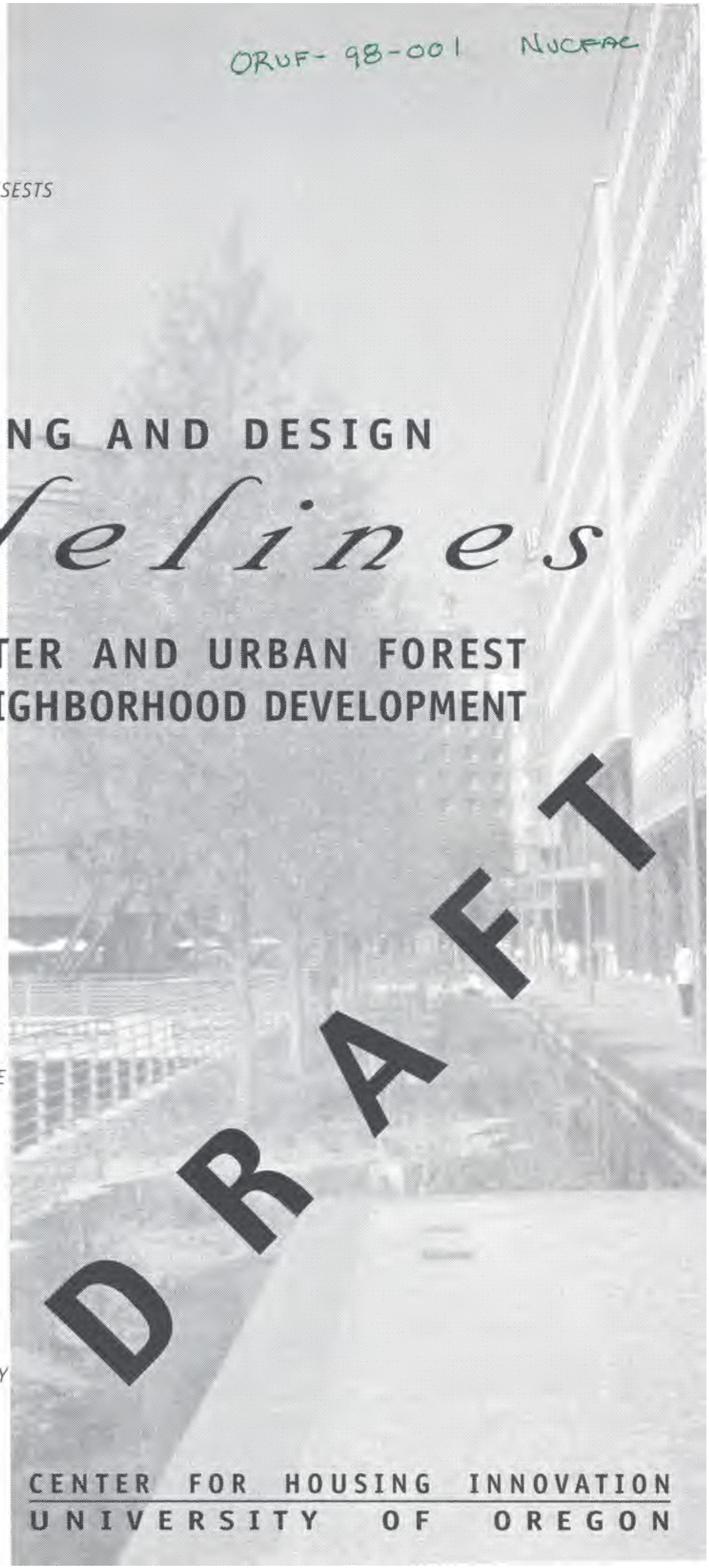
Protect And Enhance Environmental Assests

Reduce Air Pollution Sources

PLANNING AND DESIGN *guidelines* FOR AIR, WATER AND URBAN FOREST QUALITY IN NEIGHBORHOOD DEVELOPMENT



Enhance The Urban Forest

Protect And Augment Natural Drainage

Reduce Impervious Surfaces

Select Vegetation To Improve Water Quality

CENTER FOR HOUSING INNOVATION
UNIVERSITY OF OREGON

PLANNING AND DESIGN

guidelines

FOR AIR, WATER AND URBAN FOREST QUALITY IN NEIGHBORHOOD DEVELOPMENT

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ACKNOWLEDGEMENTS

Planning and Design Guidelines for Air, Water and Urban Forest Quality in New Neighborhood Development is based on work by Ronald Kellett and Cynthia Girling at the Center for Housing Innovation at the University Oregon, and the project 'Comparing the Value of Urban Forest in New Community Development' in particular. This project to compare urban forest opportunity in three neighborhood scale development patterns has been funded in part by the National Urban and Community Forest Advisory Council of the U.S. Forest Service, the City of Corvallis and Benton County, Oregon and Center for Housing Innovation.

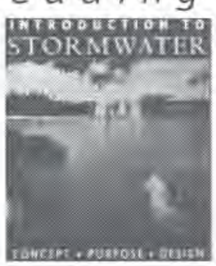
Many have made substantial direct and indirect contributions to this work. Most directly involved with this publication were our colleagues and students Jackie Rochefort who researched and compiled much of the guidelines on environmental assets, neighborhood water quality, urban forest and surface drainage; Christine Roe who researched and compiled much of the guidelines on impervious surfaces, Dior Popko who shaped and produced this publication and Leah MacDonald who formatted many of the mapped illustrations. In addition, Sarah Burrows, Prashant Gaba, Nicholas Kohler, Stephen Lamb and Kristen Lohse all made substantial contributions to the research, methods and computer-based tools upon which this publication depends. Many others have influenced this work. Chief among them the work of the Center for Watershed Protection and their 199_ publication 'Better Site Design: A Handbook for Changing Development Rules in Your Community' in particular, and also the work of Bruce Ferguson and his 1998 book 'Introduction to Stormwater: Concept, Purpose, Design.

We wish to publicly thank our project Community Advisory Group who helped develop and measure alternatives and define guidelines relevant to the Corvallis area. This group included Gary Feurstein of Endex Engineering, Roger Irvin, Jerry Davis and Al Kitzman of Benton County Planning and Development, Fred Towne of the City of Corvallis and the Robert Frankl of Oregon State University. We owe a similar debt of appreciation to our publication reviewers who included Mark Francis of the University of California-Davis, Bruce Ferguson of the University of Georgia, Cheryl Kollin of American Forests, Krista Reininga of URS Corporation, Alan Lowe of City of Eugene Planning and Development Department, Amanda Punton of Oregon Department of Land Conservation and Development Department, Ken Snyder of the Center for Excellence in Sustainable Development, and Don Yon of Oregon Department of Environmental Quality.

And finally, we thank Denny Egner and Lee Leighton of SRI/Shapiro Associates and Bill Lennertz and Lawrence Qamar of Lennertz Coyle, Architects and Town Planners for their work developing the Neighborhood Village Alternative and the opportunity to observe and document much of the process that created it.

Further Reading

Bruce K. Ferguson, 'Introduction to Stormwater: Concept, Purpose, Design', 1998.



Center for Watershed Protection, 'Better Site Design: A Handbook for Changing Development Rules in Your Community', 1998.

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FOREWORD

We are teachers and researchers, based in architecture, landscape architecture and planning, and affiliated with a housing research center at the University Oregon. Our work is broadly concerned with the growth of communities and its impact on the character and quality of life, place and environment. The models and methods of neighborhood planning and design within which we work, however, are shifting — from rule-based systems of codes and regulations toward more Local, collaborative and consensus-based systems of negotiated priorities and agreements (Abbott 1994). There is, as a consequence, an emerging need, and with it an opportunity, to cultivate the expectation and the means to integrate quality of Life, place and environment alongside the many factors, such as density or traffic or cost, already customary and familiar in public negotiation and decision-making of many communities.

Part of that need and that opportunity, we believe, is an absence of tools and techniques that make it possible to visualize, measure and compare environmental impact as quickly and easily as a community might measure and compare density or transportation networks or development costs. As a consequence, much of our work is focused on the development of tools and techniques that help communities become better informed about the options they consider and the choices and trade-offs they make about growth and development. We come to this focus in part out of concern that without appropriate tools, consideration of quality of life and envi-

FOREWORD

ronment will remain invisible or ambiguous, and therefore, poorly integrated with, perhaps in competition with, consideration of other more readily perceived and measured factors. This is a circumstance which we believe is particularly acute early in the planning and design process when, the opportunity is greatest to develop strategies that could result in better environmental performance and better overall performance at the same time but the means to make that case are as yet unfamiliar or undeveloped.

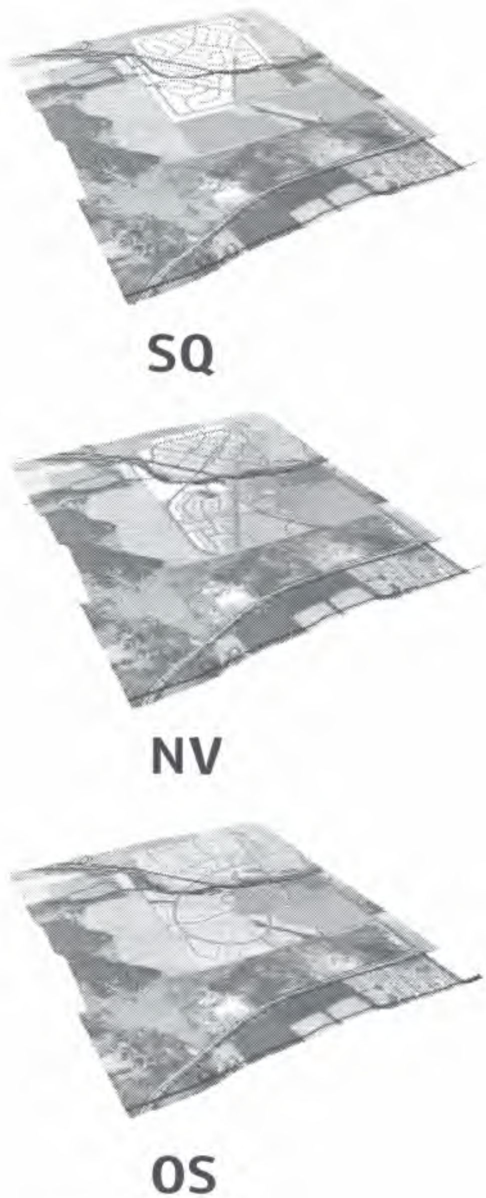
Which bring us to this publication. Informed negotiation and decision-making at the community level depends in significant part on an informed public equipped to discuss their interests and compare alternatives in equitable and substantive ways. And, being better informed is often more about access to the right information, in the right form at the right time than it is about more information in and of itself. The content and organization of this publication is intended to speak to the diverse constituency of Landowners, neighbors, developers, planners, designers, elected officials and members of the public who initiate, regulate or influence neighborhood scale planning and design within their communities. Through it, we hope these diverse of people of very different interests and agenda will be sufficiently better informed to ask the questions, seek out the instructive research and examples and make the frequent, measured comparisons that ultimately lead to better choices with more positive impact for air, water and urban forest quality in new neighborhood development.

REPORT ORGANIZATION

Planning and Design Guidelines for Air, Water and Urban Forest Quality in New Neighborhood Development was written to inform those in a position to initiate, regulate or influence neighborhood scale planning and design about air and water quality implications and opportunities in decisions they will be called upon to make in those roles. The information and advice within is drawn from many diverse sources, including a rapidly growing body of literature in the area and, experience gained from a research-based comparison of neighborhood development patterns.

To simplify the volume and potential complexity of the scope of this work, we have organized this publication into three major sections. An INTRODUCTION section outlines the principles and priorities that have shaped this effort and, findings and lessons learned from the neighborhood plan comparisons upon which the guidelines are based. A GUIDELINES section introduces the process view of planning and design that influenced the selection and organization of guidelines, outlines the 6 planning and design objectives toward which the guidelines are directed and presents each of 15 guidelines, by objective, and to a similar format. The REFERENCES section that concludes the publication cites and documents more fully the research findings, literature and illustrations upon which the Introduction and Guidelines are based.

RESEARCH BASIS FOR GUIDELINES



Side by side aerial views of plans draped on terrain model and airphoto

COMPARING THREE NEIGHBORHOOD PLANS

Planning and Design Guidelines for Air, Water and Urban Forest Quality in New Neighborhood Development reflects results and lessons learned from Comparing the Value of Urban Forests in New Community Development — a project to compare different neighborhood development patterns against measures of land use, transportation, cost and environmental impact. Three alternative neighborhood plans were created for a demonstration site (about 311 acres of valley floor land in the mid-Willamette Basin near Corvallis, Oregon) then measured and compared.

Each of the three alternatives represents a common neighborhood development pattern nation-wide. A conventional low density "Status Quo" (SQ) plan, represents many subdivision developments. A more dense Neighborhood Village (NV) plan represents a more compact and mixed use new urbanist pattern and a lower environmental impact "Open Space" plan (OS) represents similar density and land use mixes to the NV plan with greater open space, urban forest and stormwater features. Each alternative preserves different amounts of open space and pursues different approaches to infrastructure, urban forests and stormwater management.

Using computer-based planning and design tools developed at the University of Oregon, representative land use cases derived from field measured data are assigned to each of the three alternatives (Kellett 1997 and 1998 and Girling and Kellett, 1999 describe this process in detail). Based on these case assignments, each plan is inventoried for summary data such as land use area, dwellings, densities, building coverage, paving coverage, forest, tree and turf cover, and so on. From these inventories, measures of land use, environmental impact (such as impervious surfaces, areas of landscape, forest and habitat preservation, stormwater runoff and water quality) and cost are created and compared. CITYgreen (by American Forests) was used to estimate stormwater peak flows for both two year and ten year storm events. SUNOM (by the Center for Watershed Protection) was used to estimate annual water pollution loads associated with stormwater runoff. Land, infrastructure and urban forest costs used to

RESEARCH BASIS FOR GUIDELINES

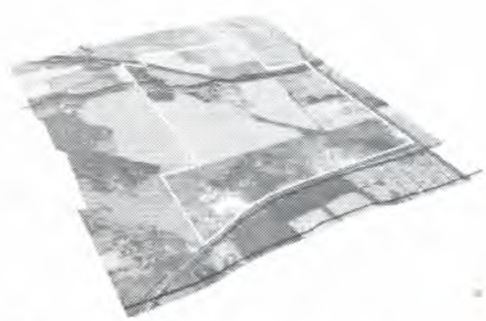


Figure
Illustrations of West Corvallis study site

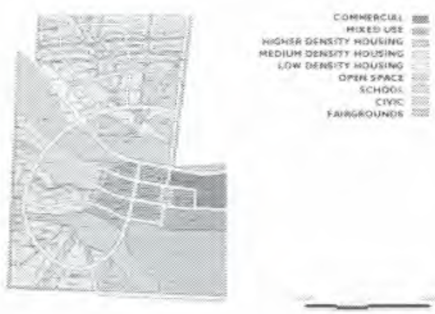
compare alternatives are based on specifications and costs common in the Corvallis area.

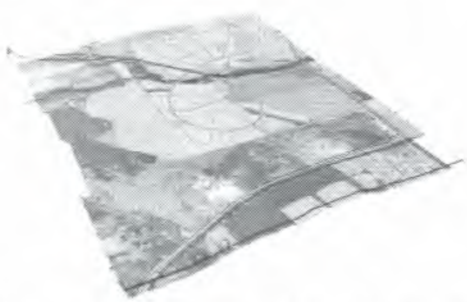
The results of these measurements demonstrate that development pattern matters. The physical planning and design characteristics of alternatives considered shape development patterns which in turn reveal significant differences against measures of land use, environmental impact, transportation and infrastructure cost. The following pages summarize the planning and design characteristics of each alternative and report some of the more significant measurement results.

A 311 acre site, west of current Corvallis city limits but within the Urban Growth Boundary, is one of six potential 'Neighborhood Villages' in a proposed growth management plan (1996). This area is constrained on three sides by permanent open space including a county park to the west and Oregon State University agricultural research facilities to the north and east. The majority of the site, with the exception of a 30-acre county fairgrounds, is in private ownership. Other existing land uses include a mobile home park, a convenience store, a ranch, pasture, hay fields and saw mills.

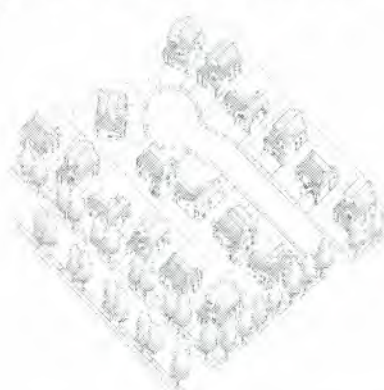
This site also presents a number of environmentally sensitive areas. Three perennial streams and associated tributaries pass through it. A Federal Emergency Management Agency floodway has been mapped along the larger one. The two smaller creeks have associated wetlands. The existing forest is approximately 27 acres of remnant oak stands and partially forested riparian vegetation along all three creeks. Bald Hill Park, a 275 acre natural park immediately to the west has an increasingly rare Oak-Madrone plant community and wildlife habitat spatially connected to the demonstration site via creek riparian corridors.

Illustration
Coraly Street, Eugene and many post-1960 subdivisions like it illustrate the character and scale of the Status Quo alternative.





Plan and aerial oblique view of Status Quo alternative.



Scheme illustrated was created by the Center for Housing Innovation based on prevailing City of Corvallis Comprehensive Plan (DATE) land use designations and comparable development patterns in the Corvallis area

STATUS QUO ALTERNATIVE

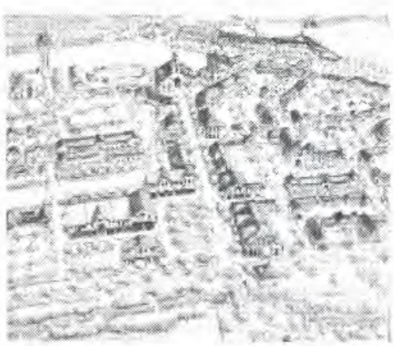
The Status Quo Alternative represents the lower density, primarily residential development pattern permitted under 1996 zoning. This plan is characterized by segregated land uses and densities, larger blocks and a street hierarchy of looping collectors and local cul-de-sacs. Housing is developed at two densities. Single family uses are typically low density (approximately 4 dwelling units per acre) on ± 8,000 s.f., back to back lots. Multi-family uses are located in the NE portion of the site at approximately 20 dwelling units per acre. Streets are typically have sidewalks and planting strips. Parking and garage access is from the street.

North and west portions of the plan are low density single family (average lot size 8,000 s.f.) land uses. A central intensive development portion accommodates a mix of commercial and residential uses with an overall gross density of 6 units per acre and greater. Along the south edge of the study area is the expanded Benton County Fairgrounds . Common green space follows the Corvallis fault line in the north portion of the site and connects to paths from cul-de-sac ends in other locations.

Street types and network layout conforms to City of Corvallis Transportation Plan (1996). The existing Oak Creek Drive has been expanded to a collector street within a 70' right of way. Loop roads in residential areas are collectors. Cul-de-sacs do not exceed 700' in length and serve no more than 18 households.

Illustration
Street of zero-lot-line houses at Northwest Landing, DuPont, WA, and many recent models of the 'new urbanism' like it illustrate the character and scale of the Neighborhood Village Alternative.

Plan and aerial oblique view of Neighborhood Village Alternative



Scheme illustrated was created by Lennertz Coyle and Associates with SRI / Shapiro and the West Corvallis North Philomath Plan Task Force based on proposed West Corvallis North Philomath Plan development guidelines.

NEIGHBORHOOD VILLAGE ALTERNATIVE

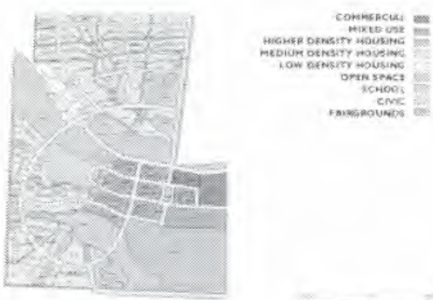
The Neighborhood Village Alternative represents principles of New Urbanism (cite New Urbanism book). This alternative is organized around a core of mixed land uses surrounded by an overall average gross density of approximately 8 dwelling units per acre and served by a gridded street network. Housing densities vary within the plan. Single family housing variations include some relatively low density (approximately 6 dwelling units per acre) conventional subdivision lots, higher density small lot and partially attached units (approximately 9 to 12 dwelling units per acre). Multi-family housing variations include rowhouses and apartments (approximately 12 to 20 dwelling units per acre).

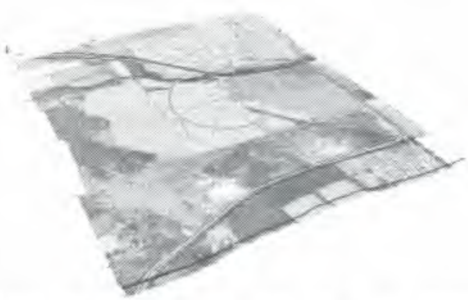
At the center of the neighborhood is a commercial area, shopping street and town square off W 53rd and Oak Creek Drive. Pedestrian-oriented commercial buildings front the shopping street. A larger anchor store, such as a grocery, sits between the shopping street and other more automobile-oriented uses on W 53rd. Mixed and higher density residential land uses are closest (within 1/4 mile) to this center. An elementary school is located on the west edge of the site with its play fields located in Bald Hill Park. The southern portion of the site accommodates expansion of the fairgrounds and a sports stadium. A 200 wide greenway along Oak Creek is set aside as a buffered riparian corridor. The North Fork of Squaw Creek is protected within a corridor that forms the center median of a divided street and accommodates a trail through the neighborhood to Bald Hill Park.

The street network is designed and scaled to create a well connected network of smaller streets and short blocks that accommodate bicycles, pedestrians and cars. Streets are narrower and buildings are sited close to the street. Planting strips, sidewalks and smaller, distributed open spaces offset the narrower streets and density. Garages are setback or accessed at rear yards by way of alleys. Distinct sub-neighborhood areas are defined by principal roadways and open space features. Each has a small associated green space. Some streets align with views of adjacent natural features such as Bald Hill and surrounding hillsides.

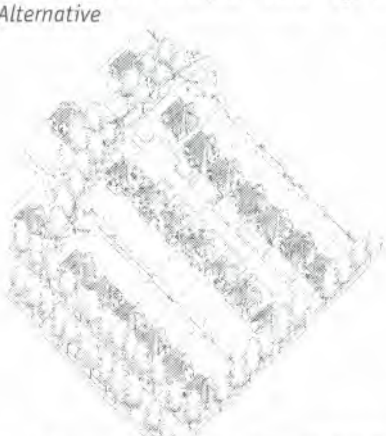
RESEARCH BASIS FOR GUIDELINES

Illustration
A street in Village Homes, Davis, CA and other planned communities such as Radburn, NJ; and the Woodlands, Houston, TX;and 'eco-burbs': such as Ecolonia, Netherland illustrate the integration of open space and neighborhood.





Plan and aerial oblique view of Open SpaceAlternative



Caption: Scheme illustrated was created by the Center for Housing Innovation based on best stormwater management practices and proposed West Corvallis North Philomath Plan development guidelines.

OPEN SPACE ALTERNATIVE

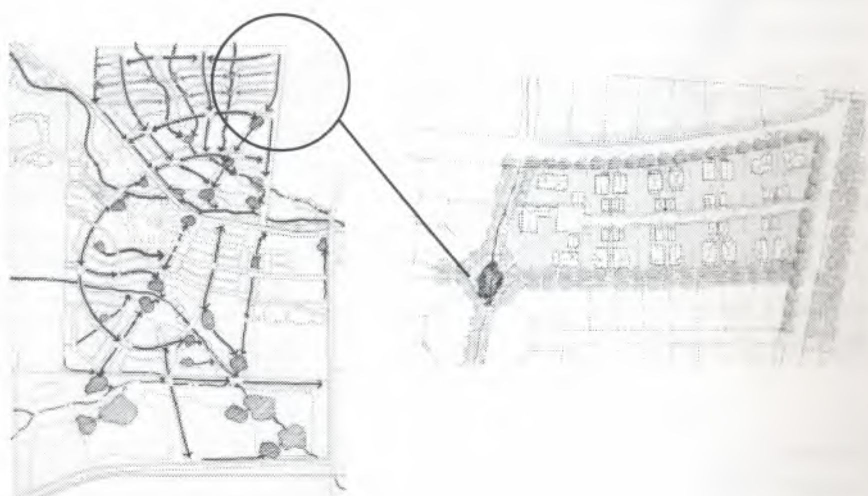
The Open Space Alternative represents a hybrid of the more dense, mixed use development pattern encouraged by the West Corvallis North Philomath Plan in combination with greater open space for stormwater management. This plan is organized around a core of mixed land uses and an overall average housing density of approximately 8 dwelling units per acre served with a reduced-paving street and open space networks. Together these support surface stormwater drainage and extensive pedestrian / bicycle paths.

At the center of the neighborhood is a commercial area, shopping street and town square. Pedestrian-oriented commercial buildings front the shopping street. A larger anchor store, such as a grocery, sits between the shopping street and other more automobile-oriented uses on the arterial street to the east. Mixed housing and commercial uses and higher density housing are within 1/4 mile of this center. An elementary school is located along the Oak Creek greenway, 3 blocks from the center. Playfields are located immediately west of the study area in Bald Hill Park. The southern portion of the site accommodates expansion of Benton County Fairgrounds including a new covered arena and additional parking.

Single family housing types provided include some relatively low density (approximately 6 dwelling units per acre) conventional subdivision lots, higher density small lot and partially attached units (approximately 9 to 12 dwelling units per acre). Multi-family variations include rowhouses and apartments (approximately 12 to 20 dwelling units per acre).

Streets are narrow and the network configured to preserve natural drainage ways. Planting strips, sidewalks and frequent points of access to the open space offset the narrower streets and more dense housing. Fewer houses have traditional front street access. Most have rear yard garages accessed by way of alleys. Many front onto open space corridors.
The entire 100 floodplain of Oak Creek and the Squaw Creek and Mulkey

Creek wetlands are protected with wide. A stormwater and recreation greenway follows the fault line that passes diagonally through the study area. A surface drainage system is built around existing drainage corridors supplemented with a network of drainage easements. Off street trails and pedestrian corridors align with this network. Additional runoff attributable to development is detained and cleansed in wetlands and ponds.or other suitable BMPs before entering natural waterways. "Clean" runoff, including runoff from roofs and plantings and turf is entirely surface drained into public greenways. Most will inflitrate to groundwater. "Polluted" runoff, primarily that which runs from vehicular areas may be partially piped and must be settled and filtered before entering natural waterways.

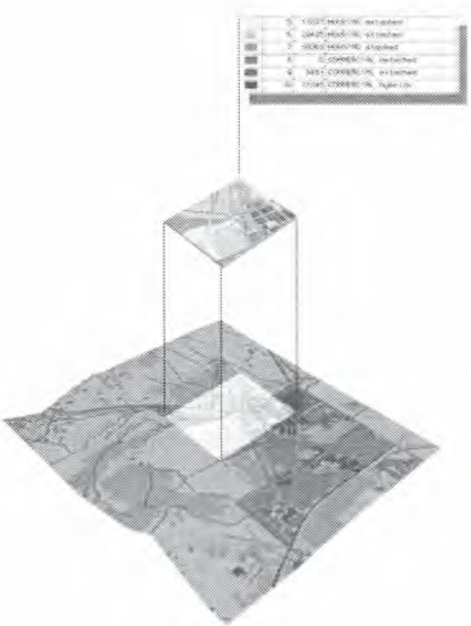


Open Space Alternative surface drainage schematic.

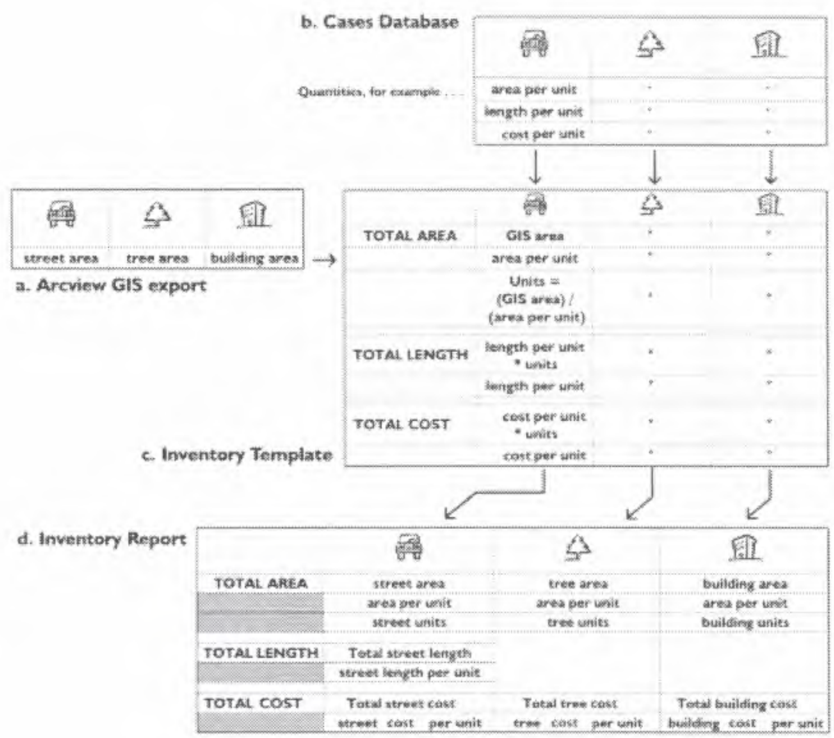
Plan of Neighborhood Village alternative for West Corvallis demonstration site partially referenced to Elements of Neighborhood cases. Selected case assignments shown for illustration purposes only.

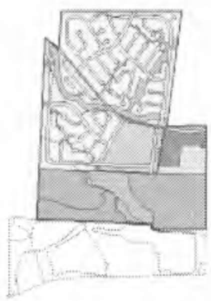
'UREMENT METHODOLOGY

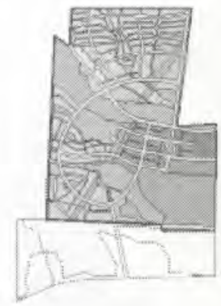
-entative land use cases derived from field measured data are assigned to each of the three alternatives. These case assignments are selected from a database (see 'Elements of Neighborhood' reference). This particular project included 63 cases of land use and infrastructure elements — 7 cases of parks and open space land uses, 19 cases of housing land uses, 10 cases commercial land uses, 6 cases of civic land uses and 10 cases of streets and paths. Associated with each case are layers of associated field-measured data from which different kinds of computations and quantitative analyses can be derived. A housing case, for example, includes data about the area of its site, the number and size of dwelling units, its density, lot coverage, off-street parking spaces, floor area, trees and pervious surfaces and so on.



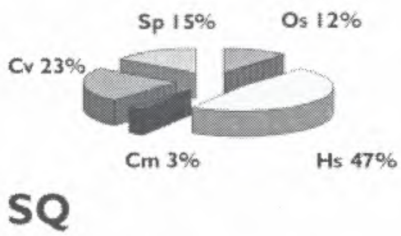
Schematic of automated land use and infrastructure element inventories.

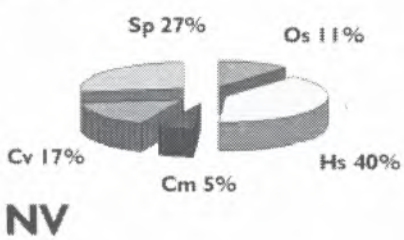


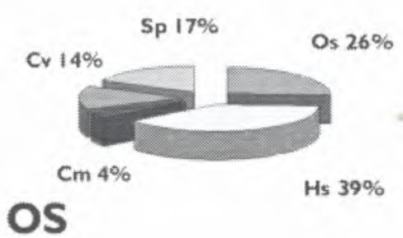




Once cases are assigned in an alternative, the tool set extrapolates quantities from each case, adjusting them proportionally to the area to which they are assigned. In the example above, one case of single family housing based on a 5,000 s.f. lot is assigned to several blocks in an alternative. If the total area of that assignment was 50,000 s.f., most data about that single family housing case would be multiplied by 10, summarized and reported accordingly. These calculations link GIS-based data about which cases are assigned to which areas of an alternative with Elements of Neighborhood database-based data about each case. Figure, illustrates the principle. By a similar process, other comparative measurements are derived from cases adjusted and reported.





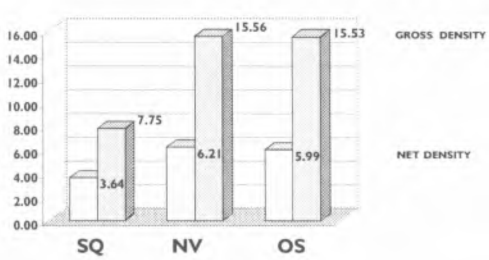


Land Use Allocations

FINDINGS

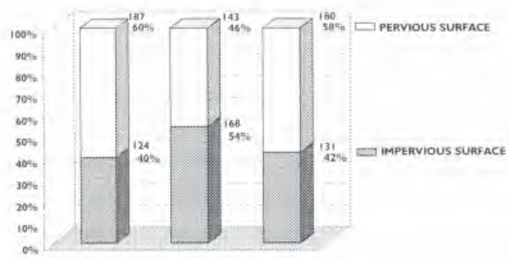
Using quantities generated by the method described, many types of computations can be created and compared. For this project, 31 measures in categories of land use, environmental quality, transportation, infrastructure and cost were created and compared for each of the three alternative plans. Of these, the following highlight the more significant and influential of forest, air and water quality in neighborhood development.

Against measures of land use and density, the Status Quo Alternative provides about 1100 dwellings at a net density of 7.75 dwellings per acre used of housing and a gross density of about 3.5 dwellings per acre of site. The Neighborhood Village Alternative provides about 1900 dwellings at a net density of 15 dwellings per acre used of housing and a gross density of about 6 dwellings per acre of site. The Open Space Alternative also provides about 1900 dwellings at a slightly higher net density of about 16 dwellings per acre used of housing and the same gross density of about 6 dwellings per acre of site.



Gross and Net Density

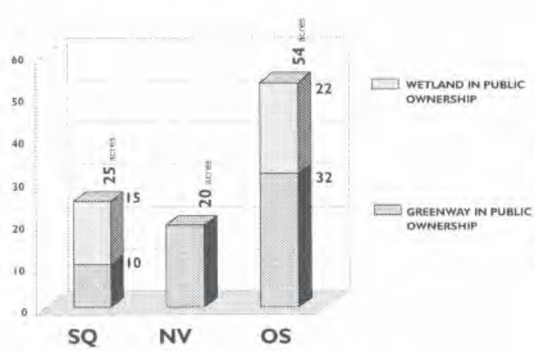
Impervious surfaces have the most direct negative impact on the volume and quality of water running off development into streams. NV is 54% the land area — in impervious cover. SQ plan and OS plan are roughly equal in proportions of impervious and pervious land (40% and 42% of site respectively). It is worth noting, however, that since SQ has 47°/0 of the site in housing, much of which is low density — a significant proportion of the permeable cover is lawn, a potentially significant source of herbicide- and fertilizer-rich runoff.



Pervious / Impervious Surface

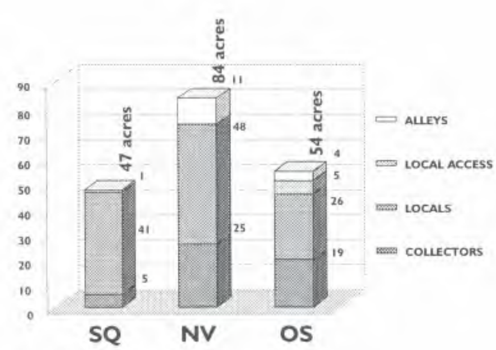
Streets are one of the significant components of impervious surface area. NV allocates the most land, about 27% of the site, to streets and paths and provides the most extensive and diverse street network. SQ allocates the least land, about 15% to streets and paths, and provides the least extensive and diverse. OS allocates slightly more land than SQ — about 17% but provides a more diverse network. The lower density SQ and the higher density NV are about equal in the amount of street paving per dwelling.

Open Space



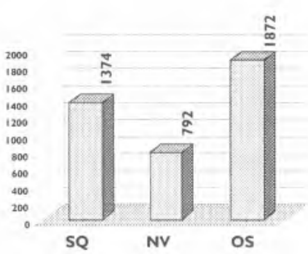
Wetland and Greenway Public Ownership

Pervious surfaces, on the other hand, have beneficial impacts on stormwater by mitigating volumes and improving water quality. Public open spaces are one of the significant components of pervious surface area. OS allocates the most land to public open space, most of which is natural greenway and wetland with beneficial filtration capabilities. SQ and NV preserve about 40% less.



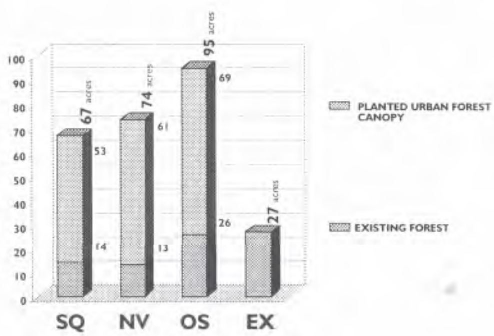
Land Allocated to Streets

Urban forest and tree cover, whether it be natural or planted, reduces runoff quantities and mitigates the impacts of urbanization on air temperature, water quality and air quality. All three alternatives more than double the area of the existing forest. SQ allocates the least land to public open space (12% of site area) and achieves the lowest urban forest cover (21% of site area). NV allocates about the same area to public open space (11%) and achieves slightly greater urban forest cover (24%). OS allocates the most land to public open space (26%) and achieves the greatest urban forest cover (30%).

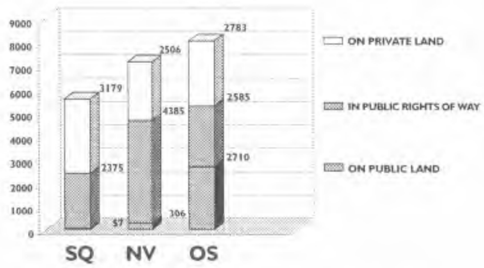


Area of open space per dwelling in square feet

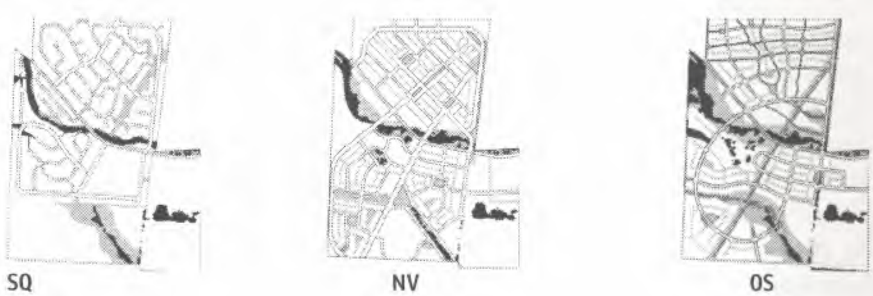
Of the original 27 acres of existing forest on site, however, OS preserves the most, about twice that of the other two alteratives. Of the urban forest area cultivated in street rights of way, public spaces and private land, NV creates about 8 acres more than SQ, and OS creates about 8 acres more than NV. OS increases the urban forest canopy on site by approximately 2.5 times through preservation of approximately 96`)/0 of the existing forest canopy and adding approximately double that amount in new forest canopy on public land and approximately equal that amount in forest canopy on private land. SQ adds about 30 ◦/0 less urban forest canopy primarily (57%) on private land.



Urban forest canopy in acres



Trees planted on private land, public rights of way, and public land



Urban Forest

TABLE: URBAN FOREST COMPARISON

Forest preserved in ;and for public open space and civic uses in acres / % change from existing

Existing site	SQ	NV	OS
26.87ac*	13.94ac	12.97ac	25.75ac
	- 48%	- 52%	- 4%

Estimated tree canopy added in land for public open space , civic and street uses in acres / numbers of trees / % of total added

Existing site	SQ	NV	OS
	22.92 ac	39.46ac	68.96ac
	2432	4691	5295
	43%	65%	66%

Estimated tree canopy added on private land for housing and commercial uses in acres / numbers of trees / % of total added

Existing site	SQ	NV	OS
	29.96 ac	21.08 ac	23.76 ac
	3179	2506	2783
	57%	35%	34%

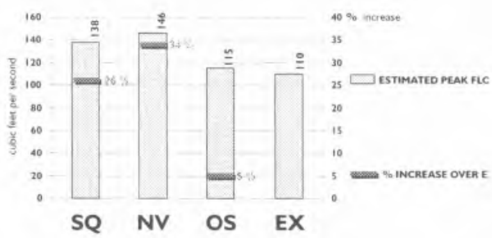
Estimated total tree canopy added in acres / numbers of trees

Existing site	SQ	NV	OS
	52.88 ac	60.54 ac	68.96 ac
	5611	7197	8078

Total urban forest / % of site area / % change from existing

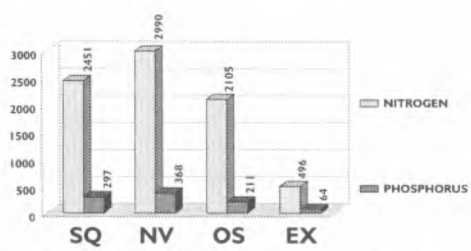
Existing site	SQ	NV	OS
	66.82 ac	73.51 ac	94.71 ac
	21%	24%	30%
	+ 149%	+ 174%	+ 252%

* existing site includes agricultural, housing, commercial in private ownership and civic uses in public ownership



Estimated stormwater peak flow and increase over existing

Against measures of stormwater runoff, both SQ and NV use piped stormwater systems, with no constructed detention facilities and stormwater outfalling to existing creeks. OS uses a partial piped, partial surface drainage system, with extensive small stormwater ponds and wetlands for temporary storage. During a 10-year storm of 4" of rainfall in a 24-hour period (the 'design storm' for flood control purposes in the Corvallis area) SQ increases peak flow rate 26% over that of the existing site. NV increases peak flow by 34°/s, OS increases peak flow by 5%.

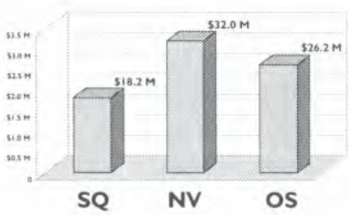


Annual water pollution load in pounds per year

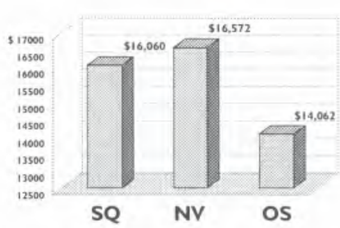
Pollutant load is a factor of total annual runoff volumes and land use. Pollutant loads are decreased by the amount of pervious surface areas for infiltration and, the filtering benefits of BMPs. The greater urban forest cover and stormwater management practices of the OS plan along with its lower volume of runoff overall yields significantly lower runoff-borne pollution. Stormwater runoff was assumed to be filtered. Total pollutant loads, however, are less than compelling for all three plans — 400% to 500% increases in annual pollutant loads (over existing) on SQ and NV and 200% to 300% increases on OS.

Against measures of infrastructure cost, SQ incurs the least total capital cost in infrastructure and associated land — about $18 million or 43% less than the Neighborhood Village Alternative which is about $32million and 25% less than the Open Space Alternative which is about $26 million. NV allocates significantly greater land, and greater cost, to its street system — roughly double that of the SQ alternative. OS allocates significantly greater land, and with it greater land cost, to public open space — more than twice as much as the other two alternatives.

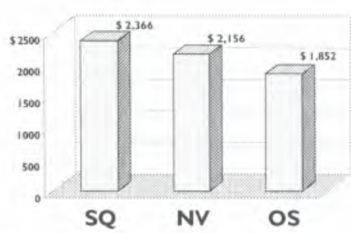
The higher open space costs of the OS alternative, however, are offset in



Estimated capital costs of infrastructure [Land for open space and streets, street and utility networks]



Infrastructure costs per dwelling [Land for open space and streets, street and utility networks]



Stormwater network costs per dwelling

part by a lower cost surface stormwater system — which also adds open space amenity and reduces stormwater infrastructure costs by about 17% over the NV alternative

On a per dwelling basis, however, OS incurs the least capital cost in infrastructure and associated land, approximately $14,000 or about 12`)/0 less than SQ and NV which are approximately equal at about $16,000

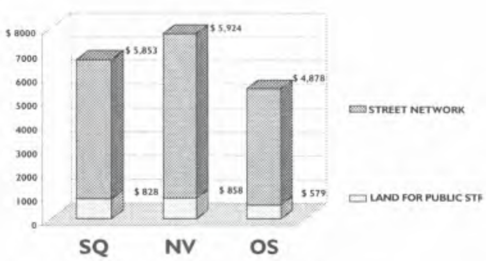
CONCLUSIONS

Comparing neighborhood development patterns from an urban forest and stormwater perspective, these findings suggest that higher densities, mixed uses and greater vehicular and pedestrian connectivity now encouraged in Oregon and elsewhere in the nation can either compete with or complement goals of urban forest protection and stormwater runoff reduction. To become complementary, strategic tradeoffs must be made between land dedicated to roads and parking and land dedicated to open space, urban forest and stormwater.

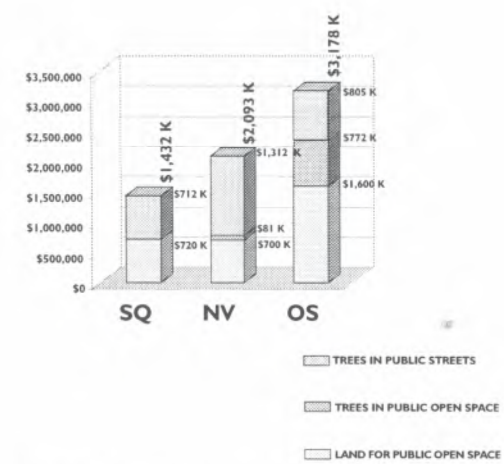
The NV development pattern, for example, may achieve many positive impacts, such as improving the distribution and proximity of services, connectivity of both vehicular and pedestrian networks, creating cultivated urban forest opportunities and potentially reducing vehicle use and vehicle miles traveled. But, as this study also demonstrates, this development pattern can also compromise opportunity for urban forest preservation, increase impervious area and increase stormwater runoff. As well, because much of the increased runoff volumes are associated with streets, this runoff will increase the quantity of common street-related pollutants entering watersheds.

This study also demonstrates that more extensive landscape preservation combined with water quality-oriented surface drainage is not by necessity restricted to lower density development patterns. It also demonstrates the degree to which surface drainage systems and on-site water storage and filtration permit those higher density patterns to perform at least as well as lower density SQ patterns and better than NV patterns against measures of public open space, urban forest protection and stormwater runoff. patterns.

Surface stormwater systems also bring significant potential value to a



Street network costs per dwelling

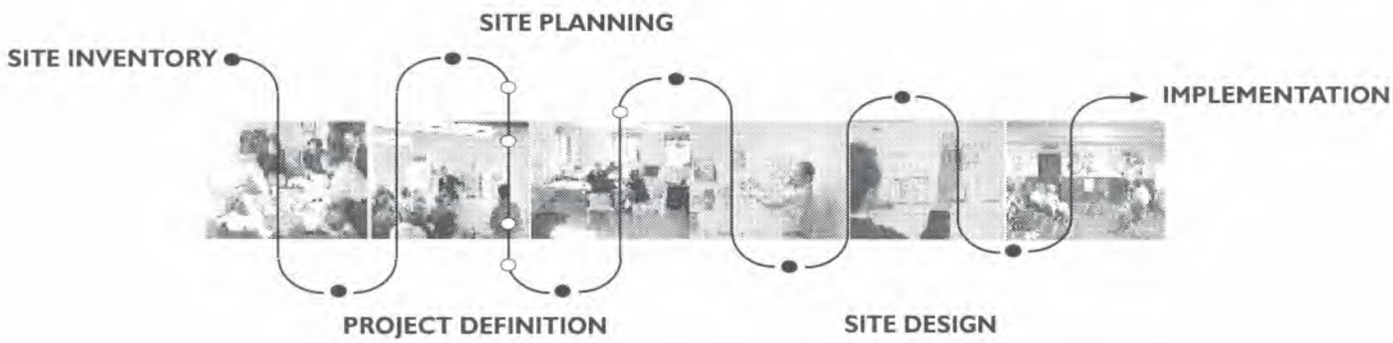


Urban forest costs

community, They significantly mitigate the runoff and water quality implications of development and create an extensive, largely natural, open space system at the same time. If the road system is reduced and other drainage principles are designed accordingly, these systems can cost less than piped alternatives. However it would not be possible to incorporate a stormwater system design such as that of the OS alternative once a site has been platted into a conventional layout as no land or only poorly situated land would remain for surface drainage.

The following section outlines means by which these and other planning and design decisions can be coordinated to achieve development patterns more likely to meet performance goals for forests, air and water quality in tandem with goals for land use, density and cost.

A PROCESS VIEW OF GUIDELINES



KEY PRINCIPLES

• organized by 'action' . . . . guidelines are grouped by intended outcome or effect

• follow planning and design process . . . guidelines are presented in the sequence in which they would likely apply to a project

• cross- referenced . . .guidelines are cited to the research on which they are based and to related, complementary guidelines

Based in part on results gained from preparation, measurement and comparison of the three alternative plans outlined in the preceding section, and in part on related work by others the guidelines presented in this section direct communities and professionals to planning and design strategies that realize better environmental performance. This guidance is directed to specific points in the process of planning and design with greater opportunity to consider environmental performance in parallel with considerations of land use, transportation, cost and livability.

A PROCESS VIEW OF GUIDELINES

Many community-based processes [reference our work and related studies] follow an interactive and iterative decision-making process that:

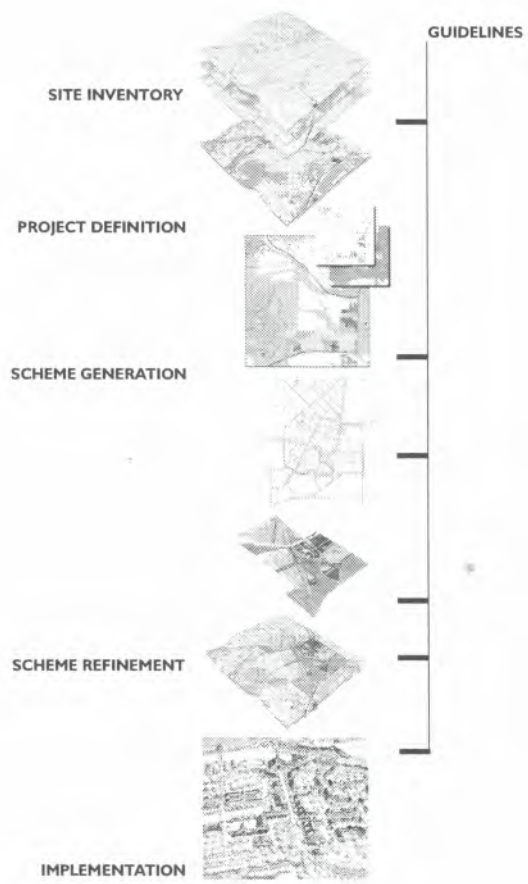
- begins with stages of SITE INVENTORY AND PROJECT DEFINITION — typically establishes goals, principles that frame planning and design decisions about a program of needs (what and how much of which land uses, networks and infrastructure, for example) and gathers information and analyses that frame planning and design decisions about the limits and opportunities of a community or a site to support that program

- shifts to stages of SITE PLANNING — typically an iterative task of generating and testing possible allocations and arrangements of a program on a site within its limits and in response to its opportunities

- continues to stages of SITE DESIGN — typically an iterative task of developing greater specificity and detail about a preferred alternative

- and concludes in stages of IMPLEMENTATION — typically a task of shaping policies, regulations and practices to realize a preferred alternative.

Decision making throughout that process is iterative and roughly hierarchical. One may make decisions about a particular element of a neighborhood at several times . Different kinds and scales of decisions about that element, however, are made at different times in a generally progressive order. More general principles and concepts are typically established toward the earlier stages while more specific details and refinements are typically established toward the latter stages.



Take the planning and design of a street system, for example. Alternatives may be considered and decisions made about streets at more than one point. Earlier in the process, the alternatives and decisions may be about the orientation and pattern of the network — how many street rights of way, how far apart, connecting which points, for example. Later alternatives and decisions may be more about the physical design and implementation of that network — how wide is the paving, planting strip and sidewalk within the right of way, how many trees are planted at what interval, for example.

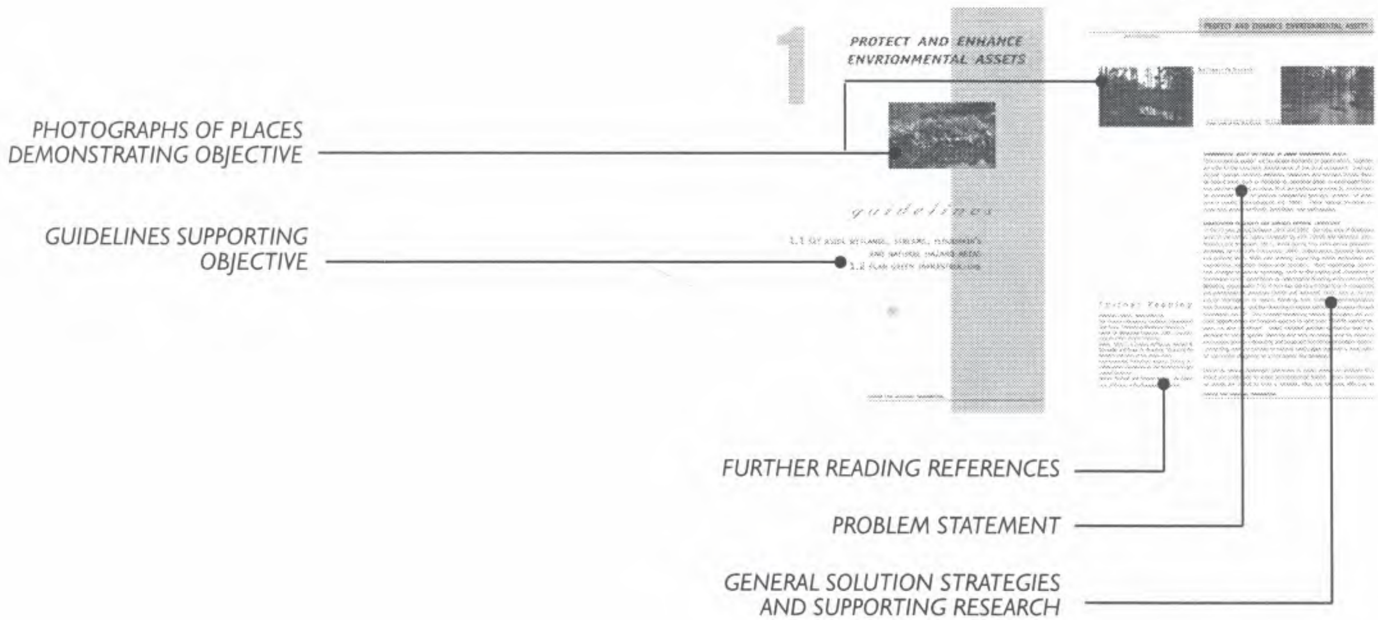
While neither objectives nor guidelines can or should be narrowly targeted only to a particular stage of planning and design — all could be distributed to some degree throughout the process depending on the project and the place — these objectives and guidelines are generally focused on beginning and middle stages of project definition, site planning and site design and not on latter stages of implementation.

Our guidelines are organized and formatted to provide information and examples in a similar, roughly hierarchical order with more coarse information and example appropriate to the earlier stages presented separately and differently from the more detailed information and example appropriate to latter stages. Within that framework, each guideline is presented as an action or a means — what a community might do through planning or design, to achieve an objective — a performance goal one might hold for the outcome of a step or stage in a planning and design process. 'Set aside existing forest areas', for example, is a means or guideline, intended to achieve the goal or objective of 'Protect environmental assets' at a problem definition or site planning stage.

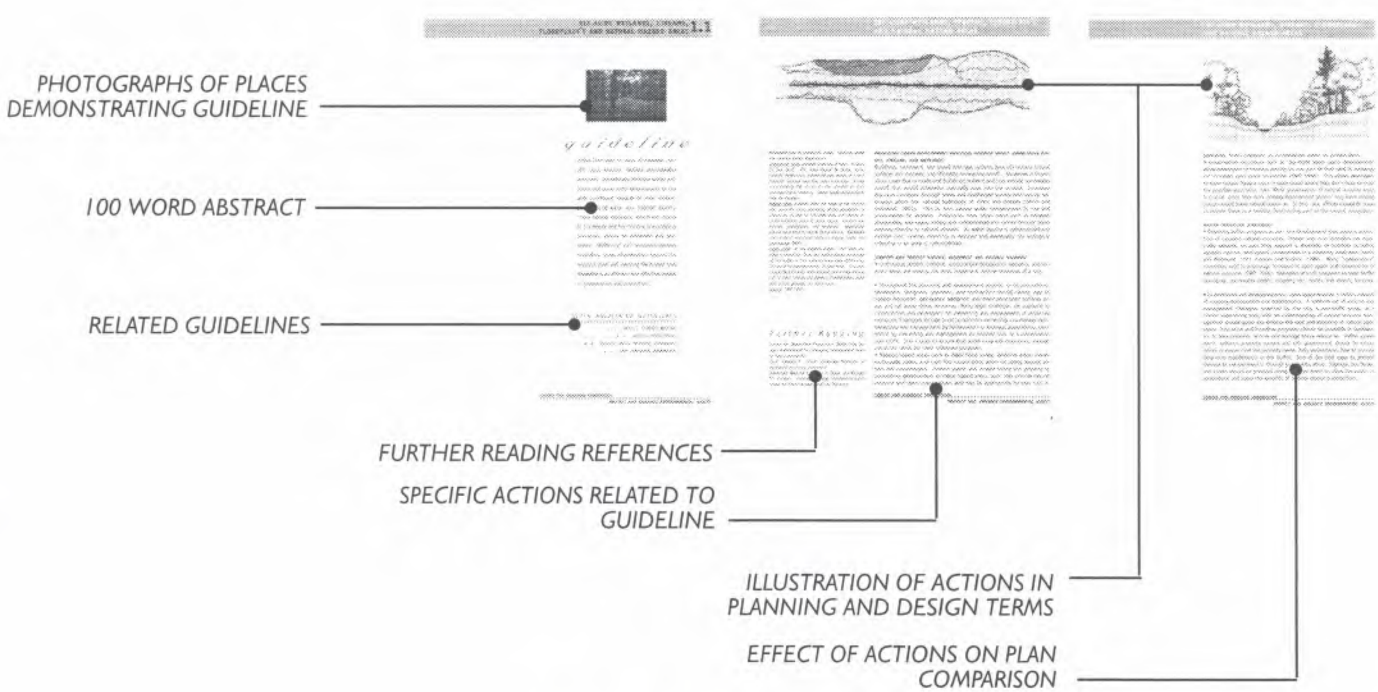
In total, we present 6 planning and design objectives that can be pursued by 15 actions or guidelines. Each objective and guideline is presented in a common format that combines narrative, illustrations, demonstrations and references to supporting research and literature as follows:

A PROCESS VIEW OF GUIDELINES

OBJECTIVES

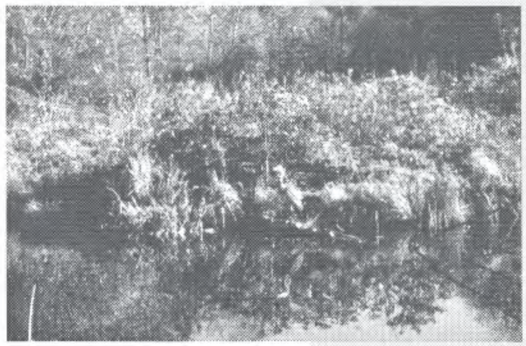


GUIDELINES



1

PROTECT AND ENHANCE ENVRIONMENTAL ASSETS



guidelines

1.1 SET ASIDE WETLANDS, STREAMS, FLOODPAIN'S AND NATURAL HAZARD AREAS

1.2 PLAN GREEN INFRASTRUCTURE

BACKGROUND

Bear Creek at the Woodlands

Bear Creek at the Woodlands - flooded

The entire floodplain of this tributary was protected in a three hundred foot greenway to allow natural flooding and concurrently provide wildlife habitat.

ENVIRONMENTAL ASSETS ARE CRUCIAL TO URBAN ENVIRONMENTAL HEALTH

"Environmental assets" are landscape elements or places which, together, are vital to the long term maintenance of the local ecosystem. Examples include riparian corridors, wetlands, meadows, and remnant forests. Natural hazard areas, such as floodplains, landslide areas, or earthquake faults may also be included as places that are particularly prone to environmental processes that can produce unexpected geologic, oceanic, or atmospheric events (naturalhazards.org , 1999). These natural processes include such events as floods, landslides, and earthquakes.

URBANIZATION FRAGMENTS AND DAMAGES NATURAL LANDSCAPES

In the 23 year period between 1959 and 1982, the total area of developed lands in the United States increased by 45% (Smith and Helmund, 1993, Heimlich and Anderson, 1987), while during this same period population increased by only 33°/0 (US Census, 1999). Urbanization typically denudes and pollutes lands while concurrently impacting whole watersheds and fragmenting important region-wide wildlife corridors. Most importantly, significant changes to natural hydrology, such as the piping and channeling of stormwater runoff, contributes to catastrophic flooding while concurrently depleting groundwater. This in turn has led to a critical loss of ecosystems and environmental processes (Smith and Helmund, 1993) such as the loss and/or interruption of natural flooding from rivers, evapotranspiration from forested areas, and the cleansing of excess nutrients conveyed through stormwater runoff. This stresses remaining natural landscapes and provides opportunities for invasive species to take over. Wildlife habitat impacts are also significant. Small, isolated patches of habitat lead to a decrease in native species diversity, and with decreased area for dispersal, encourages genetic inbreeding and Localized extinction of certain species. Connecting remnant patches of natural landscapes supports a more natural succession of species to occur across the landscape.

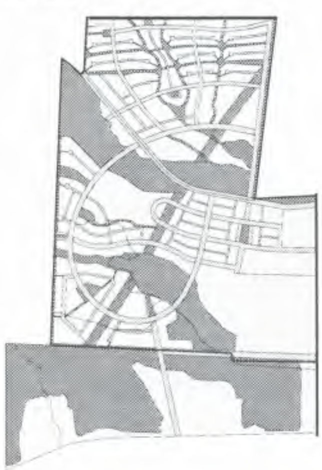
Restoring natural hydrologic processes in urban areas can mitigate this effect and contribute to urban environmental health. When environmental assets are linked to form a network, they are far more effective at protecting water quality, retaining diverse habitat and providing opportunities for recreational corridors, and generally preserving the local ecology

Further Reading

American Forests, www.amfor.org
The Federal Interagency Floodplain Management Task Force, "Protecting Floodplain Resources "
Dwyer, John F., E Gregory McPherson, Herbert W. Schroeder and Rowan A. Rowntree, "Assessing the benefits and costs of the Urban Forest

MAP OF ENVIRONMENTAL ASSETS

OPEN SPACE ALTERNATIVE



A goal to preserve environmental assets heavily influenced the layout of the Open Space alternative in the West Corvallis study.

(Ndubisi 1995 and Smith and Hellmund 1993). Protecting these environmental assets also contributes to community and environmental health in other ways:

• Riparian corridors are among the most diverse and valuable habitat areas. They are home to a rich mix of aquatic, amphibious and terrestrial species. With adequate width and without significant barriers (such as road crossings) they can provide movement corridors for both plant and animal species which helps to prevent isolation and increases genetic exchange for healthier populations. (Smith and Hellmund 1993, Dramstad et al 1996)

• Riparian vegetation along waterways helps to clean both surface water and ground water. Riparian vegetation filters sediments from runoff, utilizes excess nutrients before they reach waterways, and protects stream banks from erosion. An average buffer width of 100 feet reduces watershed imperviousness by about 5%. (CWP 1995). By shading the shallow edges of rivers from the sun, riparian vegetation can help stabilize stream temperatures.

• Riparian corridors provide excellent sites for linear recreation such as walking, jogging and biking. (Smith and Hellmund 1993)

• Protecting floodplains is flood insurance. Keeping development out of floodplains helps to prevent flooding disasters and provides areas for storage of floodwaters. These are also important areas for recharging ground water and are valuable areas for habitat or public uses such as parks. (FEMA 1996)

• Wetlands are Nature's sponges. They cleanse and absorb water and are crucial water storage areas in times of flooding. Wetlands also provide valuable habitat and, like riparian areas, support a rich diversity of plants and animals. The Minnesota Department of Natural Resources reported that increased flood storage capacity due to wetland areas and riparian and buffers resulted in a cost savings of $300 per acre-foot over "engineered" flood storage strategies (CWP, 1998).

• Forests help to cleanse the air and conserve water resources. They convert carbon dioxide to oxygen, absorb other air pollutants and help cool the urban atmosphere. They conserve water by slowing runoff and improving storage and water infiltration up to 10 times over turf (CWP 1995). They provide important habitat for many birds and mammals, particularly if naturally connected to other habitat areas (American Forests and Smith and Hellmund 1993).

• Natural hazard areas are often controlled through state and federal regulations, and while these sensitive lands may be limited in their development potential they provide excellent opportunities for open space corridors. Floodplains, for example, are a danger for human development, yet when protected, add to the size and habitat value of riparian corridors.

• Immediate contact with nature provides enjoyment, relaxation and reduced stress levels in most people. People with access to nearby natural settings have been found to be healthier than other individuals (Kaplan and Kaplan 1989)

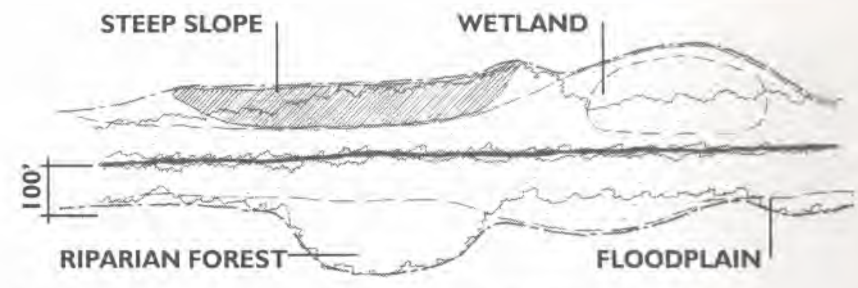
• A survey of Realtors conducted by the Bank America Mortgage Company suggested that homes near to parks and natural areas had a 20% higher value (American Forests/National Association of Homebuilders, 1995).

guideline

Urban land uses increase stormwater run-off, cause erosion, deplete groundwater resources, dramatically increase water pollution and cause water temperatures to rise with significant impacts on river, stream, and wetland water and habitat quality. These natural resources, which are crucial to the health and functioning of ecological processes, should be preserved and protected. "Buffering" such resources involves extending zones of protection beyond the resource itself and limiting the allowable human uses. Buffering is an efficient and effective means of preservation and protection.

OTHER ASSOCIATED GUIDELINES

3.1 CONSERVE EXISTING TREES AND FORESTS
4.2 PLAN DRAINAGE NETWORK EARLY



A plan of a riparian buffer incorporating principles of buffer averaging.

PREVAILING URBAN DEVELOPMENT PRACTICES SEVERELY IMPACT DOWNSTREAM RIVERS, STREAMS, AND WETLANDS

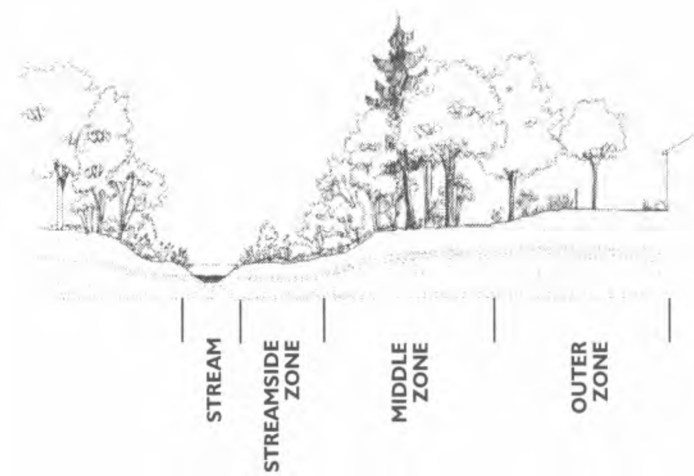
Buildings, pavement, and piped drainage systems typically replace natural surfaces and systems, significantly increasing runoff. Increases in impervious cover due to roads and buildings redirect and concentrate stormwater runoff that would otherwise naturally soak into the ground. Increased drainage conveyed through pipes and discharged quickly into natural waterways alters the natural hydrology of rivers and streams (Smith and Hellmund, 1993). This causes water temperatures to rise and groundwater to deplete. Pollutants from urban areas such as nitrates, phosphates, and heavy metals, are concentrated and carried through piped systems directly to natural streams. As water quality is compromised and habitat lost, species diversity is reduced and eventually the ecological integrity of an area is compromised.

IDENTIFY AND PROTECT NATURAL RESOURCES AND NATURAL HAZARDS

• Continuous stream corridors, undisturbed floodplains, wetlands, and forested areas are among the most important natural resources of a city. Throughout the planning and development process, local jurisdictions, developers, designers, planners, and contractors should clearly map all natural resources, delineated wetlands, and their associated buffered areas and set aside these resources.

• Natural hazard areas such as flash flood zones, landslide areas, known earthquake zones, and high fire hazard areas for safety reasons are best left undeveloped. Protect public and private safety and property by prohibiting development of these hazard areas. Such sites provide natural resource and open space values, and may be appropriate for uses such as parklands, forest preserves ,or conservation zones on private lands.

• Conservation incentives such as "By-Right Open Space Development" allow developers to increase density on one part of their land in exchange for increased open space on another (CWP, 1998). This allows developers to leave natural hazard areas in open space where they don't have to incur the possible associated risks. While preservation of natural resource areas is crucial, areas that have experienced growth may have already compromised these natural resources. In this case, efforts should be made to restore these to a healthy, functioning part of the natural ecosystem.



ALLOWABLE USES IN PROTECTION ZONES

Streamside zone: *extends from top of bank , at least 25 feet back. This area should be dense native riparian vegetation. Allowable uses would be a bark footpath located near the outer extremity. It may occasionally dip closer to the stream on rock outcroppings or clearings. Above-grade outlook decks may be allowed.*
Middle zone: *Extends from the edge of the streamside zone the outer extremity of the floodplain. It should be 50 feet to 100 feet wide and should include adjacent areas of steep slopes, riparian vegetation, floodplains, and wetlands. Vegetation should be primarily native forest plants. Allowable uses include multi-use trails or bicycle paths and stormwater BMPs.*
Outer zone: *is the buffer's buffer. This area provides a transition from the native plants landscape of the buffer to the cultural landscape of the city. It should be approximately 25 feet wide. This area should be primarily undeveloped and it may include turf or trees, shrubs and flowers. Private yards, parks and school grounds are ideal uses.*
Source: CWP 1995.

• Many legal strategies are available to communities and developers for ownership and management of protected resources. Examples include local jurisdiction ownership and management, ownership and management by homeowners or business associations, ownership by one entity and management by another such as a conservation non-profit. It is crucial to assure that some body will responsibly manage protected lands for their intended purposes.

ADOPT BUFFER PROTECTION STRATEGIES

• Requiring buffer programs as part of a development plan ensures protection of valuable natural resources. Stream and river corridors are especially valuable because they support a diversity of habitats including aquatic, riparian, and upland communities in a relatively small area (Smith and Hellmund, 1993, Forman and Godron, 1986). Many "conservation" incentives exist to encourage increases in open space and conservation of natural resources (CWP, 1998). Examples of such programs include: buffer averaging, stormwater credits, property tax credits, and density bonuses.

• In developed and developing areas, open space requires a certain amount of ongoing management and maintenance. A uniform set of policies and management strategies governed by the city, a non-profit group, or a similar supervising body with an understanding of natural resource management should guide and enforce the care and planning of natural open space. Education and incentive programs should be available to landowners to best preserve, restore and manage these resources. Buffer agreements between property owners and city government should be established to ensure that the property owner fully understands how to provide long-term maintenance of the buffer.

• One of the best ways to prevent damage to natural areas is through public education. Signage, brochures, and kiosks should be provided along buffered areas to allow the public to understand and value the benefits of natural resource protection.

Bridging a wetland adjacent to a commercial district in Bellevue, Washington

RECOMMENDED BUFFER ZONES FOR WETLANDS AND RIPARIAN CORRIDORS

• Riparian buffers are measured from the centerline of the stream for small streams and from the top of bank on higher order streams and on rivers. Buffer dimensions refer to one side only.

• A minimum base riparian buffer should include streamside, middle, and outer zone setbacks within which permitted uses might vary. Current research recommends that riparian buffers should vary in width to include important related resources such as all 100 year floodplains, any adjacent or upland wetlands, adjacent steep slopes, and the riparian forest. (CWP 1995 and Smith and Hellmund 1993).

• Wetland buffers should be at least 100 feet from the edge of the delineated wetland. Wetland buffers are measured from the edge of the delineated wetland (CWP 1995).

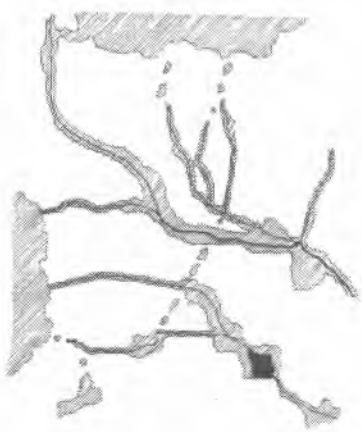
• To be effective wildlife corridors, riparian buffers must be 150 to 300 feet wide. (CWP 1995)

guideline

Green urban infrastructure is the interconnected system of parks, greenways and trails, surface stormwater conveyances, and natural areas that, together, provide the fundamental natural structure around which urbanization may occur. This serves multiple infrastructure purposes such as stormwater cleansing, passive recreation, and bicycle and pedestrian paths.

OTHER ASSOCIATED GUIDELINES

3.1 CONSERVE EXISTING TREES AND FORESTS
4.2 PLAN DRAINAGE NETWORK EARLY



Greenway corridors and "stepping stones" of natural vegetation connect large habitat "patches" to downstream habitat areas in the West Corvallis study area. Source: diagram derived from Dramstad, Olson, Forman, 1996.

URBAN LAND ECONOMICS FAVOR BORDER TO BORDER DEVELOPMENT OF URBAN LANDS

Unless protected, natural resource areas such as riparian corridors, forested areas, and wetlands are consumed or fragmented by new roads, houses, and commercial uses, Leaving them unable to perform many of the ecological processes vital to the health and functioning of natural and urban ecosystems. Where development replaces natural areas, opportunities to experience nature become limited, causing people to travel to places where they can enjoy a more natural landscape.

INTERCONNECTING GREEN SPACE HELP RESTORE ECOLOGICAL HEALTH

• Ecologically healthy Landscapes are typically an interconnected series of "patches" and "corridors" that together form a "landscape matrix" (Cook, 1991). A landscape matrix is defined as a uniform area in which small differential elements appear. Within this matrix, patches of natural areas occur (Smith and Hellmund, 1993). If Linked by corridors or greenways, these patches can function ecologically despite the large urban matrix. Such corridors can also be planned and designed to provide areas for passive and linear recreation as well as visual amenities.

• The Open Space attenuation in the West Corvallis study was characterized as a matrix of moderate density housing (-16 dwelling units /acre) around a green infrastructure of stream corridors, natural hazard corridors, and small remnant patches of forested area. Opportunities exist to connect the stream corridors and hazard areas to form natural areas of open space that can be beneficial to wildlife and simultaneously used for stormwater management, passive recreation, and pedestrian and bicycle paths.

• Once set aside as protected areas (guideline 1.1) and then connected by a series of multi purpose greenways or corridors, natural resource areas for example, can eventually lead to a linked system that can favor both ecological and land economic value. For example, homes situated near greenways in Philadelphia demanded a 33% increase in property values (CWP, 1998).

PLANNING FOR GREEN INFRASTRUCTURE:

• Lay out an open spaces network that protects and connects all natural hazards and environmental assets to the extent possible.

Further Reading

Girling, Cynthia L., Helphand, Kenneth I., Retrofitting Suburbia. Open Space in Bellevue

Smith, Daniel S., and Paul Cawood Hellmund. Ecology of Greenways

Meadowbrook Reflective Refuge and Pond, Seattle, Washington.

• The springboard for creating an integrated network of greenways should begin with the preservation of natural resource areas. Creating corridors to connect resources becomes the backbone of a green infrastructure system. Certain network elements offer ideal opportunities to establish these connections (Cook, 1991):

- transport and utility corridors
- drainage corridors
- linear parks
- urban parks
- stormwater conveyances and storage or filtration facilities

• Schematically plan a surface stormwater system and a parks and open space network that incorporates these resources. Lay out new development or redevelopment around this network of drainages, parks and natural resources.

• Take advantage of conservation easements, overlay zones, and environmentally sensitive land ordinances to protect greenway Lands (Cook, 1991). Additionally, look for opportunities for Landscape reclamation. Abandoned and derelict lands, utility corridors, abandoned railroads and ditches can be revitalized to provide vital greenbelt corridors that will provide open space while connecting natural resources (Girling, Helphand, 1994).

The predominantly natural surface drainage system proposed for the Open Space alternative took advantage of the site's natural hydrology and the need to protect other natural assets and hazards.

2

REDUCE AIR POLLUTION SOURCES

guidelines

2.1 COMPACT PLANS, MIX USES, CONNECT STREETS

2.2 PROVIDE AN EFFECTIVE PEDESTRIAN AND BICYCLE NETWORK

BACKGROUND

"Every gallon of gasoline burned sends about 20 pounds carbon dioxide, containing 5 pounds of carbon, into the atmosphere. . . . "It's like tossing a five-pound bag of charcoal briquettes out the window every 20 miles or so."

James Ryan, research director of Northwest Environmental Watch, Seattle
quoted in the Oregonian, Friday, November 28, 1997 p. C4

The rate at which we acquire and use automobiles is growing faster than population. Between 1969 and 1995, while U.S. population increased 23%, the number of cars and amount we use them increased significantly faster as we went from a society of roughly one car per household to one of roughly two cars per household. During that same period, the number of cars on the road and the number of vehicle miles traveled a year more than doubled — 143% and 127% respectively. (U.S. Department of Transportation, 1995 Nationwide Personal Transportation Survey, p.3)

"Every day, motorists drive more than 2.5 million miles on the streets of Eugene-Springfield [ed. note — population approximately 200,000 in 50 square miles] metropolitan area, sending about 1.8 million points of carbon dioxide and 19,000 pounds of other pollutants into the air Every day. Expect it to get worse . . ." Eugene Register Guard, Wednesday, June 30, 1999 p. 1A"

AIR POLLUTION

Air pollution includes a diverse array of particulates and gases suspended or mixed in the air that we breathe. It comes from many different sources, some natural (pollen, dust, forest fires and volcanic eruptions, for example), some stationary and human-made (factories, power plants and industrial processes, for example) and some mobile and human-made (cars, trucks and buses, for example). The U.S. Environmental Protection Agency (EPA) evalutes the quality of our air by monitoring levels of six principal, or criteria, pollutants. These are carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2) ozone (0_3) particulate matter (PM) and sulfur dioxide (SO_2).

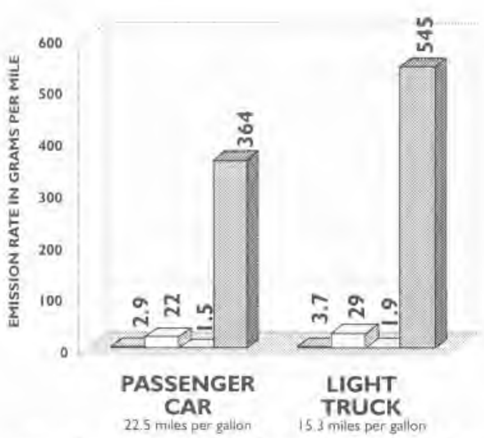
TRAVEL PATTERNS WITHIN AND BETWEEN URBAN AREAS CONTRIBUTE SIGNIFICANTLY TO AIR POLLUTION.

Despite significant and extensive improvements in vehicle technology, automobiles remain a major source of air pollution, and to a lesser extent, greenhouse gases, in metropolitan areas. In the Los Angeles Basin in 1987, for example, automobiles accounted for 44% of reactive organic gases, 60% of nitrogen oxides, 88% of carbon monoxide, 26°/0 of sulphur oxides and 5% of PM-10 particulate emissions (South Coast Air Quality Management District, 1991 Air Quality Management Plan, El Monte, CA, 1991, Table 3-1) In addition, road construction and paved road dust are major sources of PM10 but are counted among stationary, not mobile, sources.

In addition to pollutants, automobiles also contribute greenhouse gases — those gases that when added to the atmosphere increase its "greenhouse effect" and elevate the temperature of the Earth. Carbon dioxide which accounts for about 85°/0 of the greenhouse gases released in the U.S. is a product of fossil fuel combustion. Automobile exhaust is also a source of nitrogen oxides and volatile organic compounds which contribute to the formation of ground-level ozone or smog, also a greenhouse gas. Transportation contributes just over 30% of U.S. total carbon dioxide emissions and two-thirds of those emissions are produced by automobiles (U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1994. Washington, DC, 1995)

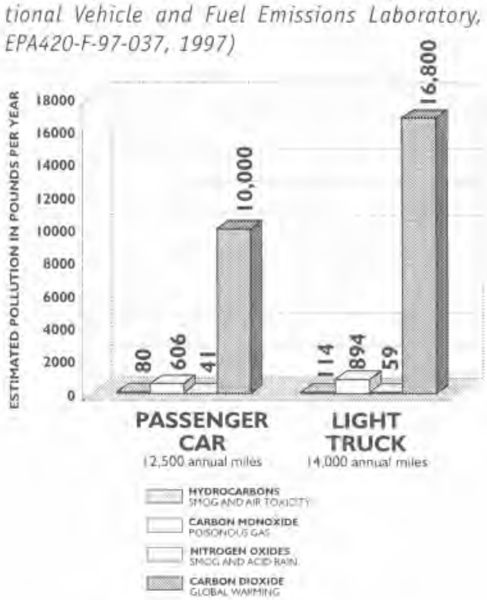
WHERE AND HOW WE USE VEHICLES ALL INFLUENCE THE TYPE AND AMOUNT OF EMISSIONS.

The number of miles we travel, the number of trips we make, the speeds at which we travel and the patterns by which we drive impacts quality. Car-



Annual Emissions and Fuel Consumption for an "Average"* Passenger Car and Light Truck

** "average" refers to standard EPA emission models which assume a properly maintained car or light truck (pickup, van, minivan or sport utility vehicle) on the road in 1997 operating on typical gasoline on a summer day (72 to 96 degrees F). Fuel consumption is based on average fuel economy of 22.5 miles per gallon for passenger cars and 15.3 miles per gallon for light trucks. Individual vehicles may travel more or less miles and emit more or less pollution. (U.S. Environmental Protection Agency, National Vehicle and Fuel Emissions Laboratory, EPA420-F-97-037, 1997)*



bon monoxide emissions, for example, are a product of incomplete combustion typically generated by any of a number of fuel rich, congested urban driving situations such as cold starts, travel at low speeds, rapid acceleration and steep grades and decline as speeds approach 55 mph. Nitrogen oxide emissions, on the other hand, increase with speed. (1000 Friends of Oregon, Parsons, Brinkeroff Quade and Douglas, Making the Connections Technical Report, Volume 8 of Making the Land Use Transportation Air Quality Connection, March 1997 pp. 24-27). It may be the number of trips, rather than vehicle miles travelled that will become more important in controlling emissions. EPA researchers, for example, estimate that by 2010 more than half of emissions will be attributable to stops and starts rather than to miles traveled (Kessler, Jon and William Schroeer, Meeting Mobility and Air Quality Goals: Strategies that Work, U.S. Environmental Protection Agency, Office of Policy Analysis, Washington D.C. 1993).

WHERE AND HOW WE USE VEHICLES IS, IN TURN, INFLUENCED BY HOW WE PLAN NEIGHBORHOODS.

The mix and distribution of land uses, the density of housing, the extent and connectivity of the street network, the accessibility of uses and attractiveness of routes to pedestrian, bicycle and transit modes of travel (and many other planning and design factors) all influence the number and length and types of trips we choose to take by automobile or some other public or non-motorized alternative.

While there has not yet emerged consensus on specific correlations, numerous studies generally agree that higher densities, appropriate mixes of land uses, well designed circulation networks and attractive pedestrian and bicycle routes are frequently associated with less automobile travel and therefore, emissions. Factors of household size, age, employment, income and vehicle ownership rates, and regional transportation context, beyond the reach of planners and designers, are also significant and on these points there is greater ambiguity and less consensus. (Crane, Randall, The Impacts of Urban Form on Travel: A Critical Review, Lincoln Institute of Land Policy, Cambridge, MA, 1999, 1000 Friends of Oregon, Parsons, Brinkeroff Quade and Douglas, Making the Connections Technical Report, Volume 8 of Making the Land Use Transportation Air Quality Connection, March 1997 and Jack Faucett Associates and Sierra Research, Background Information for Land Use SIP Policy, U.S. Environmental Protection Agency, 1998, pp. 2-6).

Of the studies that argue correlation between urban form or development pattern and travel behavior, however, most suggest that lower density community development patterns that segregate, or do not provide viable pedestrian and bicycle routes, tend to encourage longer and more frequent automobile trips. Some argue that land use mix and density are the most significant factors. Communities that are more dense, tend to produce fewer VMT per capita (Harvey 1990 and Holtzclaw 1990). Holtzclaw, in particular, provides an example that one mile of transit travel in a dense urban area replaces four to eight miles of automobile travel in lower density suburbs for a similar set of activities (LUTRAQ p.16).

Others have argued that in addition to density, land use patterns that integrate commercial, employment and housing, develop transportation networks with direct and accessible transit, sidewalks and bicycle routes, and cultivate a quality pedestrian environment can influence mode choice for work and shopping trips. (1000 Friends of Oregon, Parsons, Brinkeroff Quade and Douglas, The Pedestrian Environment, Volume 4A of Making the Land Use Transportation Air Quality Connection, December, 1993, pp. 5 - 14 and 1000 Friends of Oregon Parsons, Brinkeroff Quade and Douglas, Making the Connections Technical Report, Volume 8 of Making the Land Use Transportation Air Quality Connection, March 1997 pp. 16 - 19)

HOW WE PLAN AND DESIGN NEIBHBORHOODS CAN BE A PART OF THE SOLUTION.

Development patterns that reduce vehicle use also reduce vehicle miles traveled, vehicle starts and congestion or encourage alternative modes of travel also reduce the sources of pollution. Generally speaking, that means planning communities to meet demand for those daily shopping, recreation and school trips within the community, preferably in close proximity and easy access to sufficient households that support them. More compact, more finely grained mixed use and more finely meshed street networks that keep trips reasonably direct reduce VMT, travel times and intersection delay (see list in Ewing, Reid, Transportation and Land Use Innovations, Planners Press, American Planning Association, Chicago, 1997, note 51 page 90). In addition, if trips can be made short enough and the routes they follow safe, accessible, direct and pleasant — a greater percentage may be made on foot or by bicycle (1000 Friends Ped Env pp. 24 – 25, cited above and Vernez-Moudon, Anne, Paul Hess, Mary Catherine Snyder, Kiril Stanilov, Effects of Site Design on Pedestrian Travel in Mixed-Use, Medium-Density Environments, Washington State Department of Transportation, Olympia, 1997, pp. 4 – 14)

guideline

When the many land uses and activities that we use or do day to day are segregated from each other or dispersed over greater distances or poorly connected to each other, we are more likely to need to move among them by car. Mixing places of work, shopping, education, recreation and so on within a neighborhood potentially reduces demand for vehicle trips that might otherwise leave the neighborhood or travel farther within it. Bringing those that are dependent closer together, finely mixing those that are mutually supportive where appropriate and connecting all in ways that reduce the number and length of automobile trips can reduce vehicle-related emissions and improve air quality.

OTHER ASSOCIATED GUIDELINES

2.2 PROVIDE AN EFFECTIVE PEDESTRIAN AND BICYCLE NETWORK

4.2 PLAN DRAINAGE NETWORK EARLY

"At the household level, transportation is second on the list of household expenditures, following only housing. Yes, a the household level, more is spent on transportation than food . . ."

(Monthly Labor Review April 1996 quoted in U.S. Department of Transportation, Nationwide Personal Transportation Survey, 1995, p. 32)

"In Rockridge, a community well served by massive transit and featuring walkable neighborhoods with of density of eight units per acre, average vehicle miles traveled annually per household totaled 15,000. By comparison, annual VMT in Danville/ San Ramon, a community with more typical sprawl-type development totaled 30,000 . . . At an average cost of 30 cents per mile, the average Rockridge resident spent $4,500 less on transportation than his or her Danville counterpart. This amounts translates roughly into $51,500 of mortgage capacity." Calthorpe Associates, TOD Impacts on Travel Behavior, August, 1992)

Neighborhood Village concept from the West Corvallis North Philomath Plan. This prototype neighborhood plan proposes an average net density of 9 dwellings per acre with a neighborhood commercial center of 5 to 8 acres surrounded by another 20 to 30 acres of mixed residential and lighter commercial and higher density residential uses within 1/4 mile of the center. All areas are served by a fine-grained street network and connected to natural areas via public open space.

The typical household living in a single family detached house generates about 10 vehicle trips on an average day (ITE handbook) and about 10,000 vehicle miles traveled per capita (U.S. average in 1990) in vehicle miles traveled a year (8,175 per capita in Oregon in 1997). Both factors — number of trips and the length of those trips once taken — have economic and environmental impact and, in turn, can be positively or negatively affected by the planning and design choices we make for our communities.

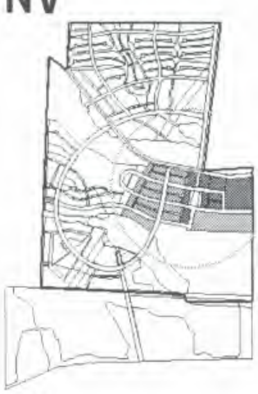
VEHICLE TRIPS AND VEHICLE MILES TRAVELLED CAN BE INFLUENCED BY THE MIX, DENSITY AND PROXIMITY OF LAND USES.

Much of the national research suggests, and many planning and design professionals argue that people are more likely to leave their car at home and walk or bicycle to jobs, stores or services when there is adequate density and mix of services available (JHK & Associates, Accessiblity Measure and Transportation Impact Factor Study, January, 1996 pp. 2-2 to 2-5) and when the routes to them are short, direct, safe and interesting. Frank and Pivo, for example found that the relationship of density to non-motorized travel choices was non-linear, with higher densities resulting in relatively higher rates of pedestrians and bicycles. (paraphrased in JHK & Associates, Accessiblity Measure and Transportation Impact Factor Study, January, 1996 pp. 2-3).Planning and design standards are beginning to reflect this linkage. Proposed recommended practice of the Institute of Transportation Engineers (ITE, Trip Generation Handbook, ITE, 1998 pp. 118-120), for example, suggests vehicle trip rate reduction factors of 2% to 7% in sufficiently dense, mixed use areas with well designed pedestrian and bicycle networks, and up to 20% when those areas are also served by transit and light rail.

In order for local stores or services to be nearby, however, there must be sufficient potential customers to sustain them economically. Time Saver Housing and Residential Development standards propose a minimum of 800 – 1000 households to support neighborhood commercial (p.251). DeChiara and Kopelman (1969) suggest 20 sf/household of retail space for neighborhoods of around 800 families and 18 sf/household for neighborhoods around 1600 families (p.231) Lynch suggests one-half to two-thirds acre (about 20,000 to 30,000 sf) of local neighborhood commercial per 1000 inhabitants (Site Planning pp. 285-6) Calthorpe proposes 15 net dua to support transit.

SQ

NV



OS

Commercial, mixed use areas and 1/4 mile SQ, NV and OS alternatives radius from commercial core.

- Establish an appropriately sized commercial and service center at or near the intersection of a collector and arterial class street in the street network. Gather compatible civic (schools and churches) and recreational uses (parks and squares) nearby.

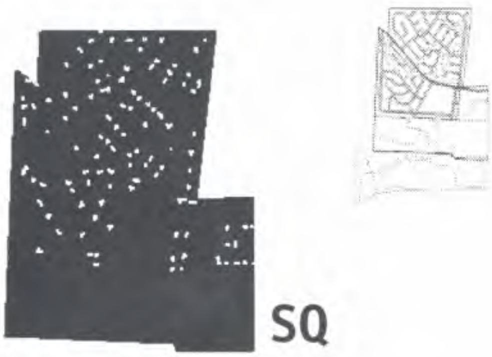
- Surround the commercial and service center with a flexibly zoned area able to accommodate a fine-grained mix of residential and smaller scale commercial uses (specialty retail, personal services, professional offices, for example).

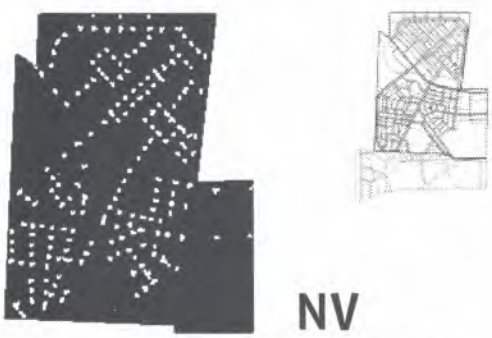
- Allocate appropriate housing types and densities (potentially a mix of detached and attached single family and multifamily building types ranging from about 6 to 20 dwellings per acre of land allocated to housing) to achieve an average net density of about 9 dwellings per acre within 1/4 mile of the commercial and service center.

In the West Corvallis comparison, all three alternatives accommodate a primary commercial area of about the same size — approximately 10 acres. The SO alternative, however, segregates commercial from residential land uses and single family from multifamily densities. Within this pattern, mostly higher density multi-family (20 net dua) dwellings are located within a 1/4 mile walking distance of the commercial center.

The NV alternative surrounds the commercial center with a more diverse range of higher density housing in an 25 acre mixed use area. Within this pattern of mid- to higher density (12 to 20 net dua) dwellings are located within 1/4 mile walking distance of the commercial core and lower to medium density (6 to 12 net dua) dwellings are located within 1/4 mile walking distance of the mixed use area.

The OS alternative also surrounds the commercial center with a diverse range higher density housing in a 23 acre mixed use area. Within this pattern mid- to higher density (12 to 20 net dua) dwellings are located within 1/4 mile walking distance of the commercial core and lower to medium (6 to 12 net dua) dwellings are located within 1/4 mile walking distance of the mixed use area.





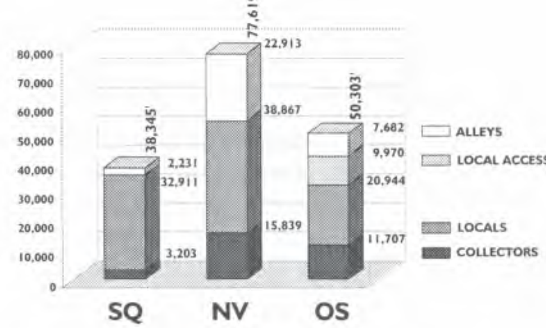
NV create the most extensive and connected street network - 77', 619' of paved streets with 194 intersections and 3 dead ends. SQ creates the least extensive and least connected - 38', 345' of paved streets with 44 intersections and 27 dead ends. OS creates 50,503' of paved streets with 84 intersections and 20 dead ends.

NETWORK ACCESSIBILITY AND CONNECTIVITY

Accessibility refers to the potential to enter and move unimpeded through a network to a destination. Connectivity refers to the potential for choice and flexibility of movement within a network. Greater accessibility can increase the likelihood that potential travelers will have opportunity to use the network. Greater connectivity can reduce traffic volume and congestion and increase choice and variety as travelers choose alternate paths to a common destination. Generally, the greater the number of access points and intersections, the greater the access, choice and the flexibility, and the higher the accessibility and connectivity of a network. Lesser accessibility and connectivity directs more vehicles onto fewer streets, increasing traffic volume and congestion potential which in turn can create a hostile environment (of speed, noise, poor air quality and few crossing opportunities) for pedestrians and bicyclists.

- Make the street networks linking housing to commercial and service centers fine-grained and connective

In the West Corvallis comparison, the SQ alternative provides the more hierarchical network of relatively few streets that eliminate or limit opportunities for pass-through traffic on any street below collector designation. The NV alternative establishes a more extensive but less hierarchical network of fully interconnected streets with at least one full-stop intersection per 350 feet of residential streets. The OS alternative provides a more extensive and interconnected network than SQ but less than NV. All three alternatives provide transit stops in the commercial area.



guideline

Guideline 2.1 suggests that mixing places of work, shopping, education, recreation and community service within a neighborhood potentially reduces demand for vehicle trips that might otherwise leave the neighborhood or travel farther. Locating those uses in close proximity to one another and connecting them with fine-grained networks of pleasant pedestrian and bicycle routes— as good or better as those available to automobiles — increases the likelihood that one might elect walking or bicycling over driving.

OTHER ASSOCIATED GUIDELINES

1.2 SET ASIDE WETLANDS, STREAMS, AND NATURAL DRAINAGE
3.2 CREATE TREE PLANTING OPPORTUNITIES
5.1 REDUCE THE EXTENT OF STREE NETWORKS

PROVIDE AN EFFECTIVE PEDESTRIAN AND BICYCLE NETWORK

". . . increased usage of bicycle and walking modes . . . replace[s] a motorized person trip with a non-motorized person trip. From the standpoint of traffic congestion and highway capacity, higher rates of bicycle pedestrian usage should reduce vehicle trip demand and traffic congestion . . . From the standpoint of air quality, . . because the trips are relatively short,. the primary benefit is in the elimination of vehicle trips ("cold start" emissions) over VMT . . . saved."

(U.S. Department of Transportation 'Implementing Effective Travel Demand Measures: Inventory of Measures and Synthesis of Experience, September, 1993, p. 4-2)

Factors that ***ENCOURAGE*** *walking*

- *Mixed land uses*
- *Dense land uses*
- *Direct routes*
- *Adequate sidewalks*
- *Adequate crossing points and crosswalks*
- *Slower traffic speeds*
- *Lower traffic volumes*

Factors that ***DISCOURAGE*** *walking*

- *Complex environments*
- *Fewer streets – larger blocks*
- *Small and fragmented sidewalk systems*
- *Indirect routes*
- *Abundant area devoted to surface parking lots*
- *Poor connectivity*

After Hess, Paul M., Evaluating Pedestrian Environments: Proposals for Urban Form Measrues of Network Connectivity with Case Studies of Wallingford in Seattle and Crossroads in Bellevue, Washington, Masters Project, University of Washington, Department of Urban Planning, 1994

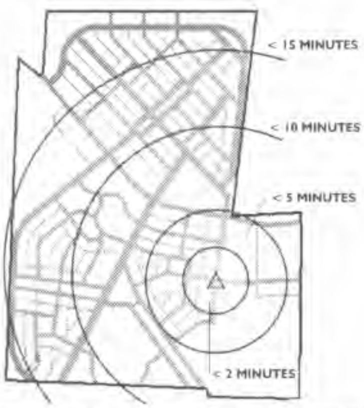
Cultivating potential for bicycle and pedestrian modes starts with identifying the travel situations for which they are most popular. Generally speaking, the most frequent choice of walking or cycling modes is for social or recreational purposes, and fewer people choose bicycling over walking. Second most frequent is shopping and personal business purposes. Commuting to and from work is a distant third. In Europe, however, and some older American cities where development patterns are more concentrated and facilities for walking and bicycling are well-integrated, these non-motorized modes are dominant for all trip purposes. (U.S. Department of Transportation, 'Implementing Effective Travel Demand Management Measures: Inventory of Measures and Synthesis of Experience' September 1993, pp. 4-4 - 4-13).

WHAT FACTORS INCREASE THE WILLINGNESS OF TRAVELERS TO CONSIDER BIKING OR WALKING?

1 PROXIMITY

Research indicates that distance the foremost planning and design variable affecting pedestrian behavior (Handy, Susan, Urban Form and Pedestrian Choices: Study of Austin Neighborhoods in Transportation Research Record: 1552, 1996). Because of the limitations in the speed at which one can walk (2 to 3 mph for walking and 10 to 12 mph for bicycling) distance establishes and envelope with which trips are likely to be made on foot or by bicycle. The research establishing how far one is willing to walk or cycle does not make a precise recommendation.

One study by Goldsmith of Ontario commuters found an average of 20 minutes or 1.25 miles . Another study by Robinson found that 80% of walking trips were less than 1 mile and 94% were less than 2 miles. The 1990 Nationwide Personal Transportation Survey calculated an average walk for all purposes at 0.7 miles and 0.9 miles for commuting purposes. Goldsmith also found that the average bicycle trip is about 2 miles long but that bicycle commute trips may be longer, in the 5 to 6 mile range. The 1990 Nationwide Personal Transportation Survey calculated an average bicycle trip for all purposes at 1.8 miles and 2.1 miles for commuting purposes. Some respondents may suggest a willingness to walk further in a survey than they will in practice. Transit studies, for example, routinely find that their customers are generally willing to walk about 1/4 mile to reach a transit stop. (U.S. Department of Transportation, 'Implementing Effective Travel Demand Management Measures: Inventory of Measures



Approximate walking distance from commercial center to NV alternate.

"Skilled bicyclists prefer to travel on the street system along with automobiles. To accommodate them, striped bike lanes or extra wide curb lines are warranted on arterials and collectors. There is some debate about which of the two . . . is safer for bicyclists. In terms of user acceptance (as opposed to safety), the bike lane seems to have an edge." (Reid Ewing in Best Development Practices, Planners Press, APA Chicago, 1996 p.78)

and Synthesis of Experience' September 1993, pp. 4-9). Ultimately, tolerable distance is a fundamentally individual variable that depends on physical condition, individual commitment and site conditions. Assuming that 5 to 10 minutes represents a conservative assumption of acceptable travel time for most, pedestrians would be able to travel approximately 1/4 to 1/2 mile and cyclists approximately 1 to 2 miles.

- Locate the most frequent neighborhood destinations within 1/4 mile of each other and most dwellings.

2 ACCESSIBILITY

After distance, the next indicator variable of pedestrian and bicycle infrastructure is the presence (or absence) of a continuous, well-connected, safe and physically accessible (in terms of topography and surface, for example) network of sidewalks and bicycle paths (1000 Friends, Pedestrian Environment p.12). "Places where bicycles tend to be a serious mode of travel tend to have miles of bike lanes and bike paths, and / or low-volume side streets paralleling arterials. Nearly all examples of ' mass bicycle commuting to school' occur where access is possible by separate bike lanes or bike paths or by low volume residential streets." (Reid Ewing in Best Development Practices, Planners Press, APA Chicago, 1996 p.78).

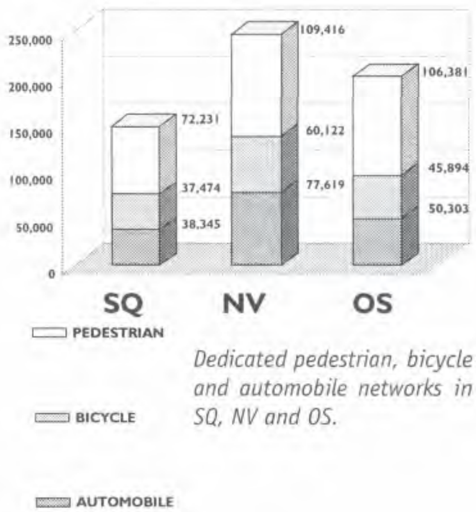
- Create routes to frequent neighborhood destinations so that travel by bicycle or foot is at least as direct, safe and flexible as the routes available to automobiles.
- Design street networks with shorter blocks or provide supplementary pedestrian and bicycle routes where the blocks are longer (less than 6 potential crossing points per mile)
- Provide sidewalks on both sides of primary and at least one side of secondary access routes.
- Layout pedestrian networks to keep most grades below 2% and few greater than 5%.

3 ROUTE AND DESTINATION ATTRACTIVENESS

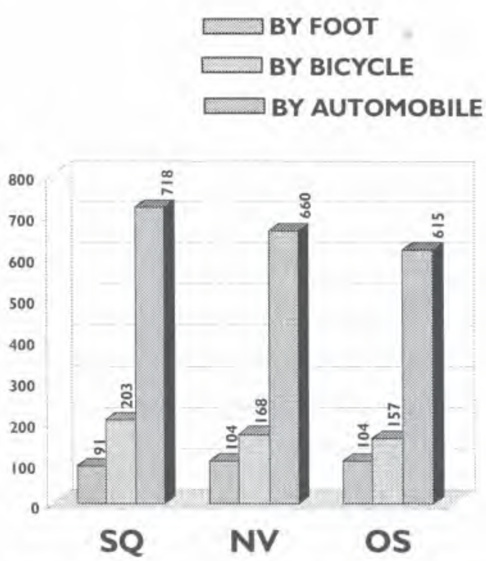
After proximity and accessibility, design of the environment for pedestrians and for bicyclists, matters as well. Perceived character and quality of the environment, for example, also affect decisions to walk or cycle. In general, and even if proximity and accessibility factors are deemed equal, an active mix of pedestrian-scaled, complementary uses and activities encourage more pedestrians and bicyclists than less active, less diverse, automobile-scaled uses and activities.

Attractiveness variables shift with different uses and activities. For commercial areas, attractiveness may be a measure of building or parking lot scale and orientation and the desirability, number and mix of stores. For schools and community centers, attractiveness may be more a function of the desirability of the services and amenities available in JHK & Associ-

"Children and casual adult cyclists outnumber skilled adult cyclists by more than 20 to 1. The less skilled majority must be separated from high-speed, high-volume traffic or they will not ride" (Reid Ewing in Best Development Practices, Planners Press, APA Chicago, 1996 p. 78)



Dedicated pedestrian, bicycle and automobile networks in SQ, NV and OS.



Average travel time to shopping area (inseconds) by foot, bicycle and automobile.

ates, Accessibility Measure and Transportation Impact Factor Study, January, 1996 pp. 2-3).

- Keep traffic speeds low — 25 mph — on streets with shared pedestrian and bicycle routes.
- Keep traffic volumes low — less than 10,000 ADT — on streets with shared pedestrian and bicycle routes.

For streets and paths attractiveness may be the perceived safety and interest of the experience. When pedestrians and motorists share the right-of-way, for example, pedestrians benefit from narrow streets and physical buffers between the street and the sidewalk. Streets that are narrow with traffic speeds under 25mph can create a sense of 'friction' that slows motorists and potentially increases their attention to, and anticipation of, activities (a pedestrian attempting to cross or a child chasing a ball) that might impinge on the travel lane at short notice. Sidewalks that are setback from streets and separated from traffic by a treed planting strip and / or parking lane also contribute to that sense of 'friction' as well as a pedestrian's sense of safety and 'insulation' from vehicle traffic.

- Locate parking in structures or off-street pocket-sized lots.
- Create lot sizes and exposures (to traffic and customers) likely to attract a complementary mix of store types and sizes likely to generate activities throughout the day.
- Create opportunities for interest points — uses likely to orient courtyards, sitting or dining areas, attractive storefronts, for example — immediately adjacent to primary pedestrian and bicycle routes

In the West Corvallis plan comparisons, provides sidewalks and street trees in planting strips along all local, collector and arterial street rights of way. NV provides 5 foot sidewalks on both sides of all streets and wider sidewalks (10 to 14 feet) on shopping streets. OS provides 5 foot sidewalks on both sides of streets above 50 foot right of way and wider sidewalks (10 to 14 feet) on shopping streets. In all alternatives, dedicated bicycle lanes are provided on collector and arterial streets. OS provides additional pedestrian and bicycle routes along open space corridors.

As a consequence, NV proved the most extensive dedicated pedestrian and bicycle network primarily through its street network. OS provides a similarily extensive pedestrian network but less dedicated bicycle network in both street and open space. SQ provides the least dedicated pedestrian and bicycle network. Based on these network designs, the SQ alternative generates the most favorable automobile travel time to the shopping area. NV and OS alternatives generate lower average walking and bicycling times for trips to the shopping area — about 16% faster for pedestrians and 29% faster for bicyclists.

3 INCREASE AND ENHANCE THE URBAN FOREST

guidelines

3.1 CONSERVE EXISTING TREES / FORESTS
3.2 CREATE TREE PLANTING OPPORTUNITIES

BACKGROUND

"Trees and forests have become more than just an overlooked and under appreciated community resource - they are a resource at risk, and one whose loss is increasingly costly to communities and the environment."

(American Forests, 1999)

An urban tree saves five to ten times more overall carbon than a rural tree, because it helps to prevent carbon dioxide production in the first place (EPA 1992).

LOSS OF TREES CONTRIBUTES TO ENVIRONMENTAL DEGRADATION

The "urban forest" encompasses all of the trees and related woody vegetation within or directly associated with urban areas (TreePeople 1990, Grey 1992). Urban forests are typically composed of native forest patches dispersed within a large matrix of cultured or non-native trees and shrubs. One of the most profound and encompassing effects of urbanization is the "urban heat island" effect. In cities, where trees and other vegetation are replaced by buildings and pavement, solar radiation is readily absorbed and stored. Building and pavement surfaces absorb and hold heat throughout the day. As cool evening air comes in over the city, the warm air is trapped, and air pollutants generated by cars and other city processes are trapped and settle (Hough, 1995), causing temperatures to increase by as much as 3 - 10 degrees (Moll, 1989). Trapped pollutants are a health hazard. Combined with warm urban temperatures, these pollutants contribute to global warming and related environmental problems.

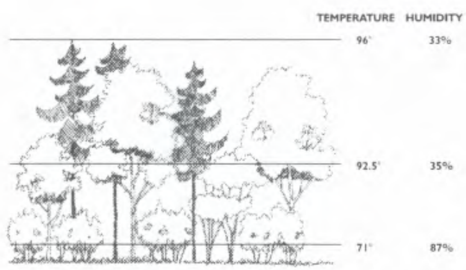
In many cities, and in the Pacific Northwest in particular, tree loss impacts water quality. As forested areas are cleared to make way for buildings and roads, erosion and subsequent water pollution increases. When trees are removed soils, sediments, contaminants from cars and construction equipment, are eroded into nearby streams and rivers. As forests give way to buildings, pavement, and turf, stormwater runoff increases, pollutant loads increase, and ultimately natural environmental process are compromised. A study of the Puget Sound regional ecosystem, a once forested region, concluded that if tree canopy lost since 1973 were replaced, the region would have saved 95 million dollars in air pollution services and 2.4 billion dollars in stormwater containment services during that 25 year period (American Forests, 1999).

THE URBAN FOREST MITIGATES HEAT ISLAND EFFECT AND URBAN POLLUTION

• The process of photosynthesis enables trees, through their leaves and needles, to filter and sequester carbon and polluting gases as well as precipitate significant amounts of particulate from the air. Some research estimates that a street lined with healthy trees can reduce airborne dust particles by as much as 7,000 particles per liter of air (Bernatsky in Cool Communities). The sun shading, wind shading, and evapotranspiration properties of trees in urban areas can also reduce the cooling load on buildings. This effect can save about 88 pounds of carbon per year attributable to electricity generation while sequestering another 9 to 18 pounds per year of carbon produced by other sources. Nitrogen oxides can also be

Further Reading

American Forests, National Association of Home Builders, Building Greener Neighborhoods
Environmental Protection Agency, Cooling Our Communities: A Guidebook on Tree Planting and Light Colored Surfacing
Moll, Gary and Sara Ebenrick, eds., Shading Our Cities



Temperature decreases while humidity increases as one moves downward through a forest canopy. Source: Grey, Urban Forestry 1996.

taken up and neutralized by foliage.
• Trees moderate the urban heat island by shading, or blocking the sun's radiation. Heavy canopy trees can block up to 95°i° of incoming radiation. Shading buildings helps to reduce the need for summer cooling, while shading outdoor areas helps to keep air temperatures lower in urban areas. Three well placed shade trees around a house can cut air conditioning energy needs by up to 50% (American Forests and EPA). Conversely, well placed trees can also reduce wind speeds and thus heating needs in cold climates (EPA 1992).

• Evapo-transpiration, or the process by which plants release water vapor utilizes heat energy, increases humidity and results in a net heat loss throughout the day (Spirn, 1984). This process consumes solar energy that might otherwise go to heating the air. Trees can transpire up to 100 gallons of water a day. This has the same effect as running five average air conditioners for 20 hours (EPA 1992).

• Trees retain carbon dioxide and control ozone. Trees and other vegetation absorb carbon dioxide in photosynthesis and release oxygen. A fast growing tree can absorb up to 48 pounds of CO2 per year (equaling ten tons per acre of trees). As a part of this process, trees store or "sequester" carbon, effectively taking it out of circulation, during their life-span. The larger the tree, the more carbon it can store. An average acre of fully stocked forest will remove about 3.6 tons of CO2 per year (American Forests). The large, mature trees of Sacramento store 2343 kilograms of carbon per tree (3.1 k tons per ha) whereas smaller trees in the suburban areas store only 640 kilograms. Forests in the US are estimated to store 202 tons per hectare. (McPherson 1998)

An urban tree saves five to ten times more overall carbon than a rural tree, because it helps to prevent carbon dioxide production in the first place (EPA 1992).

TREES IMPROVE WATER QUALITY

• Trees detain stormwater runoff, encourage infiltration and filter rainfall. Tree canopies intercept rainfall, allowing some to re-evaporate while drip is absorbed into the root system. Thus treed areas act like detention facilities. In Sacramento, California a mature, mixed forest canopy intercepted 36% of summer rainfall at the canopy level. (Drip releases some of that rainfall, thus the net interception is less at the ground level.) Winter interception was far lower in Sacramento due to the large percentage of

Heavy planting around the perimeter of this parking lot helps to mitigate the impacts of the large paved surface.

deciduous trees in the urban forest (Xiao et al 1998).

• Tree root systems act as sediment filters to trap pollutants from stormwater. Their deep root systems also uptake tremendous amounts of water, and their leaves filter out air particulate. They stabilize slopes and soils and aid in the prevention of construction and storm related erosion. In the Gunpowder Falls Basin in the Chesapeake Bay Area, forested areas released 50 tons of sediment per square mile per year to the local waters, (sub)urban areas contributed 50 - 100 tons, and land stripped for construction released 25,000 - 50, 000 tons of sediment (Moll, 1989).

• Trees and other vegetation reduce erosion by dissipating rainfall impact. The higher the percentage of forest, trees and other permeable surfaces, the Less runoff reaches piped drainage systems or streams, mitigating the high peaks, erosion and flooding associated with urban areas.

LARGER TREES ARE LOWER MAINTENANCE

• Larger, long-lived "public" trees minimize maintenance costs while maximizing environmental mitigation benefits. The "work" trees do to mitigate air and water pollution and runoff volumes is directly related to total leaf surface area, thus larger, denser trees provide more of these benefits.

• Many cities believe it is too costly to aggressively maintain the urban forest. While it is clearly understood that urban forests are integral to the environmental health of the city, many cities are not making it a priority to maintain this valuable resource. A 1992 survey of urban forestry in California revealed that the average percentage of city operating budgets for tree programs has dropped to less than 1%, an 18% decline over a four year period from 1988 - 1992 (McPherson, 1995).

• Recent studies show that when costs of planting, watering and maintaining trees are considered, tree planting is a more cost-effective energy and carbon dioxide conservation strategy than many other fuel-saving measures (Dwyer et al 1992).

guideline

One of the best ways to increase and enhance urban forest is to conserve existing forests. Existing mature trees provide an array of benefits that take decades to replace once they are lost. A thirty year old tree lost to urbanization will Likely be replaced by a three year old tree that does not have the capacity to intercept stormwater and air pollutants and due to harsh urban conditions may live only ten years (Spirn, 1984). Natural resources such as forested areas or even small groves of trees should be viewed as an asset for developed and developing areas. The integration of trees and buildings creates a setting that is beautiful, livable, and one that offers water and air quality benefits.

OTHER ASSOCIATED GUIDELINES

1.1 SET ASIDE WETLANDS, STREMS, AND NATURAL HAZARDS
1.2 PLAN GREEN INFRASTRUCTURE
6.2 USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF

A forested ridgeline preserved as parkland in Bellevue, Washington.

URBAN FOREST COVER IN DECLINE

As urbanization and sprawl creep across America, forests are beginning to recede. In the Baltimore-Washington area urban forest cover has declined by 32% since 1973. In the urban growth area around Seattle the decline is over 50%, a loss of 107,000 forested acres. (American Forests, 1999). This heavy tree loss has resulted in problems with flooding, erosion, and pollution. Loss of remaining remnant patches of mature trees and forests spells habitat destruction as well.

Some contemporary development practices treat forest resources as an inconvenience to be removed rather than a long-term benefit. Most land developers would agree that more building or parking has a higher value to them than preserved trees. Without disincentives, they clear soils of most existing vegetation before starting construction. Most communities can do little to protect these resources due to a lack of authority.

Even when efforts are made to save some vegetation from the site clearing process, specimen trees and forest clumps are often lost. Earthmoving often causes the destruction of tree roots and ultimately the loss of trees. Eighty-five percent of tree roots are concentrated in the top 18" of soil therefore even minimal soil compaction can have a significant effect on trees. Additionally, even small additions of excess soil (4 - 5") around a tree can deprive a tree's roots of oxygen (American Forests, 1999).

In each of the three West Corvallis plans compared, various amounts of forest was preserved to determine the effect conserving trees had on run-off volumes and water quality. The Status Quo and Neighborhood Village plans conserved about half the forest on the existing site (14/27 acres), the Open Space plan conserved all but one acre of the existing forest. Combined with other best management practices, existing and planted trees on the Open Space plan helped to drastically reduce increases in stormwater flow rates (see section on CHI work).

PROTECT EXISTING TREES AND FOREST PATCHES

• Create a landscape preservation plan. Where only small patches of forest remain, lay out new development or redevelopment to protect entire forest patches placing limits on the percentage of canopy cover that may be removed for development in forested areas. Protecting contiguous areas of forest is far better than protecting individual trees formerly lo-

Further Reading

Grey, Gene W. and Frederick J. Deneke, Urban Forestry

Rather than facing the street, these homes in Northwest Landing, Dupont, Washington face onto a public green graced with clusters of preserved trees.

cated in forested conditions. Trees that grew up in forest conditions are likely to have interlocking root systems that may blow down if left standing alone. Extremely large, old, rare, or handsome trees but are generally considered specimen trees and deserve special consideration. Specimen trees can add an air of distinction to a community and can serve as a landmark giving character to a place.

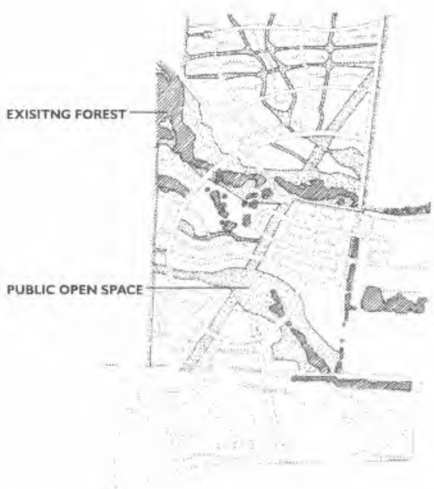
• Protect the natural forest that remains. Restorative tree, shrub and herb layer planting should be done in preserved open spaces such as greenways, parks, school yards, residential lots, and wetlands to fill in areas devoid of forest and to help discourage invasive plants. Mimic the patterns and locations of native plants in healthy plant communities and use only native plants in such areas.

• Connect forest patches to each other via greenway corridors. This strategy effectively increases habitat area for many wildlife species by allowing them to safely travel and colonize.

• Cluster homes to preserve trees. In residential development, limiting construction impacts by clustering houses to a particular portion of a site can help preserve natural forested areas. Although some leniency is required in establishing lot sizes, setbacks, and frontages, these types of changes in planning development can result in the same number of dwellings occupying a smaller amount of land, thus preserving existing trees and forests.

• Minimize impacts of construction. The largest single killer of urban trees is soil compaction (American Forests/National Association of Homebuilders, 1995). Trees need pore spaces equaling about 50% of the soil volume. Standard construction practices can be very harmful and even deadly to trees. Soil compaction, heavy equipment, and undue erosion is detrimental to tree roots often causing irreparable damage. For extra protection, fence off treed areas to the dripline

• Implement city codes and ordinances to preserve trees. Tree ordinances provide communities with legislation for planting and/or preserving trees. These regulations help ensure that trees will be protected during construction. When the ordinance specifies tree *conservation* then groves of trees will be emphasized rather than disjointed individuals. The tree ordi-



In the West Corvallis study, by preserving buffers along stream corridors and around wetlands, much of the existing forest was also saved.

nance for Atlanta, Georgia, for example, specifies that no more than 50% of existing trees be removed, damaged, or destroyed, that all trees within 30 feet of a construction zone be protected, that no excavation occur within 10 feet of a tree, and that no materials be placed in such a way as to block water and/or air circulation around a tree (Grey, Deneke, 1992).

• Consider economic benefits. Preserving native and mature trees on site may increase construction and development costs, but new developments with mature trees demand higher selling prices. The Buckingham Company in Maryland conserved as much vegetation as possible when building an apartment complex. This added $2.50 per square foot to their construction costs but they were able to make up the difference by increased revenues due to the popularity of the complex (CWP, 1998). Limiting grading to areas well away from tree roots limits grading and its associated costs. Less money is needed to landscape new developments if trees are already there and where space and budget allow it is easy to infill areas of existing trees rather than start from scratch.

• Consider maintenance options. Groves of native trees require tittle or no maintenance. These groves are usually solid and healthy and well-adapted to the environment. Removal of these trees would most certainly result in the need to plant new trees and/or turf which would require incurring additional costs. Mature and native trees usually do not need any additional water thereby saving irrigation costs. It has been estimated that corporate land owners can save $270 - $640 per acre in annual maintenance costs when open areas are managed as natural areas rather than landscaped with new exotic plants (CWP, 1998).

• New developments with mature trees add value to neighborhoods. People will pay as much as 20°/0 more for a home landscaped with mature trees (American Forests, 1995). Trees are a visual resource and break up the monotony of building walls and roof lines. The US Forest Service estimates that trees can increase property values by 7% to 20%. (Ebenrick in Moll 1989)

guideline

Urban "tree spaces" are *all* the appropriate and beneficial places for planting trees in the urban environment. (Moll, 1989) If all such "tree spaces" were planted with trees, the severe environmental impacts of cities could be mitigated. Public open spaces such as parks, schoolyards, greenbelts and municipal lands could be managed as forested areas. Areas in cities that are often "paved over" can be reduced in size to allow planting of trees such as vegetated islands in parking lots, on cul-de-sacs, or along right-of-ways. Homeowners can be encouraged to plant trees around their homes through education, ordinances, and incentives.

OTHER ASSOCIATED GUIDELINES

1.2 PLAN GREEN INFRASTRUCTURE
4.3 DESIGN STREETS TO ENHANCE SURFACE DRAINAGE
6.2 USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF

"The urban forest is only one part, although a vital part, of the larger urban development scene. To grow successfully, the urban forest must be designed as an integral part of the urban whole and considered by all members of the design team over the long period of planning and construction."

(Moll, 1989)

Trees align the edge between a bikeway and park in Eugene, Oregon. A single row is minimal. Here is space for two to three more rows of trees.

The roads, driveways, and houses of new residential developments are replacing trees at a rapid rate. Local government support for city and county tree programs is declining despite the fact that trees provide substantial economic, environmental, and social benefits (McPherson, 1995). A survey conducted in 1992 estimated that 38% of cities surveyed reported that they care for fewer trees now than they did in 1988 (McPherson, 1995). In order to maintain a healthy urban forest it is necessary to create opportunities to preserve existing trees while constantly planting and maintaining new ones.

The three West Corvallis plans compared demonstrate different tree planting opportunities. With less street length overall for tree planting, the Status Quo plan had the least street trees at 2,375 trees, although this was compensated somewhat by more land for private tree planting (3,176 trees). The Neighborhood Village plan had the most street length and thus the most space for street trees (4,385 trees), although it was lower in the number of estimated private trees (2,506 trees). The Open Space plan had "street" trees along streets as well as public drainage corridors for a total of 2,585 planted trees in public areas and 2,783 trees planted in private areas. When each of the total number of planted trees was compared to tree loss over the existing plan, the Status Quo plan had 53% tree canopy overall, the Neighborhood Village plan had 61% tree canopy overall, and when added to only a 1% loss of existing trees, the Open Space plan had the highest percent of tree cover at 69%.

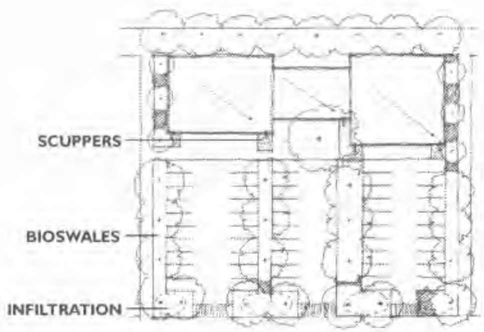
American Forests studies done in Atlanta, Sacramento, and Seattle American Forests recommend these target tree cover percentages for metropolitan areas:

Business districts: 15%
Urban residential; 25%
Suburban residential 50 %
Average city-wide 40 %

In each of the three alternative plans compared by the Center for Housing Innovation the suburban residential standard of 50% canopy cover was met and the Open Space Plan exceeded that target by nearly 20%.

Further Reading

McPherson, Gregory E., Net Benefits of Healthy and Productive Urban



American Forests recommends that each U.S. city set a goal of 40% tree canopy cover to help mitigate the deleterious environmental impacts of urbanization.

TREE PLANTING OPPORTUNITIES

• Plant trees in open areas such as streets, parking lots, and around homes. Public areas provide ideal places for planting trees and increasing the urban forest. These areas are often left unplanted, carpeted in lawns, or planted with a minimal numbers of small solitary trees. Landscaping with trees can make public areas more beautiful and contribute to the environmental health of a community. Urban forests in public areas can be a shared community resource where tree planting and maintenance parties can be held. Ideal public places where tree planting should be required include: streets, parking lots, parks, school grounds, utility corridors and all public lands. Additionally, minimum standards for tree planting on all commercial developments should be required.

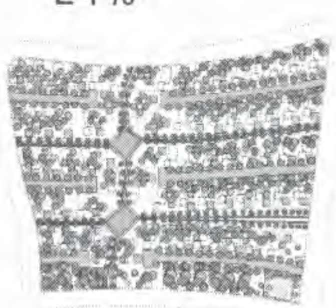
• Maximize street tree planting. Streets should be designed with required planting strips between sidewalks and the road surface wherever possible, and without conflicting overhead or underground utilities. Collector and arterial streets should have room for wide planting strips and center medians where turn lanes are not needed. Large trees should be planted at the closest healthy spacing— 30 feet on center for large trees and 40 to 50 feet on center for exceptionally large trees. Tree spacing and tree health are based on a tree's ability to take optimal advantage of above and below ground space. Planting trees too close together or in soils lacking in volume and nutrients can result in over competition and compromised health. Choose the largest trees that can be supported by the site's conditions. (private correspondence, Kitzman, 1999)

• Maximize tree planting in parking lots. Parking lots generate excessive amounts of polluted runoff, air pollution and urban heat effects. Balance the pollution production of these urban elements with the mitigating benefits of trees. Parking lots should be designed with tree-lined bioswales and walkways separating rows of parking bays(see guideline 5.3).

• Strategically plant trees around homes to save energy. Plant both evergreen and deciduous trees around homes to save on heating and cooling costs. In winter, evergreen trees can be used as a windbreak to block cold winds from the north. Deciduous trees can be planted on the south and west sides of the house to offer cooling shade in the summer and to allow sunlight to enter the home in winter. Using trees to shade while allowing air to circulate around a central heating/cooling unit or an air conditioner

17%

24%



36%

Increasing percentages of tree canopy illustrate some of the canopy coverages recommended by American Forests.

can cut energy costs by 10 ◦/0 (American Forests/National Association of Home Builders, 1995).

• Use trees to buffer noise. Planting trees is an ideal way to buffer unwanted noises. When planted in contiguous rows of at least 16' deep, trees can intercept transportation related noises. It has been estimated by some that a row of trees 100' deep at 45' high can reduce highway noise by 50 % (Moll, 1989). In windy areas trees offer their own noises which can be pleasant and act to soften other less desirable sounds.

• Select appropriate trees. To achieve maximum success, plant tree species that are most appropriate for natural site conditions. In most cases this means planting native trees, but it goes beyond that. Select riparian trees for wet conditions, large canopy trees for open spaces, narrow trees for tight spaces, and trees with high branching patterns next to roads. Evergreen trees continue to provide atmospheric and water quality benefits during the dormant season of deciduous trees. Particularly in regions with non-freezing winters, balance the planting of deciduous and evergreen trees. Where winter rains are concurrent with deciduous trees as in the Pacific northwest, plant evergreen trees to intercept rainfall. In cold climates plant evergreen trees to block cold winds thereby saving on energy consumption. Mixing different species of native trees within a grove adds to the regional character of a place, contributes to the biodiversity of a region, and guards against a total catastrophe if a certain species of tree succumbs to disease. It is generally accepted that no single species of tree should account for more than 10% of the city's tree population (McPherson 1998). Also, provide education and guidance about suitability for typical sites and supply planting details for trees in public

4

PROTECT AND AUGMENT NATURAL DRAINAGE

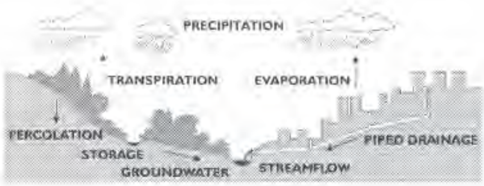
guidelines

4.1 TREAT STORMWATER AT THE SOURCE
4.2 PLAN DRAINAGE NETWORK EARLY
4.3 DESIGN STREETS TO ENHANCE SURFACE DRAINAGE
4.4 USE HYBRID SYSTEMS

BACKGROUND

"The final test of the natural drainage system at the Woodlands occurred when a record storm hit the area in April, 1979. Nine inches of rain fell within five hours and no house in The Woodlands flooded although adjacent subdivisions were awash."

(Spirn, 1984 pg. 166)



"Hydrologic restoration is not an economic or technological imposition upon nature. It is just nature. Nature wants to work. It evolves to work... Stormwater management must re-initiate the kinds of long term environmental processes that occurred before impervious surfaces were installed." (Ferguson 1998, pg. 11)

URBANIZATION DISRUPTS THE NATURAL HYDROLOGIC SYSTEM

Natural drainage systems are impacted by poorly planned development. Under natural conditions, the hydrologic system meanders following the topography of the landscape, filtering into the ground, settling in depressions, and eventually disappearing into streams and rivers. Urbanization typically involves building and paving vast areas. Increases in volume and velocity of water entering natural water systems coupled with a possible 70% increase in diffuse pollution has a number of negative impacts on water quality including eroded streambanks, increased eutrophication, increased stream temperatures, decreases in available oxygen for fish and other aquatic life, and increased sedimentation among other things (EPA, 1999).

An additional problem is that as surface stormwater travels across impervious cover it accumulates and conveys a significant amount of urban related pollutants. Diffuse sources of pollution known as non-point source pollution result from the accumulation of small amounts of pollutants that slowly enter watersheds over long periods of time (Loizeauz-Bennett, 1999). "In the United States it has been estimated that some 70 ◦/0 of all water quality impairment is due to diffuse source pollution" (Loizeaux-Bennnet, 1999, pg.56). These non-point source pollutants are derived from automobile-related oil and sediment, lawn care related pesticides and herbicides, erosion from construction sites, house and pet waste, and other pollutants resulting from daily urban activities.

The 1972 Clean Water Act specifies that all pollutant discharges to open water should be eliminated. The Clean Water Act requires cities to submit permits that include a stormwater plan to eliminate non-point source pollutant discharges in their drainage plan. Planning a drainage network early in the design process can generate innovative and integrative possibilities for ways to manage stormwater runoff. As the final rules of the Clean Water Act are enforced, urbanized areas will have to find innovative ways to clean runoff, a primary source of non-point source pollution, before it enters our nation's waters.

Further Reading

Ferguson, Bruce, *Introduction to Stormwater*
Spirn, Whiston Anne, *The Granite Garden*
Wallace McHarg Roberts and Todd (WMRT), *Woodlands New Community An Ecological Plan*

The sidewalk at The Woodlands Inn bridges over this intentional infiltration area. The Woodlands, Texas.

Restorative infiltration starts at the potential sources of runoff, with porous pavements. It continues wherever possible with vegetated swales and basins that bring runoff continuously and repeatedly in contact with vegetation and soil." (Ferguson 1998, pg. 219)

A NATURAL STORM DRAINAGE SYSTEM PROTECTS THE NATURAL HYDROLOGY

In a forested natural environment, rainfall is intercepted by vegetation, reducing its impact by slowly allowing it to infiltrate and saturate the soil. That which runs off then meanders over rough terrain as sheet flow until it finds a low area where it gathers to become a tiny first order stream. These tiny streams flow together to become higher order streams until the water eventually reaches a river, lake, wetland or estuary. The time it takes a drop to travel from the canopy of a tree to the second or third order stream is considerable and significant amounts of the rainfall are taken up by plants and soil before reaching the first stream (Ferguson, 1998).

Whereas conventional urban drainage systems gather runoff and move it and its associated pollutants quickly, "natural" or surface storm drainage systems more closely mimic natural hydrology. Protecting and augmenting a natural surface drainage system involves first and foremost protecting riparian corridors, wetlands, floodplains, and the forest canopy and forest floor to the extent possible. It further involves replacing lost storage and infiltration capacity of the site through practices such as small scale biofiltration and water harvesting, porous pavements, reducing impervious surfaces, maximizing tree cover and reducing the use of managed landscapes.

Natural storm drainage systems have been successfully implemented in North American cities, among them The Woodlands, Texas (pop. 150,000) and Bellevue, Washington (pop. 100,000). Both systems cost a fraction of conventional piped and channeled systems, perform exceptionally well under potential flooding conditions, and concurrently provide multiple other benefits listed below. Slowing the rate of overland flow as water runs over rough vegetated terrain slows the rate of runoff. Both The Woodlands (1979 and 1994) (Interview with Robert Heineman, March, 1995) and Bellevue (1984 and 1990) have survived storms in excess of 100 year levels with very little damage to private or public property. In spite of increasing its population by almost one third between 1980 and 1990 Bellevue experienced less damage from flooding in the more recent storm.

Portions of several golf courses at The Woodlands are located in flood prone areas. When flooding occurs, alternate playing routes are used.

THE BENEFITS OF SURFACE DRAINAGE SYSTEMS INCLUDE:

• They reduce runoff volumes relative to conventional storm drainage systems, and concurrently recharge groundwater by capturing rain in vegetation, duff, depressions, ponds and wetlands which allow water to infiltrate rather than to run off.

• They maintain water quality by bio-filtering or absorbing sediments and other pollutants. In urbanized areas the natural system must be augmented by pre-treatment of polluted runoff using appropriate non-structural BMPs such as stormwater ponds or wetlands.

• They protect natural vegetation and habitat. Kelsey and Coal Creeks in Bellevue continue to support "salmonid" fish populations, whereas fish populations in most of the rivers and streams in Pacific Northwest cities are listed as threatened or endangered. (Bellevue 1995, cite NOAA web site or newspaper articles about listing)

• They minimize capital costs of stormwater drainage systems and spread maintenance costs over several jurisdictions (parks, natural resources, transportation). The cost of implementing a natural drainage system at The Woodlands resulted in a savings of nearly 14.5 million dollars from an estimated cost of $18, 679,300 for a convention drainage system (WMRT, 1994).

• They provide multiple social goals such as scenic values of natural areas, passive recreation, environmental education and alternate transportation. By concurrently having more public open space along creeks and around wetlands Bellevue had ten times more miles of off-road trails than Redmond or Renton, its two neighbors (Girling 1996)

guideline

Treating stormwater runoff on site can reduce runoff and pollutant loads by 20 - 60%. (CWP, 1998) Careful site design along with the implementation of stormwater BMP's will aid in the general management of stormwater runoff and in the reduction of runoff and pollutant volumes. While there is not one ideal solution, a careful consideration of site design and BMP options can result in a comprehensive integrated stormwater management plan.

OTHER ASSOCIATED GUIDELINES

6.2 USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF

This large stormwater treatment pond at Ecolonia, The Netherlands is the central landscape feature of the community.

"FIRST FLUSH" MATTERS

Most conventional stormwater strategies are designed to consider ten year, twenty-five year, and other larger storm events. Most storm events are not considered significant, however on average across the United States, the majority of storm events generate less than 1" of rain in 24 hours. Rainfall measured in Atlanta, Georgia demonstrated that 90 ₀/0 of the storms measured during a one year period, generated less than .2" of rain (Ferguson, 1998). Similarly, 91% of the rain measured in Eugene, Oregon generated less than 1" of rain in a 24 hour period (Oregon Climate Service, 1999). Automobile and lawn care related pollutants affect water quality to a large degree in small rainstorms that are not even qualified as a specific event. The small amounts of runoff generated in these small rain storms are considered "first flush" and carry the greatest amount of concentrated pollutants. First flush can easily be treated at its origin thereby controlling the highest concentrations of nonpoint source pollution.

"END OF PIPE" STRATEGIES ARE LESS EFFICIENT

Stormwater runoff is typically considered a problem to be dealt with later. When stormwater travels away from its point of origin through a series of pipes, opportunities to reduce quantity and improve water quality are lost. Where water quality and flooding become problematic, "end of pipe" strategies, such as a sand filter or a large detention pond, are employed. These strategies, however, tend to be large, costly, more complex, and less efficient at managing stormwater runoff (Richman and Associates, 1997).

STORMWATER DETENTION SHOULD START AT THE SOURCE

"By starting at the source - reducing impervious cover and utilizing green space for stormwater treatment - communities can sharply reduce the volume of stormwater runoff that must be treated." (CWP, 1998, pg. 168)

• Understanding a given site informs designers and planners of the most effective type(s) of BMP's. The rate at which water percolates downward through soils vary dramatically with soil and slope. Highly pervious soils are ideal for rapid infiltration of clean runoff. Less pervious soils retain water longer, thus are suitable for BMP's requiring longer treatment times.

• It is important to evaluate rainfall patterns and slope for a site as these factor into the overall permeability of soils. For example, although a

Further Reading

Oregon Climate Service, www.ocs.orst.edu
Richman, Tom and Associates, Start at the Source. Bay Area Stormwater Management Association

This desert garden located in a park in Davis, California provides flood storage and infiltration for the nearby subdivision.

particular soil may not be very permeable, if the slope is gentle and rainfall comes in small amounts over long periods of time, that soil will infiltrate adequately. The Natural Resource Conservation Service (NRCS) has maps and information about soils for most counties.

• Accommodate water harvesting, storage and infiltration on each property. Water harvesting is the direct capture and use of runoff on-site. In some applications water harvesting maintains the water levels in permanent ponds and wetlands. In other cases, water is stored in tanks or cisterns for irrigation or other uses. By replacing the conventional BMPs required by the county, such as stormwater ponds, with rain gardens and extensive surface drainage throughout the development, developers of "Somerset", in Prince George's County, Maryland, spent 75% less (1999) on stormwater detention and filtration. In addition, residents are expected to save $100 to $200 each year in runoff-related fees. (US EPA "News Notes," Issue 42, January 1999). Such facilities should store, in combination, site runoff from regularly occurring storms. Wet ponds, cisterns, "rain gardens," dry wells, and infiltration basins are all examples. One family in Eugene, Oregon constructed an 8700 gallon tank under their garage. This tank collects all of the runoff from their roof and driveway during the rainy winter months and supplies all of their irrigation needs during Eugene's exceptionally dry summer (Interview with Anita Van Asperdt, November, 1999).

• Use a biofilter to encourage sheet flow. Sheet flow is a condition where shallow amounts of stormwater travels uniformly across the landscape. Sheet flow travels slowly across short distances where it is either captured in a biofiltration area or funneled into a swale or pipe system. Sheet flow can be maintained in a biofilter by constructing the biofilter with gently sloping sides (approx. 3:1) and with slopes of 1 -2 % (Bay Area Stormwater Agencies Association, 1997). As water moves slowly across a length of at least 10 feet vegetation can capture pollutants and absorb water.

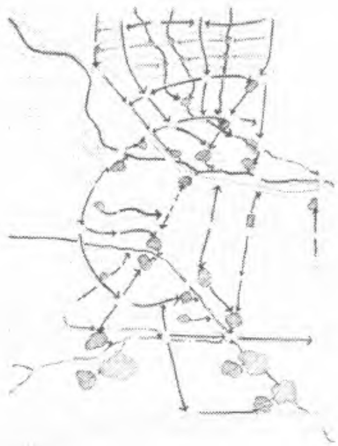
guideline

A natural storm drainage system protects and utilizes the natural hydrology to temporarily store and then drain surface runoff. As natural areas become more developed managing stormwater during small, more frequent events becomes a critical design component.

OTHER ASSOCIATED GUIDELINES

1.1 PLAN GREEN INFRASTRUCTURE
1.2 SET ASIDE WETLANDS, STREAMS, AND NATURAL DRAINAGE

PLAN DRAINAGE NETWORK EARLY



A surface drainage network, design to augment natural site drainage, can help to mitigate the impacts of urbanization while providing a network of public space for passive recreation.

"The prevention of floods and the conservation and restoration of water will only be accomplished by the cumulative effect of many individual actions throughout the city" (Spirn, 1984, pg. 154)

A NATURAL DRAINAGE NETWORK REQUIRES PLANNING FROM THE START

Natural drainage networks require enough room to allow water to follow a path through planting strips, swales, and ponds. Most conventional drainage systems are designed to detain, convey, and then carry water off of a site that is already planned to have roads, sidewalks, parking Lots and buildings. Landscaping that is planned is decorative and often is not raised above paved surfaces. If a surface drainage network is planned at the earliest stages of development, landscaped areas can carry runoff and provide attractive vegetation concurrently. The Woodlands in Houston, Texas incorporated a natural drainage system into their site plan. They began the planning phase by identifying the land features critical to a functioning natural drainage system. Identifying slope, soil, vegetation, and the relationship of physiographic conditions provided the information necessary to set aside enough Land for stormwater to slowly travel and infiltrate (WMRT, 1974). This information allowed them to then determine how to best develop the land with a natural drainage system already in place.

PLANNING A DRAINAGE NETWORK

• A planned drainage network is most effective when it is comprehensive. A drainage plan that incorporates the region, the neighborhood, and the individual lot is best. Planning at a large scale allows development to occur on sites that are already disturbed allowing areas of hydrologic function to be protected. Neighborhood scale developments can be clustered to allow more room for drainage networks in areas of appropriate slope, soils, and vegetation. Individual lots can contribute to the larger drainage system by conserving established and native vegetation, reducing impervious surfaces, and reducing soil impact during construction (Burke, 1997).

• Inventory the site's natural features to take advantage of natural drainage opportunities. An evaluation of topography, slope, natural vegetation, and soils will help determine natural drainage opportunities. Preserving or creating areas where water flows naturally, linked with areas for ponding will enhance natural drainage opportunities. An understanding of a site's soils will enable developers to preserve permeable soils for ponding and infiltration while using areas of impermeable soils for development.

By reversing the curvature of planted "islands" in parking lots, these landscape strips become filters and infiltration zones for parking lot runoff. These biofilters at the Oregon Museum of Science and Industry are estimated to filter 90% of the pollutants from runoff.

• Lay out a schematic surface storm drainage system early. This system would include biofilter strips, swales, ponds, and streams. Careful design and planning of a drainage network designed to slow and clean water will prevent pollutants from entering natural systems. Minimizing disturbances to the site's soils and vegetation will reduce problems associated with erosion such as increased sedimentation and reduced soil permeability. Establishing "sensitive" areas that are to be undisturbed are ways to minimize deleterious effects of site disturbance while simultaneously creating areas where water can pool, be cleansed by vegetation, and infiltrate the ground.

• Locate stormwater filtration sites at all points where urban stormwater may enter the natural system. These filtration facilities must occur above the point of entry of stormwater to natural waters. The outer edges of wide riparian or wetland buffers, parks, edges of school grounds and other public sites and parcels of leftover land are all ideal sites for stormwater filtration facilities.

guideline

Standard street design follows a formula of a curb and gutter system that quickly funnels stormwater runoff into pipes. Using shallow open channels instead of curbs would allow water from streets to be washed through these swales where pollutants can be absorbed and degraded by plants and infiltrated into the ground. Swale designs along roads work best when they are at least 10 - 12 feet in width and occur on one or both sides of the road (CWP, 1998)

OTHER ASSOCIATED GUIDELINES

5.1 REDUCE THE EXTENT OF STREET NETWORKS

5.2 REDUCE IMPACTS OF PAVED AREAS

DESIGN STREETS TO ENHANCE SURFACE DRAINAGE

Bioswales alongside streets can filter and infiltrate street runoff. This swale is at Village Homes in Davis, California.

CONTEMPORARY STREET DESIGNS AGGRAVATE STORM WATER PROBLEMS

Throughout the latter half of this century, American streets widened to accommodate ever-increasing volumes of traffic. These excessive street widths contribute a great deal of impervious cover to developed areas increasing stormwater runoff and contributing pollutants to natural water systems. Narrowing residential streets and modifying design standards can provide an opportunity to incorporate surface drainage systems that could collect, slow, and filter stormwater runoff directly along roads where runoff and pollutant loads are at a peak. "Treatment at Source" components should become a priority for highway and street design so that pollutants being conveyed off these surfaces by stormwater runoff are intercepted before stormwater runoff is discharged into receiving waters" (Richman and Associates, 1997). Most jurisdictions, for example, require residential streets to have curb and gutter systems as the primary mode of stormwater transport. While curbs and gutters are very efficient at quickly moving water to a piped system, they exacerbate flooding and pollution problems downstream. Stormwater transported through conventional systems accumulates and concentrates pollutants (Richman and Associates, 1997). When the water reaches its discharge point, pollutants washed off of streets and lawns drop directly into natural waters.

A street right-of-way (ROW) is a public easement that creates a corridor to move pedestrians, traffic, utilities, and stormwater through a development. Public ROW's are typically designed with wide parking and travel areas and narrow planting strips and sidewalks. Excessively wide travel and parking areas not only add unnecessary impervious surfaces, but also are believed to encourage speeding. The amount of impervious cover in the ROW is as high as 80 - 100% (Richman and Associates, 1997). To facilitate surface drainage, ROW's can be designed differently and still function as pedestrian and vehicular corridors. Street areas could be narrowed to help reduce travel speeds and to accommodate space for a vegetated channel or biofilter. Located between the street and sidewalk, these BMP's could capture runoff from both areas. They can be landscaped with combinations of trees, shrubs, and grasses to filter pollutants and enhance infiltration.

Further Reading

Richman & Associates, Start at the Source

DESIGN STREETS TO ENHANCE SURFACE DRAINAGE

STREET DESIGNS COULD ENHANCE SURFACE DRAINAGE

• Incorporate surface drainage and BMP's as part of the street network by inverting planting strips. Standard "maintained" planting strips along roadways are convex in shape, thus allowing stormwater runoff and plant maintenance-related pollutants to wash off onto streets and into piped drainage systems. This systems adds to stormwater runoff and associated pollution. Inverting planting strips so that they are concave allows some runoff from roads to infiltrate the soils of the planting areas while that running off is filtered. Concave planting strips are especially valuable for treating "first flush" runoff which typically carries the highest concentrations of pollutants (Richman and Associates, 1997).

• Stormwater draining from streets must be treated before it reaches the piped storm drain or natural waterways. On-site stormwater treatment is most appropriate for treating runoff from impervious surfaces— median strips and mid-lot basins are ideal.

• Concave road medians provide an excellent opportunity to catch and clean oils and other pollutants conveyed by stormwater coming directly off of roads. Concave medians can be designed as landscaped biofilters in the center of roads. Stormwater runoff from roads would be directed to these median strips where pollutants can be filtered by plants and soils. Because these medians are in direct contact with roads, they provide an optimum condition to manage "first flush" runoff which generally carries the highest concentration of pollutants from automobiles. (Richman and Associates, 1997)

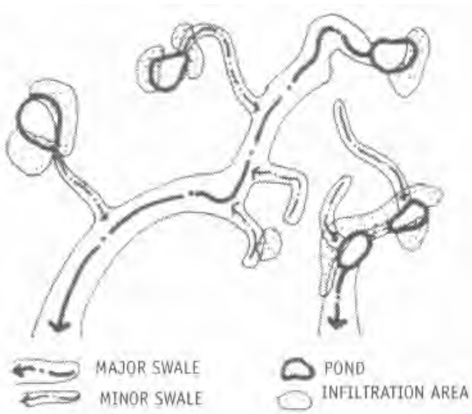
• Cul-de-sacs or "lollipops" are a popular suburban road design that is characterized by a single entry road with a round bulb at the end. A planted center island could be a planted basin used as a bioretention area, while concurrently reducing impervious surfaces.

guideline

An integration of surface drainage opportunities to manage small storms with piped systems to help control large storm events optimizes stormwater management for both water quality and flood control. An integrative approach to stormwater management at the early design phase will enable developers to incorporate systems that infiltrate soils, filter stormwater through vegetation to reduce and eliminate pollutants entering natural waterways and provide flood protection with piped systems when needed (Richman and Associates, 1997).

OTHER ASSOCIATED GUIDELINES

1.1 SET ASIDE WETLANDS, STREAMS, AND NATURAL DRAINAGE
6.2 USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF



This 1974 concept diagram for surface drainage at The Woodlands, Texas shows infiltration areas adjacent to ponds and a heirarchy of drainage swales.

BMP'S CAN SUBSTITUTE OR SUPPLEMENT TRADITIONAL PIPED METHODS OF STORMWATER CONVEYANCE

Designing a drainage system that integrates surface drainage in conjunction with traditional pipe and gutter systems will significantly reduce the amount of pollutants washing off of streets, rooftops, and lawns. Surface drainage systems such as vegetated swales and biofilters are designed to capture and slow water as it runs off of roads and chemically treated lawns so that it can filter through vegetation and infiltrate the ground.

Best management practices (BMP's, a term created by the EPA) are a whole range of facilities and management practices aimed at reducing the impacts of non-point source pollution. BMP facilities include "structural", such as oil-separating catchbasins and manufactured filtering devices and "non-structural", such as swales, ponds, and wetlands. Non-structural BMP's can be designed to augment natural or surface drainage systems while greatly reducing pollution impacts of urban stormwater. Such systems are typically inexpensive, natural in appearance, and serve multiple other purposes such as passive recreation and habitat enhancement.

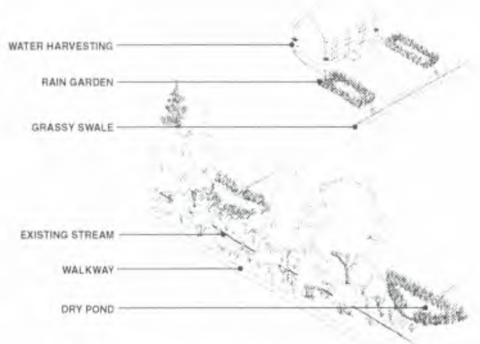
BMP's may be used in isolation or in series as "treatment trains", that working together can often mitigate a broader spectrum of pollutants. Combination systems allow pre-treatment of severe pollutants such as those generated from automobiles, so that the main treatment facility can function at an optimal level. This type of system also allows stormwater BMP's to better target specific pollutants. For example, sedimentation facilities work best at treating course particulate, while marshes are better at treating fine particulate. Multi-purpose treatment facilities optimize what each intervention does best while compensating for their weaknesses (City of Portland, 1995).

OPEN CHANNELS SPAN A VARIETY OF SURFACE DRAINAGE BMP'S.

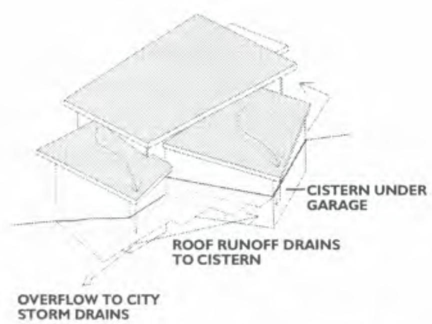
• Vegetated Swales, Grass Channels, Biofilters are variations of the same concept. These are shallow, concave basins that act as alternatives to typical gutter and pipe systems. These channels are characterized by wide bottoms, gently sloping sides and dense vegetation. They slow and detain water for at least twenty to thirty minutes so that it can be cleaned before it reaches natural water systems. (CWP,1998) Grassy swales also slow water flow enough to infiltrate the soil allowing some stormwater to be absorbed on site.

Further Reading

City of Portland, Stormwater Quality Facilities, A Design Guidance Manual
DEQ, www.deq.state.or.us/wq/wqfact/wqfact.htm
Bureau of Environmental Services, City of Portland, Stormwater Management Manual
Watershed Protection Techniques: Volume 1 Numbers 1,3.



A "treatment train" in a residential area.



An 8700 gallon cistern under this garage collects roof and driveway runoff from winter rains and stores it for irrigation purposes in the summer. Van Asperdt - Boesjes residence in Eugene, Oregon.

• Length of swale and time of residence of water in the swale are important. In a 1991 test of a grass biofiltration swale in Washington state, researchers concluded that with a 5 to 10 minute residence time in a minimum 100 foot long biofilter, reliable pollutant removals were achieved. Results ranged from a low of 15°/0 of lead to a high of 72% of phosphorous removed. Doubling the length of the swale significantly improved some pollutant removals. The researchers recommended off-line systems to avoid damage to the swales during heavy rainfalls. (Watershed Protection Techniques Vol. 1 No. 3 Fall 1994.)

• To be most effective, open channels are best suited to particular slopes, lengths, and soils. Gentle slopes of less than 5 °/0 allow water to travel slowly enough to be treated. Where slopes are greater than 5 °/0, check dams can be integrated into the swale to allow water to pond to control its entry into the system can be delayed. Contributing flow lengths of <150' work best without overwhelming the system. Soils should be permeable so that infiltration can occur, but not sandy or water will absorb before it can be treated and will make the channel too vulnerable to erosion. Entry velocities of 1.5 fps (feet per second) work best making open channels best suited to two year storm events. (CWP, 1995). Occasional mowing of the grass and routine removal of excess leaves and debris that may block the system improves performance.

• Swales are inexpensive to build and when used in place of storm sewer pipes they reduce construction costs. A 4' wide x 1' deep swale costs approximately $1.00/ft. for excavation, seeding and erosion control, while a concrete pipe of similar capacity can cost up to $40.00 . (School of Environmental Design, University of Georgia, 1997) If swales are planted and managed correctly, maintenance regimes are fairly simple and low cost.

• Dry swales are a more "engineered" version of a grass channel, designed to provide more thorough and complete treatment or to reduce or elimi nate particular pollutants. Dry swales have a deeper bottom than grass channels and are further characterized by a layer of sandy loam where water can quickly infiltrate after it has been filtered through vegetation. The filtered water absorbs through the sand and is collected in a pipe and quickly deposited into nearby rivers. An advantage to this strategy is that water is completely absorbed so that the problems associated with standing water, such as mosquitoes and slime, are eliminated. A disadvantage is that sand may not look as attractive as the vegetation associated with wet swales (CWP, 1998)

Stormwater planters at Buckman Heights Apartments in Portland, Oregon collect runoff from roofs and the plaza for up to five year storm events. Over flow is directed to drywalls.

• Bio-retention is an alternative BMP that uses native forest ecosystems and landscape processes to enhance stormwater quality. Either naturally preserved areas or created basins capture sheet flow and treat the stormwater using microbial soil processes, infiltration, transpiration and plant uptake. This shallow planted area can be fairly wide and can include trees, shrubs, perennials and groundcovers . They can be a planted border around a lawn serving the dual purpose of reducing turf and cleaning runoff. Soils are a critical component of bioretention facilities. They must be permeable enough to allow water to infiltrate and they must be vital enough to allow micro-organisms to break down pollutants as they pass through the soil. Bioretention areas act as part of the "urban forest' adding to both the health and beautification of developed areas. "Rain Gardens" are small bio-retention areas planted to mimic the physical structure of a local forest. As implemented by a Maryland developer, rain gardens are shallow basins 6" deep and 300 to 400 square feet, located in the low area of each lot. Runoff from typical rainfalls gathers in the basin and infiltrates over a 48 hour period.

• Stormwater planters are generally located next to rain gutter downspouts and filter runoff through planter soils, and eventually into native soils. As runoff passes through planter soils pollutants are captured before they infiltrate the native soils. Stormwater planters are designed to drain within 3-4 hours after a storm (Bureau of Environmental Services, 1999). Stormwater planters are an attractive amenity and should be planted with plants that tolerant both periods of drought and inundation.

• Wetlands, marshes, and ponds provide a multitude of benefits. Their primary function is to detain water so that pollutants can be trapped and absorbed by plants as well as slowly absorbed into the ground. These shallow, vegetated ponds require space to function and are therefore best suited for neighborhood and regional open space areas. An added benefit of wetlands and marshes is that they are beautiful and provide habitat for a variety of wildlife form aquatic to avian species. Vegetated ponds work well in small scale residential settings as well as in neighborhood or regional open space areas. Ponds control pollutant levels by storing water long enough so that pollutants can settle and be absorbed into the ground.

• Stormwater ponds and wetlands can be quite effective in removing urban pollutants such as suspended solids and lead. (70% of ponds/wetlands removed >60% of TSS and lead) Phosphorous removal was more variable (55% removed >60%). Nitrogen removal was much lower, in the 20°/0 to 40% range, and zinc removal was highly variable. (Watershed Protection Techniques Vol. 1 No. 1 Feb, 1994)

5 REDUCE IMPERVIOUS SURFACES

guidelines

5.1 REDUCE EXTENT OF STREET NETWORK
5.2 REDUCE IMPACTS OF PAVED AREAS

"More than thirty different scientific studies have documented that stream, lake, and wetland quality declines sharply when impervious cover in upstream watersheds exceeds 10 percent. The strong influence of impervious cover on aquatic systems presents a major challenge to communities in sustainable development."

Center for Watershed Protection, Better Site Design, p.1

A typical "strip" commercial area is 92% to 95% impervious surfaces.

URBANIZATION INCREASES IMPERVIOUS COVER

Urbanization alters natural hydrologic patterns as impervious surfaces replace natural land surfaces. Impervious surface is land covered by roads, rooftops, parking lots, driveways, sidewalks, patios, and any other surface that prevents water penetration into the soil. As land is covered with i mpervious surfaces, rain water cannot follow its natural drainage cycle of infiltrating into the soil, and replenishing groundwater. Instead precipitation runs off rooftops, over paved surfaces, along street gutters, and into the piped stormwater system. Water traverses over these relatively smooth surfaces much faster than it would grass or any other vegetated area. Runoff from impervious surfaces generates far more runoff than natural areas, and in most cities is piped to the nearest lake, river, or stream. Runoff generated from an underdeveloped watershed increases approximately 500% once developed (EPA, 1996).

PIPED STORMWATER SYSTEMS INCREASE RUNOFF VOLUME AND ACCELERATE PEAK FLOW

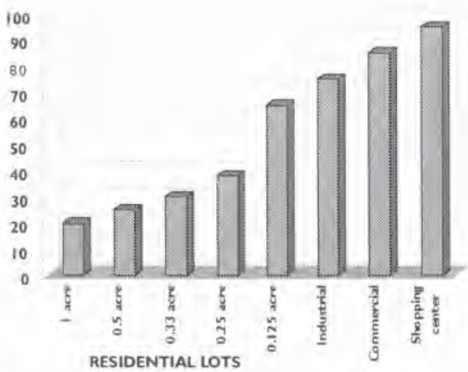
Increased volumes of runoff passing through piped stormwater systems at accelerated rates create high peak flows in downstream waters. Peak flows are calculated when the greatest volume of runoff passes through a system and how fast that water moves into streams below. The increased frequency and magnitude of peak flows erodes stream banks, creates potential flooding, increases siltation, increases water temperatures, disrupts habitat (Sediment and Stormwater Program Delaware Dept. of Natural Resources, 1997). Fish species diversity declines as impervious cover increases. For example, the Maryland Department of Natural Resources studied four similar subwatersheds in the Maryland Peidmont. The watershed with 10 º/0 or less of impervious cover, had a total of twelve species and seven sensitive species, while the watershed with the 55 º/0 of impervious surface, had a total of two fish species and zero sensitive species. (CWP,1995).

THE DESIGN OF A STORMWATER SYSTEM EFFECTS THE AMOUNT OF RUNOFF AND POLLUTION ENTERING DOWNSTREAM WATERS

In the United States, it has been estimated that stormwater pollution (siltation, salinisation, eutrophication, and water and sediment contamination) and temperature increases are accountable for 70%-80% of all water impairment. (Loizeaux-Bennett, 1999). Pollutants, such as oil, grease, and metals from automobiles and phosphorus and nitrogen from fertilizer and natural decomposition, accumulate on impervious surfaces

Further Reading

Center for Watershed Protection. "The Importance of Imperviousness."
University of Georgia School of Design. Land Development Provisions to Protect Georgia Water Quality.



With conventional development, imperviousness increases with density. Very high percentages of impervious surfaces are common in commercial developments. Integrated design of BMPs such as infiltration basins can mitigate these impacts.

between rain storms. In most north American cities, natural streams, rivers, lakes, or the ocean receive this urban water pollution, and many of theses rivers are exhibiting the effects. In Oregon, 26.6% of all streams and rivers were classified by the Department of Environmental Quality as "non supportive" of beneficial uses, such as fisheries, aquatic Life, recreation, drinking water supplies, and aesthetics (CPW, 1994). In the West Corvallis Comparison, the conventional piped stormwater system of the Neighborhood Village Plan, created considerably higher peak flow and more pollutants in comparison to the combined surface and piped stormwater system of the Open Space Plan. For a ten year storm event, the Neighborhood Village plan generated a 27% higher peak flow, 76%more nitrogen, and 108% more phosphorus than the Open Space Plan.

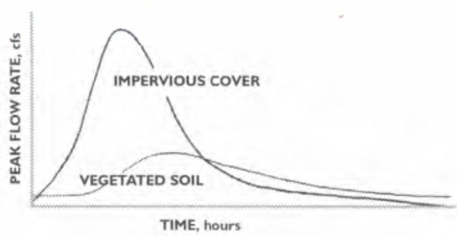
REDUCING IMPERVIOUSNESS

Development inevitably creates impervious surfaces. To what extent a watershed is impervious, however, depends on planning and design choices. Reducing the extent of street networks, decreasing street widths, using pervious pavements in communities, reducing the amount of paved parking coverage, disconnecting some paved areas from piped drainage, along with many other smaller scale design choices, *and conversely increasing areas where water can infiltrate,* all decrease the total effective area of imperviousness within a community.

- Reduce the extent of street networks. Incorporate; longer blocks with mid block pedestrian paths, cul-de-sac streets with pedestrian connections, narrow local access streets, skinnier streets, pervious alleys, and maximize number of homes for the street when appropriate. Together these strategies can decrease the amount of impervious surfaces related to the street network.

- Reduce impacts of parking areas and reduce the number of parking spaces to a minimum. Design parking lots to treat stormwater on site, reduce impervious surface through minimal parking standards, have shared parking spaces, use pervious materials, and efficient parking design.

BACKGROUND



Stormwater flows from impervious surfaces peak faster and with higher volumnes than flows from vegetated areas.

- Disconnect impervious surfaces . Reduce effective impervious area by disconnecting impervious surfaces and draining them into pervious areas. Effective impervious areas are defined as impervious surfaces that directly connect to the hydrologic system downstream. A 1999 study of the effects of disconnecting rooftops and implementing BMPs for new development in a 2,300 acre watershed found significant results. The study of a low density residential area with 30% open space found that annual runoff could be reduced by 20 percent and peak flows by 15 percent if rooftops of all new development in the watershed were disconnected (URS Greiner Woodward Clyde,1999).

guideline

Street design can have a significant effect on environmental impacts as well as costs, traffic, and character. In many new developments, little consideration is given for pedestrian safety, neighborhood character, total street length, and effects that impervious surfaces have on the environment. Street networks, including both the total length and width of paved roads and parking lots, typically consume close to one-half of urban lands. Streets produce the highest sources of urban pollutants in residential, commercial, and industrial areas. Reducing the extent of the street network through decreased street lengths, skinner streets, and pervious alleys can mitigate negative environmental impacts.

OTHER ASSOCIATED GUIDELINES

2.1 PLAN COMPACT, MIXED USE NEIGHBORHOODS
2.2 PROVIDE AN EFFECTIVE PEDESTRIAN AND BICYCLE NETWORK
4.2 DESIGN STREETS TO ENHANCE SURFACE DRAINAGE

A recent study in the Puget Sound found that over 60% of suburban imperviousness was attributed to its transportation network (May, 1997).

"Excessive street standards that require wide streets and large setbacks have major social and economic impacts. They waste land, drive up home costs, and negate the essence of residential livability." (Southworth, 1997, p. 6).

Further Reading

Southworth, Michael and Eran Ben-Joseph. *Streets and the Shaping of Towns and Cities.*

The two common types of street networks found in the United States are the grid (traditional street networks), and "loops and lollipops," the curvilinear patterns of contemporary subdivision networks (Moudon,1991). Of these two network types, the grid patterns typically generate 20 to 25 percent more total street length than the curvilinear patterns (CWP, 1998, p.37). Traditional grid networks are designed to have short block Lengths, straight streets, and back alleys in every block, hence increasing the network's overall impervious surface. The "loops and lollipops" networks incorporate longer block lengths, branching networks, and cul-de-sacs into the overall design (CWP, 1998).

Although the grid system generates more street length than the curvilinear system, it does have other potential advantages; greater connectivity for pedestrians and automobiles, oriented for mass transit, more "livable" streets with car storage on the alley side, and the ability to site more homes/unit length of street.

STREET SYSTEMS WITH REDUCED IMPERVIOUS SURFACES:

Since street paving represents a significant portion of urbanization, planning and design strategies that reduce the total amount of impervious surface attributable to street systems can be important to environmental protection. Reducing the total amount of impervious surfaces and increasing pervious surfaces, for example can, decrease stormwater runoff volume and associated pollution. The West Corvallis plan comparison found that despite similar net densities of 15 dwellings per acre, plans differed significantly in their amount of street area due to the street type. The Open Space plan, using a hybrid street system, contained 54 acres of impervious streets and paths, in comparison with the with the Neighborhood Village plan, which had 83 acres of streets and paths. The reduction of impervious surface while maintaining density in the Open Space plan was accomplished by using longer streets with mid blocks and pedestrian paths, skinny streets, T-shaped cul-de-sacs, deep narrow Lots with more houses per street block, and pervious alleys.

- With traditional grid street systems, use longer blocks with pedestrian or mid-block paths. Creating longer blocks will immediately reduce impervious surface because of fewer cross streets. Pedestrian or mid-block paths enhance a neighborhood's pedestrian and cycling network. These paths are not only narrower, they can also be paved with pervious surfaces.

SQ _____ *acres of streets*

NV _____ *acres of streets*

OS _____ *acres of streets*

In 1999, it cost approximately $144.50 per linear foot to pave a twenty foot wide road, with less than a ten percent grade. (Center for Housing Innovation, 1999). These costs include; pavement (streets and sidewalks), curbs and gutters, and storm sewer construction. Many other infrastructure costs are also related to road length, such as stormwater collector and trunk pipes, and other utility infrastructure costs: gas, water, and electricity, which tend to be distributed to households along road right of way.

- Consider hybrid street systems in which traditional grids are combined with pavement reducing systems; cul-de-sacs where neighborhoods meet open space paths or greenways; larger vehicular blocks with more finely scaled pedestrian connections; alley access behind houses with parks or greenways in front.

- Use narrow deep lots in residential areas to create a compact street network. Deep narrow lots increase the total dwellings per unit of street length and conversely result in less oeverall street network.

- Design streets to work with existing natural amenities and less impervious surfaces. Modifications to traditional finely gridded streets and to conventional "loops and lollipops" can be used to reduce impervious surfaces while maintaining a good pedestrian system.

- Minimize the pavements in cul-de-sacs or dead-end streets. The radius of a cul-de-sac should be just large enough for emergency vehicles to turn around, and should have vegetation in the center, to reduce overall paving. After on the ground testing with fire crews, Portland, Oregon, has reduced the minimum turning radius for cul-de-sacs to 35 feet, whereas the national standard is closer to 45 feet. Creating pedestrian connections between cul-de-sacs restores lost connectivity without increasing imperviousness.
- Use pervious paving materials for alleys, cul-de-sacs and all low volume vehicular areas. Pervious paving should only be used in areas of low vehicle traffic and on appropriate soils (not on unstable or swelling soils).

INCORPORATE SKINNY STREET DESIGN

In many communities residential street standards call for 50-60 foot right of way with 36 feet of pavement. However, "several national engineering organizations have recommended that residential streets be as narrow as 22 feet in width (AASHTO, 1994; ASCE, 1990), if they serve neighborhoods that produce low traffic volumes (less that 500 daily trips, or 50 homes)," (CWP, 1999, p.29). In Portland, Oregon, the city created a Skinny Street program that has reduced many residential streets by as much as 12 feet. to 20-26 feet wide depending on parking needs (Southworth, 1997). Simple reductions in the dimension of streets, sidewalks, and right of way may

Recent studies indicate that reducing the width of residential streets may increase safety. The Federal Highway Administration (1997), ITE (1997), and ULI (1992) all noted that narrow street widths tend to reduce automobile speeds (CWP,1998)

appear insignificant in streetscape designs from block to block. However, these changes compounded at a larger scale, can have a tremendous effect on the reductions of impervious surface, stormwater runoff, stormwater pollution, and the overall character of a neighborhood.

Design streets to have minimal amount of paving appropriate to the street's traffic volume.

- Use skinny streets for residential streets under 500 average daily trips (ADT). Narrower streets not only decrease the amount of impervious paving but increase safety, and add opportunity for additional street trees, swales and areas for treating stormwater runoff.

- Use queuing streets. The queuing street, allows for parking on one or both sides of the street with and the center lane shared by traffic going both ways. The street type can be appropriate when ADT is under 500 trips per day.

guideline

The impact of the automobile is evident not only through extensive street networks, but also through the amount of land dedicated to parking. Most parking lots and residential driveways are impervious and directly connected to the stormwater system. This means many road pollutants wash off into the stormwater system. By reducing the overall size of paved parking, using pervious pavements, and disconnecting paved surfaces from the piped drainage systems, significant improvements can be made.

OTHER ASSOCIATED GUIDELINES

4.1 TREAT STORMWATER AT THE SOURCE
6.2 USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF

"Traditional solutions for stormwater management have not been widely successful; in contrast, permeable pavements can be one element of a more promising alternate approach to reduce the downstream consequences of urban development."

(Booth & Leavitt, 1999,p.314)

A new residential development near Copenhagen, Denmark utilized crushed limestone for driveways and parking.

COMMERCIAL AND OFFICE PARKING HAS BEEN OVER-SUPPLIED NATIONWIDE

Although it necessary to have adequate parking, a study done by Wilson in 1995, showed that much suburban commercial and office parking has been over-supplied nationwide (Ferguson, 1997). Parking standards often require a minimal number of parking spots per land use rather than maximum number. Cities typically require 4 parking spaces per 1,000 square feet of office floor. However a study by Wilson found that only 2.8 spaces were actually used during peak parking hours (Ferguson, 1997). Developers also tend to size parking lots for the holiday rush instead of everyday use, creating paved areas that are under utilized.

EFFICIENT PARKING LOT DESIGN CAN SIGNIFICANTLY DECREASE PARKING LOT AREA

"The standard parking stall occupies only 160 square feet, but when combined with aisles, driveways, curbs, overhanging space, and median islands, a parking lot can require up to 400 square feet per vehicle, or nearly one acre per 100 cars" (Richman, 1997, p.46). Certain components, such as overhanging spaces and median islands should be a pervious surface. Parking codes often require standard parking stalls geared to larger vehicles, despite the fact that smaller cars comprise 40 to 50 ◦/0 of all cars on the road (ITE, 1994a). Efficient parking lot design can decrease imperviousness; through smaller stall sizes, using one way aisles, and incorporating pervious areas for overflow parking.

IMPERVIOUS COVER CAN BE MITIGATED BY THE USE OF PERVIOUS PAVEMENTS

The use of pervious pavements is a practical solution towards reducing impervious surfaces while accommodating urban lifestyles. Pervious pavements allow water to infiltrate through the pavement and can be used for most of the same purposes as impervious covers. Pervious pavements fall into three categories, pervious concrete and asphalt, unit pavers, and granular materials. A recent study found that "the differences in runoff responses from permeable and impermeable surfaces are quite dramatic. If soil conditions are suitable, permeable pavements are quite successful at managing runoff from small and moderate storms" (Booth & Leavitt, 1999, p323).

DISCONNECT IMPERVIOUS SURFACES FROM STORMWATER SYSTEM

Conventional parking lots drain directly into the piped stormwater system. A study in Wisconsin conducted by Bannerman in 1992, found that within commercial and industrial areas, parking lot runoff accounted for

Biofiltration swales replace conventional traffic islands in a Portland, Oregon parking lot. These swales are found to be __% effective at removing XXX pollutants associated with vehicular areas (Bureau of Environmental Services, 1999- get report from Tom L.)

"Driveways can comprise up to 40% of the total transportation network in a conventional residential development, with streets, turn-arounds, and sidewalks comprising the remaining 60%," (Richman, 1998, p.49).

one-fourth to two-thirds of the total suspended solids, total phosphorus, total copper, and total zinc Loads in the areas studied (CWP, 1998). Redirecting runoff into biofiltration areas within the parking lot detains and cleanses water on site.

Parking lots collect pollutants that leak, drip, or wear off from automobiles, along with atmosphere deposited pollutants.

- Evaluate local parking standards. Require maximum and minimum parking standards per each land use.

- Define primary parking and overflow parking. Use pervious materials for overflow parking.

- Encourage parking structures, shared parking opportunities between commercial and residential (night and daytime) users, and subsurface storage reservoirs under parking lots when possible. Although parking structures are expensive, incorporating them into building design means for less impervious cover is dedicated to parking.

- Reduce the amount of impervious cover dedicated to each parking stall. Create some parking spaces for compacts and some for larger vehicles. Use pervious pavements for low volume parking areas. Use one-way aisles in conjunction with angled parking when possible.

- Use pervious pavements in parking lots when proper conditions exist; appropriate soils and low volume parking. Pervious pavement materials, such as grasscrete, gravel or pavers, should be used with well draining soils and for spillover parking areas that are only used during occasional peak times. Use impervious pavements very selectively in parking areas. In high use areas and accessible parking spaces, impervious surfaces are needed for durability and for the smooth even surface.

- Use permeable paving for driveways. Residential driveways provide an obvious opportunity to decrease impervious surfaces. Many of these permeable pavements are far more attractive than asphalt and concrete, thus contribute to the value of the home. There are a variety of materials that residents can choose from: gravel, unit pavers on sand, paving under wheels only, and turf pavers.

A very narrow access road in Houten, The Netherlands provides a safe, attractive street environment, while drastically reducing paved area.

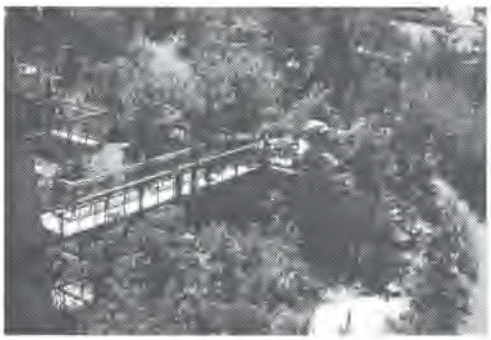
- Reduce driveway length and area by reducing or relaxing front setback requirements for houses. Reducing front setbacks results in shorter driveways but may cause other problems, such as less privacy because houses are closer to the street, or garages sitting in front of houses, generating poor ugly non pedestrian friendly streetscapes. When setbacks are reduced design standards may be needed.

- Disconnect impervious parking areas from stormwater system. Require swales, vegetated areas, and trees to be incorporated in parking lot design, and direct the runoff into these areas. Residential driveways can also be sloped to drain into adjacent vegetated areas. This allows runoff to be treated on site, and reduces total runoff and the amount of pollution entering the stormwater system.

6

SELECT VEGETATION TO IMPROVE WATER QUALITY

guidelines



The new REI store in Seattle, Washington mimics the Pacific Northwest forest landscape with dense native plantings.

SOME LANDSCAPING CONTRIBUTES TO STORMWATER RUNOFF AND POLLUTANTION

Daily activities and traditional land use patterns contribute to the degradation of streams and rivers as pollutants enter natural water systems. Forests, for example, provide habitat as well as stormwater runoff, air and water pollution mitigation by absorbing rainwater before it reaches the ground, stabilizing soils to prevent erosion, and by using their root systems to trap excess sediments. Certain land covers such as turf lawns require a considerable chemical interventions. These chemicals are known to be entering natural water systems through leaching and runoff. While turf areas do provide stormwater mitigation by diffusing runoff, if cultivated and maintained, they can also contribute to water pollution in the form of exported nutrients.

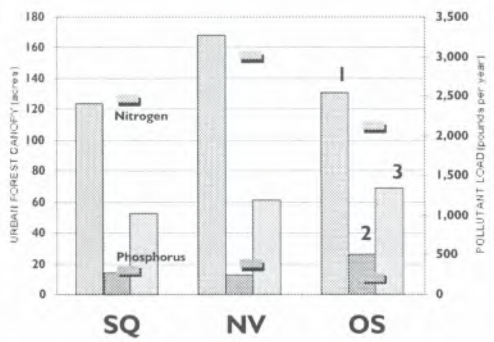
While all types of vegetation contribute to the slowing and infiltration of stormwater, not all types of vegetation contribute to the reduction of water pollution. Those that do not require fertilizers and irrigation, such as native plants, are typically not contributors. Maintained landscapes that require large amounts of fertilizers, pesticides, and fossil fuels are net losers, since some of these chemicals are washed into nearby rivers and streams. Large amounts of chemical treatments combined with intense watering regimes encourage pollutants to accumulate and travel. Additionally, the thatch root system of a single species lawn leads to soil compaction which increases runoff. Some estimates indicate that 60% of nitrogen applied to lawns leaches into groundwater or is washed off into local rivers and streams (Bormann et al., 1993). Residential lawns contributed 20% of the phosphate load of an urban stream in Wisconsin (Scheuler, 1995).

Increased levels of phosphorous and nitrogen cause rapid growth of aquatic plants and subsequent decomposition using excessive available oxygen, depriving fish and other aquatic life of oxygen, thus causing an eventual failure of a natural ecosystem. Studies have indicated that 44% of nitrogen and 28% of phosphorous fertilizers concentrate in the Mississippi River where nitrate concentrations have doubled in the last century. The Mississippi River has continuously shown increased levels of eutrophication. Although it is difficult to distinguish the source of excess nutrients , urban lawn or agriculture, there is a clear link between the introduction of nitrates and phosphates and their effect on watershed health (Bormann et al., 1993).

Further Reading

Bormann, Herbert F., Balmori, Diana, Gebelle, Gordon T., Redesigning the American Lawn

BACKGROUND



1 EXISTING FOREST CANOPY

2 NEW TREE CANOPY

3 IMPERVIOUS SURFACES

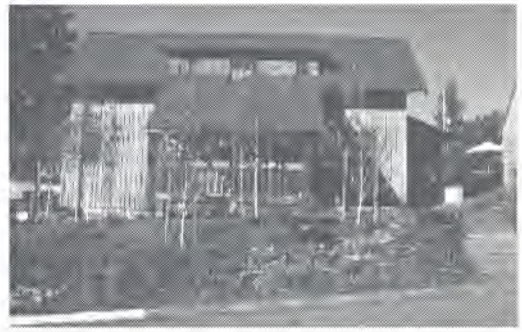
Water quality is best served when considered part of an integrated design strategy combining natural and cultural values

• Vegetation in the landscape can contribute to stormwater management in a number of ways. Deep rooted vegetation such as trees, shrubs, and perennial bunchgrasses intercept rainfall by absorbing moisture through their roots and leaves. They also have the unique ability to capture stormwater-related pollutants and either store or degrade them before they reach natural water systems (see guideline 6.2).

• Reductions in areas of high maintenance landscapes in favor of native low-maintenance landscapes reduces the amount of pollutants entering natural systems. Appropriate landscaping can enhance the visual appearance of roads while simultaneously mitigating the effects of pollutants being washed into local watersheds.

• Storm water management facilities that incorporate native planting such as vegetated swales, ponds, and wetlands, provide public amenities, habitat, and stormwater benefits concurrently. Such facilities contribute to the cleansing and slowing of stormwater runoff by allowing water to percolate in the ground and through plants absorbing pollutants before they enter nearby streams and rivers (The School of Environmental Design, The University of Georgia, 1997). In essence, an integration of landscape design, stormwater management, and development opportunities can best serve people and the environment.

REDUCE TURF AREA 6.1



guideline

A reduction in turf area and its associated maintenance regimes could help improve water quality by eliminating chemical run-off from lawns and incorporating plants that slow and filter run off before it enters natural water systems. Lawn alternatives such as groundcovers, meadows, perennials, shrubs, and trees require little or no maintenance in the form of chemical treatments, have root systems that loosen soil so that water can infiltrate rather than run off, and add biodiversity to the ecosystem. Landscapes that combine small amounts of lawn with other diverse plantings are beautiful and contribute to the overall health and character of a neighborhood.

OTHER ASSOCIATED GUIDELINES

4.4 USE HYBRID SYSTEMS

"The Lawn is the American garden, and grass is the nation's Largest crop"

(Helphand, 1993)

In a survey of 200 residents of Corvallis, Oregon, __% preferred the appearance of the "forested" front yard and __% ..... (Rochefort, 1999).

Further Reading

Bormann, Herbert F., Balmori, Diana, Gebelle, Gordon T., Redesigning the American Lawn
Helphand, Kenneth I., Vernacular Architecture Newsletter
Jenkins, Virginia Scott, The Lawn A History of an American Obsession
Scheuler, Tom, (CWP) Urban Pesticides: From the Lawn to the Stream

SHARED RESOURCES

• Use neighborhood common areas or parks as shared lawns. Impending issues of environmental concern may require a change in neighborhood planning and design. Smaller yards subsidized by more common areas could reduce the amount of turf grown in individual yards. These "common areas" could serve as places for community play and social activities while providing a shared place for lawn-intensive activities. These resources could be managed by members of the community, homeowners associations, or by a single maintenance service.

• Restore parks and public lands. Natural parks and public lands are ideal places for native landscape restoration projects. A restoration project is intended to recreate the natural landscape, rather than to plant things that are easy to obtain, hardy or attractive (Smith and Helmund, 1993). Studying other native vegetation in the area can serve as a guide for these types of projects. In Rio Grande Valley State Park in New Mexico, a project has been underway to protect existing native vegetation and to remove exotic species to allow the regeneration of native trees and shrubs (Smith and Helmund, 1993).

REDUCING TURF REDUCES ENVIRONMENTAL IMPACTS

• Evaluate how much lawn is really needed in the landscape. Lawns can provide a level surface for playing games, reading a book, or picnicking. An evaluation of how much lawn is needed for these types of activities may reveal that residential lawns can be reduced and still meet homeowner needs (Boorman et al., 1993). Other types of plantings such as groundcovers can be alternative places to enjoy these activities.

• Utilize lawn alternatives. Meadow mixes combining short bunchgrasses and wildflowers are available for all regions and for many different growing conditions. Bunchgrasses can take foot traffic, require only small amounts of water, require no fertilizer, and have deep roots that loosen soil and allow for greater infiltration of water. Wildflowers are beautiful, attract butterflies, require only annual mowing, give regional character, and add to local biodiversity. Groundcovers can be used as lawn alternatives and can often serve many of the same functions as traditional turf lawns. They offer the same uniformity and tidiness as turf lawn, but require far less maintenance. When locally appropriate species are selected, groundcovers thrive without the use of fertilizers, pesticides, and

"The democratic symbolism of the lawn may be appealing, but it carries an absurd and, today, insupportable environmental pricetag. In our quest for the perfect lawn, we waste vast quantities of water and energy. Acre for acre, the American lawn receives four times as much chemical pesticide as any US farmland." (Michael Pollen, New York Times, 1991 as quoted in Cities and Natural Processes, Michael Hough, 1995)

routine watering.

• Use trees, shrubs, and perennials to reduce lawn area. Small amounts of turf, meadow or groundcover bordered with perennials and shrubs add year-round interest to the garden, promotes wildlife and species diversity, and absorbs excess water and pollutants from storm-related runoff. Although they require regular maintenance in the form of watering and pruning they generally don't require chemical intervention and provide a multitude of flowers, foliage, and scent to the landscape.

CHANGING LAWN MANAGEMENT PRACTICES ALSO REDUCES ENVIRONMENTAL IMPACTS

• Careful selection of grass species along with selective management practices can greatly reduce the environmental detriments of traditionally managed lawns. When mowing the lawn set the blade for the greatest height possible. Longer blades of grass require less water. Use a mulching mower to chop and leave grass clippings on the ground so substitute for fertilizers. Hand-pull or allow some acceptable amount of weeds, and water only in the early morning or late evening to avoid evaporation. Allowing lawns to sustain a natural cycle of dormancy will also reduce watering needs during certain times of the year (Bormann et al., 1993).

THE AMERICAN LAWN REQUIRES A GREAT DEAL OF MAINTENANCE AND INCURS AN ENVIRONMENTAL COST

"In order to create and maintain the ideal lawn at its desired color, texture, and height we have brought the full weight of modern science to the task. Chemicals encourage or inhibit growth, water is redistributed and polluted, terrain is denuded, and machines mow incessantly." (Girling, Helphand, 1994 pg. 217)

Facts (Bormann et al., 1993)

• Lawnmowers pollute as much in one hour as driving 350 miles
• 30 - 60% of urban fresh water is used to water lawns
• $5,250,000,000 is spent annually on lawn fertilizers derived from fossil fuels
• 67,000,000 pounds of synthetic pesticides are used on US lawns each year
• 580,000,000 gallons of gas are used for lawnmowers each year
• $700,000,000 is spent on lawn pesticides
• Lawn pesticides are carried by stormwater runoff into nearby rivers
• 20,000,000 acres of the United States are planted in residential lawns
• Lawnmowers contribute to noise pollution

USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF 6.2

guideline

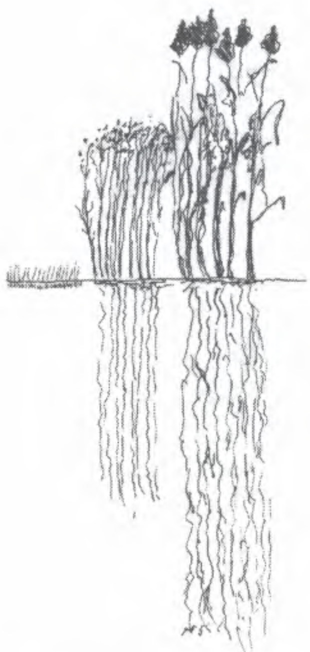
Landscaped areas provide opportunities for the cleansing and infiltration of stormwater. Deep-rooted plants help improve a soil's porosity so that runoff can more easily infiltrate the ground. The leaves of plants collect, intercept and absorb rain water before it reaches the ground. Plants make a significant contribution to an area's stormwater management capacity. Curb-and-gutter systems move stormwater with virtually no treatment, while open vegetated channels remove pollutants by allowing infiltration and filtering to occur. Additionally open channels encourage groundwater recharge, and can reduce the volume of stormwater runoff generated from a site.

OTHER ASSOCIATED GUIDELINES

4.1 TREAT STORMWATER AT THE SOURCE

4.2 PLAN DRAINAGE NETWORK EARLY

4.3 DESIGN STREETS TO ENHANCE SURFACE DRAINAGE



Turfgrass, shown on the far left, forms a dense, shallow-rooted mass that encourages runoff. In contrast, native bunch grasses have very deep roots that break up soils and absorb runoff.

AS NATURAL LANDSCAPES BECOME MORE URBANIZED FEWER PLANTS ARE AVAILABLE FOR NATURAL PROCESSES

Water quality is greatly affected by urban stormwater runoff. Pollutants from rooftops, streets, cars, and lawns are primary sources of water pollution. Stormwater is generally directed over streets and into catchbasins where it is quickly piped and flushed into nearby streams and rivers. In natural areas, stormwater moves slowly across vegetated areas and in the process is filtered and absorbed through a matrix of trees, plants and soils (Bay Area Stormwater Management Agencies Association, 1997). "A single street tree can have a total leaf surface area of several hundred to several thousand square feet..." (Bay Area Stormwater Agencies Association, 1997, pg.54)

USE PLANTS TO FILTER URBAN RUNOFF AND ABSORB AND DEGRADE POLLUTANTS

• Plants are the most natural way to filter runoff. Whether they are lining an open channel, buffering a roadway, or growing in ponds plants have an excellent capacity to absorb pollutants. Many plants have the ability absorb excess nutrients, filter out sediments, and break down certain pollutants such as some petroleum products.

• Plant's ability to absorb and degrade pollutants varies. Organic substances and excess nutrients such as those that wash off of lawns are readily absorbed by plants through water and nutrient uptake. As plants metabolize substances they are incorporated into the leaf or woody structure of the plant or degraded into water and gas

• Filtering urban runoff through vegetated areas helps to slow water so that it can infiltrate the ground and absorb and degrade pollutants before they are washed into natural water systems. Through the process of phytoremediation, plants are able to amend soil and water pollution (Kirsch, 1996). Following a toxic spill in southern Oregon, scientists from the University of Washington used hybrid poplars to absorb the toxins that would otherwise pollute groundwater and nearby wells. While it will take some time to collect data from this experiment, they created similar conditions in the laboratory using potted Poplar trees. Results demonstrated that the trees were able to remove 97% of the introduced toxins (www.sciam.com/1297issue/1297techbus4.html).

• Selecting plants that are hardy to the site's unique growing conditions to ensure success. Plants that are well-adapted to periodic inundation as

Further Reading

Kirsch, Kathleen M. Christensen, *Phytoremediation and Wastewater Effluent Disposal: Guidelines for Landscape Planners and Designers*
Mitchell, Martha S., *Choosing What to Plant*

At Ecolonia, The Netherlands, street runoff passes through dense wetland plants on its way to a stormwater pond that is the central feature of the community.

well as long dry spells are logical choices for stormwater BMP's. Good root structure breaks up soils increasing permeability and allowing water to infiltrate. Native bunchgrasses tend to have very large root systems with as much as 90% of the plants biomass occurring below the ground (Environmental Building News, 1995). These massive root systems stabilize soils to prevent erosion, help plants survive dry periods, and contribute to stormwater infiltration.

• Substitute vegetated swales for conventional gutter and pipe systems. Vegetated swales, grass channels, and biofilters are variations of the same concept. These are shallow, concave strips that are alternatives to typical gutter and pipe systems for moving runoff. Grass channels removed 15% of the nitrates and 25% of the phosphates washed off of a grass field (CWP, 1998). Open channels are typically planted with grass that can easily be mowed, however, other options are available. They can be planted with trees, shrubs, or bunchgrasses to increase diversity and aesthetic value. An assessment of a site's topography will reveal places where natural depressions provide perfect opportunities for open drainage systems. In the OMSI parking lot in Portland, Oregon, swales removed all of the .83" of rain that fell in a 24 hour period. Additionally, computer models demonstrated that 90% of pollutants washed off of the parking lot can be absorbed in the parking lot swales (Thompson, 1996).

• Incorporate bioretention facilities into the landscape. Bioretention facilities are planting areas that clean stormwater and allow infiltration. Bioretention planting areas can be a collection of any plants that are hardy enough to treat pollutants and grow well without chemical interventions of their own. They must be well-adapted to periodic inundation. This shallow planted area can be fairly wide and can include trees, shrubs, perennials and groundcovers. They can be a planted border around a lawn serving the dual purpose of reducing turf and cleaning runoff (see guideline 6.1) or can be a road median. Since healthy, permeable soils are a critical component of these facilities, deep rooted plants that break up soils are important.

PLANTED INFILTRATION AREAS HELP MITIGATE RUNOFF

• Water storage areas such as ponds and wetlands temporarily store, filter, and clean runoff from nearby lawns, rooftops, and pavement. Ponds and wetlands can be beautifully landscaped with grasses, shrubs, trees,

Potsdammer Platz: 100% of the stormwater runoff from this urban redevelopment project in Berlin is harvested and reused on-site.

and herbs that withstand both wet and dry periods. They often attract wildlife add regional and biodiversity to a site and are generally considered to be valued amenities.

• In a residential setting much of the stormwater accumulated on a site comes from rooftops (see guideline 4.3). These large impervious surfaces convey water quickly and can easily be captured and filtered by careful placement of temporary storage areas such as dry wells, infiltration areas, or ponds. Directing rooftop runoff through a vegetated area before it reaches roads, pipes, and eventually drains into rivers can help reduce runoff volume by as much as 50% (Scheuler, 1998). Careful design consideration must be given to ensure that runoff is directed far enough from the foundation of a house, and temporarily held so it can be cleaned and absorbed.

• For stormwater management facilities there are common groups of plants that are uniquely appropriate to inundations and drought conditions. The following is a list of common trees, shrubs, herbs, and grasses. These plants will be listed by genus only as species vary from region to region.

TREES:

Acer (Maple)
Fraxinus (Ash)
Betula (Birch)
Salix (Willow)
Shrubs
Cornus stolonifera (Red Osier Dogwood, occurs through out U.S.)
Amelanchier (Serviceberry)
Salix (Shrub willows)
Rosa (Wild Rose)
Spirea (Hardhack)

HERBACEOUS AND FLOWERING PLANTS

Iris (could be considered a grass)
Mimulus (Monkeyflower)
Ranunculus (Buttercup)
Saggitaris (Arrowhead)

GRASSES

Deschampsia (Tufted Hairgrass)
Juncus (Rushes)
Carex (Sedges)
Festuca (Fescues)

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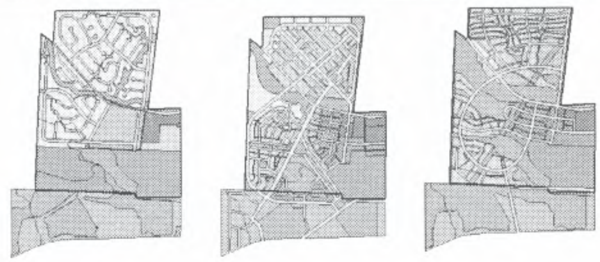
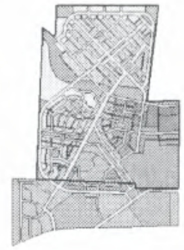
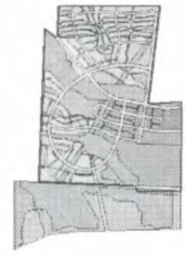
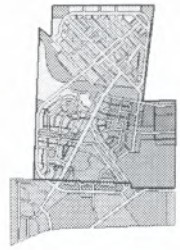
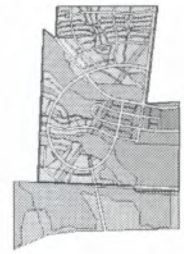
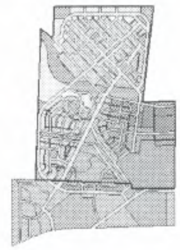
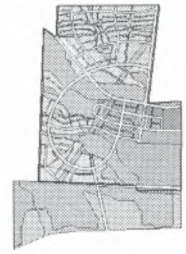


LAND USE MEASURES	SQ	NV	OS
1 SCENARIO SUMMARY			
1 LAND ALLOCATION	311	311	311
Public Open Space	36	35	80
Housing	146	124	120
Commercial	10	17	13
Civic	72	52	44
Public Streets and Paths	47	83	54
2 DWELLING UNITS PROVIDED	1134	1933	1864
Total bedrooms	3564	4639	4623
3 GROSS DENSITY	3.64	6.21	5.99
2 OPEN SPACE ALLOCATION			
1 LAND ALLOCATED TO PUBLIC OPEN SPACE	36	35	80
Greenways	10	24	55
Wetlands	15	0	22
Parks	11	11	3
3 PUBLIC OPEN SPACE PER DWELLING (in square feet)	1,383	789	1,870
3 HOUSING ALLOCATION			
1 LAND ALLOCATED TO HOUSING (in acres)	146	124	120
2 HOUSING TYPES (in dwelling units)	1134	1933	1864
Detached (<6 dua)	544	164	14
Detached (>6 <9 dua)	0	143	269

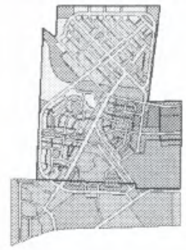
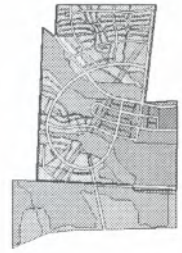
			
Detached (>9 dua)	104	224	482
Attached (>9 <20 dua)	0	401	337
Attached (>20 dua)	133	677	477
Stacked (>9 <20 dua)	0	72	57
Stacked (>20 dua)	353	0	0
Hybrid (>20 dua)	0	252	228
3 HOUSING FLOOR AREA (in square feet)	**2,368,231**	**3,035,938**	**2,962,616**
4 HOUSING NET DENSITY (dwellings per acre of housing land)	**8**	**16**	**16**
5 HOUSING SITE AND FLOOR AREA PER DWELLING (in square feet	**7,696**	**4,365**	**4,393**
Average housing floor area per dwelling	2,088	1,571	1,589
Average housing site area per dwelling	5,608	2,794	2,804
4 COMMERCIAL ALLOCATION			
1 LAND ALLOCATED TO COMMERCIAL (in acres)	**9.9**	**17.0**	**13.0**
Land allocated to commercial only areas	9.9	14.0	7.0
Land allocated to commercial in mixed use areas	0.0	3.0	6.0
2 LAND ALLOCATED TO COMMERCIAL BY TYPE			
Detached	0.2	2.5	2.0
Attached	9.7	14.1	10.6
Hybrid *	0.0	7.8	7.1
* includes land also assigned to housing			
3 COMMERCIAL FLOOR AREA (in square feet)	163,208	286,775	220,877

4 COMMERCIAL NET FLOOR AREA RATIO	0.38	0.40	0.40
5 COMMERCIAL LAND AND FLOOR AREA PER DWELLING (in squa	**528**	**531**	**423**
Commercial floor area per dwelling	144	148	119
Commercial land area per dwelling	384	383	304
6 CIVIC ALLOCATION			
1 LAND ALLOCATED TO CIVIC (in acres)	**72**	**52**	**44**
Fairgrounds / stadium	72	45	34
Schools	0	1	10
Churches	0	3	0
Daycares	0	3	0
3 CIVIC FLOOR AREA (in square feet)	**258,286**	**205,852**	**169,157**
4 CIVIC NET FLOOR AREA RATIO	**0.08**	**0.09**	**0.09**
5 CIVIC LAND AND FLOOR AREA PER DWELLING (in square feet)	**2,994**	**1,278**	**1,119**
Civic floor area per dwelling	228	106	91
Civic land area per dwelling	2,766	1,172	1,028
7 STREETS AND PATHS ALLOCATION			
1 LAND ALLOCATED TO PUBLIC STREET AND PATH R.O.W. (in ac	**47**	**83**	**54**
Collectors	5	25	19
Locals	41	48	26
Local access lanes	0	0	5
Alleys	1	11	4
Off-street paths (not in open space)	0	0	0.4

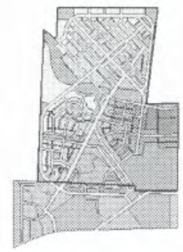
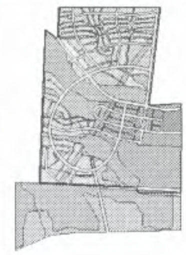
				
3 **STREET LENGTHS (in feet)**	**38,347**	**77,622**	**50,303**	
Collectors	3,204	15,841	11,707	
Locals	32,912	38,868	20,944	
Local access lanes	0	0	9,971	
Alleys	2,231	22,913	7,681	
4 **DEDICATED NETWORKS BY MODE (in feet)**	**185,295**	**306,865**	**219,091**	
Automobile network	38,347	77,622	50,303	
Dedicated bicycle network (not in open space)	37,474	60,122	45,894	
Sidewalks and dedicated pedestrian network (not in open space)	109,474	169,121	122,894	
4 **STREET AND PATH LAND PER DWELLING (in square feet)**	**1,805**	**1,870**	**1,262**	
ENVIRONMENTAL QUALITY MEASURES	**SQ**	**NV**	**OS**	**EX**
1 LANDSCAPE PRESERVATION				
1 GREENWAY / WETLAND IN PUBLIC OWNERSHIP (in acres)	**25**	**20**	**53**	
Greenway preserved in public ownership	10	20	32	
Wetland preserved in public ownership	15	0	22	
2 LAND COVER				
1 PERVIOUS / IMPERVIOUS COVER (in acres)	**311**	**311**	**311**	
Impervious surfaces	124	168	131	
Pervious surfaces	187	143	180	
2 PERVIOUS COVER (in acres)	**187**	**143**	**180**	
Turf	111	96	114	
Other pervious surfaces	75	45	60	

Water	0.5	1.8	6.2	
3 STORMWATER RUNOFF				
1 ESTIMATED PEAK FLOW (10-year storm) (in cubic feet per second)	**138**	**146**	**115**	xxx
% increase over existing	26%	34%	5%	0%
4 WATER QUALITY				
1 POLLUTANT LOAD (with BMP's) (in pounds per year)	**2,748**	**3,358**	**2,316**	**0**
Nitrogen	2,451	2,990	2,105	xxx
Phosphorus	297	368	211	sss
5 URBAN FOREST				
1 EXISTING FOREST CANOPY PRESERVED IN PUBLIC LAND (in ac	**14**	**13**	**26**	**27**
% of existing	52%	48%	95%	100%
2 FREESTANDING TREES PLANTED (in trees)	**5,611**	**7,197**	**8,078**	
In public open space and civic land	57	306	2,710	
In public street rights of way	2,375	4,385	2,585	
In private land	3,179	2,506	2,783	
Total freestanding tree canopy (in acres)	53	61	69	
TRANSPORTATION MEASURES	**SQ**	**NV**	**OS**	
1 TRANSPORTATION NETWORK HIERARCHY				
1 NETWORK ELEMENT LENGTHS (in feet)	**38,345**	**77,619**	**50,303**	
Collectors	3,203	15,839	11,707	
Locals	32,911	38,867	20,944	
Local access lanes	0	0	9,970	
Alleys	2,231	22,913	7,682	

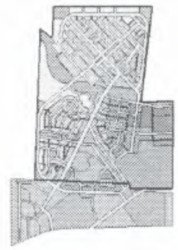
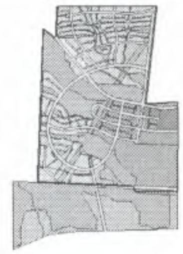
  

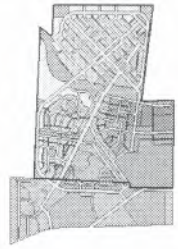
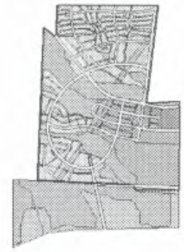
2 DEDICATED NETWORKS (in feet)	**148,050**	**247,157**	**202,578**
Dedicated automobile network	38,345	77,619	50,303
Dedicated bicycle network	37,474	60,122	45,894
Dedicated pedestrian network	72,231	109,416	106,381
2 TRANSPORTATION NETWORK DESIGN			
1 NETWORK CONNECTIVITY (intersections)	**71**	**198**	**109**
3-way intersections	40	158	57
4-way intersections	4	38	27
Dead-ends	27	2	25
2 TRIP GENERATION	**15,351**	**26,854**	**20,073**
3 TRAFFIC VOLUMES (ADT)	**15,351**	**26,854**	**20,073**
North bound trips	0	0	0
South bound trips	3,088	5,406	4,119
East bound trips	10,737	18,752	14,428
West bound trips	1,526	2,696	1,526
4 COMPARATIVE TRAVEL COST (in seconds)			
Maximum time on automobile network to shopping	170	196	192
Maximum time on bicycle network to shopping	382	316	369
Maximum time on pedestrian network to shopping	1226	1162	1188
Average time on automobile network to shopping	91	104	104
Average time on bicycle network to shopping	203	168	157
Average time on pedestrian network to shopping	718	660	615

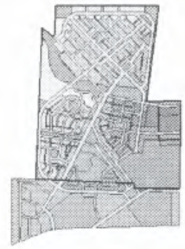
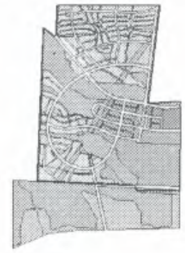
  

UTILITY INFRASTRUCTURE MEASURES	SQ	NV	OS
1 STORMWATER NETWORK			
1 STORMWATER NETWORK ELEMENTS	**33,018**	**50,082**	**52,735**
Major trunk	394	1,386	0
Minor trunk	1,113	832	0
Major collector	10,311	14,639	2,659
Minor collector	21,200	33,225	39,135
Grass swales	0	0	10,941
2 SANITARY SEWER NETWORK			
1 SANITARY SEWER NETWORK ELEMENTS	**34,700**	**47,725**	**43,131**
Trunk (in feet)	4,017	6,193	4,728
Collector (in feet)	29,977	40,140	37,239
Laterals (connections)	706	1,392	1,164
3 WATER SUPPLY NETWORK			
1 WATER SUPPLY NETWORK ELEMENTS	**34,603**	**52,706**	**45,757**
Major distribution pipe (in feet)	3,981	6,738	3,836
Minor distribution pipe (in feet)	29,916	44,576	40,757
Building service (connections)	706	1,392	1,164

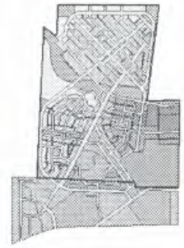
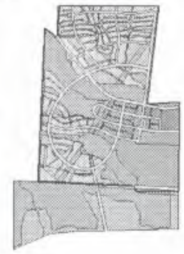
INFRASTRUCTURE COST MEASURES	SQ	NV	OS
1 TOTAL INFRASTRUCTURE COST	**$18,212,610**	**$32,033,902**	**$26,211,993**
TOTAL INFRASTRUCTURE COST PER DWELLING	**$16,061**	**$16,572**	**$14,062**
1 COST OF LAND ALLOCATED TO INFRASTRUCTURE	**$1,660,000**	**$2,360,000**	**$2,688,000**
2 INFRASTRUCTURE EMPLACEMENT COSTS	**$0**	**$0**	**$0**

			
3 INFRASTRUCTURE ANNUAL MAINTENANCE COSTS	**$425,025**	**$739,081**	**$646,074**
4 INFRASTRUCTURE EMPLACEMENT COSTS / DWELLING	**$14,597**	**$15,351**	**$12,624**
5 INFRASTRUCTURE ANNUAL MAINTENANCE COSTS / DWELLIN	**$375**	**$382**	**$345**
2 PUBLIC OPEN SPACE AND URBAN FOREST COST	**$1,496,860**	**$2,191,706**	**$3,240,988**
Cost of land allocated to public open space	$720,000	$700,000	$1,600,000
Cost of turf emplacement in public streets	$64,360	$98,206	$62,988
Cost of tree emplacement in public open space	$0	$81,000	$772,500
Cost of tree emplacement in public streets	$712,500	$1,312,500	$805,500
1 COST OF ANNUAL TREE MAINTENANCE IN PUBLIC SPACE	**$3,973**	**$7,709**	**$8,192**
Cost of freestanding trees in public open space annual maintenance	$0	$1,600	$3,916
Cost of freestanding trees in public streets annual maintenance	$3,716	$5,716	$4,026
Cost of turf in public streets annual maintenance	$257	$393	$250
2 COST OF OPEN SPACE LAND AND TREE EMPLACEMENT / DWE	**$635**	**$404**	**$1,272**
Cost of public open space land per dwelling	$635	$362	$858
Cost of freestanding tree emplacement in public open space per dwelling	$0	$42	$414
3 COST OF PUBLIC OPEN SPACE TURF AND TREE ANNUAL MAIN	**$4**	**$3**	**$2**
Cost of tree emplacement in public streets per dwelling	$3	$3	$2
Cost of turf emplacement in public streets per dwelling	$1	$0	$0
3 TRANSPORTATION NETWORK COST			
1 COST OF LAND ALLOCATED TO PUBLIC STREETS AND PATHS	**$940,000**	**$1,660,000**	**$1,080,000**

			
2 COST OF PUBLIC STREETS AND PATHS EMPLACEMENT	**$6,637,680**	**$13,384,556**	**$9,094,430**
Collector/Arterial	$762,314	$4,283,118	$3,435,754
Local on Grade	$3,927,300	$4,587,804	$2,545,920
Alleys (paved)	$178,480	$1,833,040	$1,511,860
PCC sidewalk (5')	$1,263,990	$1,914,710	$1,142,785
Curb and gutter	$505,596	$765,884	$458,111
3 COST OF PUBLIC STREETS AND PATHS ANNUAL MAINTENAN	**$79,915**	**$174,311**	**$121,751**
Collector/Arterial	$10,890	$61,187	$49,082
Local on Grade	$65,455	$76,463	$42,432
Alleys (paved)	$3,570	$36,661	$30,237
4 COST OF PUBLIC STREETS AND PATHS EMPLACEMENT PER DV	**$6,682**	**$7,783**	**$5,458**
Cost of land for streets and paths	$829	$859	$579
Cost of streets and paths emplacement	$5,853	$6,924	$4,879
5 COST OF PUBLIC STREETS AND PATHS ANNUAL MAINTENANCE PEI	$70	$90	$65
4 STORMWATER NETWORK COST			
1 COST OF STORMWATER NETWORK EMPLACEMENT	**$2,683,600**	**$4,169,175**	**$3,452,760**
Major collector pipe	$866,124	$1,229,676	$223,356
Minor collector pipe	$1,505,200	$2,358,975	$2,778,585
Major trunk pipe	$125,292	$440,748	$0
Minor trunk pipe	$186,984	$139,776	$0
Grass swale	$0	$0	$311,819
Major pond	$0	$0	$54,000
Minor pond	$0	$0	$85,000

2 COST OF STORMWATER NETWORK ANNUAL MAINTENANCE	**$37,971**	**$57,595**	**$83,645**
Major collector pipe	$11,858	$16,835	$3,058
Minor collector pipe	$24,380	$38,209	$45,005
Major trunk pipe	$453	$1,594	$0
Minor trunk pipe	$1,280	$957	$0
Grass swale	$0	$0	$12,582
Major pond	$0	$0	$6,000
Minor pond	$0	$0	$17,000
3 COST OF STORMWATER NETWORK EMPLACEMENT PER DWEL	**$2,366**	**$2,157**	**$1,852**
4 COST OF STORMWATER NETWORK ANNUAL MAINTENANCE P	**$33**	**$30**	**$45**
5 SANITARY SEWER NETWORK COST			
1 COST OF SANITARY SEWER NETWORK EMPLACEMENT	**$3,321,840**	**$5,394,245**	**$4,683,465**
Trunk pipe	$261,105	$402,545	$307,320
Collector pipe	$1,648,735	$2,207,700	$2,048,145
Laterals	$1,412,000	$2,784,000	$2,328,000
2 COST OF SANITARY SEWER NETWORK ANNUAL MAINTENAN(	**$137,936**	**$220,233**	**$192,218**
Trunk pipe	$10,043	$15,483	$11,820
Collector pipe	$74,943	$100,350	$93,098
Laterals	$52,950	$104,400	$87,300
3 COST OF SANITARY SEWER NETWORK EMPLACEMENT PER DV	**$2,929**	**$2,791**	**$2,513**
4 COST OF SANITARY SEWER NETWORK ANNUAL MAINTENANC	**$122**	**$114**	**$103**

6 WATER SUPPLY NETWORK COST			
1 COST OF WATER SUPPLY NETWORK EMPLACEMENT	**$3,132,630**	**$5,234,220**	**$4,459,940**
Major distribution pipe	$278,670	$471,660	$268,520
Minor distribution pipe	$1,794,960	$2,674,560	$2,445,420
Building service	$1,059,000	$2,088,000	$1,746,000
2 COST OF WATER SUPPLY NETWORK ANNUAL MAINTENANCE	**$165,231**	**$279,222**	**$238,539**
Major distribution pipe	$11,943	$20,214	$11,508
Minor distribution pipe	$89,748	$133,728	$122,271
Building service	$63,540	$125,280	$104,760
3 COST OF WATER SUPPLY NETWORK EMPLACEMENT PER DWEI	**$2,762**	**$2,708**	**$2,393**
4 COST OF WATER SUPPLY NETWORK ANNUAL MAINTENANCE I	**$146**	**$144**	**$128**