of missing middle housing; **NOW, THEREFORE,**

BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF AUSTIN:

The City Council directs the City Manager to address the equitable protection of the environment throughout the City of Austin as part of the Watershed Protection Strategic Plan, with emphasis on the protection of Blackland Prairie. Regulations related to cut and fill and creek protection shall be among the considerations. The City Council directs the City Manager to provide a plan to achieve this direction on or before November 1, 2022.

BE IT FURTHER RESOLVED:

The City Council directs the City Manager to create procedures that achieve:

1. an appropriate monitoring approach that would assess potential watershed threats from higher risk facilities such as quarterly sampling of creeks located immediately downstream from semiconductor manufacturing plants, concrete batch plants, automobile manufacturers, battery manufacturing plants, fuel storage tanks, and other industrial businesses staff would recommend for inclusion; and
2. a documented and transparent process that would address high levels of communication with the Austin Water Utility when high levels of E.coli are found in particular creeks so that Austin Water can investigate and repair any leaking wastewater pipes located within creeks in a timely manner.

The City Council directs the City Manager to create these procedures on or before September 15, 2022.

BE IT FURTHER RESOLVED:

The City Council initiates code amendments, including amendments to Title 25, that:

1. Establish criteria that prioritize when green stormwater methods should be required or incentivized over conventional stormwater controls;

2. Require surface parking lot stormwater to enter pervious parking lot islands, landscaped medians, and perimeter landscapes as a method of water quality and require that pavement be graded to allow runoff to enter planting areas;

3. Implement Functional Green requirements for properties with more than 80% allowable impervious cover;
4. Require that all subdivisions and site plans in Urban Watersheds meet steep slope protections;
5. Allow cisterns to be sized beyond the required storm capture amount and remove requirement for stormwater release so that they can supply irrigation needs throughout the year;
6. Require new and redeveloped projects to use greenfield conditions as a baseline when calculating drainage requirements;
7. Prohibit in-channel detention ponds, except for capital projects or private/public partnerships where no other alternative is feasible;
8. Require projects to relocate replaced or upsized wastewater pipes outside of the inner half of the critical water quality zone;
9. Provide wetland protections and buffers equally along Lady Bird Lake to help to stabilize and prevent erosion along the shoreline;

10. Require utility easements to meet the same standards as utility pipes within the creeks and creek buffers; and
11. Address current environmental code inconsistencies and other minor code revisions in Chapters 25-7 and 25-8 that staff have previously identified and reviewed as part of the Code Next and the Land Development Code revision processes.

The City Council initiates other code amendments, as necessary, to accomplish the goals of this Resolution. The City Council expects that these code amendments will use the previous staff work and, where appropriate, adhere as closely as possible to the language and intent of the ordinances previously drafted and reviewed through the proposed revision of the Land Development Code.

The City Manager shall present these code amendments for Council consideration no later than September 15, 2022, except for amendments regarding the greenfield conditions as a baseline for redevelopments and steep slope protections.

The City Council directs the City Manager to engage stakeholders and develop recommendations that would seek to offset the impact on affordability and capacity of requiring greenfield conditions as a baseline and steep slope protections on properties where there are not currently required. Offsets could include additional entitlements or waivers for impacted tracts. The City Manager shall present these recommended code amendments for Council consideration no later than November 3, 2022.

BE IT FURTHER RESOLVED:

The initiated ordinances will ensure that, for the same environmental impact as a single-family home, the City does not disincentivize small-scale missing middle housing projects.

BE IT FURTHER RESOLVED:

The City Council directs the City Manager to evaluate the effectiveness of existing Critical Water Quality Zone and Erosion Hazard Zone buffers on the Colorado River downstream of the Longhorn Dam and to propose protections that will provide adequate protections to the river that will ensure a healthy riparian corridor to stabilize the riverbank and protect property from erosion.

BE IT FURTHER RESOLVED:

The City Council directs the City Manager to conduct an Affordability Impact Analysis and a Fiscal Impact Analysis for each proposed code or process change resulting from this resolution. The City Council directs the City Manager to provide the results of these analyses to Council at least two weeks prior to the implementation of any process change or the presentation of code amendments for Council consideration. The City Council directs the City Manager to include these analyses as part of the Council agenda back up when an item resulting from this resolution is presented to Council for its consideration. Additionally, the City Council directs the City Manager to address the estimated costs of doing nothing to further protect against water pollution, localized flooding, and the heat island effect; of stabilizing creeks and shorelines after scouring and erosive floods; mitigating algae and bacteria in creeks and lakes; and increasing stormwater

infrastructure throughout the City. If additional construction costs result from these code amendments, the City Manager shall provide information for the costs of compliance for single family homes, small scale missing middle projects, and larger multifamily projects.

BE IT FURTHER RESOLVED:

The City Manager is directed to provide a memorandum of projected required city staff hours to complete this resolution within two weeks. The memorandum should differentiate the hours required to complete each part of this resolution.

ADOPTED: June 9, 2022 **ATTEST:** _____
Myrna Rios
City Clerk