GREEN STREETS

an innovative design approach for northern california

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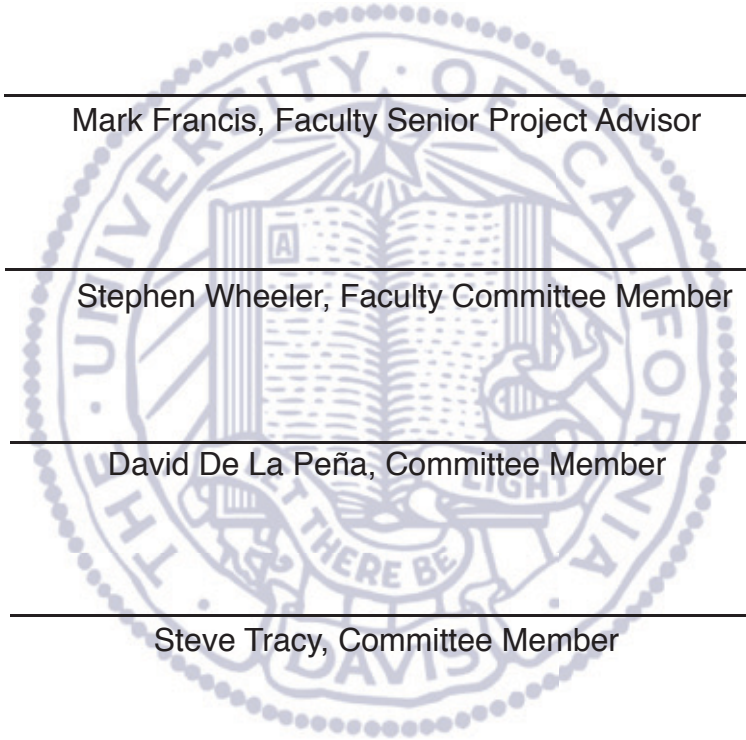

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[abstract]

Despite all the hype and commercialization attached to it, the wave of “green” awareness currently sweeping across society is hopefully an honest recognition that our natural environment is desperately in need of a “fix”. It is a growing crisis that requires multi-faceted responses wherever and in whatever manners possible, to change the way we live and use vital resources.

With urban streets such prominent features of industrialized societies, both in terms of numbers and paved surface areas they cover, it is understandable that they represent both a problem and potential solution in dealing with the environmental problems facing us. The problem lies in the runoff and related pollution associated with streets; the congestion and pedestrian “unfriendliness” created by poorly designed and maintained roadways and the overall “hostile” atmosphere associated with thoroughfares that seemingly neglect the human component in their use and make-up. The solution involves a “green” approach to street planning and design that puts people, their numerous activities, and environmental concerns as the top priority, and uses streets to increase the “livability” factor of urban areas.

Designing green streets involves paying attention not only to stormwater management, a feature most commonly associated with the concept, but also applying ideas of added green space, traffic-calming, walkability and bicycle access to create streets that are “livable” and functional. The research, case studies, and guidelines contained within this project will provide readers with the necessary tools to design streets to be “green” and to understand the methods, processes, and benefits of constructing these types of systems.

[dedication]

This project is dedicated to my parents, for putting up with me throughout the years, allowing me to experiment on their backyard, and for always supporting and encouraging me to work my hardest and accomplish my goals. I could not have done this without you.

[acknowledgements]

I would like to thank the following people for all of their advice, support and encouragement throughout this process and for helping me to accomplish this great task.

Mark Francis... for introducing me to urban design and encouraging me to travel and fall in love with Scandanavia, I will return one day and explore the fjords.

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Steve Tracy... your enthusiasm for street design and your committment to community involvement and innovative street design is inspiring, thank you for all of your wisdom and for sharing your family travels

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[preface]

Observe the roadways in any urban or metropolitan area, and it's apparent that not all streets are created equal. In accommodating the numerous functions assigned to them, many thoroughfares have become nothing more than bland, innocuous corridors of concrete and asphalt choked with traffic and congestion of all sorts. They lack any elements that make them memorable in a positive way, existing primarily to accommodate the flow of vehicles and commercial traffic. Seemingly in a constant state of repair or renovation, they are often nightmares to traverse for both pedestrians and vehicles. People often deliberately try to avoid them, utilizing only when necessity requires or dictates. There are other streets however – ones carefully thought out and planned – that draw people back not just because of the activities that are centered there, but because they have qualities making making them desirable places to be,

ones that leave strong, long lasting positive impressions. Such streets are an integral part of a community, both establishing an identity and providing residents with a physically comfortable and safe place to spend time, live, work and play, and contributing to what a city should be. They provide something for everyone-the pedestrians on foot or on a bicycle, the casual observers who are content to just sit in a green setting and watch the world going by, or the shoppers patronizing a wide variety of stores, markets or street vendors. It is in exploring the latter perspective of the "ideal" street that this project was undertaken.

In its current context, the word "green" has inevitably established a strong link to environmentalism and to the implications of the entire environmental movement as it has evolved. It would seem that many things can now be defined with some reference to 'green' – green business, green networks, green political parties, green roofs, green buildings – and the list goes on.

For this project, I originally sought to combine the concept of 'green' while also incorporating the idea of "sustainability" as applied to the design of municipal streets. Another goal was to develop a set of guidelines and basic principles or standards for use by students as well as professionals who are involved with urban planning and street design, particularly in Northern California where a growing awareness of "green street design" is emerging. While I knew the concept was not unheard of, my research revealed that green streets in current applications are seen principally as streetscape design intended to manage stormwater. When I think of the term "green", however, I tend to widen the scope to not only include environmental or ecological benefits, but to incorporate sustainable, social and economic ideas as well. I wanted to show how this concept of "green" could be incorporated into streetscape design to involve the management of stormwater as well as integrating concepts of walkability and bicycle-usage, enhancement of green space and the

and the associated benefits and livability.

It is the purpose of this project to examine what it is that makes something as ordinary as a street a special and desirable place to be, and to define what the “green concept” in street design consists of and requires in terms of planning and application. Based on examination of research and the analysis of successful streetscape projects, a set of guidelines and recommendations will then be presented as a blueprint for developing new streets to incorporate “green” and “sustainability” concepts in creating more livable urban environments. It will then conclude with the application of the presented guidelines to local streets and explain some practical considerations regarding the whole notion of “greenness” in design and planning, as well as the implications for the future of urban “green streets”.

[chapter 1]

defining the green street

While historically they can be viewed from different social, economic and even ritualistic perspectives, streets in their earliest form were pretty much meant to serve one basic function: facilitating the efficient movement of people and goods between two given points. Usually taking the path of least resistance, early man first used roads to accommodate his most basic needs. Such has been their purpose since the establishment of nation states, and each successive civilization has contributed to the further development, refinement, and evolution of streets across the world and throughout time. The Romans were arguably the best at it, and modern streets are still constructed on the models and methods of a civilization that used them to expand its influence throughout most of the known world at the time. Indeed, the cohesion and survivability of many nation-states was often determined by the degree of “connectedness” achieved

through transportation networks that moved goods and food, as well as armies and ideas.

The contemporary street has taken on added responsibilities most likely not even imagined by the original architects, including serving as a pathway for waterlines, sewer tunnels, electrical cables, internet service lines, telephone connections, and fiber optic cables as well as moving motorized traffic of all kinds. In addition, streets are now places for human, social and commercial interaction. They allow people to be outside, to see and be seen, to meet other people and carry on a whole range of social activities and relationships for those living within the limited confines of an urban environment. They are the places where protests and revolutions have arisen, and where people can stroll under trees alone in deep reflection or enjoy the company of others for an evening saunter. Street performers and their audiences gather along them, as well as the homeless and hapless looking for any help that might come their way from from a generous passerby, Preachers and zealots on street corners seek converts to their cause, alongside artisans, craftsmen and sidewalk vendors seeking to eke out a meager living. It's obvious that streets have moved far beyond their original intentions, and successful, well thought out street design is a necessary component to any urban or rural environment.

1.1 - La Rambla, Barcelona, Spain

With the advent of a rapidly emerging “green” consciousness, it is only inevitable that the role of the street should also be included in incorporating environmentally friendly technologies and designs. The concept of a “green street” can be characterized using a number of features or designations, and often is defined differently according to various public and private agencies and institutions. Regardless though, the idea of a “green street” remains generally the same – a planned and engineered creation intended to be both ecologically friendly and environmentally sustainable.

1.2 - N Willamette and Denver Ave, Portland, Oregon (sustainablestormwater.com)

For the purposes of this project, a definition was sought that not only incorporated stormwater management concepts (something by which “green streets” have mainly been characterized) but a definition that allowed for the address of various street issues using sustainable approaches. The following definition was selected based upon its inclusion of these various aspects of street design:

> “ A green street meets the transportation need and applies environmental stewarship to improve the natural, built and social environments (Rosales 128).”

[chapter 2]

green street objectives

The design of a street to incorporate “green” concepts addresses numerous objectives, among them: more effective management of stormwater runoff, the implied addition of green spaces to render streets more aesthetically and socially appealing, the inclusion of traffic-calming applications, increased shared access to streets for both pedestrians and bicycles, and improvement in overall street livability. These general objectives will be elaborated upon further in Chapter 3.

stormwater management

The removal of stormwater runoff is one of the most challenging and important objectives of “green” design, especially given the dramatic increase of impermeable surfaces in municipal areas – everything from paved roadways and shopping center parking lots, to massive sports venues and city sidewalks- each of which

contributes its own special brand of polluting toxins. The pollutants contained in runoff from these areas eventually find their way through sewers and storm drains into the rivers, lakes, and water supply systems for cities and towns. The health effects of this pollution on the public, and the environment in general, can be extremely detrimental. For example, it is not uncommon for large storm events to subsequently cause beach closures, for fear of pathogenic (disease causing) bacteria contamination that can affect beachgoers through skin-contact or ingestion (CA Beach Closure Report 2000).

2.1 - Beach closure warning sign (epa.gov)

Fish, fowl and other aquatic organisms also pay the price as polluted stormwater is drained directly into their habitats sometimes devastating the existing ecosytem. By managing stormwater at the point where it falls or is collected, and putting it through extensive natural filtering, many of these problems can be alleviated.

Designing streets to somehow slow down, collect and filtrate runoff is one of the main goals of green street design, and cities across the country are increasingly exploring and implementing different techniques to accomplish this. Channeling stormwater runoff through specially landscaped areas that contain plants specific for the task, can effectively remove debris and sedimentation from the water. The use of collecting ponds, in conjunction with aeration troughs, can help put needed oxygen into the water before it reaches a river or lake.

green space

While green street design has abundant underlying goals, one obvious objective (and one that is clearly implied in the name) is the creation of green space. The spaces can take the form of “islands” planted with low vegetation at intersections, parks with fountains and gardens strategically located along main city streets, planters of various shapes and sizes to separate pedestrians from vehicle traffic, and of course trees of appropriate size and variety to form canopies of shade along sidewalks.

2.2 - Green Street, Belgium (pps.org)

traffic calming

Responsible environmental stewardship can also be applied in working to reduce vehicle speeds on streets, creating a more hospitable and shared environment for bicyclists, pedestrians, and transit. Traditionally, the most fundamental way to manage speed and calm traffic has been the posting of designated “speed limits” on various roads and highways, the principal objective of these regulations to inform drivers of the appropriate speed and trust that motorists will abide by the posted upper boundaries. Unfortunately, and as many of us can attest to, the posting of a designated speed limit does not necessarily guarantee the desired change in traffic speeds, often serving merely as a suggestion or a minimum. Through the use of various design techniques also known as traffic calming methods, traffic speed management can be achieved.

According to the Institute of Transportation Engineers,

> "Traffic calming involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes (trafficcalming.org)."

Instead of completely rebuilding a street system, layout can simply be altered. The idea of traffic calming first originated in Europe where the basic objective was to achieve calm, safe, and environmentally improved conditions on local streets and can most recognizably be observed in the Dutch "woonerf" schemes of the early 1970s (Transportation Research Board 169).

In too many urban areas, the flow of traffic at high speeds along city streets is a hazard for both pedestrians and bicycle riders alike. Facing the prospect of a speeding car or truck – one trying to beat the lights or time the crossing at intersections – can often become a life or death situation for the casual stroller or bicycle rider who has to get to the other side of the street. It's a case where size does mater, and the advantage goes to the motor vehicle.

walkability

Walkable streets are to be viewed as shared spaces, and not ones that exclude cars or pit pedestrians against motorists. It is a designed environment in which vehicles, bicycles, and pedestrians are all meant to co-exist. One of the main components that determine "walkability" of streets is the perceived safety of users from a wide variety of groups. Partnership for a Walkable America suggests asking yourself the following questions outlined in their "Walkability Checklist" to determine if a street is "walkable": Do you have room to walk? Was it easy to cross streets? Did drivers behave well? Was it easy to follow safety rules? Was your walk pleasant?

"Green" design can approach walkability from many different angles. It goes without saying that wide sidewalks are an essential component for pedestrian activity to occur as well as perceived safety in regards to traffic concerns, but how does a design use environmental stewardship to create a pleasant experience for pedestrians as well as provide visual and social encounters? Green space can greatly influence how "pleasant" a street feels to pedestrians and can also be used in various traffic-calming approaches. Appropriate signage is key for street walkability.

2.3 - Brugge, Belgium (pps.org)

bicycle access

For both economic and health reasons, many people are beginning to use bicycles as a means of transportation, especially where distance and climate are favorable. Whether to work, school, or on weekend social outings, bicycle usage is becoming a viable means of moving people. Many cities, however, still have not incorporated sufficient bike lanes in their overall traffic design. In areas where motor vehicles and people on bicycles come together on the same thruway, the encounter for the bike rider can be more than a nuisance - it's often a matter of survival. The guidelines provided for green street design plans for the integration of both means of transit by establishing "bike only" lanes for riders, by providing secure bike racks at various points along a street where businesses are located, and through recalibration of traffic signals to give bikers an easier way to cross a street without having to compete with cars, trucks, or buses.

livability

As streets serve multiple functions in our daily lives, one of the most significant goals of green street design is to make them “livable”. While the term “livable street” may be hard to define, its underlying principle suggests comfort, safety, and community. In its essence, the goal of street livability refers to many of the aforementioned goals including lush green space, the enhancement of the pedestrian setting, increased bicycle access and overall functionality, but the concept of livability goes beyond that to incorporate ideas about how comfortable various user groups feel in the street environment, perceived safety and the created opportunity for community interaction and development. These ideas are at the core of successful street design.

[chapter 3]

design strategies

Realization of any objective depends upon the successful implementation of specific strategies. These strategies are essentially the means to an end and consist of detailed methods necessary to execute a plan. The following strategies are possible applications for use in creating green streets, and the specific choices selected for implementation will generally be determined by conditions at the site. The available options will be expanded upon further, based on street type, in Chapter 7.

stormwater management

While numerous and varied strategies exist for managing stormwater runoff, this project will focus specifically on the following: bio-retention action through the use of swales and vegetative filter strips, and effective percolation utilizing pervious pavement treatments.

According to the U.S. Environmental Protection Agency, both approaches are among their Best Management Practices for stormwater runoff mitigation.

Bio-retention, also referred to as bio-filtration, is defined as a:

> "water quality and water quantity control practice that utilizes the chemical, biological and physical properties of plants, microbes and soils for removal of pollutants from stormwater runoff (T.E. Scott and Associates 2008)."

It is an effective process that occurs on its own in the natural environment and existing ecosystems, but one that is often eliminated or severely disrupted when man-made development takes place.

One particular approach used in stormwater management, rainwater harvesting, and soil conservation, is utilization of what is known as a swale -

> a "vegetated channel that looks similar to, but is shallower and wider than a ditch. Swales are designed and maintained to transport shallow depths of runoff slowly over vegetation (Portland Metro 22)."

These linear depressions spread runoff horizontally, thus facilitating infiltration into the soil while also providing aesthetic interest and land contours. The same concept behind a swale can be seen with the use of a landscape retention planter or rain garden.

Another technique, the installation of vegetative filter strips, is generally used in conjunction with swales or retention planters as a pretreatment and employs vegetation to reduce or remove sediments, chemicals, nutrients and organic materials usually carried in stormwater runoff. Originally used in an agricultural setting, filter strips have recently evolved into an effective urban

practice. Filter strips should generally be placed 2-4ft away from ground water to prevent contamination. Sturdy, tall perennial grasses do the best job of trapping sediment and a species must be chosen based on its ability to withstand high velocity flows and both wet and dry periods (Grismer, O'Geen and Lewis 2006).

3.1 - Runoff collecting in a swale, Portland, Oregon (oregonlive.com)

Pervious or porous pavement is designed to allow the flow of stormwater into the ground soil where water is naturally filtered and absorbed. Combined with other methods such as previously described, stormwater management can be even further improved. However, as with other methods, site-specific conditions must be considered. Pervious pavement is generally not recommended for high-traffic volumes due to durability, maintenance issues and load bearing concerns. For these reasons, this technique is specifically recommended for low-traffic volume roadways, parking lots, driveways and walkways (epa.gov).

green spaces

The creation of green spaces functions as a kind of fabric that ties together the existing urban landscape (whatever it may be) with the created man-built environment that is often the dominant feature, in an attempt to complement the concrete urban form.

There are numerous ways in which green space can be added to a streetscape, especially when considering the implied design of green streets and the related concepts of bio-retention or bio-filtration. The use of street trees and other forms of landscaping are indispensable to successful street design, and greatly assist in stormwater management, traffic calming, while both increasing environmental benefits and improving the general atmosphere of any given street.

In utilizing trees as a central element in the "greening" of streets, attention must be paid to zone requirements and limitations, growth patterns and the implications for traffic visibility issues, and the degree of maintenance required, specifically the responsibility for watering, pruning and leaf collection. Regardless of these requirements, when considering planting trees along a street the size and placement of the tree canopy is an important element. In general, tree plantings should be continuous and spaced appropriately to create a constant canopy along the length of and across the width of the street. Deciduous trees are ideal as they provide summer shade and allow winter sun (Moving to Solutions 2006).

3.2 - Tree-lined street, Sacramento, California

The major challenge faced in planting trees in paved urban areas is the lack of adequate soil volume for root growth. When roads and developments are

constructed, soil becomes highly compacted to meet load-bearing requirements and engineering standards, consequently damaging roots and ultimately causing premature death of urban trees. One innovative solution that successfully addresses these issues is structural soil. According to the Urban Horticulture Institute of Cornell University, structural soil is:

> "is a designed medium which can meet or exceed pavement design and installation requirements, while remaining root penetrable and supportive of tree growth… The materials involved are gap-graded gravels made up of crushed stone, clay loam, and a hydrogel stabilizing agent, all of which can be compacted to meet relevant pavement design requirements yet allow for sustainable root growth. The new system essentially forms a rigid, load-bearing stone lattice and partially fills the lattice voids with soil (Bassuk, Grabosky, Trowbridge and Urban 2005)."

Structural soils are especially relevant in highly urbanized areas where the use of tree-grates is generally more appropriate than linear sidewalk planters.

While street trees are an essential component, various other landscaped elements provide additional opportunity for stormwater management, pedestrian buffering, and streetscape decoration. These elements can include but are not limited to: sidewalk planters and planted medians, bulb-outs, and traffic circles.

traffic calming

According to Jeff Kenworthy of the Institute for Sustainability and Technology Policy at Murdoch University, traffic-calming applications have six major objectives: to reduce the severity and number of accidents in urban areas; to reduce local air, noise pollution and vehicle fuel consumption; to improve the urban street environment for non-motor car users; to reduce the car's dominance on roads by reclaiming road space for living space; to reduce the barrier effects of motor traffic on pedestrian and cycle movement, and to enhance local economic activity by creating a better environment for

for people (Kenworthy 2000). These objectives can be accomplished through various methods.

One approach to traffic calming involves slowing traffic through use of such common methods as adding a strong vertical element in the form of large trees planted along the streets, the use of planted curb extensions, and the designation of chokers and marked bike lanes. All of these create the perception of a narrower street, even though the lane width has not physically been altered, and encourage drivers to decrease their vehicle speed. Throughways without these amenities tend to appear wide and free of hazard, ultimately encouraging higher speeds. Even the addition of on-street parking can significantly alter how drivers see the width of the road.

Traffic calming treatments also include measures to physically change the path of the traveling vehicle with roundabouts, planted traffic circles, “chicanes”, lane centerline shifts and other various lane diverters. These obstacles, on an otherwise straight path, tend to force drivers to reconsider their speed and slow accordingly.

Measures that make higher speeds uncomfortable for drivers - speed humps, tables, raised intersections or crosswalks, rumble strips or an assortment of pavement treatments - are also seen as successful approaches used in traffic calming.

walkability

As Boulder, CO based transportation planner Jim Charlier states, “Walking is a critical human function, and urban streets must be designed with pedestrians in mind (Hawley 2009).” So how does a community create “walkable” streets? Many essential components and amenities go into creating and sustaining a walkable street including safety measures, human-scaled dimensions and the creation of a pleasant walking environment.

First and foremost it is essential that pedestrians feel safe on the street, regardless of traffic speed or volume. Pedestrian safety and comfort is directly related to the width of sidewalk, and to the extent pedestrians using them are buffered from vehicular traffic. Sidewalk width should be directly proportional to pedestrian traffic, and should provide adequate space for all activities including loading and unloading of people at on-street parking, through walking traffic, window shopping traffic, and use of street furniture (Moving to Solutions 2006). Physical barriers including bicycle lanes, on-street parking and sidewalk planters all contribute significantly to how safe a pedestrian feels on a street.

One obvious safety issue for pedestrians on any street is intersection crossings or crosswalks. Pedestrian crossings are best located at intersections as opposed to mid-block placement (Moving to Solutions 2006). At crossings, there are various methods available to increase the safety of pedestrians including special paving treatments to separate the pedestrian realm from the travel-way realm, noticeable signage, clear crosswalk signals and ample stopping space separating stopped cars from pedestrian crosswalks.

3.3 Downtown Walnut Creek crosswalk

Along with designed safety measures, people tend to feel most comfortable and protected when they are in “human-scaled” spaces (Nozzi 2009). Vertical relationships should not be disproportionate to pedestrians or bicyclists, and street amenities such as lighting, signage and storefront awnings should all contribute to a feeling of being in an outdoor “living room”.

bicycle access

Successfully incorporating increased bicycle access on a street, involves much more than simply adding lanes. Safety, width, connectivity and bicycle amenities all play significant roles in determining how well streets support this type of traffic.

Safety is the overriding element when considering the movement of cyclists. When bicycles share the roadway with motorists, there is an inherent danger to the bicyclists, and conversely when they share the pedestrian way, they endanger pedestrians – it is therefore essential that bicyclists be given a separate right-of-way. Most commonly this is done by painting or “striping” a bicycle lane of a given width, which has a lot to do with how safe it feels. According to the California Highway Design Manual a striped bike lane sharing a roadway, or Class II Bikeway, must be a minimum of 5ft in width, and if parking volumes are high or 35 mph, additional space is needed (Department of Transportation 2006). The only case in which a striped bicycle lane may not be needed is in a residential setting where the roadway is considered shared space. In this case, both motorists and bicyclists are required to share the travel way with absolutely no lane designations. This is a common standard for residential streets in Davis, CA.

Connectivity to other bike routes, trails, commercial and residential districts, is another key component in successfully increasing bicycle accessibility. If people are being encouraged to use bicycles more, they need to be provided with the most direct and convenient routes to

to take them where they would be going as if they were in a motorized vehicle. Bike paths leading to nowhere, do not encourage use for anything other than weekend exercise or recreational rides.

To successfully support bicycle traffic and encourage activity along a bicycle route, appropriate amenities are essential. The most obvious and fundamental amenity would be adequate bicycle parking which can take the form of “u-type” or “grid-style” racks, covered bike lockers or pods or even storage rooms specifically for bicycle parking.

3.4 - Bicycle parking (fabb-bikes.org)

livability

In terms of green street design, the livability of a street is partially determined by how successfully elements of stormwater management, green space, walkability and bicycle access are all combined, and how well they function together. Through design, a livable street prioritizes people and all their activities – shopping, eating, observing, driving, bicycling, resting, etc. while still providing functionality and aesthetics to a streetscape.

[chapter 4]

the benefits of going green

The creation of green spaces within and around urban areas, is not merely a current “fad” or popular “in” concept for city planners, transportation engineers landscape architects and other design professionals. The inclusion of green areas in urban design carries with it numerous environmental, social and economic benefits, all of which can be long term in nature, and continue bringing benefits for years to come.

environmental

The most apparent and immediate benefits provided by green streets and sustainability concepts are environmental. Stormwater management, green space (in just about any form), traffic-calming strategies, and implementing methods that encourage pedestrian and bike use are positive assets to an environment regardless of where, how, or to what extent they are included.

Stormwater managament is a key environmental benefit. Stormwater is a term describing the flow of water resulting from precipitation that occurs immediately after rainfall or snowmelt. (N.C. Division of Water Quality). As water flows over various urban and suburban surfaces, it has the potential to pick up numerous polluting substances and debris. According to the U.S. Environmental Protection Agency, the health effects of this pollution on the public in general can be extremely detrimental in six major ways:

1) Sediment gathered from roadways and parking lots in the form of tire wear, brake linings and motor oil, can cloud the water, making it difficult or impossible for aquatic plants to grow. Sedimentation can also lead to the destruction of critical aquatic habitats such as marshlands and estuaries, both of which constitute an integral component of the food- fish chain upon which many depend for daily sustenance.

2) Excess nutrients entering the water, particularly those originating from fertilizers and industrial processes using nitrates and phosphates, can trigger massive algae blooms. When algae die and sink to the bottom of a river, lake, or ocean, the resulting decomposition removes oxygen from the water. Fish and other aquatic organisms can't exist in water with low dissolved oxygen levels, and stagnation followed by death of the aqua system ensues.

3) Bacteria and other pathogens often wash into swimming areas and public beaches, thus creating health hazards and often making beach closures necessary. Surfers in particular who ignore "pollution hazard" warnings at ocean beaches to ride the big waves usually associated with storms, frequently pay the price with conditions ranging from skin and eye irritations, to internal reactions.

4) Debris - plastic bags, six-pack rings, bottles, and cigarette butts - washed into bodies of water of all sizes, often choke, suffocate, or disable aquatic life like ducks, fish, turtles, and birds. For many, it is often a slow, painful and unnecessary death.

5) Household hazardous wastes including insecticides, pesticides, paint, solvents, used motor oil, and other auto fluids improperly disposed of, can poison aquatic life. Land animals and people can become sick from eating diseased fish and shellfish or ingesting polluted water.

6) Polluted stormwater, especially during periods of flooding, often enters a city's drinking water system resulting in human health consequences and significantly increasing treatment costs for the drinking water supply. (epa.gov)

4.1 - Rogue River drainage, Oregon (frw.ca)

Green street designs work to manage polluted stormwater on site, most often absorbing and filtering the water to make it less environmentally detrimental to receiving bodies of water.

From an ecological standpoint, green space, among its many positive attributes, has the ability to create habitats and allow for increased linkage between existing habitat corridors and greenways. Planted areas have the capacity to become homes for birds, small

creatures and tend to attract bees, insects and other organisms. These inhabitants are essential in creating healthy urban ecosystems and determining the overall sustainability of an eco-community.

Reducing the amount of paving on a street (and replacing it with vegetated areas) also decreases the urban heat island effect, which can best be described as an urban area that experiences considerably warmer temperatures than its surrounding, more rural, areas. The higher temperatures encountered in urban areas increase energy demand for cooling, typically resulting in greater emissions of air pollutants and greenhouse gases (epa.gov). Green spaces replace or shade areas that would otherwise be absorbing solar radiation, and also assist in cooling indirectly through evapotranspirational cooling, a natural process in plants.

Trees and plants provide the added function of absorbing some of the carbon dioxide and other air pollutants that tend to plague urban areas. A mature tree can absorb CO2 at an astonishing rate of 48 lbs. per year. (McAliney 1993).

Designing for bikes and pedestrians ultimately benefits the environment: effortless access to these facilities promotes modes of transportation other than driving. Bicycling reduces fuel consumption, air and water pollution, greenhouse gas emissions and is a viable method of transportation, especially in an urban setting. Walking has much the same benefits.

social

The built environment has obvious potential to influence social interaction and physical activity; and by developing and incorporating green street design, there exists added possibility of creating more enjoyable social spaces and increasing opportunity for interaction and activity.

The most apparent social benefits green streets provide are the increased opportunity for physical activity. The claim can be made that if expanded opportunity is created through street design for improved walkability, bicyclibility and general livability, than physical activity would ultimately increase.

4.2 - Kids running on street sidwalk (walkablestreet.org)

Incorporating greenery into a streetscape has also proven to induce a calming effect for both motorists and residents. A study conducted by the University of Washington indicated that the stresses of driving and commuting were lessened significantly when exposed to “roadside nature”. For many who live in dense urban areas, or spend much of their day in places devoid of contact with anything but concrete, steel and glass, the inclusion of greenery of any kind can have a calming effect on nerves already frayed by an artificial and sterile environment. A study in the Netherlands, exploring the relationship between health and green space, further concluded that people in a greener environment report fewer health complaints, and have better perceived mental health (Erewash Borough Council 2007). Likewise, green space can also have an effect on the overall “mood” of an area. Green space works to visually change the appearance of blighted areas.

These shaded streets, wherever they occur, represent a haven from the sun in summer time and draw people to an area, especially if benches and other sitting places are provided. These outdoor “living rooms” foster social interaction and community.

4.3 - Sidewalk cafe, Seret, France (livablestreets.com)

Green streets in particular, also have the added opportunity to be educational. As they are relatively underutilized, there is importance in educating the public on their goals or benefits. Green space can often function as an “outdoor classroom” offering formal and informal learning opportunities for schools and communities.

economic

Although it may be counterintuitive, (because why would you leave green when you could build?) green space has noteworthy and in some cases well documented, economic advantages.

For example. green space along a street provides a pleasant environment for commercial establishments to thrive. A study conducted by the Georgia Urban Forest Council found that “shoppers are willing to pay up to 11 percent more for products purchased in shops along tree-lined streets than they pay for the same items in a barren setting (Buscaino, Toomey 2005).”

While often only thought of in beneficial environmental terms, the management of stormwater can also provide economic benefits when viewed in terms of nearby downstream effects. When stormwater runoff is managed successfully, it can produce noteworthy reduction of costs of pollution treatment mainly by reducing costs associated with water treatment. By reducing peak runoff volumes, stormwater management ultimately decreases related treatment storage costs and overflow damages (Braden and Johnson 2004).

[chapter 5]

designing streets

While many state and local government agencies actively set policy and guidelines for street design, for the purposes of this project, the focus will be on the design policies outlined by AASHTO, a national organization whose guidelines are used consistently by transportation engineers, planners, landscape architects and urban designers and the California Department of Transportation Highway Design Manual.

AASHTO, is an acronym for the American Association of State Highway and Transportation Officials, a

> "nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. It represents all five transportation modes: air, highways, public transportation, rail, and water. Its primary goal is to foster the development, operation, and maintenance of an integrated national transportation system (transportation.org)."

They set standards and publish specifications, test protocols and guidelines that are greatly used within the transportation and planning professions. Information about AASHTO can be found at www.transportation.org

AASHTO publishes A Policy on Geometric Design and Highways and Streets, also known as the Green Book, which contains nationally accepted guidelines for designing geometric elements of streets and highways. Updated in 2004, this publication will be primarily what directs the recommendations outlined in this guidebook.

The California Department of Transportation, a government agency that provides standards for the state of California, also publishes their own set of guidelines for highway design in California. While heavily conformed to AASHTO standards, where standards differ, predilection will be given to their guide, the Highway Design Manual.

a functional classification system

Since different streets serve different purposes, a functional classification system, which is a hierarchy of street designations, provides a framework for identifying which street elements to include in a street's design. The general classification system used is based on the fact that "roads and streets do not serve travel independently. Rather, most travel involves movement through networks of roads and can be categorized relative to such networks in a logical and efficient manner (AASHTO 4)." Street design and the implementation of green streets are thus significantly dependent upon functional classification among other things.

Depending on the area in which highways, streets or roads are located; they are categorized as urban or rural roads. While there is much debate centered on exactly defining the difference between rural and urban, according to the Federal Highway Administration in Section 101 of Title 23, U.S. Code, urban areas are those places

within boundaries set by the responsible State and local officials having a population of 5,000 or more. Rural areas are those outside the boundaries of urban areas. (fhwa.dot.gov). For the purposes of this project, the focus will be primarily on the urban functional classification system, which consists of the following organizations:

Urban Principal Arterial System

According to AASHTO, who divides arterial systems into principal and minor systems, a principal arterial "serves the major centers of activity of urbanized areas, the highest traffic volume corridors, and the longest trip desires and carries a high proportion of the total urban area travel even though it constitutes a relatively small percentage of the total roadway network (AASHTO, 2003 11)." This category includes interstates, freeways, and any other large transportation systems that transect urban areas. For this reason, principal arterial streets will not be included in these design guidelines, as their considerable size, traffic speed and use make them inhospitable to the major goals or green street design. A Northern California example of an urban principal arterial system would be the Capitol City Freeway (or Interstate 80 Business) located in Sacramento, CA. For general design consideration, see page ?

5.1 - Capitol City Freeway, Sacramento, CA (Google Earth)

Urban Minor Arterial System

Streets that interconnect with and augment urban primary arterials are classified as urban minor arterials (AASHTO 2003). Generally, these types of major streets include controlled intersections (e.g., traffic signals, stop signs, etc.) and carry the traffic of local and collector streets to

and from the freeway and other principal arterial systems. Minor arterial streets in an urban setting provide many opportunities to benefit from green street design. A Northern California example of an urban principal arterial street would be The Embarcadero in San Francisco, CA. For general design consideration, see page ?

5.2 - Embarcadero Blvd., San Francisco, CA (Google Earth)

Urban Collector Street System

Essentially, a collector street can be classified as a street for traffic moving between arterial and local streets. Unlike arterials, urban collector streets can move through residential neighborhoods and channel local traffic (AASHTO 2003). A Northern California example of an urban collector street would be Anderson Road in Davis, CA. For general design considerations, see page ?

5.3 - Anderson Rd., Davis, CA (Google Earth)

Urban Local Street System

Urban Local Street System: “The local street system comprises all facilities not in one of the higher system (AASHTO, 2003, 12).” The main objective of a local street is to provide direct access to properties, and thus also known as residential streets. They are primarily designing to discourage through traffic and deter high speeds. The urban local street definition can also be applied to suburban local systems. A Northern California example of an urban local street would be E Street in

Sacramento, CA. For general design consideration, see page ?

5.4 - E St., Sacramento, CA (Google Earth)

The design guidelines in Chapter 7 will be categorized accordig to this functional classification system. While other systems exist, this particular one is the most basic and therefore is most applicable in a wide number of situations.

[chapter 6]

case studies

As in many instances, there is no reason to “reinvent the wheel”, the streets selected for examination as case studies have already been designed, constructed and lend themselves to study and analysis. These successful examples of street design will serve to further determine and formulate proposed design guidelines. The following streets exemplify contemporary thought in green design and applications including not only storm-water management, but also concepts of walkability, bicycle access and general livibility.

SE Siskiyou Street - Portland, Oregon

SW 12th Avenue - Portland, Oregon

Embarcadero Boulevard - San Francisco, California

6.1 case study analysis chart

	SE Siskiyou St. (Portland, Oregon)	SW 12th Ave. (Portland, Oregon)	Embarcadero Blvd. (San Francisco, California)
Street Type	LOCAL	COLLECTOR	ARTERIAL
# of Lanes	1-2	2	4
Lane Width	14 ft. combined travel lane	13 ft.	11-12 ft. with 10 ft. turn lane
Posted Speed Limit	25 mph	35 mph	45 mph
On-Street Parking? (width if applicable)	Yes, 7 ft. wide adjacent to bulb-outs	Yes, 8 ft. wide on street	Yes, 8 ft. wide on street
Median? (width if applicable)	N/A	N/A	Approx. 50 ft.
Bike Lane? (width if applicable)	No bike lane present	No bike lane present	Yes, bike lane present, approx. 5 ft. wide on street
Sidewalk Width	6 ft.	6 ft.	18 ft.
Bulb-outs? (# and width if applicable)	2 mid-block, planted, at 7 ft. wide each	None present	Yes, at crosswalks, multiple
Planting Strip? (width if applicable)	Present, 3.5 ft. wide, both sides of street	Stormwater planter at 4 ft. wide	Multiple sidewalk planting and tree wells

6.2 se siskiyou green street project

LOCATION	NE Portland, Oregon between NE 35th Pl. and NE 36th Ave.
DATE DESIGNED/PLANNED	Designed in 2002
CONSTRUCTION COMPLETED	Completed in October 2003
CONSTRUCTION COST	$20,000 for stormwater retrofit to existing street
SIZE	Captures runoff from approx. 9,300 ft. of paved surface
LANDSCAPE ARCHITECTS	Kevin Robert Perry, Nevue Ngan Associates
CLIENT/DEVELOPER	Sustainable Stormwater Management Program, Portland
CONSULTANT/ARCHITECT	The City of Portland
MANAGED BY	Portland Parks and Recreation

context

This particular portion of NE Siskiyou Street is located between NE 35th Pl. and NE 36th Ave. in a primarily residential neighborhood of Northeast Portland, Oregon. The area is one of mainly single-family dwellings, with the closest major arterial being NE 33rd Ave. It is part of a lengthier NE Siskiyou Street that runs from approx. NE 7th Ave to NE 89th Ave. and disconnects at NE 35th, where it briefly turns into NE 35th Pl. and just before the section under review. This particular “green” section is approximately 245 ft. long, breaking off from the larger NE 35th Pl. NE Siskiyou Street and not establishing itself again until NE 42nd Ave.

6.3 - Portland contextual map

site analysis

This portion of NE Siskiyou Street is bounded on two sides by single-family residences, with equally low-traffic local roads running perpendicular. A canopy of large deciduous trees frame both sides of the street. There are six residential driveways located on this street.

6.4 - NE Siskiyou Street, Portland, Oregon

project background and history

In 2003, Portland's Bureau of Environmental Services- specifically the Sustainable Management Team- undertook the NE Siskiyou Green Street Project as part of the department's "on-going evaluation of techniques for managing runoff from streets (Siskiyou Report 2005, 2)." The purpose of this specific retrofit project was to serve as a demonstration site for similar projects throughout the city, and is considered to be the first of its kind within Portland. Landscape architect Kevin Robert Perry, a designer employed by the Bureau, finalized the design.

genesis of the project

The NE Siskiyou Green Street Project was initially developed to test new stormwater management technology and if successful, to improve existing techniques with the overarching goal of recreating the project elsewhere. Portland's Bureau of Environmental Services created the program specifically to analyze stormwater management and to develop more successful approaches in dealing with the copious amounts of seasonal water runoff in the city of Portland. The Sustainable Stormwater Management program strives to create "management systems

that mimic nature by integrating stormwater into building and site development, [believing that it] can reduce the damaging effects of urbanization on rivers and streams (www.portlandonline.com)." The main goal of this project was essentially to remove this portion of NE Siskiyou Street from the cities storm/sewer system, and instead manage the stormwater locally. According to the American Society of Landscape Architects in its documentation and award for the NE Siskiyou Green Street Project in 2007,

> "this street retrofit project demonstrates how both new and existing streets can be designed to provide direct environmental benefits and be aesthetically integrated into the neighborhood streetscape (asla.org)."

design and development

Approximately $20,000 worth of stormwater retrofit was implemented on this section of the larger street which was selected on the basis of various site-specific criteria. For one, "city traffic engineers considered the low-traffic residential setting ideal for a demonstration project (Siskiyou Report, 2005, 3)." The proposed catchment area was also studied and was deemed to be generally representative of conditions in the surrounding areas, as well as possessing the appropriate space needed for curb extensions. Little conflict existed in terms of utilities, nor the need to eliminate existing parking spaces. The street slope measured at 2% and was considered suitable for this demonstration. The site lent itself to easy monitoring, as the configuration of the local sewer allowed for placement of a flow metering device. (Siskiyou Report 3) Kevin Robert Perry, a landscape architect employed by Portland's Bureau of Environmental Services, finalized the design in 2003.

One of the most important elements of the design and development process was community involvement. "Public outreach to the residents was extensive to assure acceptability and consensus (asla.org)."

role of the landscape architect

Kevin Robert Perry, a graduate of UC Davis Landscape Architecture, was the primary landscape architect of the project. A storm-water management specialist, Perry has been successful in creating a variety of projects similar to NE Siskiyou Street.

6.5 - Inside curb extension catchment

primary program elements

Program elements include:

- Residential parking
- Curb extensions with built-in catchment areas
- Check-dams for water filtration
- Aesthetic/functional plantings
- Pedestrian sidewalks
- Street calming elements
- Educational placards describing project, goals, etc.

6.6 - Educational placard at site

maintenance and management

In accordance with agreed upon maintenance procedures, adjacent property owners in conjunction with the city will be responsible for irrigation needs, although irrigation in the 2-year start up period was considered minimal. The city will be responsible for further maintenance including weeding, trimming, planet replacement and debris removal. Long term maintenance arrangements were made by the Portland Environmental Services Department in 2005. (Siskiyou Report, 2005)

peer reviews

The NE Siskiyou Green Street Project Landscape Architect Kevin Robert Perry has won numerous awards for his storm water management and green street schematics, including an American Society of Landscape Architects Design Award in 2007 for NE Siskiyou Green Street (asla.org)

criticism

The NE Siskiyou Green Street Project seems to be without any major criticism as it is generally viewed as a positive public amenity. Public acceptance of, and participation in the maintenance of the landscaping, seems to be working well and both are key elements in the ongoing effectiveness of the project.

siginificance and uniqueness of project

This was Portland's first Green Street project implementing storm water curb extensions. The success of this project has influenced numerous other Green Street projects in the Portland region. The most impressive thing about this system is that it

> "manages nearly all of NE Siskiyou's annual street runoff- estimated at 225,000 gallons- and does so all within a local context, and even accommodates the equivalent load of the old city system (urbanneighborhood.com)."

The $20,000 cost of this project also showed city officials and the general public that something as beneficial as this can be generally low-cost and simple.

lessons learned

As the NE Siskiyou Green Street Project was primarily a demonstration project, it was heavily monitored and studied to determine what works and doesn't. To that end, numerous observations have yielded some useful data. For one, it was observed that during heavy rainfall the pea gravel used in the check dams tended to wash away, leaving exposed earth susceptible to erosion. It was also noted that sediment build up, especially in portions of the project that have full tree canopy cover, frequently blocked the first check dam in the series. (Swanson 2004). While on site, this particular issue was observed quite dramatically as leaves tended to block water from even entering the catchment basins.

Future designs should pay special attention to maintenance issues and ensure that debris is taken care of in a timely manner to alleviate any build-up.

major project features

- Two vegetated curb extentions - each approx. 7 ft. deep and 35 ft. long
- Native vegetation used, and densely planted
- Typical mature height of plants - less than 2 ft.
- Curb cuts which measure approx. 12" wide
- Multiple compacted clay and pea gravel check-dams

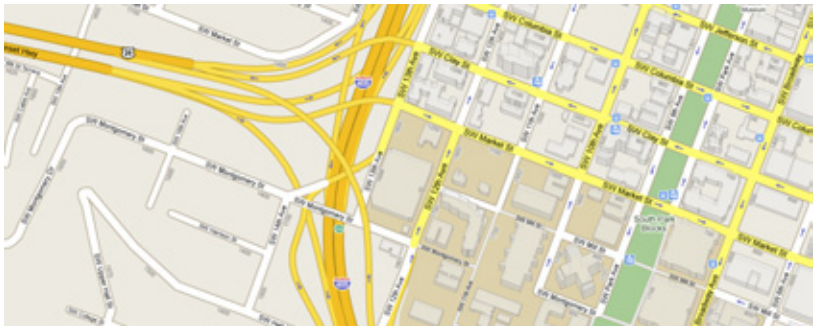
6.7 - Stormwater planter curb-cut

6.8 sw 12th ave green street project

LOCATION	Adjacent to PSU between SW Montgomery St. and Mill St.
DATE DESIGNED/PLANNED	Designed in 2004
CONSTRUCTION COMPLETED	Completed in May 2005
CONSTRUCTION COST	$38,850 for stormwater retrofit to existing street
SIZE	Captures runoff from approx. 7,500 ft. of paved surface
LANDSCAPE ARCHITECTS	Kevin Robert Perry, Nevue Ngan Associates
CLIENT/DEVELOPER	Sustainable Stormwater Management Program, Portland
CONSULTANT/ARCHITECT	The City of Portland
MANAGED BY	The City of Portland

context

This portion of SW 12th Ave. located between SW Montgomery St. and SW Mill St. in downtown Portland, Oregon, is a high-density urban setting near the 405 Freeway. It is situated directly between buildings of Portland State University and is part of a longer SW 12th Ave. that runs from approximately SW College St. to SW Stark St. where it becomes NW 12th Ave.



6.9 - Portland Contextual Map

site analysis

This section of SW 12th Ave. is bordered by Portland State University campus buildings on both sides of the street, and continues on further through the university campus itself. On the NNW border of the street is a university parking garage, while on the SSE are two residential halls, Stephen Epler Residence Hall and Joseph C. Blumel Residence Hall. The retrofit has taken advantage of the proximity to the residence halls with the runoff planters principally on that side. This side of the street is by far more aesthetically pleasing and much "greener" than the one opposite.

6.10 - SW 12th Ave Street Image

project background and history

This portion of SW 12th Ave. was constructed in the Summer of 2005 by Portland's Bureau of Environmental Service's Sustainable Management Team to demonstrate how an urban street could be retrofitted to "capture, slow, cleanse, and filtrate street runoff (12th Ave Report, 2005, 2)." Based on past successful stormwater retrofit projects, this one sought to highlight the environmental benefits that can be achieved by redesigning existing urban streetscapes. Landscape architect Kevin Robert Perry, known for his stormwater management design and retrofit projects, finalized the design.

genesis of the project

The SE 12th Ave. Green Street Project was developed in order to demonstrate the capacity of existing urban streetscapes for redesign to incorporate local stormwater management and to yield lasting environmental benefits. Before the retrofit took place in 2005, the

stormwater from this portion of SE 12th. Ave. (and the surrounding urban areas) drained directly into the Willamette River increasing the considerable pollution that already existed. This project sought to manage this stormwater onsite, using similar stormwater management techniques implemented in the NE Siskiyou Green Street Project constructed in 2003.

design and development process

A storm water retrofit costing approximately $38,850 was implemented on the site. This section of the larger street was chosen based on various site-specific criteria. First off, it was determined that the project would have no traffic impacts, an important consideration in an urban setting. Little conflict existed in terms of utilities with the original lighting remaining in place and design considerations made with regard to a gas shut-off valve on-site. The street slope was measured at 2%, and was considered suitable for this demonstration.

The site could be easily monitored, as the configuration of the local sewer allowed for placement of a flow monitor, and a nearby rain gauge allowed for easy rainfall event monitoring. (SE 12th Street Report 4). The main site specific issue was finding sufficient space to locate

> "the stormwater planters while minimizing conflict with other streetscape elements. It was difficult to accommodate pedestrians, on-street parking, street trees, landscaping, street lighting, signage, and stormwater planters within the 8-foot wide zone of space (asla.org)."

Kevin Robert Perry, a landscape architect employed by Portland's Bureau of Environmental Services, finalized the design in 2004.

role of the landscape architect

Kevin Robert Perry, was the primary landscape architect on the project. A stormwater management specialist, Perry has been successful in creating a variety of projects ranging from residential to urban.

primary program elements

Program elements include:

- On-street parking
- Four consecutive stormwater planters
- Trench-drains
- Pedestrian oriented sidewalks
- Educational placards describing project, goals, etc.

6.11 - SW 12th Ave educational placard

maintenance and management

General maintenance on the project include weeding, trimming, plant replacement and the removal of debris on a regular basis. For the initial two years of the project, the Portland Parks and Recreation Department were primarily responsible for maintaining the project, and during the first two years, removed debris and sediment four to five times. The City of Portland is principally in charge of continued maintanence. (SW 12th Ave. Report 2005)

peer reviews

The SW 12th Ave, Green Street Project Landscape Architect Kevin Robert Perry has won numerous awards for his stormwater management and green street schematics, including an ASLA Design Award in 2006 for this project.

criticism

While the SW 12th Ave Green Street Project has received little public criticism, an on-site interview conducted brought up one issue concerning local residents. A student at Portland State University who resides in the adjacent residence halls complained of sediment backup (mainly fallen leaves during the fall/winter seasons) lessening the aesthetic appeal of the planters and ultimately occasionally blocking the trench drains.

6.12 - SW 12th Ave. inlet

significance and uniqueness of project

This project was primarily built to demonstrate the ability of even highly urbanized streets to be retrofitted using “green street” principals and stormwater management techniques.

> “Although the project has a strong functional component, it is the integration of the landscaped stormwater planters into the urban environment that has gained the interest of the design community, developers, policy makers, and local citizens in the City of Portland’s commitment to promote natural systems to manage urban stormwater runoff (SW 12th Street Report, 2005, 2).”

The relatively low-cost of the project further showed how great an impact these retrofits could have on an urban setting with minimal financial impact.

lessons learned

One of the major lessons learned from the green street project on SW 12th Ave. was the importance of regular maintenance and debris/sediment removal. While on site, this issue was observed at every designed stormwater planter and an interview with a local resident confirmed that it was a major issue. Without proper maintenance, these stormwater planters become less productive and less aesthetically pleasing.

As this project used a new strategy for stormwater management, different then methods used for previous projects, such as NE Siskiyou in Portland, Oregon, issues with drainage, particularly forcing runoff to turn 90 degrees into curb cuts, came into play. This issue was resolved successfully using asphalt berms to facilitate water to enter inlets.

major project features

- 4 vegetated stormwater planters - each approx. 7 ft. deep and 18 ft. long
- Densely planted with vegetation tolerant of both wet and dry soil conditions
- 12” curb cut with ornamental trench drain
- 3’ parking egress zone
- Street trees placed in planters

6.13 - Kids walking down SW 12th Ave.

6.14 embarcadero boulevard

LOCATION	NNE Downtown S.F. between Bay St. and Harrison St.
DATE DESIGNED/PLANNED	Process began in 1990
CONSTRUCTION COMPLETED	Completed in 2002
CONSTRUCTION COST	Approx. $570,000,000
SIZE	Approx. 3 miles long, proving approx. 5 acres of open space
LANDSCAPE ARCHITECTS	Martha Ketterer, Project Lead, Dept. of Public Works
CLIENT/DEVELOPER	Port of San Francisco
CONSULTANT/ARCHITECT	S.F. Dept. of Public Works Bureau of Engineering
MANAGED BY	Port of San Francisco

context

The Embarcadero is a large stretch of arterial roadway located in the NNE portion of downtown San Francisco between Townsend Street and Taylor Street. The particular portion of Embarcadero Blvd., named Herb Caen Way in honor of a San Francisco Chronicle columnist, being studied is located between the South Beach Pier and Pier 39. High-rise urban development borders Embarcadero Blvd. on one side, and the San Francisco Bay on the other.

6.15 - San Francisco Contextual Map (Google Maps)

site analysis

This arterial is a landmark site for San Francisco, serving as a major circulation corridor for pedestrians, bicyclists and motorists providing access to Port facilities and waterfront tourism. This portion of Embarcadero Blvd. is bordered on one side by various Port buildings and restaurants that sit atop the San Francisco Bay, and on the other side is a mixture of mid to high-rise residential, office, and commercial buildings that begin downtown San Francisco. There exists a great deal of on street metered parking as well pay lots. A bike lane runs the entire length of Embarcadero Blvd, and as observed, is used frequently. A public transit line runs down the center of the street, providing a pedestrian median with large palm trees. The Embarcadero Promenade, the Ferry Building, and the Ferry Building Plaza are all key points along the boulevard.

project background and history

Hard to believe in its current state, The Embarcadero was once considered an eyesore of the City of San Francisco originally built as a large connecting freeway originally planned to link the Bay Bridge and the Golden Gate Bridge, a plan that was never fully realized. Instead, the freeway acted as a concrete barrier, cutting off the waterfront of the bay from the rest of the city.

In 1989, the Loma Prieta Earthquake struck at a 7.1 magnitude, damaging the freeway structure to the point of closure, although it still stood. As traffic adjusted to the now closed artery, it proved the city could function without Embarcadero freeway, and after extensive support from various influential civic groups, in April 1990 plans for removal commenced. Ideas for a grand waterfront boulevard with a pedestrian promenade with multiple public space nodes began to take form.

genesis of project

The current design of The Embarcadero was developed as a great public space along the waterfront, replacing what was once a largely hidden industrial zone and freeway. The redesign of Embarcadero Blvd. included numerous public projects including the reintroduction of historic streetcars that run along a center median, a series of waterfront parks and plazas, a pedestrian promenade and a renovation of The Ferry Building. This dynamic multi-use boulevard was created not only to accommodate significant auto traffic, but also to provide residents and tourists alike the opportunity to enjoy the waterfront and utilize various alternative modes of transportation.

6.16 - View of the Embarcadero

role of the landscape architect

Landscape Architects Martha Ketterer, Scott Burbank, and Edward Chin of the San Francisco Department of Public Works took the lead on the project (Driscoll, 1996). The project team included landscape consultants Roma Design Group and Sasaki Associates, both of San Francisco, engineers at the San Francisco Department of Public Works Bureau of Engineering, and transitway designers from San Francisco Public Utilities Commission.

6.17 - Crosswalk at The Embarcadero

primary program elements

Program elements include:

- On-street parking
- Streetcar line through center median
- Wide pedestrian promenade
- Public space incorporation including plazas and park.

maintenance and management

Embarcadero Blvd. and The Embarcadero Promenade are managed and maintained by both the Port of San Francisco and the City of San Francisco.

peer reviews

The redesigned Embarcadero Blvd. has become a tourist attraction in itself and many contribute the success of the design for enlivening the waterfront. In an article published in Urban Land, “Changing Spaces: Adjusting to the Loma Prieta Earthquake and A New Economy”, Rose Evans touts,

> “The emergence of the waterfront as a major asset has created a public open space that redefines the edge of the city with a farmers market, marinas, historic trolleys, condominiums, and more. The waterfront is now lively and magnetic, filled with tourists, inline skaters, strollers and people just admiring the view and setting (Rose, 2003, 87).”

6.18 - Looking down Embarcadero Blvd.

6.19 - Ferry Building Street Vendors

criticism

While little criticism exists about the actual design of the project, detractors express concern about the connectedness of Embarcadero Blvd. to the rest of San Francisco. Mark Hinshaw, the director of urban design of LMN architects in Seattle observes that the elevated

sat so long at the site, than any development turned itself away from the waterfront, causing a disconnect between the city and the San Francisco Bay (Hinshaw 2002).

significance and uniqueness of project

This project was primarily conceived as a public space project, incorporating various elements to accommodate vehicular traffic, public transportation, bicycles, and pedestrians. Embarcadero Blvd. and The Embarcadero Promenade have become major assets to the city of San Francisco and its associated tourism industry.

lessons learned

One of the most difficult challenges of redesigning the Embarcadero is its excessive width and how to best make the street pedestrian friendly and accessible within the sizeable right-of-way. A promenant feature, which both contributes to increased accessibility and visually compressing the width of the street is a large median, which historic trolley cars run along. This median provides a “safe-haven” for crossing pedestrians as well as assist in traffic-calming, an essential element on a high traffic volume cooridor.

major project features

- Large pedestrian promenade
- Various parks and open spaces located along boulevard
- Historic trolley line running down median

[chapter 7]

design guidelines

Based upon the research that was gathered and the defined objectives, the following design guidelines are recommended for consideration in the planning of “green street” projects. The recommendations are intended as an ideal and can be applied mainly to new construction. The guidelines are categorized according to the three major street types that exist in most urban areas:

Urban Arterial Streets

Urban Collector Streets

Urban Local Streets

urban arterial streets

General Design Considerations:

- The normal range for urban arterial streets is between 4 and 8 lanes of combined travel space, depending upon available right-of-way.
- In some cases, streets can be narrowed to 3 lanes, and in which case, the lane closest to the center should be narrower with the lane closest to bicyclists designed wider to allow for increased safety.
- Lane widths of 11 ft. are used extensively for urban arterial street design. Depending on traffic-volume, lane widths of 10.5 ft. may be suitable. These widths apply through lanes, continuous two-way, and two-way lanes adjacent to a median
- At intersections where left hand turns are made, a left turn lane is desirable. A 10 ft. wide lane is acceptable with a two-foot wide medial separator.
- Center medians are generally desirable for urban arterial streets, width can range from 12-14 ft.
- Parallel parking is optional on urban arterial streets and should only be present where commercial or residential establishments exist, and in which case, they should be a maximum width of 7-8 ft.
- Urban arterials should be designed for 30-35 mph

7.1 - Sketch section of urban arterial

Stormwater Management:

- Elements of both bio-retention and vegetated filter strips should be implemented
- A combination of stormwater management strategies is more effective in managing runoff from urban arterial streets due to the large total surface area involved
- The following are appropriate methods and should be used in combination, as determined by site specific conditions and available right-of-way:
  - Planted Curb Extentions - exact dimensions vary depending on site dimensions, but should not extend beyong the alloted space for parking. Curb cuts should be present at strategic points to allow runoff water to enter planter. A mini-swale can be implemented within the extension, with appropriate plantings to be used as vegetative filter strips.

7.2 - Planted Curb Extension

  - Planted Median - Depending on the number of lanes provided right-of-way, a planted median is desirable. Swales and vegetated filter strips can be implemented to collect and clean runoff. If raised, the median must provide an adequate amount of curb cuts to allow stormwater runoff to enter system. If curb-cuts are angled at 90 degrees, asphalt berms should be added to facilitate water to enter inlets.

7.3 - Sidewalk Planter

— Sidewalk Planters - exact dimensions will vary depending on sidewalk width and available pedestrian traffic space. Sidewalk planters should only be placed where planted curb extensions do not exist. A swale and vegetative filter strip are also appropriate for use in sidewalk planters.

Green Space:

• Green space can be included in a variety of forms. Gven the objective of stormwater management, green space can be most effectively added through planted curb extensions, sidewalk planters and medians.

• Street trees are an essential green component of street design. Ideally, deciduous species should be chosen and spaced continuously at a given width dependent upon species. Spacing should work to create canopy over right-of-way.

• In highly urbanized areas, trees are best incorporated using tree grates with a structural soil base.

• Sufficient maintenance should be available to ensure quality of plantings and maintenance of aesthetic value.

Traffic - Calming:

- Lane widths can generally be reduce to 11 ft. where appropriate, with turning lanes designed to be 10 ft. wide. By making the lanes physically smaller, drivers become more aware and generally slow down.
- If appropriate, and dependent upon various factors including traffic volume and existing right-of-way, lanes can be dropped to implement what is known as a “road diet”.
- The addition of strong vertical elements, such as large street trees, should be added to make the street appear narrower.
- Making drivers more aware of the shared space is also another successful way in which to calm traffic. These elements can include pavement treatments and markings and appropriate street signage.
- Raised center medians with vegetation should be implemented where appropriate.
- Consider multiple-lane roundabouts

7.4 - Double lane round-about, Florida

Walkability

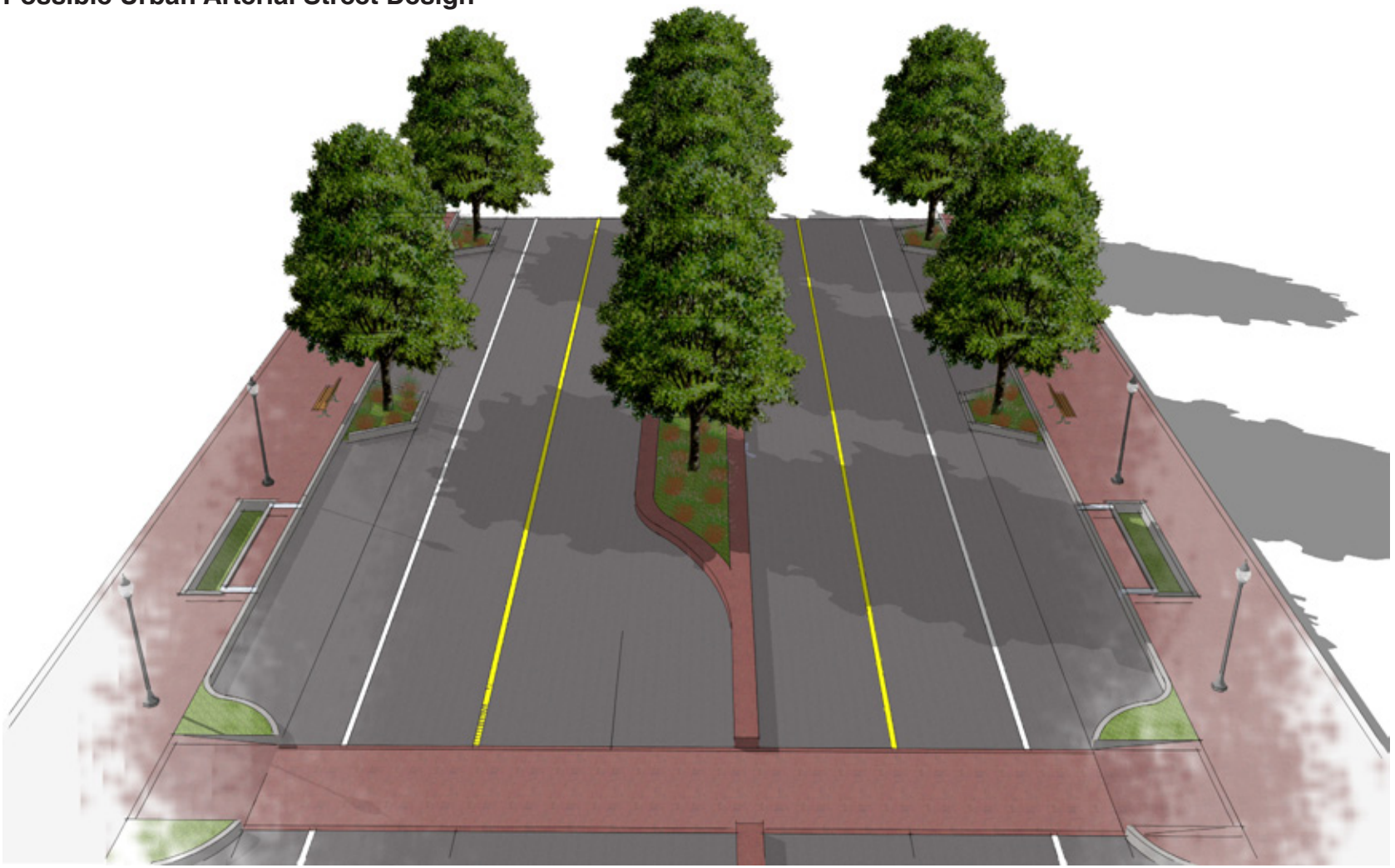
- Provide adequate width for all sidewalk uses. In commercial areas, provide an 8 ft. minimum width, with the desirable width range between 10 and 15 ft. This not only allows for pedestrian activity, but also for loading and unloading of people at on-street parking, window-shopping traffic, street furniture, and various local business activity including outdoor dining and vendors.

- Provide crosswalks at all controlled intersections. Avoid mid-block crossings unless necessary. Each crosswalk should be clearly designated as such and visiblly delineate the pedestrian realm through striping or other pavement treatements.
- Pedestrians should be adequately buffered from street traffic. Planters, tree wells, and light fixtures can all help in defining and shielding the pedestrian realm.
- Always consider human-scaled street amenities such as benches, lighting, planters, fountains and art installations.

Bicycle Access:

- Provide bicycle lanes within the street right-of-way with striping at a minimum of 5 ft. If directly next to a curb, 6 ft. is appropriate. A bike lane should never be striped larger than 7 ft., otherwise cars will think of it as a travel lane.
- Appropriate signage should be placed at strategic points to assist in reminding motorists that they share the roadway.
- Provide adequate bicycle amenities, particularly bike parking along heavily commercialized areas.

Possible Urban Arterial Street Design



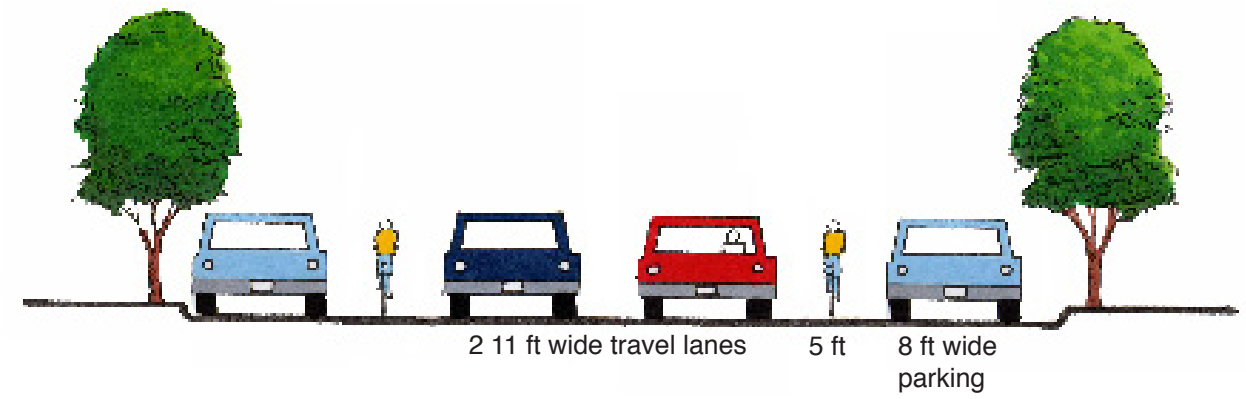
7.5 - Urban Arterial Street Design

Design includes a combination of stormwater management methods, a colored crosswalk and centered median

urban collector streets

General Design Considerations:

- The normal range for an urban collector street is between 2-3 lanes of travel combine, depending upon available right-of-way, street uses and traffic volumes.
- Lane widths of 10 - 11 ft. are acceptable for urban collector streets. These widths apply to through lanes, continuous two-way, and lanes adjacent to a painted or raised median.
- Parallel parking is generally needed if commercial or residential is present, and in which case should be a minimum of 8 ft. in width.
- Medians are optional on urban collector streets and generally are not needed. They should only be used where space permits and and multiple turn lanes do not exist.
- Urban collectors should be designed for 25 mph



7.6 - Sketch section of urban collector

Stormwater Management:

- Elements of both bio-retention and vegetative filter strips should be implemented.
- Depending upon available space, a combination of stormwater management strategies is most effective in managing runoff and should be implemented if possible.
- The following are appropriate methods and should be used in combination determined by site-specific conditions and available right-of-way.
  - Planted Curb Extensions
  - Sidewalk Planters
- Depending upon expected traffic volume, pervious pavement or concrete can be used in place of impervious materials, especially in allotted on-street parking. This allows for infiltration of stormwater into the ground soil, ultimately reducing runoff and assisting other methods in successful management.

Green Space:

- Green space can be added in very similar ways as an urban arterial street. Gven the objective of stormwater management, green space can be most effectively added through curb extensions and sidewalk planters. Medians are generally not needed on urban collector streets.
- Street trees are an essential green component of street design. Ideally, deciduous species should be chosen and spaced continuously at a given width dependent upon species. Spacing should work to create canopy over right-of-way.
- In highly urbanized areas, trees are best incorporated using tree grates with a structural soil base.
- Provide sufficient maintenance to ensure quality of planting and aesthetic value.

Traffic-Calming:

- On urban collector streets, lane width can generally be reduced to 10 ft. where appropriate
- The addition of strong vertical elements, such as large trees, should be added to make the street appear narrower.
- The use of varying pavement treatments can help to visually narrow street, particularly when implemented in space allotted for on-street parking.
- Lane diverters can be implemented to slow down traffic. Most appropriate for moderate traffic volume streets would be traffic lane diverters in the form of roundabouts, chokers, chicanes, or lane centerline shifts.
- Consider the use of speed humps, tables or raised intersections to further slow traffic.

7.7 - Chicane in Oceanside, CA (livablestreets.com)

Bicycle Access:

- Provide bicycle lanes within the street right-of-way with a striping at a minimum width of 5 ft.
- Appropriate signage would assist in reminding motorists that they share the roadway
- Provide adequate bicycle amenities, especially bicycle parking along heavily commercialized areas.

Possible Urban Collector Street Design

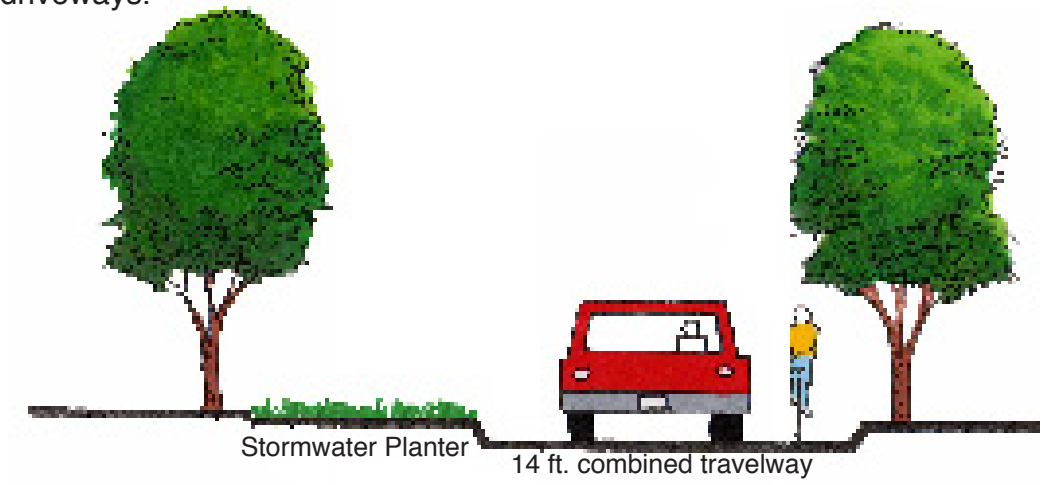
7.8 - Urban Collector Street Design

Design includes a combination of stormwater management methods and various traffic calming techniques

urban local streets

General Design Considerations:

- The normal range for urban local streets is between 1-2 lanes of travel combined, depending upon available right-of-way.
- Lane widths of 9-10 ft. are acceptable for urban local streets or even less if considered shared space roadways.
- Parallel parking is generally needed and should be a minimum of 8 ft. in width. Special consideration should be paid to residential driveways.
- Urban locals should be designed for 20 mph



7.9 - Sketch section of urban local

Stormwater Management:

- Elements of both bio-retention and vegetated filter strips should be implemented.
- Depending upon available space, a combination of stormwater management strategies is most effective in managing runoff and should be implemented if possible.
- The following are appropriate methods and should be used in combination determined by site-specific conditions and available right-of-way.
  - Planted Curb Extensions
  - Sidewalk Planters
- Due to the low traffic volume and speed of urban local streets, pervious concrete and other alternative pervi-ouse paving treatments can be used throughout road-way and sidewalk spaces, particularly on designated private roads or alleyways.

Green Space:

- Green space elements can be added in very similar ways to all other street types. Given the objective of stormwaterwater management, green space can most effectively be added through planted curb extensions and sidewalk planters.
- Street trees are an essential green component of street design. Ideally, deciduous species should be chosen and spaced continuously and uniformly, dependent upon type, at a distance to create significant canopy over righ-of-way.
- In highly urbanized areas, trees are best incorporated using tree grates with a structural soil base.
- Residential green space will also significantly contribute to the overall objective.
- Provide sufficient maintenance to ensure quality of plantings and aesthetic value.

Traffic-Calming:

- On urban local streets, shared space is acceptable. Driving lanes can be shared with bike lanes and can be reduced to a width of 20 ft. lanes of travel combined. Drivers can negotiate these types of streets depending on other motorists and bicyclists.
- Due to the general low-traffic volume and speed of urbal local streets, a variety of traffic-calming methods can be used. By themselves or in combination, the following are appropriate methods and should be used in combination, as determined by site-specific conditions and available right-of-way:
  - Strong Vertical Elements
  - Planted Curb Extensions or Bulb-Outs
  - Chokers
  - Roundabouts or Planted Traffic Circles
  - Traffic Diverters
  - Speed humps, Tables or Rumble Strips
  - Rasied Intersections of crosswalks

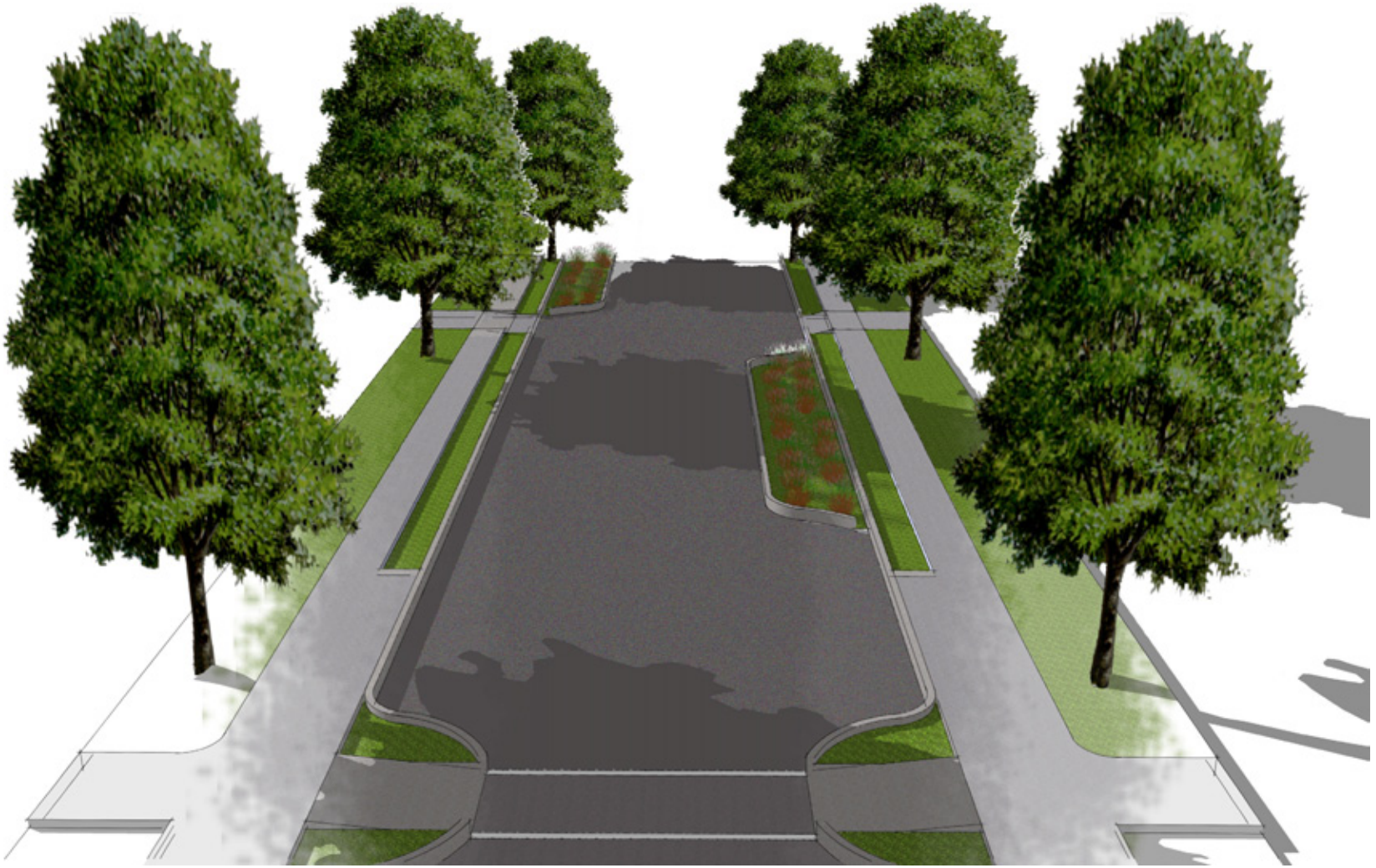
Walkability

- In a residential setting, sidewalk should range between 6-8 ft.
- Pedestrians should be adequately buffered from street traffic. Sidewalk planters can greatly assist in defining and shielding the pedestrian realm.

Bicycle Access:

- Due to the general low volume traffic and speed of urban local streets and residential neighborhoods, striped bicycle lanes are not needed, especially if significant traffic-calming methods have been implemented.

Possible Urban Local Street Design



7.10 - Urban Local Street Design

Design includes curb extension stormwater planters and various traffic calming techniques

[chapter 8]

the future of green streets

As awareness grows regarding the scope and breadth of the environmental degradation descending upon us, so too is an emerging recognition of the multi-faceted approach needed to deal with the problems. The battles must be fought at any and every level possible, from energy use and resource conservation, to sustainable applications in the way we design, build and live our daily lives. It makes perfect sense that streets and roads – given the vast distances and surface areas they cover – be included in an overall approach to creating a more people friendly and ecologically sustainable environment. As an integral component of any community, urban streets (and the way they are designed) have the capability to define the demeanor and livability of a neighborhood or downtown area. Rather than merely being a means of moving goods and vehicles from one point to another, a street planned with the “green concept” in

in mind, can give a social and psychological life to a community.

From a conceptual standpoint, the “green streets” movement is alive and growing as evidenced by the number of projects already in place or in planning stages in various cities across the country. On the West Coast, specifically in Washington, Oregon, and California, public reaction to the prpojects has been positive, and the overall benefits are continuously being evaluated.

The more critical area of concern with regard to green projects, is the response from the federal government which will inevitably involved in the funding and regulation of projects. Here too, the future also looks promising. Owing largely to an extensive lobbying effort by the Aamerican Society of Landscape Architects, approximately 30 legislators form both Congress and Senate have introduced the Complete Streets act of 2009. It is a broad, comrehensive piece of legislation that makes available federal monies for the “green” design and construction of transportation projects, with specific objectives in mind. As stated, the goals of the act are to: “improve pedestrian safety, encourage healthy and active lifestyles, help to mitigate climate change, and reduce dependence on foreign oil (Complete Streets Act 2009).”

As with any legislation, however, it is a slow process andone that requires a continuous and relentless effort to have enacted. The recognition is there however, that the “greening” of transportation projects and streets at both a state and national level is a desireable and positive way to go in designing with the future in mind.

In looking at the future of the green street movement, it seems Northern California is becoming increasingly aware and involved in the creation of standards for greening municipal streets. Although still behind such places as Portland and Seattle, the wave of change appears to be moving south.

In the Bay Area, two separate cities have taken on the task of producing viable guidelines to incorporate into city planning strategies. In San Francisco, the Better Streets Plan,

> "will result in a street system designed to promote human needs for the use and enjoyment of these public spaces by all. It will prioritize the needs of walking, bicycling, transit use, and the use of streets as public spaces for social interaction and community life (Better Streets Plan, 2007, 1)."

In San Mateo, the Sustainable Streets Program has become very successful in implementing street designs that manage stormwater through the use of pervious pavement and planters.

Closer to Davis, the City of Sacramento has designated a five-block long section of Dixieanne Avenue as a green street pilot project. Featured will be laying of sidewalks that have never had them, the installation of planter strips, and a storm water mitigation system.

Green street design

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