PLANNING COMMISSION

Planning and Development Services • 201 N. Stone Avenue • Tucson, AZ 85726-7210

DATE: **February 1, 2012**

TO: **Planning Commission**

FROM: for **Ernie Duarte**
Executive Secretary

SUBJECT: **Sustainable Land Use Code – Target Research Memo #1 - Study Session**

Issue: In May 2011, the Mayor and Council gave direction to pursue the Sustainable Land Use Code Project following the recommendations of the Sustainable Code diagnostic report prepared by the consultant, Clarion Associates and reviewed by the Planning Commission, community stakeholders and staff.

The recommendations were three types 1) proceed with a text amendment or policy as needed on a given topic e.g., prepare definition for community gardens, 2) consider some topics after more research as to whether the item should be pursued as a text amendment or policy or possibly postponed e.g., allowing on-site sales of produce in residential areas, and 3) postpone, that is, do not put any further effort into the item at this time or as part of this project e.g. inclusionary housing ordinance.

This memo addresses several items that were classified as needing more research before committing time and effort to a text amendment or development review policy.

Attached to this memo is Target Research Memo # 1. It covers several areas that the consultant has provided analysis. The topics are the following: 1) use of pervious pavement, 2) encouraging passive water harvesting, 3) encourage trees and green infrastructure in street rights of way, 4) address solar reflective pavement, and 5) clarify rules on sale of on-site produce.

In developing a way to proceed, the policy suggestions in the Target Research Memo will be looked at in relation to the four areas of concern put forth by community stakeholders during the development of the diagnostic report. They were the following:

- Try to offer cost effective solutions especially if it is mandatory;
- Focus on option or a menu of options;
- Be flexible whenever practical;
- Make it easy to do;
- Emphasize items that have more than one pay off.

Note: Because of the quick turn around between the January 18 and February 1 Planning Commission meetings some comments from reviewers will be coming in a separate memo that will be sent electronically prior to February 1 and delivered in a hard copy at the public meeting.

Recommendation: The consultant proceed with a text amendment incentive, clarification of terms, or a policy option to be added to the new Unified Development Code or Technical Manual regarding sustainable policy where the result spells out the correct and appropriate way to proceed considering the factors appropriate to Tucson.

Further, these items below will be screened by the criteria suggested by community stakeholders noted above. These items will continue to be reviewed more thoroughly and potentially modified, postponed or dropped based on a broader review from the Commission, stakeholders, and staff.

Background: Below are brief summaries of the consultant's position followed by staff or local experts comments on the Target Research item.

Pervious Pavement (PP) Policy Overview -

The consultant points out that a key relationship is that between stormwater runoff and PP especially in a desert environment. Currently, the City policy only addresses PP as an option without much clarity or guidance. The consultant points out some potential benefits of PP which include reducing runoff substantially, assisting in meeting EPA stormwater regulations, reducing the need for underground stormwater systems, requiring less repair and patching, and reducing temperatures by three to seven degrees Fahrenheit.

They further indicate the gap in current City policy noting that 1) pervious materials are not required for street or sidewalks, 2) current policy does not provide a clear process to propose them, 3) policy does not provide incentives to reduce impervious surfaces.

They suggest the following:

- Allow broader variety of pervious paving materials on streets and sidewalks;
- Provide clear criteria for approval of pervious surfaces;
- Do not count pervious surfaces towards lot coverage limits, or discount surfaces some percentages, e.g. 50 per cent;
- Clarify what types of pervious materials are suitable for Tucson's soils and climate.

They also note that Scottsdale, AZ grants points for its Green Building Program to construct 80 percent of exposed paving with light colored and permeable materials.

Pervious Pavement Policy Evaluation by PDSD Engineering staff -

Below are comments by our department's civil engineer, Jim Vogelsberg. A key point is that a pervious pavements policy is received as debatable here in the desert with its tendency toward less permeable soils.

His recommendation is that permeable surfaces may work on a case by case basis after first evaluating a set of findings that may look at the features of the setting, the effectiveness of the material, and the downstream impact on adjoining property. Below is a summary of his comments:

Clarion's evaluation as how we handle pervious pavements (PP) is essentially correct.

The current LUC is quite specific regarding hardscape materials;

- it can and has been interpreted that unless it is "asphalt or concrete" permission to use alternate materials must be obtained;
- There is no clear criteria for the application of the pervious materials;
- And pervious materials alone may not be used to as part of the stormwater calculations to comply with Floodplain Ordinance.

Stormwater Retention/Detention Manual

The current Stormwater Retention/Detention Manual does the following

- gives us the flexibility to consider and allow pervious pavements to accept some of the stormwater runoff demands;
- This point is not noted in the Clarion research memo;
- Much of Clarion's generic discussion of the advantages of PP does not apply to the Tucson area. The benefit combination mentioned of sewers with storm & sanitary sewer discharge in the same pipes are not allowed here;
- Aquatic thermal shock requires standing or running water for this to be an issue and both are not common in Tucson.

Floodplain Ordinance

Key points are the following:

- all on-site runoff must be accounted for;
- an on-site retention/detention system meters the off-site discharge to the pre-development runoff conditions;
- groundwater recharge from individual systems, in our area, is a fallacy;
- the most effective way for stormwater to recharge our aquifer is to transport runoff as quickly as possible to the major watercourse to allow percolation via their sandy bottoms.

Analysis

A PP system could be attractive in jurisdictions that do not have floodplain management regulations. In situations, for example, where the individual is responsible not to cause any

downstream problems, PP systems might be an option.

Permeable pavement is just one component of a stormwater disposal system i.e, the top layer. Once the water travels down through the pavement, around the pavers, then what ? The local soils are not very permeable. Once the stormwater travels through six inches of pavement, the water will sit and pond.

A PP system has a reservoir of some type below grade. This usually consists of a graded area with the same sized aggregate, that varies a few to many feet in depth. This subterranean, stone filled vault contains the water and if successful the stormwater will percolate into the earth.

Comparing the above system to the commonly used surface retention/detention systems, there is a hole, but there is no rock or pavement on top of it. Occasionally, the designers will cover a retention/detention basin so they may park on it. Rather than the stormwater flowing through countless little pores in the pavement the only effective way to rehabilitate the PP is to have an industrial vacuum cleaner periodically clean the entire parking lot.

A PP system has the potential to create an environmental "hot spot". Heavy metals and pollutants are concentrated in the stone under the permeable pavement. Unlike an open air retention/detention basin where the contaminated top layer of soil can be removed and safely disposed of, the entire PP system surface must be removed and all of the contaminated aggregate must be removed and transported to a suitable disposal site.

PP maintenance can cause issues on surrounding property. If they cease to function properly, water damage may occur to downstream properties.

In summary, our floodplain regulations give the designer and staff the ability to review and weigh the merits of the use of PP systems. Considering the soil and runoff issues in Tucson, PP systems have debatable elements.

Conversely, if the PP system adequately disposes of the stormwater and there is an assurance the system will be maintained to function per the Floodplain Ordinance, we would not discourage the applicant's proposal.

We do not see many parking lot subgrade systems because they are prohibitively expensive to install and maintain. Unless a parking area is at a premium, there is no incentive or benefit to install a subterranean system.

One option to consider is to remove references to specific paving materials, e.g. concrete, asphalt from the Code. Staff can review a set of findings in approving an appropriate paving material is on a case-by-case basis.

Passive Water Harvesting (PWH) Overview -

The basic elements of PWH include no mechanical or structural methods to harvest and there is no long term storage for future use. The consultants display a table showing the various methods of PWH including swales, riprap channels, and detention ponds. They point out the benefits that include it reduces erosion and flooding; it filters out dust, dirt and pollutants, and decreases surface runoff; installation can be simple and inexpensive; and PWH can help ensure a stable groundwater source.

Tucson's current policy include, an education program teaching residents how to do PHW, a reclaimed water system, and a multi-jurisdiction policy coordination on water conservation practices. The consultant also points out the Land Use Code focuses on drought tolerant plants, limitations on turf use, emphasis on efficient irrigation and requiring reclaimed water on some projects. They do not mention the commercial rainwater harvesting ordinance which would also be part of the City's strategy. They point out the lack of a comprehensive strategy on water conservation in the Land Use Code.

They suggest provisions to include PWH in the City's water conservation strategy. The suggestions include the following:

- Establish more aggressive water conservation goals by increasing the capacity of on-site stormwater retention/detention;
- Require rainwater harvesting for single –family and multi-family residential projects;
- Require earthworks in front yard and private rights of way in residential developments governed by homeowner associations;
- Prohibit covenants that ban PWH systems.

Passive Water Harvesting Evaluation

Comments will be coming in a separate memo.

Trees and Green Infrastructure in Street Rights of Way Overview-

Green Infrastructure refers to an interconnected network of open space and vegetated areas that naturally manage stormwater, capture pollution and improve water quality. Green infrastructure in the right of way can include planting trees and vegetation and installing hardscape to help channel and store stormwater.

The consultant discusses some of the ways green infrastructure can yield benefits for a community. The benefits include reducing the urban heat island effect, carbon sequestration, capturing stormwater, enhancing economic development by creating inviting and enjoyable places, creating buffers from traffic, and creating overall pedestrian comfort in an urban area.

The consultant states that Tucson already has some impressive programs. They include an increased number of trees in parking lots, and a commercial development water harvesting ordinance. They suggest these programs could be enhanced by the recommended strategies.

They suggest the development of requirements need to include height and setback requirements for installing vegetation and hardscape elements in the rights of way as well as site and access clearance for residents and utilities. Further, the requirements should attempt to balance the access and mobility needs of all users. There also needs to be a balance among safety, roadway infrastructure, utility services, and the environment.

They mention Seattle, WA as one of the best examples of a green infrastructure policy.

Trees and Green Infrastructure in Street Rights of Way Evaluation
Comments will be coming in a separate memo.

Solar Reflective Pavement Overview -

The Target Memo notes that 30 to 45 percent of urban areas are paved surfaces. Pavement absorbs energy from the sun. The surface temperatures increase and release the stored heat into the urban atmosphere. The albedo is the ratio of the reflected solar radiation to the total amount of radiation that falls on the surface. Albedo values have a large impact on the heat island effect.

The report also states that the most effective solar reflective pavement are made of white Portland cement concrete and reflective aggregates. Reflective concrete is a practical choice in urban areas and is commonly used as sidewalks and parking areas.

Arizona State University is studying established and emerging designs that optimize pavement albedo emissivity, thermal conductivity, heat storage capacity and density in laboratory and field sites.

The consultant points out benefits to solar reflective pavements also known as cool pavements. A Los Angeles study showed that the temperature decreased by 1.5 degrees associated with solar reflective changes. Cool pavements also tend to last longer than hotter pavements. They site a study that states theat every ten percent increase in solar reflectance could decrease surface temperatures by seven degrees Fahrenheit.

Tucson has as one of its sustainability initiatives reducing the urban heat island effect. The consultant recommends requiring paving materials to have a solar reflectance index of at least 29 to reduce solar gain and the urban heat island effect. One option is offering certain development flexibility for installing highly reflective pavement materials. They go on to say cost of installation may or may not be greater than hot pavements. However, cool pavements may be part of a larger strategy to lower overall energy bills.

Solar Reflective Pavement Evaluation

Comments from Katie Gannon, Drachman Institute, UA College of Architecture and Landscape Architecture:

The Consultant's assessment of the need for and benefits of solar reflective pavements is supported by the literature. Cool pavements, including both solar reflective pavement and porous paving, are important strategies for mitigation of the urban heat island and climate change preparedness. Especially in Tucson, an arid desert climate with extreme summer temperatures, vast expanses of surface parking lots, overly wide streets, and sparse tree cover, cool paving is an important and effective tool to create a more livable, sustainable urban environment.

Multiple benefits accrue from the use of solar reflective paving including reduced surface temperatures, reduced energy use, longer lasting asphalt (simulations of asphalt pavement temperatures found that pavements that were 20 degrees Fahrenheit cooler lasted ten times longer than hotter pavements, and pavements that were 40 degrees Fahrenheit cooler lasted 200 times longer), slowed rate of ground-level ozone formation (which especially effects vulnerable populations such as children or elderly), and numerous quality of life improvements such as better nighttime illumination, and improved human comfort.

It is good policy to encourage the use of cool pavements, especially for parking lots; using high-albedo aggregate in chip seals carries little additional cost while providing numerous benefits over time. Requiring paving materials to have a solar reflectance index of at least 29 is good policy. *Offering density bonuses, additional height, or other desirable development benefit for installing highly reflective pavement materials, in excess of 29, is a good way to encourage adoption of cool paving strategies. With* Arizona State University's National Center of Excellence SMART Innovations for Urban Climate and Energy studying established and emerging designs that optimize pavement albedo, emissivity, thermal conductivity, heat storage capacity, and density in laboratory and field, up to date guidance on selection and performance of materials should be easy to provide to Tucsonans.

On-site Sale of Produce Overview -

Cities are beginning to define a class of agriculture as urban. Urban gardening takes into account small spaces such as yards, roofs, vacant lots and common functional open space areas. The point of this proposal is to allow local residents to sale produce from their property be it a backyard garden or a community garden.

Some benefits cited include the plant foliage can decrease stormwater runoff as well as promote biodiversity and species preservation. On-site sales can promote new food-related businesses that support local restaurants, a community kitchens. A New York City study showed that community gardens had increased local property values. In some cases the local produce was more accessible to local neighborhoods than more remote supermarkets.

Tucson does not have an urban food policy currently. Work on the sustainable code project and updating of the General Plan are both moving to include this program in the future. If on-site sales are allowed in the zoning regulation it must be done in a way that does assures this land use is compatible with the residential areas.

On-site Sale of Produce Evaluation -

Comments from Merrill Eisenberg, Ph.D. UA Zuckerman

Benefits:
Allowing home and community gardeners to sell produce from the site where it was grown helps gardeners recoup part of the cost of maintaining a garden, and therefore is one way to encourage the development of food-producing gardens in Tucson. Urban small scale food production creates many benefits that accrue to the individual gardeners, their neighbors, and the community at large. Since fresh fruits and vegetables are difficult to access in many sections of the City, and the cost of fresh fruits and vegetables that are available in supermarkets is high, encouraging home gardening is a public health strategy to improve household diets, and combat the obesity epidemic. While home and community gardeners grow primarily for themselves, the benefits of a diet that includes fresh fruits and vegetables could be enjoyed by others in the neighborhood if produce could be sold where it is grown.
Concerns
Neighborhood concerns are likely to be related to traffic and parking issues. Although most Tucsonans tolerate an increase in traffic and parking occasionally (for parties or events), a steady stream of traffic is not compatible with residential use.
Current code and traffic/parking compatibility: Currently, uses that are permitted in R-1 and R-2 zones, include some uses that involve patrons coming to the site, and therefore also create traffic and parking issues. These are summarized in Table 1. Restrictions on these activities that are stipulated for zones R-1 and R-2 are also shown.

Table 1: R-1&R-2 Land Uses That Bring Traffic to the Neighborhood

Group	Class	P/SE/S/A*	R-1 & R-2: Restrictions
Commercial Services	**Adult day care**	**P**	**Up to 10 adults Site size requirements**

	Child day care	**P**	**Up to 30 children** **Limit hours of operation** **Site size requirements**
	Child care	**SP**	**Unlimited children** **Extended hours**
Residential Use	**Home occupations: General**	**S**	**Compatible with the neighborhood** **No employees from outside the home** **No sale of goods** **No more than 5 clients per day**
***P=Permitted** **SE= Special Exception** **S=Secondary to Family Dwellings**			

Table 1 shows that current zoning policy allows up to 30 children to be cared for during the day in R-1 or R-2 residences, bringing in traffic from outside the neighborhood up to 60 times per day.

In addition to the uses shown in Table 1, "yard sales," which bring traffic from distant neighborhoods, are permitted in all residential zones, but restricted to once a quarter.

Recommendation: Produce yields are cyclical with the growing season; sale of home grown produce would be occasional, occurring during harvest months only, and not large-scale, given the lot sizes in R-1 and R-2 districts. A code revision that allows on-site sale of produce could include limitations to mitigate any traffic and parking concerns. For example:

- The hours of operation could be restricted, as is done with child day care.
- The number of patrons could be restricted, thereby discouraging gardeners from advertising the availability of fresh fruits and vegetables to the community at large and then attracting large traffic volumes. To be consistent with the amount of traffic permitted for child day care, the number of patrons could be set at 60 per day, which is far more than we expect would occur.

Conclusion:
Staff will continue to monitor these items and work with the consultants in packaging them as policies or text amendments for the future. Further, assessment will occur in relation to the suggested criteria made by community stakeholders to look at efficiency and flexibility. With the Unified Development Code project coming forth simple items may be ready to be packaged with it. Where more time is needed to meet with stakeholders or prepare the item, those items will return when ready.

ED/JM

Attachment:
Target Research Memo #1

City of Tucson

Sustainable Land Use Code Integration Project: Phase II

Targeted Research Memo—Task 1.3

STAFF DRAFT: OCTOBER 2011

C L A R I O N

Contents

Introduction

This memo fulfills Task 1.3 of the second phase of the Sustainable Land Use Code Integration Project. The purpose of the memo is to provide targeted research on the following "consider after more research" items as identified in the Phase II work plan for the Sustainable Land Use Code project:

WATER QUALITY AND CONSERVATION

- Broaden the Use of Pervious Materials (Reduce Barrier)
- Encourage Passive Water harvesting Earthworks (New Requirement)
- Encourage Trees and Green Infrastructure in Street Rights-of-Way (New Requirement)

GREEN BUILDINGS

- Solar Reflective Paving Materials (New Requirement/Incentive)

URBAN FOOD

- Clarify the Rules for Sale of On-Site Produce (Reduce Barrier)

For each of the bulleted items listed above, this memo includes: an introduction to the topic, the benefits of the recommended measure, an analysis of how Tucson addresses the topic today, key questions, and current trends and best practices.

Water Quality and Conservation

BROADEN THE USE OF PERVIOUS MATERIALS (REDUCE BARRIER)

Introduction

Asphalt and concrete are the primary materials used to pave roads, sidewalks, and paths. There are two broad types of asphalt and concrete pavements: impervious and pervious. Impervious pavements are made from finely-graded (various sized) aggregate, where the aggregate is compacted into a solid.[1] Pervious pavements are made from open-graded (uniformly sized) aggregate, which leaves air spaces that enable water to pass through the surface.[2] Pervious asphalt also includes a subbase, which is typically a thick layer of gravel, between the pavement and the soil. Pervious[3] pavements allow stormwater to percolate or infiltrate through the surface into the soil below, which decreases stormwater runoff and naturally removes pollutants from the water.[4]

The open-graded mix allows water to flow through the paving material. Image from the Asphalt Pavement Association of Indiana.

Pervious asphalt and concrete can replace impervious pavement for most pedestrian and vehicular applications, but the U.S. Environmental Protection Agency recommends using it for low-volume and low-speed applications, such as pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways.[5] When applied, cities can integrate pervious pavements into their stormwater management programs and green infrastructure or low-impact development programs.

Pervious and impervious asphalt and concrete have similar appearances, so cities can anticipate the aesthetic impacts of using pervious pavements throughout the city.[6] Pervious pavement manufacturers are expanding the market for permeable products by applying the concept to traditional landscaping materials, such as pavers. Pavers can be a pervious or a solid block with an open space between each

unit, and provide a visually pleasing alternative to traditional impervious or pervious asphalt or concrete applications.

Table 1 identifies and describes different pervious pavement products:

Table 1: Pervious Pavement Products[7]

	DESCRIPTION	USE	COST
Crushed stone/gravel/shell	Non-bound aggregate that is spread over soil and used as a pavement. The aggregate is angular.	Suitable for pedestrian and low-speed vehicle use so it is often used in parking areas, alleys, and rear lanes. Applicable in areas with non-compacted soil or regions susceptible to soil displacement.	Depends on the type and cost of the aggregate used.
Pea gravel/washed stone	Non-bound aggregate on top of natural or compacted earth. The aggregate is smooth and round.	Can withstand moderate to heavy vehicle use. Suitable for alleys and rear parking areas or in place of grass for some park and pedestrian areas.	Approximately $0.50 - $0.75 per square foot to purchase.
Cast/pressed concrete paver block	Solid blocks with spaces between each unit and loose aggregate, pea gravel, sand, soil, or grass in the joints.	Can withstand moderate to heavy vehicle use. Not suitable for steep slopes or areas with high sediment levels when the joints are not filled.	Depends on the size of the pavers and the materials used in the joints. Low maintenance costs.
Stone/masonry paving blocks	Solid blocks with spaces between each unit and loose aggregate, pea gravel, sand, soil, or grass in the joints. Differs from cast/pressed concrete paver blocks because the blocks are made from naturally occurring stones.	Can withstand moderate to heavy vehicle use. Not suitable for steep slopes or areas with high sediment levels when the joints are not filled. The stone-pavers form a semi-rigid grid system.	Purchase price depends on the material, type, and size. Expensive to install because each block must be laid individually.
Stabilization mat	A tightly woven grid of plastic cells that are manufactured in large rolls and covered with soil and grass.	Used to stabilize soil under paved roads or on steep slopes. Suitable for steep pedestrian paths that are subject to erosion. Not suitable for vehicle traffic unless it is used with another paving material.	Inexpensive to purchase and simple to install.
Stamped asphalt or concrete	Impervious or pervious pavement that is imprinted with a pattern or decorative design while still wet. Can add a stamp to asphalt after it is poured and dried by reheating it.	The grooves break up the surface tension of water, which provides additional traction. Suitable for heavy vehicle traffic.	Asphalt is approximately $4 - $6 per square foot to install. Concrete is approximately $6 - $9 per square foot to install.

These products are available through several different manufacturing companies that distribute their products throughout the nation, and many of the manufacturers have representatives in Arizona or the Southwest.[8]

Benefits

Pervious materials have been linked to the sustainable development movement because they provide several environmental, economic, and social benefits. The following list identifies these benefits:

ENVIRONMENTAL

- Porous pavements improve water quality because they absorb water into the pavement and soil, which decreases stormwater runoff, recharges soil moisture and groundwater, and filters out dust, dirt, and pollutants.
    - Outdoor tests found that permeable pavements can reduce runoff by up to 90 percent.
    - Reducing runoff decreases scouring of streams and in areas with combined sewers, this flow reduction can help minimize combined sewer overflows that discharge sewage and stormwater into receiving waters.[9]
- The EPA recognizes pervious materials as a cool pavement because it lowers the temperature of stormwater runoff, which ameliorates thermal shock to the aquatic life in waterways that stormwater drains into. Laboratory tests found that permeable pavers can reduce runoff temperatures by three to seven degrees Fahrenheit.[10]
- Installing pervious pavements helps municipalities meet EPA stormwater regulations.[11]
- It also helps meet air quality standards because the air spaces from the open graded-aggregate absorb pollutants from cars, which decreases evaporative emissions. This effect is primarily evident in parked cars.[12]

ECONOMIC

- Increasing the use of pervious pavements throughout the city is a cost-effective method to manage stormwater runoff because: [13]
    - It reduces the need for retention ponds, swales, and other stormwater management device and decreases the overall project costs,[14] and
    - It reduces the need for an underground storm drain system or a curb and gutter system.[15]
- They require less frequent repair and patching than conventional paving.[16]

SOCIAL

- Pervious Pavements help ameliorate the urban heat island effect because a cool pavement allows air, water, and water vapor into the voids of the pavement. When wet, the pavements lower temperatures through evaporative cooling, i.e., water passes through the voids and into the soil or supporting materials below and the moisture within the pavement evaporates as the surface heats, thus drawing heat out of the pavement and making the urban environment more comfortable for residents and visitors. This effect is more prevalent in desert climates than in wetter settings.[17]
- Permeable pavements enhance safety because increased drainage reduces water spray from moving vehicles, increases traction, and my improve visibility by decreasing glare.[18]

How Does Tucson Address This Today?

Even though Tucson is recognized as a leader in water conservation, the current practices do not include pervious materials as a method to manage stormwater. The regulations do not: (1) specifically allow pervious materials on streets or sidewalks; (2) provide a clear process to propose them; or (3) provide significant incentives to reduce impervious surfaces.

If the city decides to integrate pervious materials into the Land Use Code (LUC), such provisions should include the following:

- Allow broader variety of pervious paving materials on streets and sidewalks;
- Provide clear criteria for approval of pervious surfaces; and
- Do not count pervious surfaces towards lot coverage limits, or discount pervious surfaces some percentage, e.g., 50 percent. Calculations for stormwater detention requirements should also be

reduced if it is safe to do so. The regulations should clarify what types of pervious materials are suitable for Tucson's soils and climate.

In 1980, Arizona enacted the Groundwater Management Act of 1980, which prohibits the depletion of groundwater throughout the state by delineating a number of Active Management Areas (AMA) and requiring that cities conserve the groundwater in the AMAs. Requiring or providing incentives to use pervious materials can help the city and developers meet this requirement because porous surfaces help recharge soil moisture and groundwater.[19] Furthermore, the Diagnosis identified opportunities to increase groundwater conservation in residential and commercial development, and pervious materials are best suited for low volume and impact sites that are common to such areas.

Key Questions

The effects of pervious pavements depend on several factors, such as climate and regional characteristics, site location, and maintenance. Variations in each of those factors will have an impact on the micro and macro benefits of each application. This section outlines several considerations for each factor and the cost compared to impervious pavements.

CLIMATE AND REGIONAL CHARACTERISTICS

Climate and regional characteristics are the first factors that one must consider when regulating or installing pervious pavement because the temperature and soil conditions determine the type of porous material and its specifications.[20] For example: (1) Cities in colder climates apply/put sand on the streets and parking lots to increase traction in icy areas. If sand is applied on or near an area with pervious pavement, it can clog and disrupt the pavement's filtration process.[21] (2) Northern cities also use snow plows for several months out of the year, and the plows can damage or dislodge pavers.[22] And, (3) soils that have a low infiltration rate, e.g., clay, require a thicker subbase to store the stormwater until the soil can absorb it, while soils with a high infiltration rate, e.g., sand, so do not require a thick subbase.[23] As a result, it is necessary to test the soil infiltration rate before selecting a porous material for the project and determines its specifications. Cities should also require a minimum soil infiltration rate of 0.27 inches per hour. At that rate, the system should drain between 12 and 72 hours after a rain storm.[24]

SITE LOCATION AND ENVIRONMENTAL FACTORS

The second factor that one must evaluate is the location of the specific project and analyze whether the site restricts certain techniques or designs. In general, pervious pavements can be applied in a variety of conditions and situations, so it is best to identify the circumstances that are not suitable for porous materials. The following list identifies sites where pervious pavements should not be located:

- Within four feet above bedrock or a water table's high point because the amount of water that the porous pavement absorbs will be greater than the infiltration capacity of the soil;
- Within 100 feet of a well because it takes time for the soil to filter the stormwater runoff and if permeable pavements are too close to a well, it is likely that the pollutants will get into the water source;
- Within ten feet of a building foundation that is above the ground level or 100 feet for a building foundation that is below the ground level because the slope between the building foundation and the pervious pavement increases the likelihood that sediment will collect in the base of the permeable pavement;
- Within close proximity to buildings or areas where hazardous materials are loaded, unloaded, and/or stored because if the hazardous material is spilled or leaked, they would percolate through the air spaces and into the soil and groundwater; and/or
- On slopes that are greater than five percent because water runoff flows faster on steep slopes and increased speeds decrease the likelihood that the porous pavement will absorb the water. If the location has a slope greater than two percent, the project should terrace the soil subgrade base to slow the runoff from flowing through the pavement structure.[25]

MAINTENANCE

Maintenance is another important factor because it affects how effective the system is and how long it lasts. The main concern is the degree of clogging in the pavement's pores. Clogging occurs from fine particles that are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent surfaces and increases with age.[26] To mitigate this problem, the EPA recommends periodic maintenance to remove fine sediments from the porous material.[27]

Routine maintenance includes vacuuming and/or power washing, and if the pavement is extremely clogged, half inch holes can be drilled through the surface every few feet to allow stormwater to drain to the aggregate base. If that does not solve the problem, a stone apron can be installed that is connected it to the aggregate base and subbase around the pavement. The stone apron will catch the stormwater that the clogged pervious pavement cannot absorb.[28]

Even though there are a few different methods to manage clogging, it is important to address the issue before the pervious pavement is installed because regular maintenance will increase the pavements lifetime. Most studies and manufactures project that pervious pavements are effective for 15 to 20 years.[29] To accomplish this, an analysis of permeable pavements in Duluth, MN, recommends maintenance contracts that stipulate quarterly cleanings.[30]

COST

Table 1 demonstrates that the cost of pervious pavements depends on the size of the area, the material used, the amount of installation required, and the frequency of routine maintenance. Each of these factors varies by region, manufacturer, and contractor, and therefore, it is difficult to identify the specific costs. However, it is well documented that the cost to purchase and install pervious materials is higher than impervious pavements. More specifically,

- Porous asphalt is ten to 15 percent higher than regular asphalt;
- Porous concrete is approximately 25 percent greater than regular concrete; and
- Pavers can be four times as expensive as regular concrete or asphalt.[31]

The higher cost for pervious pavement has not deterred developers from installing or manufacturers from investing in porous materials because several reports argue that the higher cost for pervious pavements is offset by its benefits to both the site and community as discussed above.

Current Trends and Best Practices

The following cities promote pervious pavements either through regulation or a public program:

- Golden, CO, offers one sustainability point, out of a required 25, for each 500 sq. ft. of pervious pavement.[32]
- Scottsdale, AZ, grants points for its Green Building Program to construct 80 percent of exposed paving with light colored and permeable materials.[33]
- Evanston, IL, includes permeable pavements in its assessment of green buildings.[34]
- Bellingham, WA, created new construction development guidelines for porous concrete. The Public Works Department created the guidelines and promotes them as an advanced method and material.[35]
- Los Angeles, CA, proposed an ordinance to permit specific alternative paving materials in driveways and parking lots. The ordinance provides clear standards for alternative paving materials and increases the efficiency of processing the requests.[36]
- Toronto, Canada, created a manual of design guidelines to 'green' parking lots, and the manual encourages reflective and permeable pavements to reduce surface temperatures.[37]

- Houston, TX, adopted a heat island reduction initiative as part of the city's overall approach to improving air quality and public health. The plan takes three approaches: (1) targeting alternative paving options for specific surfaces, such as highways or parking lots; (2) educating local and state decision makers about the public health, environmental management, and public works maintenance; and (3) combining and embedding alternative paving incentives into larger programs and regulations.[38]
- Chicago, IL, started a green alley program through its department of transportation. The program retrofits alleyways will green infrastructure such as pervious asphalt or concrete, open bottom catch basins, and high albedo pavement.[39]

ENCOURAGE PASSIVE WATER HARVESTING EARTHWORKS (NEW REQUIREMENT)

Introduction

Water harvesting is an ancient technique to collect and use rainwater for human, household, and irrigation needs.[40] It dates back to the Sixth Century B.C. and has sustained several societies around the world for thousands of years; some rural areas still use water harvesting as a primary water source.[41] As societies and technologies evolved, most cities replaced small-scale water harvesting methods with municipal infrastructure systems that access, pump, and transport huge volumes of ground and surface water using large amounts of energy.[42]

Even though modern cities no longer use water harvesting systems, it does not mean that they are no longer effective. In fact, water harvesting techniques can be used to relieve overburdened infrastructure systems, because water harvesting is the process of intercepting stormwater runoff from a surface, e.g., roof, parking area, or any other surface, channeling it to a collection area, and storing it for future use or until it can infiltrate into the soil.[43]

There are two methods to harvest water: active or passive systems. Active harvesting systems direct surface water to storage containers that collect, filter, and store rainwater for future use. The water can be reused for irrigation or indoor potable and non-potable uses. Some active harvesting systems, e.g., rain barrels, do not filter the water so they cannot be used for potable purposes. Passive harvesting systems, i.e., earthworks, direct surface water by using natural landscaping practices to catchment areas that collect, clean, and store rainwater until the soil naturally absorbs it. The main difference between active and passive systems is that passive systems do not use any mechanical or structural methods to harvest the runoff, e.g., passive systems clean the water through natural vegetation and passive systems do not store water for future use.[44]

Both methods are effective, but each system performs better in certain situations, so it is important to permit both techniques and encourage tailoring water harvesting systems to each project. This memo focuses on passive water harvesting techniques because the LUC already permits rain barrels as an active water harvesting method and the city is a national leader in that regard. If the city adopts the suggested amendment, residents will be able to apply both techniques.

Table 2 identifies and describes different passive water harvesting methods.

TABLE 2: PASSIVE WATER HARVESTING METHODS[45]

	DESCRIPTION	USE	COST
Terracing	A stepped or sloped embankment that follows a contour across a slope. It prevents stormwater runoff from sheeting down a slope and eroding the topsoil because the contours divert the water to the sides of the hillside, which slows the water flow and allows the water to infiltrate the soil as it moves down the hillside.	An ancient method for agriculture on steep slopes and preventing soil erosion.	High initial costs, but continuing costs are minor.
Vegetative swale	A manmade shallow depression planted with vegetation that filters and collects runoff.	Used to collect and treat sheet flow runoff before reaching a stream. Requires a large amount of ground space, therefore in a residential context, it is ideal for subdivisions or planned developments.	Inexpensive to purchase the vegetation.
Drainage ditch	A swale that channels storm water. Drainage ditches collect sheet and piped runoff and channel it to a storage area or natural creek.	It can be applied on a residential property to direct water to a rain barrel or in a subdivision or planned development to direct water to a pond or creek.	Inexpensive and fairly easy to install because it does not require a professional contractor.
Stone/ rip rap channel	A swale that contains large rocks to help slow the flow of stormwater and carry it to a collection point.	Capable of handling large amounts of runoff without erosion, therefore in a residential context, it is ideal for subdivisions or planned developments.	Installation involves digging the trenches and purchasing large quantities of stone.
Vegetative/ stone swale	A swale that contains small rocks to help the soil absorb the water faster. The swale is a slight depression planted with grass and has a three to five inch base of small stones.	Most effective in porous soils. It can be applied on a residential property to direct water to a rain barrel or in a subdivision or planned development to direct water to a retention area.	Purchase price depends on the type and quantity of stone.
Irrigation pond	A small, still body of water formed by stormwater runoff or excavated to retain stormwater. If located in a depression, it can collect runoff naturally.	Commonly used in neighborhoods for community landscaping and to store rainwater.	Depends on excavation costs and the type of pump used.
Detention (dry) pond	Stores water after a rainfall, but is dry at other times. Size and shape depends on the intensity, frequency, and duration of rainfall, but it is designed to store a large amount of water and release it within 18 to 36 hours.	Since a detention pond is a large, dry basin, it is ideal for subdivisions or planned developments where it can also be used for recreational purposes.	Depends on the cost to excavate the basin.
Dry well/ French drain	A basin, trench, pit, or drain of granular material, e.g., gravel, that captures stormwater or runoff as it gradually infiltrates the soil. Performance depends on the permeability of the soil.	An efficient way to store small to moderate quantities of water, but it should be used in conjunction with other filtration tools. Can be used on an individual property.	Depends on the cost to purchase and install granular material.
Bio-retention swale	A planted tract that has a layer of soil (bottom layer), sand, and natural vegetation. The layers absorb and filter stormwater and runoff from impervious areas and/or overflow from landscaped areas.	Used in areas without curbs or in medians, so it is ideal for rural subdivisions or planned developments.	Installation requires excavation, sand and soil infill, and purchasing specific plants.

TABLE 2: PASSIVE WATER HARVESTING METHODS[45]			
	DESCRIPTION	USE	COST
Rain garden	A naturally occurring or manmade depression that temporarily retains water and filters it before it percolates deeper into the ground. It is planted with specific natural vegetation.	It can be applied on a residential property to collect small to moderate runoff. Rain gardens are not meant to serve an entire neighborhood.	Installation costs depend on the existing soil.

These methods do not require special materials and landowners or landscape companies can install the systems.

Benefits

Passive water harvesting systems have become an element of the sustainable development movement because they provide several environmental, economic, and social benefits. The following list identifies these benefits:

ENVIRONMENTAL

- Passive water harvesting systems improve water quality because they absorb water into the soil and natural vegetation, which
  - Decreases surface runoff;
  - Reduces erosion and flooding;
  - Recharges soil moisture and groundwater; and
  - Filters out dust, dirt, and pollutants.[46]

ECONOMIC

- The systems use simple technologies that typically are easy and inexpensive to maintain.[47]
- They reduce the need for outdoor watering, which lowers water bills and saves money. This is particularly important because outdoor watering accounts for as much as 50 percent of household water use.[48]

SOCIAL

- The natural collection, filtration, and absorption process helps ensure a stable groundwater source for many years.[49]

How Does Tucson Address This Today?

Tucson currently employs several different water conservation methods, and they include:

- An education program to teach residents how to conserve water and its benefits;
- A reclaimed water system;
- A multi-jurisdictional and comprehensive "City/County Water and Wastewater Infrastructure, Supply, and Planning Study;" and
- The LUC regulates water usage in several different ways.

These practices have made the city a leader in water conservation, but despite this, there are areas where the city can improve. After reviewing the LUC, it is evident that the city does not address or regulate water conservation in a comprehensive manner. For example, (1) most of the regulations are in the civil code, are technical, and do not relate to land use, (2) the regulations that are in the LUC focus on the types of conservation measures, such as limiting turf grass, requiring drought-tolerant landscaping, efficient irrigation systems, and requiring the use of reclaimed water for some projects,

rather than the overall goal of water conservation, and (3) the LUC does not link water conservation practices to development regulations.

If the city decides to integrate passive water harvesting earthworks into the LUC, such provisions should include the following:

- Establish more aggressive water conservation goals by increasing the capacity of on-site stormwater retention/detention;
- Require rainwater harvesting for single-family and multi-family residential projects;
- Require earthworks in the front yard and private rights-of-way in residential developments governed by a HOA; and
- Prohibit covenants that ban passive water harvesting systems.

Similar to requiring or enabling the use of pervious pavements, passive water harvesting can help the city and developers meet the State AMA requirement because the systems help conserve and recharge groundwater. As mentioned above, the Diagnosis identified opportunities to increase groundwater conservation in residential and commercial development, and earthworks are designed for residential and commercial landscapes and can be integrated into new and existing developments. Thus, it is an easy way to promote water conservation without much disruption or cost.

Key Questions

According to Brad Lancaster, the accredited author of *Rainwater Harvesting for Drylands*, earthworks systems are most successful when they follow eight guiding principles.[50] Lancaster developed the principles for individuals that wanted to create a passive water harvesting system on their property, and therefore, they do not provide hard and fast rules for where and how to create earthworks systems. Instead, the principles serve as a thought process for designing and maintaining your water harvesting system. Nevertheless, they are important to identify and consider because some principles may be appropriate regulatory requirements for an earthworks system.

The following list identifies and briefly describes the eight principles:

- Observe the current water flow patterns – identify where the surface water is coming from, where it naturally collects, areas with and without vegetation or bare soils, and areas with erosion.
- Create your water harvesting system from the top (or highpoint) of the catchment area and work your way down – spread the water throughout the harvesting area and direct it to areas that can retain large quantities of water until the soil can absorb it.
- Start small and simple – it is an inexpensive and effective way to learn what works and does not work on your site.
- Spread and infiltrate the water flow – this will slow down the surface water and direct it into the soil.
- Plan an overflow route and manage it as a resource – direct overflow runoff to spillways that can hold the excess water until the soil absorbs it. Stabilize the spillways with heavy tightly packed rock or well-rooted vegetation.
- Maximize living and organic groundcover – mulch and native vegetation increases infiltration into the soil.
- Design and place water harvesting systems in relationship to the overall landscape and not just the catchment area – improves efficiency and productivity for the same amount of effort, and can perform additional functions, such as windbreaks and stabilizing the pits.
- Continually reassess the system – a form of long-term maintenance.[51]

Local governments can easily translate two of the eight principles into regulatory requirements -- requiring (1) an overflow route and (2) mulch and/or native vegetation to cover the soil. The other principles, while no less important, are difficult to implement through regulations because they are personal considerations, i.e., not everyone will want to start small or relate their system according to the overall landscape.

Current Trends and Best Practices

The following governments promote passive water harvesting either through regulation or a public program.

- Santa Fe, NM, awards points for active and passive water harvesting systems through its Residential Green Building Code.[52]
- Santa Fe County, NM, requires the use of rainwater for all commercial and residential developments. The ordinance requires a water harvesting plan as part of the development review process and the plan must demonstrate that the water harvesting system can capture 85 percent of the water drained from the roof.[53] (Tucson already has this requirement for commercial developments but could expand it to residential projects.)
- Oro Valley, AZ, requires establishes rainwater harvesting as a landscape conservation method in its zoning code. The regulation includes the following standards:
  - Requires a rainwater harvesting plan as part of the development review process;
  - Defines passive and active rainwater harvesting systems;
  - Requires vegetated passive water harvesting systems;
  - Permits active water harvesting systems pursuant to approval by the Town Engineer and Building Official;
  - Requires that standing water dissipates in a maximum of 12 hours; and
  - Establishes specific standards for the single-family and townhome residential districts and the multifamily residential, commercial, technical park, and other non-residential districts.[54]
- San Juan County, WA, permits alternative water sources as a single-family residential use and establishes rainwater harvesting systems as an allowed method. The Department of Health and Community Services provides a checklist for rainwater harvesting system requirements.[55]

ENCOURAGE TREES AND GREEN INFRASTRUCTURE IN STREET RIGHTS-OF-WAY (NEW REQUIREMENT)[56]

Introduction

Green infrastructure is the interconnected network of open space and vegetated areas that naturally manage stormwater, capture pollution, and improve water quality. The term includes many different landscaping or building methods and materials where their primary purpose is to mimic natural hydrologic functions within the built environment.[57] In regards to the rights-of-way, green infrastructure includes planting trees or natural vegetation, growing produce, and installing hardscape elements, e.g., pavers and raised beds, to channel or store stormwater. [58]

Green infrastructure in rights-of-way can incorporate a variety of trees, vegetation, and hardscape elements into the same space. Table 3 identifies and describes different tools to add green infrastructure to the rights-of-way:

Table 3: Green Infrastructure in Rights-of-Way Tools[59]			
	DESCRIPTION	USE	COST
Shallow channel footpath/ rainwater conveyor	A slight depression in the earth with pavers at the lowest point. The depression is flat so it is walkable when dry and collects stormwater and runoff during rainstorms.	Well suited for pedestrian traffic so it works well in parks or for sidewalks.	Purchase price depends on the material, type, and size. Low maintenance costs.
Planting strip trench	A gently sloping vegetation area in a street rights-of-way that channels and slows down the flow of stormwater.	Can be part of an overall stormwater management system.	Inexpensive to purchase plant materials and simple to install.
Landscaped tree well	Allows the tree to have exposed soil to receive water or collect and store runoff. Can plant smaller vegetation in the well to help infiltration.	Ideal for street trees in an urban area or a right-of-way.	Installation can be moderately expensive.
Grated tree well	A method to incorporate trees into sidewalks and to collect and store runoff. Beneficial because it can fit into small spaces.	Ideal for street trees in an urban area.	Installation can be moderately expensive.

These techniques do not require special materials and most landscape companies can install the systems.

Benefits

Trees and green infrastructure have become an element of the sustainable development movement because they provide several environmental, economic, and social benefits. The following list identifies these benefits:

ENVIRONMENTAL

- Street trees reduce the urban heat island effect by shading paved roads. According to a study by Glatting Jackson, Walkable Communities, Inc., the sidewalk temperature under street trees is five to 15 degrees cooler than in direct sunlight.[60]
- Trees and green infrastructure filter the air and reduce air pollutants such as particulates and carbon dioxide.
- The plants and soils from the street trees and green infrastructure serve as a source of carbon sequestration, i.e., they capture and remove carbon dioxide from the atmosphere through photosynthesis and other natural processes.[61]
- The vegetation captures stormwater, which reduces runoff to and strain on sewer infrastructure. More specifically,
    - Street trees absorb the first 30 percent of rainfall through their leaf system, which is water that never hits the ground and evaporates back into the atmosphere; and
    - They absorb approximately another 30 percent through their root system, which relieves pressure on stormwater infrastructure and helps recharge the soil moisture and groundwater.[62]

ECONOMIC

- Trees and green infrastructure enhance economic development along transit corridors. Several studies have shown that businesses along tree-lined streets have higher income streams than businesses in non-vegetated locations.

- According to a 2008 study by the USDA Forest Service PNW Research Station, street trees increased annual property tax values of houses in Portland, OR, by a total of 1.3 million dollars.[63]
- The same study found that a house with a street tree with a 312 foot canopy in front of it adds $7,593 to its value.[64]
- In Philadelphia, a green retrofit program that converted unsightly abandoned lots into "clean & green" landscapes increased the value of surrounding homes by as much as 30 percent. This translated to a $4 million gain in property values through tree plantings and a $12 million gain through lot improvements.[65]
- The energy bills for neighborhoods shaded by street trees are 15 to 35 percent lower than neighborhoods without street trees. [66]
- Street trees can increase the life of pavement by 40 to 60 percent because they reduce the daily heating and cooling, i.e., expansion and contraction of asphalt.[67]

SOCIAL

- Trees and green infrastructure increase safety by:
  - Buffering pedestrians from vehicular traffic;
  - Reducing traffic urban traffic speeds because trees establish a vertical wall that creates a defining edge and helps drivers gauge their speed; and
  - Shading roadways, which reduces glare for pedestrians and drivers.[68]
- They enhance the overall experience of developments and neighborhoods by creating character and a walkable scale.
  - Recent research has linked the presence of trees, plants, and green space to reduced levels of inner-city crime and violence, a stronger sense of community, improved academic performance, and even reductions in the symptoms associated with attention deficit and hyperactivity disorders.[69]
- They improve pedestrian experience along the rights-of-way because they create an aesthetically pleasing environment.

How Does Tucson Address This Today?

Tucson is well aware of the effect that landscaping has on its urban environment because it has an impressive set of policies and programs to encourage the planting and maintenance of native and landscaped trees on development sites. Despite this, the street development standards do not reserve any of the public rights-of-way for trees or green infrastructure.

If the city decides to integrate urban forestry regulations into the LUC, such provisions should require that a certain portion of the rights-of-way be reserved for trees and other green infrastructure. The suggested requirement will support two regulations that currently require trees and green infrastructure throughout the city. More specifically, the city requires one tree for every four parking spaces to better shade private parking lots, and established a water harvesting ordinance for commercial developments to irrigate landscaping. If the city pursues this amendment, it could enhance the effects of these regulations because it could require trees and green infrastructure in residential areas.

Key Questions

It is evident that placing green infrastructure in street rights-of-way has several benefits, however if the infrastructure is not installed properly, these benefits may not be fully realized and may even become a hazard. Therefore, it is important to anticipate several factors when requiring green infrastructure in street rights-of-way.

The regulations need to address the environmental functions of the green infrastructure itself and the impacts of the infrastructure on the surrounding area. Environmental functions include:

- Designing the infrastructure to mimic local hydrology prior to development;
- Incorporating the infrastructure into the existing stormwater management system; and/or
- Linking the project to other local green infrastructure initiatives.[70]

Regulations that address the impacts of green infrastructure should consider and attempt to balance the access and mobility needs of all users on the street rights-of-way, i.e., pedestrians, non-motorized vehicles, automobiles, transit, and freight. They should also maintain or improve the balance among safety, roadway infrastructure and utility services, and the environment.[71] To accomplish this, the regulations should include height and setback requirements for installing vegetation and hardscape elements in the rights-of-way as well as site and access clearances for residents and utilities.[72]

Seattle, WA, addresses these concerns by establishing (1) setback requirements for the green infrastructure from the curb face, edge of the sidewalk, utilities, and driveways; (2) separate clearance requirements for street trees in commercial and residential districts; (3) maintenance requirements according to the distance between the tree and the sidewalk or the roadway; and (4) a list of permitted trees.[73]

Current Trends and Best Practices

The following cities promote trees and green infrastructure in street rights-of-ways through their municipal or land use codes:

- Santa Fe, NM, has a street tree regulation in its land development code. The purpose of street trees is to reduce heat, dust, and glare and the need for cooling or heating; help clean and oxygenate the air; reduce road noise; and develop continuity between developments. The regulation has multiple requirements, but the following list identifies the standards most applicable to this initiative:
  - Sets an average height for street trees based on the size (e.g., major, secondary, minor) of the arterial;
  - Prefers that street trees are planted in swales or basins to collect run-off and precipitation; and
  - Expressly prohibits counting street trees towards the landscaping requirements in parking lots.[74]
- Austin, TX, permits residents to use the public right-of-way as a landscaped area or for a structure as long as it does not interfere with the use of the easement. Residents must obtain a permit to use the right-of-way.[75]
- Portland, OR, sets different levels of landscaping and screening standards throughout the city in its land development code. The standards are applicable to various situations, e.g., street setbacks, along streets, parking lots, etc, but it does not apply to trees in the rights-of-way. The municipal code has a street tree regulation that requires planting of street trees for new development or improvements to existing developments that exceed $25,000 in value.[76]
- Seattle, WA, passed a resolution to clarify that residents may plant street trees and raised-bed gardens in the rights-of-way. The Department of Transportation created a rights-of-way manual to ensure that this requirement is implemented in a manner that provides a public benefit and is compatible with other infrastructure. The manual establishes design standards for street trees and landscaping for planting strips and tree pits and according to clearance, grade, width, and treatments. It also identifies design considerations to enhance the 'sense of place,' increase public safety, and improve tree health and maintenance.[77]

Green Buildings

SOLAR REFLECTIVE (COOL) PAVING MATERIALS (NEW REQUIREMENT/INCENTIVE)

Introduction

Paved surfaces, e.g., highways, roads, runways, parking areas, sidewalks, and driveways, comprise approximately 30 to 45 percent of urban areas and in some respects, are the largest percentage of a community's land cover.[78] This has become the bane of urban areas because pavement absorbs energy from the sun, which creates heat and increases surface temperatures, and releases the heat into the urban atmosphere, increasing air temperatures and creating a so-called "heat island effect."[79] Urban areas are up to eight degrees Fahrenheit warmer than the surrounding rural area.[80]

To combat this effect, researchers at the Lawrence Berkeley National Laboratory (LBNL) investigated methods to develop pavement that reflected the sun's energy.[81] Solar reflectance, or albedo, is the ratio of reflected solar radiation to the total amount that falls on that surface. Albedo values range from zero to one, with zero being a perfect absorber and one being a perfect reflector.[82] Since most paved surfaces are either asphalt or cement, their albedo values have a large impact on the heat island effect.

Aged asphalt on the left and new asphalt on the right illustrating changes in albedo values of asphalt and concrete over time. Image from the Cool Houston Plan.

According to the American Concrete Pavement Association, the albedo values of asphalt and concrete change over time because asphalt lightens due to oxidation and binder wear,[83] while concrete darkens due to dirt and tire marks.[84] Table 4 identifies the solar reflectance levels for asphalt and concrete:

Table 4 Solar Reflectance of Pavement Surfaces

PAVEMENT TYPE	SOLAR REFLECTANCE VALUE
Asphalt	0.05-0.10 new
	0.10-0.15 weathered
Gray portland cement concrete	0.35-0.40 new
	0.20-0.30 weathered
White portland cement concrete	0.70-0.80 new
	0.40-0.60 weathered

Given that concrete has a higher albedo than asphalt, the most effective solar reflective pavements are made from white portland cement concrete and reflective aggregates, [85] where reflective aggregate is either a clear binding resin or a specific pigment.[86] Reflective concrete is also practical in urban areas because most sidewalks and some roads and parking areas are paved with concrete,[87] and according to the U.S. EPA, reflective concrete is best suited for lower traffic areas such as sidewalks and parking areas.[88]

LBNL developed the first reflective concrete pavements in 2002, and since then, researchers and manufactures have developed reflective pavements using other materials, e.g., asphalt and blended cements.[89] For example, Arizona State University's National Center of Excellence SMART Innovations for Urban Climate and Energy is studying established and emerging designs that optimize pavement albedo, emissivity, thermal conductivity, heat storage capacity, and density in laboratory and field

sites.[90] They are developing models to help decision-makers predict the effects of material properties, shading, and energy use on urban temperatures in the Southwest.[91]

Benefits

Solar reflective paving is a tool embraced the sustainable development movement because it provides environmental, economic, and social benefits. The following list identifies these benefits:

ENVIRONMENTAL

- Reflective pavements are also referred to as a cool pavement because they decrease energy demand, which results in lower associated air pollution and greenhouse gas emissions. Cooler air temperatures also slow the rate of ground-level ozone formation and reduce evaporative emissions from vehicles.
    - In 2007, a study estimated that increasing the reflectance of pavement from an average of 35 to 39 percent in cities worldwide could reduce global carbon dioxide emissions by an amount that is worth about $400 billion.[92]
- A case study of the Los Angeles area found that the temperature decreased by 1.5 degrees Fahrenheit from solar reflectance changes. A subsequent report analyzed the effects of increasing pavement reflectance and the energy cost savings from temperature reductions. It estimated over $90 million/year in savings by increasing cool pavements.[93]

ECONOMIC

- Reducing pavement surface temperatures can increase the useful life of pavements, which also reduces waste. Simulations of asphalt pavement temperatures found that pavements that were 20 degrees Fahrenheit cooler lasted ten times longer than hotter pavements, and pavements that were 40 degrees Fahrenheit cooler lasted 200 times longer.[94]
- Reflective pavements can enhance visibility at night, which reduces lighting requirements and saves energy and money. Some sources state that reflective pavements enhance nighttime illumination by ten to 30 percent.[95]

SOCIAL

- LBNL estimates that every ten percent increase in solar reflectance could decrease surface temperatures by seven degrees Fahrenheit. Furthermore, if pavement reflectance was increased from ten to 35 percent throughout the city, the air temperature could potentially be reduced by one degree Fahrenheit.[96]

How Does Tucson Address This Today?

One of Tucson's sustainability initiatives is to reduce the urban heat island effect because its current regulations do not target this issue. There are several methods to reduce the heat island effect, one of which includes solar reflective pavements. If the city decides to adopt regulations that mitigate the urban heat island effect through reflective pavements, such provisions should include the following:

- Requiring paving materials to have a solar reflectance index of at least 29 to reduce solar gain and the urban heat island effect, and
- Offering density bonuses, additional height, or other desirable development benefit for installing highly reflective pavement materials.

Key Questions

Similar to pervious pavements, the effects of reflective pavements depend on climate and regional characteristics, site location, and maintenance. However, unlike pervious pavements, reflective pavements are an emerging technology so the factors are not well-researched and documented, and

they do not provide a guide to installing and maintaining the material.[97] If a study addresses any of these factors, it does so in abstract terms or situations.

For example, the U.S. EPA identifies potential site location issues in two hypothetical conditions. First, high-albedo pavements will absorb less heat and stay cooler than darker pavements, but they are not appropriate for places where people 'hangout' for a long period of time because higher-albedos reflect more solar radiation, which is uncomfortable in large doses. Second, other pavements will absorb and retain more heat during the day, and at night, the surfaces will release the stored energy. This effect is more appropriate in situations where the main concern is the daytime heat.[98]

The EPA suggests that the overall success of implementing reflective pavement regulations depends on the audience, i.e., the developers and residents installing the material, and the regulations themselves.[99] This section outlines several considerations for each factor and the cost compared to conventional pavements.

AUDIENCE

Beyond the city, developers and residents are the primary entities that will install reflective pavements so it is important to understand their purchasing, technical, and visual perspectives. The audience for reflective pavements includes landowners, product engineers or suppliers, and contractors. Even though each entity has a specific perspective, together they address the major impediments to installing reflective pavements on private properties throughout the city, such impediments include their:

- Interpretation of costs – Decision-makers typically focus on the initial costs and do not calculate the life-cycle costs in their evaluation because either they do not understand the long-term benefits of albedo pavements and perceive that the higher initial costs are not worth the investment or they have a tight budget and do not want to invest in an unfamiliar technology. This is especially true for developers that do not own the facility for very long, because they are less likely to invest in a technology that they will not directly benefit from;
- Expertise or knowledge in the field – For many private developers, paving is a secondary function, and they have limited in-house expertise on the subject matter. As a result, they are more likely to use a material that they understand and frequently use unless they believe that the performance of an alternative is competitive with conventional pavements; and
- Responsibility to serve the customer by meeting specific technical and visual needs – This is the main concern for contractors and developers, because they may be liable if a pavement does not meet technical standards or the projected lifetime. Performance is gauged according to durability, reliability, structural integrity, skid resistance, and visual quality, and each standard must maintain specific measures for ten to 30 years. Landowners are also concerned about the aesthetic quality of different pavements. For example, some owners prefer a lighter pavement because it provides nighttime illumination, while others prefer a black pavement because it looks 'crisp.'[100]

LAND USE REGULATIONS

Cities typically exercise little control over private-sector paving in development codes. However, local governments can require the use of reflective pavements by enacting minimum standards and specifications for pavements. They can also encourage the use of the materials by connecting its benefits to existing policy objectives, e.g., air quality mitigation and water quality improvement. This is an important component to regulating new technologies, such as reflective pavements, because it promotes the material under recognized and accepted mechanisms and expands funding opportunities.

However, the success of encouraging reflective pavements through new and existing regulations depends on whether the landowners understand the rationale for the regulations. If land owners understand the rationale, they are more likely to recognize, accept, and install reflective pavements.

Local governments can achieve this by providing information on reflective pavements. The information should document the need, available technology, cost feasibility, and demonstrated benefits.

COST

The cost of reflective pavements depends on the size of the area, the material used, the amount of installation required, and the frequency of routine maintenance. Each of these factors varies by region, manufacturer, and contractor, thus it is difficult to identify the specific costs.[101] However, it is well documented that the cost to purchase and install some reflective materials is higher than conventional pavements. For example, in 2002, initial install costs of white cement concrete were almost twice as much as concretes made with normal gray cement.[102] The difference between the cost of conventional and solar reflective asphalt is not as great/high as concrete, but this may be due to the fact that the albedo value for solar reflective asphalt is not as high as white cement concrete.[103]

Existing literature frames the potential for solar reflective pavements in terms of the competitive life-cycle costs of the materials, i.e., lower surface temperatures and reduced heat island effect, which can lower energy bills. The higher initial cost for solar reflective pavements may overshadow the life-cycle costs, especially when budgets are tight. In addition, landowners may view pavements that are not commonly used as a performance risk.[104]

Best Practices

The following cities promote solar reflective pavements either through regulation or a public program:

- Toronto, Canada, created a manual of design guidelines to 'green' parking lots, and the manual encourages reflective and permeable pavements to reduce surface temperatures.[105]
- Houston, TX, adopted a heat island initiative as part of the city's overall approach to improving air quality and public health. The plan takes three approaches: (1) targeting alternative paving options for specific surfaces, such as highways or parking lots; (2) educating local and state decision makers about the public health, environmental management, and public works maintenance; and (3) combining and embedding alternative paving incentives, such as cool paving incentive payments, property and sales tax provisions, utility fee adjustments, FAR benefits, and water detention credits, into larger programs and regulations.[106]
- Miami, FL, adopted a 'Heat Island Effect – Non-Roof' regulation. The regulation establishes solar reflective paving as a tool to reduce the heat island effect and sets minimum standards for the quantity of alternative hardscapes (50 percent) and where appropriate, a minimum albedo value (.30). The alternative hardscapes include: (1) shade from solar panels or roofing materials with a solar reflectance of at least .30, (2) shade from trees with five years of occupancy, (3) paving materials with a solar reflectance of at least .30, and (4) pervious pavement systems. The regulation only applies to new construction projects.[107]
- Austin, TX, passed a heat island mitigation resolution that recognized albedo pavements as a method to reduce the heat island effect.[108] In response to the resolution, the city created a Climate Protection Plan that incorporates heat island reduction through green building and energy efficiency elements.[109]
- Dane County, WI, requires developments to reduce thermal pollution of runoff from impervious surfaces.[110]

Urban Food

CLARIFY THE RULES FOR SALE OF ON-SITE PRODUCE (REDUCE BARRIER)

Introduction

Urban agriculture encompasses the growing, processing, and distributing of food or other products through plant cultivation and animal husbandry in and around cities. Throughout the world, communities and organizations are utilizing new technologies and techniques for urban gardening. In response, people are transforming small spaces, such as yards, roofs, street areas, vacant lots, porches, and planters, to grow food for themselves and their neighbors.

Cities are legitimizing this transformation by establishing multiple urban agriculture use classifications and permitting them in all or most zoning districts. In addition, some cities are promoting this use as an independent business venture by allowing landowners with gardens to sell their products to residents and local businesses from their property. This is a logical step in the transformation for several reasons, but the most prevalent is that it increases access to fresh and healthy food.

Benefits

Urban agriculture has been linked to the sustainable development movement because it provides several environmental, economic, and social benefits. Multiple scholars are researching specific aspects of urban agriculture, such as small farm animals, farmers markets, and the health benefits. However, on-site sales of produce is an emerging aspect of the transformation so its benefits are not well-documented as of yet. The following section identifies the benefits of urban agriculture that are rationally related to selling produce on the same site that it was grown:

ENVIRONMENTAL

- Urban agriculture increases plant foliage, which can decrease stormwater runoff and air pollution as well as urban biodiversity and species preservation.[111]
- Food products shipped into urban areas typically travel between 1,500 and 2,500 miles from farm to plate.[112] Growing and selling produce in the same area limits the food miles to the confines of the city or region and greatly reduces fossil fuel use and emissions.

ECONOMIC

- Residents can supplement their income by selling the produce grown in their backyard.[113]
    - The following example is not from on- site sales, but it demonstrates the value of produce grown in an urban environment: In 2008, community gardens in Philadelphia produced approximately $4.9 million in summer vegetables, which as more than the combined sales of all of Philadelphia's farmers markets and urban farms.[114]
- Permitting on-site sales of produce promotes new food-related businesses, such as processing facilities, restaurants, community kitchens, farmers markets, transportation, and distribution equipment.
- Community gardens increase property values.[115]
    - The following example is not from on- site sales, but it demonstrates how much urban agriculture increases property values: A recent study of community gardens in New York City found that within five years of a community garden's opening, neighboring property

values increased by as much as 9.4 percent and continued to increase over time. The study also showed that community gardens can also increase tax revenues by approximately 1/2 a million dollars per garden over a 20-year period.[116]

SOCIAL

- A 2008 study on a low-income neighborhood in Denver, CO, identified that the distance from the neighborhood to a grocery store was over three miles,[117] and therefore selling produce in residential neighborhoods dramatically increases access to healthy food.
- Urban agriculture increases neighborhood interaction.[118] Permitting on-site sales of produce in residential districts supports this idea, because it encourages residents to purchase food from their neighbors and provides more opportunities for neighbors to gather over a common interest, i.e., local food. More specifically, it can foster community building, mutual trust, sharing, feelings of safety and comfort, and friendships.[119]

How Does Tucson Address This Today?

Tucson does not address urban food in the LUC or planning, thus the rules that typically permit or prohibit progressive urban food practices are not clear. For example, it appears that residents are not permitted to grow and sell food on the same property in any zoning districts, especially residential districts. If the city decides to integrate urban food practices into the LUC, such provisions should clarify this issue by allowing on-site sales of produce grown in a community or backyard garden and establishing standards that ensure the use is compatible with residential districts.

Key Questions

Selling produce on the site that it was grown, such as a community or individual garden, inherently affects the character of the neighborhood because it increases the number of people traveling to the area. However, the city can control the effects by establishing regulations that address the issues before they occur. Communities that permit on-site sales of produce should anticipate increases in traffic and noise and concerns over the safety of residential neighborhoods.

However, the city can mitigate these issues by regulating the type, hours, quantity, and signs of the on-site sales. The following list identifies each of these regulations and outlines several considerations for each factor:

TYPE OF SALES

- Does the city want to limit sales to produce or does it want to permit value added products?
- If the city permits small farm animals, such as chickens, does it want to allow residents to sell eggs?[120]

HOURS OF SALES

- If the city regulates the hours that growers can sell their produce, it needs to make sure that the hours are convenient for potential customers. For example:
  - Working families or individuals are more likely to purchase goods on the weekend or weekday evenings, and
  - People that work evening or night shifts, stay at home parents, and restaurants or businesses are more likely to purchase goods during the weekdays.

QUANTITY OF SALES

- Does the city desire the operation and sales to be a full-time or part-time business?
- The city should consider how the regulations will affect the ability of the grower to make a viable return on their produce.

SIGNS

- Sign regulations should consider how they limit the ability of the growers to identify the location of their business.
- What kind of customer does the city want to target, i.e., neighbors or community members?
    - For example, neighbors could hear about the business through word of mouth, but other community members could hear through other means and need a sign to easily identify the location.
    - A sign is an easy way to inform neighbors about the business and may limit the need for growers to advertise their operation to the larger community.
- Sign standards should ensure that the signs are consistent with the neighborhood regulatory environment.

The following section demonstrates how cities have addressed these considerations.

Best Practices

The following cities permit on-site sales of produce in residential areas:

- Cleveland, OH, established farm stands as a permitted agricultural use in residential zones.[121] If agriculture is the primary use or occupies at least 75 percent or 4,000 square feet of the property the landowner can sell agricultural products, plants, eggs, and honey grown or produced on their property or within 1,000 feet from their stand. Farm stands can sell prepared foods as long as the primary ingredient is grown on the property or within 1,000 feet and the stand obtains a license by the Department of Public Health. Sales must be between eight a.m. and dusk.[122]
- Los Angeles, CA, defines 'truck gardening' as the "cultivation of berries, flowers, fruits, grains, herbs, mushrooms, nuts, ornamental plants, seedlings or vegetables for use on site or sale or distribution off-site." The city permits truck gardening as an exception to the requirement that all home occupation activities are conducted within the dwelling unit and not visible from the outside. It also permits sales of truck gardening products as an exception to the requirement that prohibits selling produce or food as a home occupation. Sales are permitted in the A1 Agriculture Zone and all of the residential districts and restricted to one client per hour and from eight a.m. to eight p.m.[123] The city expressly prohibits the keeping of animals for commercial purposes.[124]
- Pittsburgh, PA, permits on-site sales of non-mechanical agricultural and farm products that are grown, used, and produced on-site or are part of an affiliated "community supported agriculture program" for agricultural uses on residential properties. The sales are subject to the outdoor retail sales and service (accessory use) provision, which requires a letter of compliance from the fire prevention, county health department, and any other agency or department that is appropriate. The city has three agricultural uses that it allows in all of its residential districts:
    - Agricultural (general) – requires a minimum size for the use and permits the keeping of animals. The use is subject to an exception from the zoning administrator and is subject to special standards.
    - Agricultural (limited) – no size requirements and prohibits the keeping of animals. The use is subject to obtaining an exception from the zoning administrator.
    - Agricultural (limited) with beekeeping – includes the standards from agricultural (limited) but also permits two beehives per 2,000 square feet. The use is subject to special standards.[125]

- Seattle, WA, defines 'urban farm' as "a use in which plants are grown for sale of the plants or their products, and in which the plants or their products are sold at the lot where they are grown or off side, or both, and in which no other items are sold. Examples may include flower and vegetable raising, orchards, and vineyards. The city permits urban farms in all residential zones and allows on-site sales from produce grown on the property from 7 a.m. to 7 p.m. every day of the week. The city restricts commercial deliveries and pick-up to one per day (on-site sales are not considered a commercial pick-up). The city also allows community gardens in all zones, but the garden cannot exceed 1,000 square feet on any lot and prohibits on-site sales of produce.[126]
- Oakland, CA, is proposing to modify their zoning regulations to allow "crop growing activities" as a home occupation and regulate the sales of produce the same as the sale of other home occupation products. The proposed ordinance defines "crop growing activities" as the cultivation of fruits, vegetables, plants, flowers, herbs, or ornamental plants for sale. The ordinance excludes animal raising.[127]
- Minneapolis, MN, established a local food policy council to evaluate local food initiatives and propose policies and programs that promote urban agriculture. The task force is analyzing whether to allow on-site sales of produce grown on a residential property through its home occupation ordinance. They are considering the following issues: (1) restricting sales to a number of days each week, (2) limiting the hours for sales, and (3) limiting the size or scale of sales. The task force and the change to the home occupation regulation was prompted by a comprehensive urban agriculture report by the Metropolitan Council, which is the regional planning agency in Minneapolis/ St. Paul.[128]

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