Design Centre for Sustainability
School of Architecture + Landscape Architecture
THE UNIVERSITY OF BRITISH COLUMBIA

Monday, August 11, 2008

Heather Boyer, Editor
Island Press
1718 Connecticut Avenue NW Suite 300
Washington, DC

Thank you for your support in this book writing venture. My book proposal, attached, includes:

- ☐ Question Responses,
- ☐ Book Outline,
- ☐ Chapter 1 – 4 and chapter 7, all in draft form.

This book is intended to be accessible, comprehensive and useful to a variety of readers. The strategy is to present an easy to read main text with additional detail, graphic interpretation and source material included in the notes. It will act as a companion to the Charrette book.

The manuscript will be finished by January 1, 2009

Sincerely,

Professor Patrick M. Condon
James Taylor Chair in Landscape and Livable Environments
Design Centre for Sustainability

BOOK PROPOSAL 8/11/2008

1. Describe the contents of the book. What is its thesis? What do you hope to accomplish in writing this book? What need does it fill?

   The author hopes to provide a useful rulebook for creating complete, low carbon, sustainable communities. It will be the only book of its kind to take a North America wide perspective, and to productively compare and contrast the US experience to its similar yet distinct Canadian counterpart.

   The global climate change imperative and the second energy crisis have focused renewed attention on the costly way we regulate and build North American cities. This book seeks to simplify the interactions between transportation, land use, greenhouse gas, water quality, housing affordability and economic performance found therein. The book is designed to be accessible and informative for everyone, from the average citizen to the sophisticated policy maker. Our attempt to reach such a broad audience explains its unique two track structure; one track provides a concise and narrative explanation of the seven sustainable urban design issues, or rules, the second track provides a much more precise and research based set of elaborations.

   But why try to reach such a broad audience? We feel it necessary because the lack of a common language across cultural and professional groups is a very large impediment to progress. This book and others like it must attempt to bridge the gaps between interest groups and professional disciplines. We attempt to provide a simple to understand yet systems-based approach to help build this bridge. The two-track approach allows the same book to communicate with both the layperson and the specialist, and thus contribute to the formation of a common language between them.

2. How would you characterize the book? Is it policy analysis or practical how-to information? Does it develop a theory? Is it a practical tool that professionals will use? Does the reader require specialized knowledge to understand it? What is unique about this book?

   This book provides simple real world rules and associated examples for creating sustainable communities. These rules and examples will allow citizens to participate on an equal footing with technical specialists, and allow technical specialists to understand how their own expertise interfaces with that of others. It is a practical how-to book that integrates the disparate elements of the urban puzzle, avoiding silo thinking by presenting an accessible systems based alternative. The main body of the text presents simply stated overviews, conclusions and arguments, requiring no specialized knowledge – the extensive citations and research summaries in the side bar provide a more in-depth explanation of the issues, and provide the confidence inherent to fact rich analysis. No other book on sustainability is structured this way.

3. Who is your audience?

- Educated and interested citizens
- Planning and design students
- Planners, architects and landscape architects
- Community activists
- Elected officials
- Planning board members.

4. What topics does your book cover? Are there any topics that have not been covered before?

   The topics covered in the book are: transportation, climate change, energy, land use, neighbourhood design, district and regional design, green infrastructure design, environmental protection and healthy communities. They have been covered before but rarely synthesized in one book. We also believe that the section on green infrastructure is unique and is the first time that the broad issues of green infrastructure have been integrated into a rule book for sustainable community design. Finally we believe that the section on the "streetcar city" is unique in explaining the organic relationship between land use and mode, and how this arrangement provides clues for addressing climate change and the energy crisis.

5. What other books have been published on this subject? How will your book relate to other books in the field?

   Books such as *Suburban Nation* by Andres Duany, Elizabeth Plater-Zyberk and Jeff Speck, and the *Geography of Nowhere* and *The Long Emergency* by William Kunstler aptly describe the cultural, political, and physical incapacities intrinsic to our post WWII urban landscape. *New Urbanism* by Peter Katz articulates the theoretical underpinnings of the New Urbanist movement and similarly critiques post WWII development in North America. However unlike these books my intention is not to convince the reader of the problem but rather to offer a set of simple rules, in a practical, self-help format, that shows how the problem may be solved.

   Toward Sustainable Communities by Mark Roseland and *Sustainable Urbanism* by Douglas Farr also approach the topic from the perspective of a guidebook but Roseland focuses predominantly on policy and politics. The book that is closest in design and intention to this book would be Doug Farr's. I view this book as a compliment to his, rather than a competitor. This book also differs from Farr's as his is largely essays from leading lights in New Urbanist thought. This book represents a more singular view resulting from the authors own experience.

6. What is the approximate length of the final typed manuscript? Assume 8-1/2-x-11 double-spaced pages with one-inch margins.

   200 pages. A companion book to Design Charrettes for Sustainable Communities.

7. What elements will the manuscript include: charts, graphs, tables, photographs, glossary, index, bibliography, and so on? Please be as specific as possible.

   The manuscript will include tables, photographs, diagrams and maps. Sidebar research notation is fundamental to the concept, and will be used to support and expand upon topics presented in the main text. An extensive bibliography will be generated as a consequence of these sidebar notations, and can be used as an important resource for interested parties. Simplified diagrams will make complex concepts visually accessible, providing an additional avenue for communication and ultimately aiding in comprehension. Two case studies of complete sustainable communities will be included to provide concrete examples and valuable lessons that support the arguments laid out in the book.

8. Do you have any particular conception of the production, design, or marketing of the manuscript that we should know about?

   Production, design and marketing of the manuscript should be similar to that done for *Design Charrettes for Sustainable Communities* including black and white printing to minimize the cost of the final product. The concept is to present the main text with easily read arguments and rules along with the sidebar text conveying more detailed proofs and research information.

9. When will the manuscript be complete?

   January 1, 2009

BOOK PROPOSAL: Outline

Chapter One: A Short Review of the Disease and its Symptoms

The Search for Affordable Housing

The search for affordable housing for families was the primary motivating force behind most of the post WWII development in North America and, facilitated by the development of the interstate highway, led to a massive redistribution of the population from high density urban centers to low density suburbs.

Separation by class and income

Many suburban towns adopted zoning policies that led residents to become distributed by class and income. Towns that allowed subdivisions became home to middle class and lower middle class residents while towns that allowed only large, very low density lots attracted only upper income earners.

The Problem Emerges

After the oil shock in 1974 the national security implications of car dependence became more obvious and exposed the weakness of the economy to external interruptions in the oil supply. At the same time North America continued to develop in a way that soon found more than half of its population living in car dependent neighbourhoods.

The Problem of infinitely increasing car dependence

Driving is no longer a discretionary expense in landscapes where walking or public transit are not possible. In these auto dominated landscape families are forced to devote ever larger shares of their income to transportation.

Health effects

Car dominated landscapes reduce our daily activity and have been linked to increased rates of obesity and juvenile onset diabetes as well as social isolation.

Spending and spending to stay in one place

To accommodate the huge increase in vehicle trips necessitated by our urban form would require a doubling of highway lanes per square mile simply to get the system back to the efficiencies of thirty years ago. However, we simply don't have the space or resources to accommodate these increases.

Climate Change

Thirty percent of the worlds CO_2 production comes from the United States and Canada, almost a quarter of which comes from transportation. The community of nations recommends cutting GHG emissions by 50% by 2050 to avoid a planetary disaster. Clearly reducing transportation demands should be high on the list of priorities for climate change action.

Reasons for hope

America has over invested in a system that has made a sprawling and highly inefficient urban landscape but the same system that unleashed these forces is of such a size and extent that it can accommodate through infill the massive increases in population expected in the coming years.

Seven principles for sustainable communities

1. A restored Streetcar City

2. An interconnected street system
3. A five minute walking distance to commercial services and transit
4. Good jobs near home
5. Difference housing types on the same street
6. Lighter greener cheaper smarter infrastructure
7. Linked parks and natural areas

Chapter Two: A restored Streetcar City

A day in the life

> A narrative account of how the form of traditional streetcar cities impacts a day in the life of a worker in Vancouver, 1922.

Streetcar City as a unifying principle

> The Streetcar City principle is about a sustainable relationship between land use, walking and transportation.

Basic structure of the Streetcar City

> Streetcar cities were laid out in a gridiron with most homes located within a five minute walk of the nearest streetcar stop and commercial services occupying the ground floor of street fronting buildings along the streetcar line.

Streetcars made detached housing possible

> With the emergence of the streetcar, the radius within which urban North American's could operate expanded dramatically allowing the urban middle class to buy detached home outside of the city centre while still maintaining a reasonable commute to work and services.

Forty percent still live there

> About 40% of North America's urban residents live in pedestrian and transit friendly districts once served by the streetcar.

Linear not nodal

> Linear public space is the distinguishing feature of the streetcar city with development happening predominantly along important corridors rather than the model most planning and urban design strategies follow: isolated nodes linked by high speed transportation systems.

Web vs Hub and Spoke

> Most transit strategies focus predominantly on trips between the suburb and the centre, this is called a hub and spoke pattern. However, job distribution trends are finding more jobs located outside of the city centre and the suburb to suburb transport this creates is not being accommodated by transit solutions meant to facilitate trips to and from the centre.

Streetcar city was more grid

> Streetcar City transportation systems were grids, not hub and spoke systems, that allowed efficient movement between any part of a city.

Buses and streetcars

> Buses require less initial investment and provide more flexibility than streetcars but streetcars provide a much smoother ride, which is especially important for elderly passengers, greater ridership capacity and they don't pollute. In addition, their longer lifespan and increased capacity actually recoup the additional construction costs in a short amount of time.

Portland and investment

Streetcars stimulate investment and buses don't as demonstrated in Portland where lands astride the streetcar line have increased significantly in value.

Does it have to be streetcar?

There are examples of streets that operate effectively as streetcar streets without the streetcars, demonstrating that the concept is about more than vehicle choice. For example, along the Broadway corridor in Vancouver walkable districts, sufficient density, three minute headways, hop-on-hop-off access to commercial services and five minute walking distance to destinations at both ends of the trip contribute synergistically to support a well used transit system.

Conclusion

Chapter 3: An Interconnected Street System

Interconnected street system vs. dendritic street systems

Street systems either maximize connectivity or frustrate it. Gridiron streets form interconnected networks made up of narrow residential streets and urban arterial streets while the dendritic system, characterized by cul-de-sacs and freeways, creates a hierarchical, disconnected system.

Why is the dendritic system a problem?

The basic problem with the dendritic system is that all trips collect at one point, usually the major intersection of two suburban arterials or on the ramp to the freeway, causing inevitable congestion and overbuilt infrastructure, and unsafe pedestrian, and bicyclist environments.

Big boxes

The dendritic traffic network that forces all trips to one point creates a commercial circumstance that favors big box developments over other more neighbourhood scale developments.

Dendritic systems and gated communities

Gated communities are highly compatible with dendritic systems because cul-de-sac communities will generally only have one access point to surrounding collectors or arterial roads. This allows gates to be erected and further promotes the isolation of the development from its surrounding community.

But people like cul-de-sacs!

Many people prefer cul-de-sacs because of the reduced traffic flows in front of their homes, however, because only 25% of the population can be realistically accommodated in cul-de-sac developments, those unfortunate enough to reside 'downstream' of the cul-de-sac will have to tolerate many more cars past their homes than would the average resident living within an interconnected street system.

Why is the interconnected system better?

Interconnected street systems allow trips to be by the shortest possible rather than by an artificially lengthy and circuitous route therefore five minute walking distances cover much more ground. Interconnected systems also reduce congestion, and encourage narrower, more pedestrian friendly streets.

Four types of interconnected street systems

1. The Gridiron

2. The radial system
3. The informal web
4. The warped grid

Block size

Traditional cities have much smaller block sizes than the suburban superblock. Superblocks exclude through traffic, provide greater flexibility and require less road length while smaller urban blocks are much more permeable for car and pedestrian traffic and allow for more walkable transit service.

Pluses and minuses

Superblocks exclude traffic across the block and require less road length than gridirons but they overload arterial intersections and make pedestrian and bicycle trips long and unfriendly.

Parcel size

The single family home parcel size has led to car dominated landscapes; however they can be retrofitted to accommodate much higher densities that can support adequate transit service.

Single family home parcels

The single family home parcel has traditionally been a major driver in sprawl but there are configurations (based on smaller lots) that are compatible with sustainable community design.

Ideal block and parcel size

Lots that are narrow parallel to the street and deep perpendicular have a number of benefits while rear lane access keeps driveways from crossing sidewalks and allows the front façade to be free of garage doors.

Road width

Traditional urban streets are generally narrow with parking on both sides, trees in the boulevard and pedestrian sidewalks, all of which encourage vehicles to travel at much slower speeds making them safer and more pedestrian friendly.

Fire access

The average size of North American fire equipment has been steadily increasing leading to larger and larger streets and turn-arounds to accommodate them. Smaller fire departments more evenly distributed throughout the city are more effective from a safety perspective and support smaller trucks that reduce the need for such large streets.

Queuing streets

The traditional 24-28' street in an interconnected system calms traffic, saves pavement, and makes a more attractively scaled pedestrian friendly streetscape.

Lanes and Alleys

Lanes and alleys are part of a healthy urban infrastructure however municipalities are often adverse to lanes because of maintenance and service concerns.

The corner

The challenge of the intersection is to reconcile the need to move large vehicles around corners with the need to safely and comfortably get pedestrians across them. Since cars are prohibited from parking near intersections this space can be given over to sidewalk and boulevard uses.

Conclusion

Chapter Four: Five minute walking distance to commercial services and frequent transit

The walk to the store

North Americans will walk only if it's easier than driving and the break point for walking trips seems to be the five minute walk. Compelling destinations within a five minute walk of residences encourage daily walking trips which reduces vehicle miles traveled and supports healthier lifestyles.

Sense of place in corridors

If one accepts the proposition that suburban auto-oriented areas are virtually devoid of public realm space, then streetcar streets were and still are the most commonly experienced and widely distributed urban public realm space in North America. Corridors allow for shared and similar experiences that enrich the lives of residents and the quality of the street life.

Transit

Transit and small scale (walkable) commercial enterprises have a synergistic relationship by allowing people to perform errands while using transit.

Bus or Streetcar Headways

If a bus or streetcar stops at a stop every seven minutes or less people will only have to wait on average four minutes for a ride without consulting a schedule and are therefore much more likely to use transit. Unlike Streetcar Cities, low density suburban neighbourhoods can't support five minute walks and seven minute headways.

Residential Density

The higher the density in a service area the more likely it is that residents will use transit. The threshold density for a viable transit system is ten dwelling units per gross acre. Strip commercial corridors in suburban neighbourhoods offer the best opportunity for increasing low density suburbs to support this type of transit.

The walk to school

Attracted by the concept of "economies of scale" school districts are becoming larger and larger and hence fewer and fewer students are able to walk to school. In contrast schools in a Streetcar City are provided within each 160 acre square bounded by streetcar arterials. In this way no child would have to walk more than 6 minutes to school or cross a busy arterial to get there.

Conclusion

Chapter Five: Good Jobs Near Homes

The Historic Relationship Between Work and Rest

North American cities were once characterized by an intimate relationship between jobs and homes; we have lost this relationship.

Disintegration in the Modern Era.

Radical segregation of working families by income, far from jobs, has led to social segregation and excessive transportation charges.

Exposure of the Most Vulnerable

Citizens in far-flung suburbs have the least amount of economic resiliency and are most exposed to disruptions in housing markets and the rising cost of oil; the "mortgage meltdown" of 2008 makes this phenomenon abundantly clear.

Solutions

Eight five percent of new jobs will be in clean and quiet spaces, easily integrated into community settings; many examples now exist.

There are very few barriers to retrofitting suburban zones for job density.

Conclusion

Chapter Six: Different Housing Types on the Same Street

Zoning as a tool to segregate by income and class

Municipalities continue to impose and enforce segregation through the tool of zoning. "Snob zoning" restrictions and state and provincial legislation are beginning to take hold.

New mixed communities are the trend

New communities are being built with highly mixed housing types, notably rental units integrated into single family homes.

Existing mixed house type areas holding value best and can be intensified

Urban areas with mixed housing types have held value better than homogenous single family homes areas during recent mortgage retrenchment.

Conclusion

Chapter Seven: Lighter, Greener, Cheaper, Smarter Infrastructure

Introduction

The Site is to the Region What the Cell is to the Body

Natural Watershed Function

Water Quality and Water Quantity

Water Quantity, not Water Quality! What We're Doing Wrong

Impervious Surfaces

Impervious surfaces don't kill fish. Pipes kill fish. Relationship between impervious surfaces and fish kill

Storm Sewers

Storm sewer history and cultural tradition

It's the small storms stupid

Fish can survive the rare cataclysm, it's the day to day disruptions caused by the way small storms are treated that kills them.

Retention ponds

Total impervious surface vs effective impervious surface

TIA and EIA

Four Rules for Infiltration

- Rule 1: Infiltrate, infiltrate, infiltrate
- Rule 2: One inch per day
- Rule 3: Infiltrate everywhere
- Rule 4: Heavy soils are good soils

The Two Elements of the Urban Watershed: Parcels and Streets

Green Infrastructure for Parcels

- Building footprints
- Rooftops
- From roof to yard to street
- The soils below
- Raingardens
- Walkways
- Parking and service areas

Right of Ways

Pervious Paved Streets

- Pervious Pavement: Types and Characteristics
- Pervious pavement roadway structural section
- Storing water in the section
- Residence time in the reservoir
- Flow within the section
- What is not a problem
- Water pollution issus
- Protection during construction
- Conveyance above the section

Impervious Paved Infiltration Street examples.

- Example 1: Amble Green Community, Surrey BC
- Example 2: Blenham Street, Vancouver, BC
- Example 3: East Clayton, Surrey BC.

Rear Lanes/Alleys

Conclusion

Chapter Eight: Linked Natural Areas and Parks

Urban Areas as Natural Watersheds

When linked together individual sites become watersheds, and the tertiary branch tips of a dendritic ecological system; storm water, stream protection, habitat protection, and recreation should be systematically considered to work with and not against this fundamental reality.

Green Infrastructure Defined and Used

Green infrastructure is a systems approach to city building where stream and road systems are understood as one system. The preservation and extension of stream system function right to the front door of each house leads inevitably to linking natural areas and parks with streets, sidewalks, lanes and drives.

Green Urbanism

The regional development system that this produces resembles traditional streetcar communities but where stream systems have been brought even deeper into neighbourhoods. Retrofitting existing neighborhoods for green function is possible if coordinated with normal schedule for rebuilding infrastructure.

Conclusion

Chapter Nine: Case Studies

Fairview and Pringle Creek, Salem OR, USA

Project under construction in Salem Oregon; features sustainable community design with the first American LEED Platinum home and largest application of pervious street system for a residential community in North America. Part of the larger Fairview Community for 2,000 homes. Project can be viewed at: http://www.pringlecreek.com/

17th Avenue Neighborhood, Calgary AB, Canada

Part of the larger Calgary “Plan-it Calgary” project. This proposal demonstrates how the above principles can be integrated into an existing 1950-70 era community organized around strip commercial areas.

Information on this project is available on line at: http://www.calgary.ca/portal/server.pt/gateway/PTARGS_0_0_104_0_0_35/http%3B/content.calgary.ca/CCA/City+Hall/Business+Units/Development+and+Building+Approvals+and+Land+Use+Planning+and+Policy/Land+Use+Planning/Plan+It/Plan+It.htm or search “Plan It Calgary”

Chapter One: A Short Review of the Disease and its Symptoms

There are many books describing the current failures in the North American metropolitan landscape. *Suburban Nation* by Andres Duany, Elizabeth Plater-Zyberk and Jeff Speck, and the *Geography of Nowhere* and *The Long Emergency* by William Kunstler are three compelling works that aptly describe the cultural, political, and physical incapacities intrinsic to our post WWII urban landscape. While indebted to these books and others like it this book is not in their class. This is a book for citizens who know their cities and regions are sick, and want to help heal them.

Thus all we need is a bit of context: a concise summary of the disease that has stricken the North American city, and its symptoms. The intention is not to convince the reader that there is a problem. Having chosen this book the reader likely agrees with that proposition already. Rather, the intention is to organize the symptoms of the illnesses that afflict most North American metropolitan regions in a logical and concise way, identifying key areas of concern that will be repeatedly returned to in later chapters.

The Search for Affordable Housing.

The search for affordable housing for families was the primary motivating force behind most of post WWII development in North America. After the war a variety of policy inducements, notably the mortgage interest deduction and the development of the interstate highway system in the US, led to a massive redistribution of population across the metropolitan landscape.[1] Middle class and working families that had previously found homes in higher density walk able and transit served neighborhoods fled, for better and worse, to much lower density and car dependent suburbs.[2] Average densities began to fall and transit ridership as a percentage of all trips began to fall with it. Older pre war parts of the metropolitan landscape still maintained healthy transit ridership, but transit use in newer areas plunged to near zero.[3] For the first three decades the relatively new interstate system allowed car owners to move large distances to employment centers with relative ease, making it possible for workers to live very far from jobs. Buying fuel for the family car was an insignificant consideration as prices were

Figure X. Sprawl outside of Calgary, Alberta
Photograph by

1. As North America's population moved outwards from the central cities, urbanized population density dropped dramatically. In the United States this trend has continued with a drop from 3,175 persons/square mile in 1960 to a density of 2,191 persons/square mile in 2000 (Cox, 2001). A similar pattern can be seen in Canada where the urbanized population density dropped from 6,803 persons/square mile in 1960 to 5,062 persons/square mile in 2000 (Cox, 2001).

2. In Canada the rate of decentralization was most pronounced between 1941 and 1961 and again between 1966 and 1971 when there was a second major expansion of highway construction in metropolitan Canada (Edmonston et al. 1985). "Focused primarily on the single function of moving motor vehicles, urban freeway planning has formed the armature for urban growth patterns in all of our major metropolises and their hinterlands" (Edmonston et al. 1985). There are clearly a number of factors influencing growth and development patterns in cities (see Burchfield et al. 2006; Ellis 2001) however there is little doubt of the significant role highway construction has on expanding boundaries and decreasing density in metropolitan areas (Handy 1993). In the words of Dr. Mike Hirsch, head of sociology at Huston Tillotson University in Austin, Texas, "interstate highways transformed urban America and gave rise to urban sprawl as we know it. It opened up for development the peripheries of cities…and facilitated the blending of communities along those corridors" (Milner 2007).

3. Pucher and Renne (2003) show that public transit ridership (all trip purposes) in the United States has continued to decline, falling from 3.2% in 1969 to 1.6% in 2001. According to Schimek (1996) transit ridership declined most rapidly from the 1950s, stabilizing somewhat in the 1970s. Transit ridership is lowest in the suburbs where low population densities make reliable service difficult. This is illustrated by the difference in auto-oriented areas such as South Surrey/Langley, BC where the transit ridership is 3% and streetcar neighbourhoods such as Vancouver, BC where the transit ridership is 20% (Canadian Facts 2000). In Canada transit ridership has been consistently higher (approximately twice that of the United States) which Schimek (1996) attributes to a combination of subsidies and urban development patterns. However, with the exception of a small number of major population centres, most communities in Canada are too sparsely populated to provide comprehensive transit services (Cohn, 1999).

low.[4] Much more important was the time required to get to and from work. Interstate highways meant that workers could, for the first time in history, conveniently hold jobs located 25 miles or more from their home.[5] To give some sense of how great a distance this is, in 1950 the Boston metropolitan urbanized area was only 345 square miles. It now sprawls 1736 square miles (US Census Bureau). Since land was generally less expensive on the peripheries of the metropolitan area, development occurred ever further away from the metropolitan center, with single family homes generally dropping in price as you moved further out. This concentric phenomenon gave rise to the saying "drive till you qualify," a widely used and humorous phrase meaning that home buyers are induced to push a home search further and further out from the center of the region until their income matched the qualification requirements for the mortgage on a new house. With so much unprecedented freedom of movement in this new urban landscape, house price became a much more important factor than location.

Figure X. An aerial view of Levittown, NY (1948) shortly after completion
Photo: Associated Press

School quality was a crucial deciding factor however, and here newer communities had a distinct advantage over older ones. Newly developing areas naturally had new schools while older areas had older schools populated by children from families without the economic resources to follow the migration, and in cities hampered by declining property values (also a consequence of the devaluing influence of middle class flight exacerbated in many areas by white flight) to fund them adequately.

Unquestionably, this new low density and car dependent city successfully supplied millions of new housing units at prices that North Americans could afford. This success has led many to claim that sprawling urban areas are more affordable than those with controls. Well financed lobbying groups have attacked Oregon's land use law on this ground for decades, even though

4. In the United States families spent an average of 3.1% of their household expenditures on transportation; by 1950 this number had risen to 13.8% (Johnson and Tan 2001). Adjusting for inflation, personal consumption expenditures in real terms have risen 3.1% annually over the 1960-1992 period (US Bureau of Transportation Statistics 1994). In 2001 households spent 21% of all household expenditures on transportation surpassed only by the amount they spent on housing which was 31%. Between 1991 and 2001 consumer spending on private transportation increased substantially. Even when expenditures were adjusted for inflation the amount households spend on new and used motor vehicles increased by 47%, vehicle expenses increased by 14% and fuel expenditures increased by 3% (US Bureau of Transportation Statistics 2003). Berstein et al. (2005) found that lower income households generally spend more than the average 19% but regions that have invested in public transportation are not being hit has hard, even as gasoline prices are rising. In Canada, Marshall and Bollman (1999) demonstrate a discrepancy between urban and rural transportation spending. In 1996 they found that in rural households transportation accounted for 15% of their total expenditure while in urban areas this number was 12%. Urban households spent 10% of their total transportation budget on public transit, compared to only 3% for rural households (Marshall & Bollman (1999).

5. In both US and Canadian cities commuting distance is increasing. Between 1969 and 2001 commuting distance in the United States increased from 15.12 km (9.4 miles) to 19.48 km (12.11 miles) (Hu, 2004) while in Canada the commuting distance increased by 0.2 km between 1996 and 2001 with one out of eight people traveling more than 25km to work (Statistics Canada, 2001). In the United States this increase in commuting distance was greatest between 1983 and 1990 with a jump from 13.75km (8.54 miles) to 17.15km (10.65 miles) (Hu, 2004). In the US the average commuting time increased by 2.1 minutes between 1990 and 2000 resulting in a much higher increase than the 40 second increase from 1980 to 1990. The relatively small increase in travel time in the 1980's has been attributed to a greater number of suburban and exurban residential areas and employment centers resulting in commutes that are longer but traveled at faster speeds. The decline in travel time is also influenced by changes in commuting modes, with a decrease in transit and carpooling and an increase in driving alone (US Department of Transportation, 2003). In Canada travel time has increased from 54 minutes in 1992 to 63 minutes in 2005 (Statistics Canada, GSS 1992, 1998, 2005).

Portland's housing costs are lower than other comparable Western US communities like San Diego, Seattle, San Francisco and Sacramento – metropolitan areas that do not have similar land use controls. At its core the claim that low density is more affordable than higher density cannot be credible.[6] Low density sprawl costs much more per dwelling unit to service than higher density development. A small lot subdivision of single family and duplex detached units on 3,000 square foot lots can be serviced for 75% less per dwelling unit than single family homes on lots of 7,000 square feet. The land component of the house cost will also be proportionately less as density increases.[7] This is simple fourth grade math that the current allegiance to post WWII patterns is somehow blinding us to.

Separation by class and income

The "drive till you qualify" concentric rings of increasing affordability discussed above does not capture the whole story. After the war a second finer grain distinction emerged, particularly noticeable in metropolitan landscapes made up of dozens of quite small former rural communities like Boston's. Whether by accident or intent, Boston's new suburban towns adopted zoning policies which insured that new residents would occupy a narrow income demographic.[8] Towns that allowed subdivisions comprised of land into one eighth, one quarter, or half acre lots attracted middle class and lower middle class home buyers. Towns that allowed only large lots of two, four, or five acres per dwelling unit attracted only upper income earners. At these low densities, land was quickly used up (it only takes 122 houses at one per five acres to consume a square mile of land). In many cases these low density communities went so

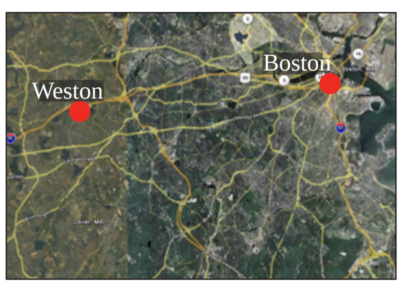


Figure X. Boston area context map

Figure X. Weston, MA has excellent access to freeways and commuter rail but the population density remains low at 1 dwelling unit per 3 acres

6. Condon, P. and J.M. Teed. 1998. Alternative Development Standards for Sustainable Communities: Design Workbook. Available online: http://www.jtc.sala.ubc.ca/projects/ADS.html

7. The common assumption is that by limiting the supply of developable land, all growth management policies reduce the supply of housing. Basic economic theory suggests that if housing supply is low relative to demand, then the price for it will be high, reducing its affordability. While this reasoning may seem logical, it is far too simplistic. Housing prices are actually determined by a host of interacting factors, such as the price of land, the supply and types of housing, the demand for housing, and the amount of residential choice and mobility in the area (Nelson, 2002). Evidence supports the fact that Urban Growth Boundaries can affect land values but their effects on housing affordability remain in dispute. Research done in Portland shows that growth in housing prices is more attributable to increased housing demand, increased employment, and rising incomes than urban growth boundaries (Phillips, 2000). Traditional zoning and land use regulations often place greater limits on the supply and accessibility of affordable housing (ie. low-density-only, minimum housing size, bans against attached or cluster homes) (Nelson et al. 2002). Properly designed growth management programs protect green space or farmland but also increase densities and mandate a mix of housing types including affordable housing.

8. Davidoff (2005) found that the Boston MSA is heavily income sorted by jurisdiction and that housing quality and extra-governmental amenities play a large part in this process. Boston's suburbs show a large range in both median home price and household income. Newton has the highest median home price at $438,400 (in 1999 dollars) compared with Lawrence at $114,100 (Census Bureau 2000). The highest median household income of $141,818 is found in Dover while the lowest, at $27,983, is found once again in Lawrence (U.S. Census Bureau 2000).

far as to exclude any new commercial development to serve new residents, leaving it to neighboring communities to supply supermarkets and other shops.

The Problem Emerges

The cracks in the system began to emerge after the 1974 oil shock, where the national security implications of car dependence became more obvious. Spending hours in line for fuel exposed the weakness of the economy to outside interruptions of oil, by now a clearly vital resource. Unfortunately the crisis provoked little action, as car dependence and dependence on imported oil has increased dramatically in the intervening decades. These were the same decades during which suburban low density development moved the US from being a country where most of its residents lived in districts where options to the car were possible to one where the majority of residents now live in districts where options to the car do not exist.[9] Rather than put in place national, state and regional policies to reverse or at least mitigate an ever rising per capita use of fuel for the single passenger automobile the reverse occurred. Transportation bills from the 70s through the 90s favored the expansion of the interstates and feeder highways over transit, and no policy proposals to require walking distance access to transit and commercial services in new districts was ever seriously considered.[10]

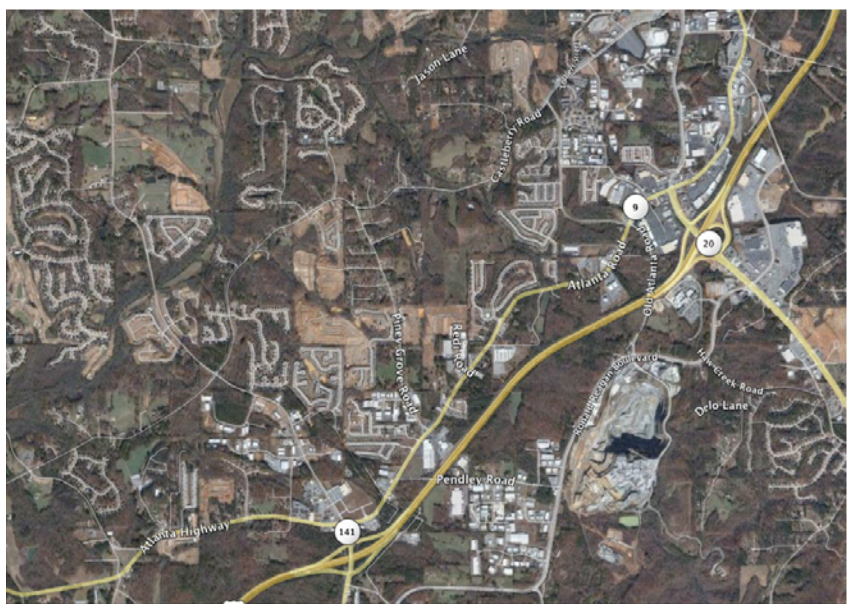


Figure X. Leapfrog sprawl at the exurban fringe north of Atlanta where agricultural land is subdivided for residential or commercial uses without the benefit of a plan. Eventually former rural roads become congested and dangerous suburban collector and arterial streets.

9. Central Cities are defined by The Office of Management and Budget (OMB) as the largest city in each metropolitan statistical area (MSA). Additional cities may be central cities if they meet specified population and commuting thresholds. According to the U.S. Census Bureau (2000) 21% of the total U.S. population lived in central cities in 1910 while only 7% lived in suburbs. From 1910 to 1930 population increased rapidly in both central cities and suburbs however after 1940 suburbs accounted for more population growth than central cities and by 1960 the proportion of total U.S. population living in the suburbs (31%) was almost equal to the proportion living in central cities (32%). From 1940 to 2000 the proportion of the population living in central cities remained relatively stable (ranging from 30 to 32.8%) while the proportion living in suburbs continued to grow steadily, finally reaching the 50% mark in 2000.

10. Transportation plans from the 1920s and 1930s were simpler designs with less capacity and lower speeds than those eventually built; they were meant to facilitate a multimodal system, were often connected to adjacent land uses, and were tied closely to existing roads (Taylor, 2000). However, ambitious planning goals including rejuvenating communities, reducing congestion, preserving central business districts and improving public transit suffered dramatically when the depression brought a severe drop in property tax revenue and with it, urban road and highway finance (Taylor, 2000). State departments and federal transportation boards took control from cities and implemented their own agendas focused around moving people long distances quickly rather than supporting local communities (Taylor, 2000). Broad, limited access freeways were adopted by engineers as the best way to guarantee high speed intercity movement (Brown 2005)

Figure X. The urban blocks shown in this photo were once filled with homes. Now only a small fraction of these homes remain. Billions of dollars worth of urban infrastructure now goes unutilized in Detroit. Its upkeep puts tremendous strain on local taxbases, furthering the collapse of city life.

Absent any national and state policies (Oregon was the single exception with the passage of Senate Bill 100 the "Land Use Law" passed in 1973) average densities in metropolitan regions continued to drop till at least the year 2000. Exceptions were few, Vancouver BC notable among them. More numerous were the extreme examples of centrifugal forces pushing population to peripheries, impelled by vast new highway expenditures, even where regional population was stable. Detroit and St. Louis are two instructive examples. Unabated freeway construction even absent significant population increase has left the older center cities of St. Louis and Detroit virtually abandoned, losing two thirds of their population to the suburbs during that period.[11]

Current aerial photos of once attractive Detroit single family home neighbourhoods, many of them single family home districts on small lots, show urban blocks with all but one or two houses razed. The same population that once lived there has been spread out over a landscape four times its original size. Now a population that prior to WWII lived almost entirely in walkable transit served communities mostly lives in auto dependent low density districts.

The problem of infinitely increasing car dependence

All of these forces combined to create an entirely new North American urban landscape. Many thoughtful voices argue that this is a good landscape where families can find a house they can afford with a yard for the kids in a community of their own choosing. This is a strong argument, but an argument that can only be sustained if we are willing to forever increase the percentage of our national treasure we commit to highway construction and the amount of personal wealth poured into the gas pump. The trends are not hopeful. Per captia driving is steadily increasing and until 2008 was resistant to large increases in fuel prices.[12] Driving is no longer a discretionary expense. There is no other mode to shift to. Walking and taking the bus are not possible in these landscapes. When fuel becomes unaffordable discretionary trips are eliminated, forcing families to give up the activities they once enjoyed to preserve fuel for trips to work.

Auto dominated landscapes have forced families to devote ever larger shares of family income to transportation, a share that now for the first time in history approaches the share consigned to paying for a home. While in 1965 most families owned one

11. U.S. cities with the largest population losses from urban cores to lower density exurbs and suburbs, in order, are Detroit, Philadelphia, St. Louis, Baltimore and Cleveland (Joint Centre for Housing Studies of Harvard University 2006). Birch (2005) found that between 1970 and 2000 the cities with the largest decreases in central city populations were St. Louis (-52%), Columbus, OH (-52%), Columbus, GA (-46%) and Detroit (-46%). Berry and Dahmann (1977) attribute growth away from central cities in part to the building of the highway system in the United States. Chi (2006) found that the growth of suburban areas often occurs as a result of the impacts of highways on central cities: congestion, residential deterioration and increased access to the city's fringe areas. Goldberg and Mercer (1980) argue that urban freeway development reduces the viability of central areas, and enables the availability and accessibility of cheaper suburban land which further reduces the competitiveness of central city locations for people and commerce. In Canada, Saskatoon and Regina exemplify this "donut hole effect," but in a less extreme way. According to the 2001 census Saskatoon's core population grew by 1.6% while its surrounding grew by 14.6%; Regina's core declined by 1.2% while its surrounding increased by 10% (Statistics Canada 2001).

12. Turcotte (2008) shows that the proportion of people aged 18 and over who went everywhere by car rose from 68% in 1992 to 74% in 2005 while the proportion of Canadians who made at least one trip by bicycle or on foot has declined from 26% in 1992 to 19% in 2005. In low density neighbourhoods over 80% of residents made at least one trip by car per day while less than half of the people living in very high density neighbourhoods did so (Turcotte 2008). In Canada, the Montreal Metropolitan Region has the lowest percentage of people making all their trips by car (65%) and also has the lowest proportion of single-detached houses (4% compared to Vancouver's 21%) (Turcotte 2008). In the United States the number of miles driven every year per capita by Americans rose by 151% between 1977 and 2001 (Polzin 2006).

car, now two cars is the norm.[13] The growth in two income households is one crucial contributor to this trend. The two incomes needed to pay off the mortgage on the home can only be maintained if both workers have a car to get to work. Dropping children at daycare and driving older children to otherwise inaccessible schools makes a car even more indispensable.

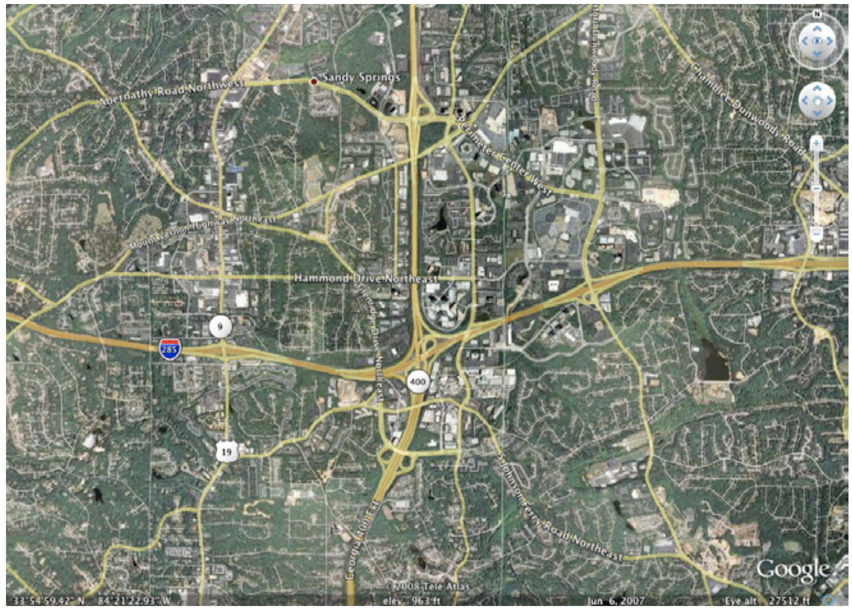


Figure X. Sprawl pattern at interstate 285 and Georgia rt. 400 north of Atlanta. Classic features include commercial services only accessible by car and pod development lacking any connectivity between the streets of one pod development to the streets of the adjacent pod development.. Many situations exist where the walking distance to commercial services is only a minute or two as the crow flies from many homes, but on foot would be an hour or more due to the winding denditic street pattern dominated by pod development and cul-de-sac streets. As a result, walking is avoided.

Health effects

But its not just “bread winners” who need a car. Everyone of driving age needs one too. To be without a car in these landscapes imprisons one in the home. Imprisonment leads to a strong desire for escape and a car of your own is the only means. But escape does not mean freedom.[14] A landscape where walking is impossible is a landscape where our legs are only used to get from the couch to the refrigerator and from the front door to the driveway. Residents of auto oriented suburbs walk less and weigh more than people in walkable areas. While direct causation is difficult to definitively ascribe the evidence is highly suggestive. The body is designed primarily for walking. If walking is systematically denied by ones environment this cant be a good thing. Many studies suggest that the epidemic increase in teenage obesity and alarming rise in juvenile onset diabetes can at least partly be ascribed to the physically paralyzing influence of auto oriented landscapes.[15]

13. In both Canada and the United States the number of vehicles per capita has been steadily increasing from 1950 to 1995 (Schimek 1996). In 1940 there were nearly 40% more cars per licensed driver in the U.S. than in Canada however by the 1970s this gap had significantly narrowed (Schimek 1996). By the 1980s there was one vehicle per licensed driver in the U.S. (Schimek 1996). Historical data shows that in 1947 the proportion of total household spending dedicated to transportation was 9% and housing was 24.2% (Johnson et al. 2001. In 1966 transportation spending rose slightly to 11.1% and housing rose more rapidly to 30.2% but by 1979 transportation spending had risen significantly to 21.1% while housing spending actually decreased to 29.9% (Schimek 1996). Lipman (2006) found that when many working families move far from work to find affordable housing they end up spending their savings on transportation and by moving 12 to 15 miles the increase in transportation costs outweighs the savings on housing.

14. Much work has been done on the sociological impacts of suburban living, particularly on those members of the community that lack regular access to a car. For many people the suburban home is little more than a place to sleep, eat a meal or two and store personal belongings; most of their waking hours are spent elsewhere, either at work, school or in recreation (Gurstein 2001). This leaves people who work from home, especially those with young children, particularly isolated. Because the majority of people in their age group work outside of the community, the streets and other public spaces where passive social interaction would normally occur are empty and therefore ineffectual places for socializing (Gurstein 2001). Similarly, suburban teenagers suffer from the lack of active and passive participation in street life. Neighbourhoods separated from their main streets and from each other in highly disconnected street networks deter walking (Barnett 1995) and create a street environment often devoid of life. By the early 1990s, 60% of women living in the suburbs were in paid employment but they were “disadvantaged by the lack of locally available, affordable, quality child care at convenient locations and easy access to appropriate paid employment opportunities” (England 1993). Research has shown that suburban women are willing to forego well-paid jobs in favour of locally available but less well paid positions that allow them to attend to their domestic obligations (England 1993).

15. Ewing et al. (2003) found that residents of sprawling counties were likely to walk less during leisure time, weigh more and have a greater prevalence of hypertension than residents of compact communities. Frank et al. (2004) found that land-use mix had the strongest association with obesity and that each quartile increase was associated with a 12.2% reduction in the likelihood of obesity. Their study also found that each additional hour spent in a car per day was associated with a 6% increase in the likelihood of obesity while each additional km walked per day was associated with a 4.8% reduction in the likelihood of obesity. Papas et al. (2007) reviewed the literature on built environment and obesity between 1966 and 2007 and found that 84% reported a statistically significant positive association between some aspect of the built environment and obesity.

Spending and spending to stay in one place

For these and other reasons a system that had the capacity to accommodate the family trips of thirty years ago utterly fails now that family trips have doubled. Yet the highway system as built absolutely necessitated this doubling and should have been forseen. To get the system back to the efficiencies of thirty years ago would require a doubling of highway lanes per square mile in most metropolitan areas,[16] a proposition that most metropolitan regions have understandably shied away from.

But even if we could double the amount of national treasure committed to such an enterprise the dream cannot become real. The space demands of the car are such that in many sprawling metropolitan areas there are ten parking spaces scattered around

Figure X. This aerial photograph shows an example of the extent of paved area typical in Los Angeles, Florida.

the region for every car. That's an acre of land for every fifteen cars not counting the roads, garages, driveways and freeways they also demand. In the city of Sacramento, California over 35% of all city lands are paved,[17] devoted to car use. As auto dependence increases the percentage of land required to keep the system smoothly flowing increases steadily even beyond 35% to absurd heights. Many metropolitan areas are in danger of being consumed by roadways and parking lots while worthy destinations to drive to and from become increasingly rare. If one accepts the thesis that the trend towards more and more per capita driving is the inevitable consequence of the system as described above then at some future point it cannot be sustained, even if tax and personal resources poured into the system double and triple.

16. Over the past 15 years Houston has invested billions of dollars annually in highway improvements resulting in significant progress in relieving traffic congestion, far above that of most other metro areas in the United States (Cervero 2003, p159).

17. Litman (2008) found that assuming there are two to three off-street parking spaces per capita there would be approximately 1,000 square feet of parking pavement per capita and 2,000 square feet of urban land devoted to paved roads and parking per capita. In Canada this is about three times the land devoted to homes (Litman 2008). A study in the United States from Purdue University surveyed the total area devoted to parking in a midsize Midwestern county and found that parking spaces outnumbered resident drivers 3-to-1 and outnumbered resident families 11-to-1 (Purdue University 2007). Myrup and Morgan (1972) calculated that 14 percent of Sacramento, California was streets (including curbs and sidewalks) and 22 percent was "other impervious surfaces" (defined as parking lots, airport runways, and highway shoulder strips). McPherson (1998) who also analyzed Sacramento found that in low-density residential areas paved surfaces accounted for 27 percent of the land while in industrial areas they accounted for 50 percent. Manville and Shoup (2005) conducted an extensive literature review and found that no such aerial analysis has been done on Los Angeles to determine the percentage of land given over to the automobile therefore most region-wide estimates are simply guesses. However they did find that although denser cities tend to use a larger share of the land for streets they also use less street space per capita. For example, while New York's share of land in streets is 2.3 times that of Dallas, low-density Dallas has 1,575 square feet of streets per capita while compact New York has only 345 square feet per capita (Meyer & Gomez-Ibanez 1983). Los Angeles has the most lane-miles per square mile (7.6) of any urbanized area in the United States but a fairly low number of lanes miles per 1,000 persons (1.4) (2000 U.S. Census as cited in Manville and Shoup 2005). In terms of freeway lane-miles per square mile, London has 0.58, Paris and New York are similar with 1.52 and 1.50 respectively and Los Angeles has 2.57 (Demographia 2006).

No economy however vibrant should be so burdened with supporting a system that seems to produce so much energy and money consuming motion without productive purpose.[18] The strain of the current system on taxes has been apparent for years and is, according to many, already a crisis – a crises made vivid by the collapse of the Mississippi crossing of I 35W in Minneapolis in 2007.

Climate Change

The impossibility of curing congestion through road building absent any strong regional and national land use controls should be obvious to a sixth grader. But if the inevitability of eventual fiscal failure and congestion paralysis are not convincing enough we can add the collapse of our planetary support systems to the list. Thirty percent of the worlds CO2 production comes from the United States and Canada, where about 6% of the worlds people live. Of this about a quarter comes directly from transportation, and the bulk of that from single passenger automobiles. This number does not include the CO2 consequences of the immense infrastructure of car manufacturing and support, and the CO2 production consequent to building the roads and highways all those cars need (concrete production is the largest single industrial producer of climate change gas, with most concrete in North America used for highway and bridge construction).[19] Factoring those in brings the number closer to 40%.

The community of nations is finally agreeing that planetary meltdown can only be avoided if we cut climate change gases by 80% by 2050. Even the US and Canada, who have heretofore been the most reluctant of the G8 nations to acknowledged the crisis have agreed. During a period where just the US alone will add 130 million more people, it is madness to assume a 85-90% per capita reduction can be achieved unless we reverse the trend to ever greater auto dependence. No breath will here be wasted to debunk the pathetic faint hope of industry technocrats who point to hydrogen and ethanol as the way out of the dilemma without telling the truth. Both of those sources do nothing to change the fundamental entropy of our transportation choices, require huge energy inputs in their creation, lead to food scarcity in third world countries, and in the case of corn based ethanol require more petroleum to make the fertilizer, drive the farm equipment, and to truck the raw materials here and there than they give back in fuel.

Reasons for hope

At this depressing point no doubt the reader is tempted to reach for a strong drink and ignore the problem. It seems too big to solve. When completely unpacked in all its depressing detail, anesthesia beckons. But all is not lost. Robert Yaro, director of

18. Transportation-related final demand is the total value of transportation-related goods and services purchased by consumers, businesses and government. This includes personal consumption such as the purchase of new vehicles, fuel and services as well as government investment in the construction, maintenance and administration of transportation infrastructure. In 2003, the total transportation-related final demand in the United States reached $1.113 trillion and accounted for 10.7% of the national GDP (US Bureau of Transportation Statistics 2005). In Europe the transportation of goods and people accounted for 7% of the Gross National Product (EurActiv Policy 2006) while in Canada the total transportation expenditures in 2003 accounted for 13% of all expenditures in Canada's economy. Personal expenditures on transportation accounted for 8.5% of the Gross Domestic Product (Transport Canada 2003). A passenger-mile of travel is a traditional measure of transportation output and represents the movement of one person for one mile. In the United States expenditures per passenger mile rose from 3.71 cents in 1960 to 4.95 cents in 1970, 11.67 cents in 1980 and 16.55 cents in 1990 (US Bureau of Transportation Statistics 1994). Even when accounting for inflation, expenditures per passenger-mile have increased more than either the Consumer Price Index (CPI) or the Implicit Price Deflator (IPD) for most the recorded years.

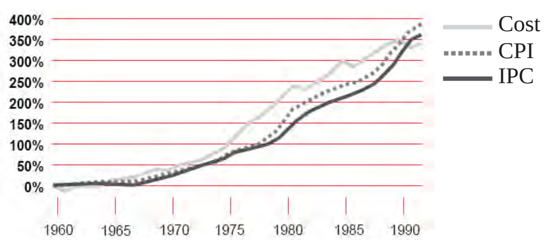


Figure X. Passenger Transportation Costs (per passenger-mile) vs Consumer Price Measures

19. In 2006 the US transportation sector's Greenhouse Gas (GHG) emissions from fossil fuel combustion totaled 1,856 $TgCO_2$ Eq., accounting for 26.3% of the total GHG emissions in the United States (US EPA 2008). This estimate did not include vehicle, fuel or infrastructure lifecycle emissions such as the extraction and processing of raw materials, production of fuel or infrastructure construction and maintenance. The total lifecycle emissions for the transportation sector (not including raw material production of non-highway vehicles or emissions from the construction and maintenance of transportation infrastructure) are estimated to be 27 to 34% higher than direct fuel combustion emissions (US EPA 2003). Emissions associated with the construction and maintenance of transportation infrastructure have yet to be studied in depth but CO_2 emissions from the chemical process of cement production is the second largest source of industrial CO_2 emissions in the United States at 45.7 $TgCO_2$ Eq. (US EPA 2008). According to the World Business Council for Sustainable Development (2002) only 50% of the CO_2 emissions produced from the production of cement come from this chemical process; 40% are from the combustion of fossil fuel for energy and are not included in the GHG inventory for the cement industry. Taking the chemical, combustion and energy emissions into account Worrel et al. (2001) estimate that the cement industry is responsible for 5% of global anthropomorphic CO_2 emissions.

the Regional Plan Association of New York often says: "The bad news is that we have massively overbuilt the freeway system. The good news is that we have massively overbuilt the freeway system." By the first part of this sardonic aphorism he means: America has over invested in a system that has, in the absence of any other land use planning controls, made a sprawling and highly inefficient urban landscape inevitable, as the excessive transportation demands that this infrastructure unleashes became impossible to satisfy. By the second part he means: The exact same system that unleashed these forces is of such a size and extent that it could accommodate through infill the massive increases in population expected. Less than ten percent of all land in North America's most sprawling metropolitan area is covered by buildings. The rest is consumed by parking areas, service roads, other roadways, highway rights of ways, driveways, yards and the other elements of the suburban landscape. Here, two cars per family are the minimum requirement for survival. Services are always too far away to get to on foot and too dispersed to be efficiently served by transit. If a way could be found to increase the intensity of all of the land within the freeway service area to double or triple its present level (and surely given the low coverage by buildings such a thing should be easily possible), then per capita demand for long distance travel should gradually drop. When land use intensity increases, alternatives to the car become possible, allowing a gradual mode shift to transit walking and biking. What this suggests is that the retrofit and intensification of the North American suburb is both eminently possible and a means to address the three linked sustainability problems of the city; our downward cycle of ever increasing car use, our increasingly unaffordable infrastructure maintenance costs, and the larger global crisis of climate change and our own responsibility for it.

The good news is that this infill is already underway in many areas. According to the US Census Bureau, the year 2000 marked the first time in fifty years that the average density of metropolitan areas has gone up. This is not just because young professionals are flocking to high density warehouse districts; it's much more systemic than that. The five room ranch house of the 1950's, a 1,200 square foot home on a 20,000 square foot lot is now a thing of the past. Now the 2,500 square foot home on the 5,000 square foot lot is much more the norm.[20] While these puffed up houses on smaller lots are decried by many, they represent a huge shift in the market to a density that is at least conceivably compatible with walkable and transit served communities. This trend is most advanced in Vancouver, where in the years between 1986 and 2001 the percent of Greater Vancouver's residents living in compact neighbourhoods increased from 46% to 62%.[21] Vancouver also has been North

20. Looking at neighbourhoods of varying age in five study areas (Maricopa County, Arizona; Orange County, Florida; Minneapolis-St. Paul, Minnesota; Montgomery County, Maryland; and Portland, Oregon), Knapp et al. 2004 found that lot sizes rose between 1940 and 1970 and then fell continuously, reaching an all time low in 2000. Hubble (2003) found similar trends in Las Vegas where the average lot size for a new home fell 500 square feet in the last two years. In 2001 only 13% of new residential lots were smaller than 4,000 square feet, however, in 2003 this number had doubled to 26% (Hubble, 2003). According to the US Census Bureau's American Housing Survey the median lot size fell 26% between 1995 and 2001(US Census Bureau). The US Census shows an increase in the density of urbanized areas in the United States from 3,052 people per square mile in 1990 to 3,176 in 2000 (Demographia 2001)..

21. Northwest Environment Watch. 2002. Sprawl and Smart Growth in Greater Vancouver: A comparison of Vancouver, British Columbia, with Seattle, Washington. Northwest Environmental Watch/Smart Growth BC. Available online at: http://www.sightline.org/research/sprawl/res_pubs/sprawl_smart_van

America's most successful example of center city densification. In the ten years between 1990 and 2000 the population of the downtown peninsula increased from 40,000 to 80,000. During that same time the total number of car trips into and out of the downtown actually decreased, while average commute times in the region dropped by six minutes (Vancouver was the only Canadian city where commute times went down during this period, a period where no additional freeway miles were added but during which population increased by over 20%).[22]

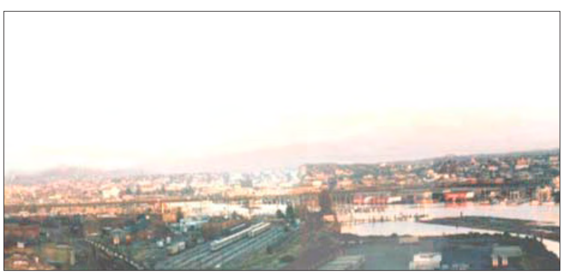
And there is more. Center city urban infill projects have been very successful in this decade, notably in Portland's "Pearl District". Three decades spent maintaining Portland's compact metropolitan region, often against the weight of tremendous political and industry opposition, have helped Portland avoid the value flight experienced in Detroit and St. Louis. By controlling land use and limiting freeway construction Portland successfully protected inner city values, making reinvestment in that city's former warehouse district possible. What is now sadly inconceivable in Detroit or St Louis is an accepted fact in Portland: There is a strong market for center city high density housing even in a relatively small city like Portland. Young professionals are willing to invest up to $500 per square foot for an urban lifestyle, if past decisions have been such that there is any urban life remaining (sadly in the case of St Louis and Detroit there is not). The success of Vancouver, echoed later by Portland, and increasingly copied by San Francisco and San Diego give reason to hope that efforts to infill, complete, and re urbanize the metropolitan landscape are possible, and indeed seem to be compatible with current market demand.

So while the symptoms of the disease are most certainly debilitating, and the disease itself life threatening, there are signs that the patient is capable of responding. As in so many other things there has to be a desire for change, and this desire is starting to be made manifest. The first step in recovery is always an admission that there is a problem and a taking responsibility for change. But proven therapies for restoring the health of the region are required. Citizens are justifiably insecure about how and what to change. Changing the way we build regions is like changing any habitual behavior. Habitual behaviors, like drinking, smoking or drugs, anesthetize us in the near term, but lead to larger problems in the long term. Building sustainable regions is the same. A reflexive NYMBYism in the face of development proposals that exceed existing district density is tremendously satisfying for citizens who justifiably feel they have protected their community through their opposition; but the long term effects of this action, multiplied by many thousands of other equally habitual actions, is to worsen the disease. A set of principles, call them rules for healing cities if you will,

22. Nationally, the average time spent commuting to work in Canada increased between 1992 and 2005 from 54 minutes to 63 minutes. In contrast, residents in Vancouver spent no more time on average getting to work in 2005 than they did in 1992. (Source: Turcotte, M. 2005. The Time it Takes to Get to Work and Back. Statistics Canada, General Social Survey on Time Use: Cycle 19, Catalogue no. 89-622-XIE)

Figure X. Pearl District in Portland, OR

The two photographs below, taken from the exact same spot but 25 years apart on Granville Street Bridge, show the dramatic change in Vancouver's skyline between 1978 and 2003.



are a necessary tool for recovery. Over the years many have recognized the same thing. The list of simple rules, or "steps to recovery" that form the core of this book are not original. A debt is owed to hundreds who have worked developing and promulgating similar design principles to correct the pathologies of the North American city. What is unique to this book is the attempt to simplify and order them clearly as a set of integrated urban design therapies for healing the North American urban landscape. The hope is to provide citizens and leaders in the public and private sector with a simple but credible framework for action. What follows then is listing of the principles followed by a one sentence explanation, which introduces and anticipates the seven following chapters where they are explicated in much greater detail.

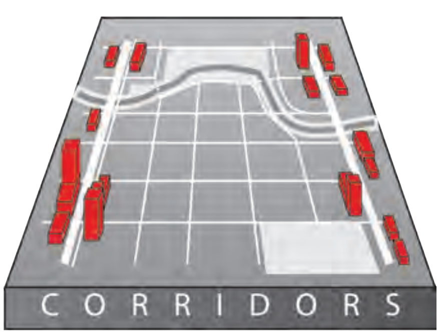
Seven principles for sustainable communities

1. A restored Streetcar City

The North American city was and is a streetcar city. Streetcar cities are characterized by easy access to transit, medium density, and linear commercial and activity corridors. Planning and design strategies of the past 50 years have largely ignored this fact. It needs rediscovery.

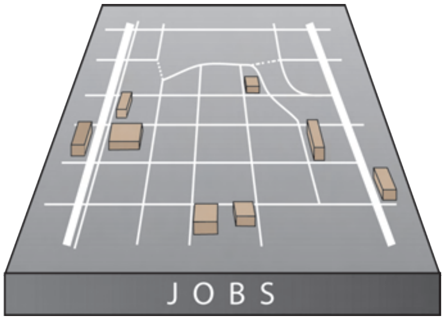
2. A five minute walking distance to commercial services and transit

North Americans will walk if there is something to walk to. The most important walking destination is the corner store and a bus stop with frequent service. A minimum density of ten dwelling units per acre gross density is required for this to work.



3. An interconnected street system

It does no good to be five minute walking distance from the store if it's as the crow flies. Interconnected streets are as important to pedestrians as they are for cars. Fine grain grids disperse congestion and insure that walking trips are as short as possible.

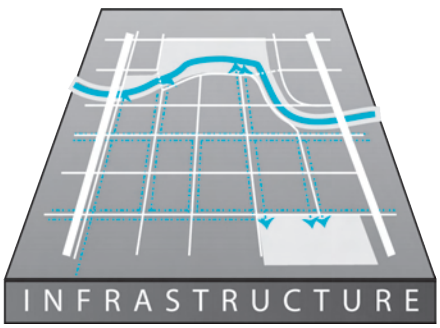


4. Good jobs near home

The trend to ever larger commute distances for workers must be reversed. "Good jobs close to home" is a fundamental requirement. The vast majority of new jobs in North America are compatible with complete neighborhood districts.

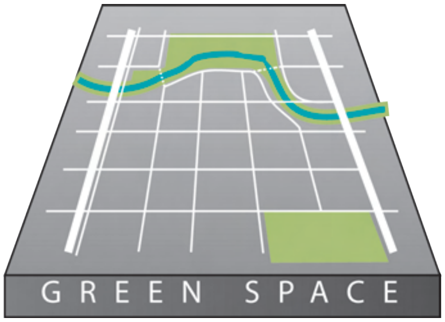
5. Different housing types on the same street

Zoning laws have been an instrument to segregate communities by income. Communities designed for only one income cannot be complete and when repeated throughout the region add to transportation problems.



6. Lighter, greener, cheaper, smarter, infrastructure

Suburban homes have at least four times more infrastructure per dwelling unit than do walkable streetcar neighborhoods. Exaggerated standards for road widths and cul de sacs cost too much, are difficult and expensive to maintain, and destroy watershed function. Smarter, cheaper, and greener strategies are required.



7. Linked parks and natural areas

To meet the performance targets of the water quality act requires a rethinking of urban drainage systems and stream protection policies. Articulation or recovery of these systems must be a first design move when planning new communities. Far from protecting these systems through restriction, these systems must form the public space armature of new and restored communities.

Love one principle, love them all

These principles represent the elements of a whole. Achieving one without the others, and particularly if it is at the expense of the others, will be of limited value and could be counterproductive.

Chapter Two: A restored Streetcar City

North American cities built between 1880 and 1945 were streetcar cities.[1] While this fact is mentioned now and then, seldom is it acknowledged how fundamentally the streetcar established the pattern of North American life, and how that pattern still constitutes the very bones of our city, even now that most of the streetcars are gone. A “day in the life” story will start to reveal this skeleton.

A day in the life

The year is 1922 and Mr. Campbell is house shopping. He has taken a job with Western Britannia Shipping Ccompany in Vancouver. He and his family must relocate from Liverpool England, and he is house hunting. The company put him up in a hotel in downtown Vancouver for the first few weeks. This weekend is his first chance to shop for a family home. He plans to explore a couple of new neighbourhoods presently under development, and to use the new streetcar system to get there. A quick look at the map tells him that the new district of Kitsilano might be a good bet. It’s not too far from downtown and located a five minute walk from the seashore. The Fourth Avenue streetcar line will take him there from downtown in fifteen minutes. The streetcar enters the district of Kitsilano. Construction is everywhere. Carpenters are busy erecting one story commercial structures next to the streetcar line and very similar bungalow buildings on the blocks immediately behind. As he rides further into the district the busy construction sites become less frequent, replaced by still standing forests. The paved road is replaced by one of gravel - the streetcar line, ties placed right on the raw gravel, the only improvement. It looks so odd to have a streetcar line serving what appears to be raw wilderness. Taken aback by the wildness of the landscape, Mr. Campbell steps off the streetcar where a sign advertises the new Collingwood street development. Here things are more encouraging, as workers are laying fresh concrete to sidewalks and asphalt to the new grid of streets. Fifth, Sixth, Seventh and Eighth street are complete for a few blocks before disappearing into the forests of the as yet undeveloped lots to the east and west. For sale signs are tacked on forest trees still standing on as yet undeveloped lots. Stepping into the project show home, he is immediately surrounded by activity. Carpenters and job foremen are using the house as an office, while sales agents occupy the front parlor. They waste no time inviting Mr. Campbell in, offering coffee and dropping him in a seat before the printed display of new homes. All the different styles fit on the same size lots, with the bungalow detached single family home style seeming to predominate. Shocked a bit by the wildness of the

1. Between 1850 and 1900 horse-drawn and then electric streetcars enabled large numbers of upper and middle class commuters to move further out of the city eventually giving rise to residential enclaves organized around streetcar lines referred to as “streetcar suburbs” (Warner 1962). By 1910 almost every American city with more than 10,000 people had one or more streetcar lines and per capita transit ridership peaked in 1920 at about 287 annual rides per urban resident (American Transit Association 2006). In 1917 there were 72,911 streetcars in service in the United States but due to a number of factors that number had dropped to 17,911 by 1948 (Toronto Star 1999).

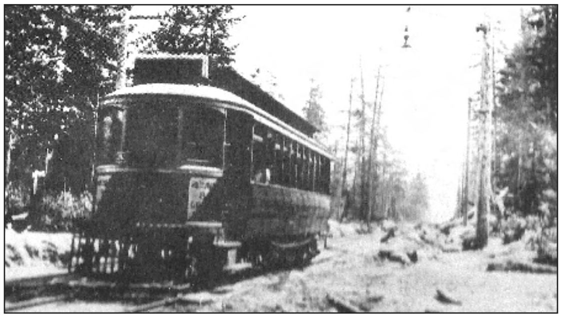


Figure X. Fourth Avenue Streetcar line freshly installed. Streetcars were provided before roads were improved or land subdivided for homes as a necessary precondition for development. Here is the scene a few years before these other urban featrues are built.
Source: Vancouver: The Way it Was (Whitecap books)

Figure X. Streetcars going over the Kitsilano trestle, west of Granville trestle, now Granville Street Bridge (1909)
Source: Vancouver Public Library

Figure X. Shown on Arbutus street in Vancouver (1952) this streetcar is an example of the Interurban type vehicle which was used for longer trips and between rural communities in the Lower Mainland.

Figure X. Shows the 5 minute walking distance from the 4th Avenue streetcar line. The land developer for this zone would also provide the streetcar.

2. Early in the 20th century "streetcar lines and their adjacent residential communities were typically developed by a single owner who built transit to add value to the residential development by providing a link between jobs in an urban center and housing at the periphery"(Belzer & Autler 2002). Private developers built transit to serve their developments and as part of this formula small retail outlets were often built in clusters around streetcar stops, both to serve commuters and local residents (Belzer & Autler 2002).

3. This is what is called "tax lots" or "taxpayer blocks" and it refers to developers who built for low density interim land uses on land believing it would eventually gain value therefore making more permanent commercial buildings worth their while (Rowe 1991). The low density buildings produced enough revenue to pay taxes and essentially held the land for future development however, at least partially due to the depression, WWII, and highway expansion, land values didn't rise and the low density developments remained (Rowe 1991).

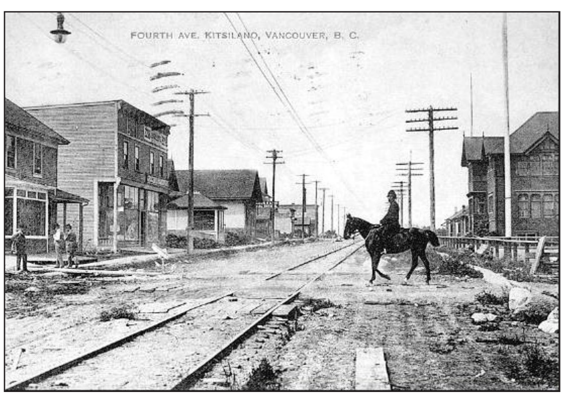


Figure X. One story commercial buildings on 4th Avenue, Vancouver, BC
Source: Abe Charkow (postcard collection)

landscape, he asks if this will change. The salesman laughs and says "Oh my, by this time next year all that will be gone and a whole new neighborhood will exist. Buy now while the prices are good because next year they will cost twice as much!" he laughs.

"Well how do I know I can get downtown to my job from here dependably?" asks Campbell.

Again the salesman laughs good naturedly and says "Because we own the streetcar line of course! Naturally we had to put the streetcar in before we built the houses, and a pretty penny it cost too! But nobody will buy a house they can't get to will they!" he laughs.[2]

"You mean the developers build the streetcar lines before they build the neighborhoods? Wow, that's incredible!"

"Just a fact of life around here Mr. Campbell. The streetcar lines have to be within a five minute walk of the house lots or we can't sell em! People have to get around don't they? But we make enough on the houses to pay it off. If we didn't we'd be out of business. But there have to be enough houses to sell per acre to make it all work,[3] that's only natural right! We have it down to a formula: eight houses to the acre give us enough profit to pay off the streetcar and enough customers close to the line to make the streetcar profitable too! That's why all the lots are the same size even when the houses are so different. You're a smart business man Mr. Campbell I can tell. I'm sure you understand, eh?" he laughs.

"But what of commercial establishments sir" asks Mr. Campbell with reserved formality, "Where will we buy our food, tools and clothing?"

Again the salesman laughs. "Oh all along Fourth Avenue sir. Don't worry! By this time next year it will be wall to wall shops. One storey ones to be sure at first but when this neighborhood fully developed we expect Fourth Avenue to be lined with substantial four and five story buildings to be proud of! Liverpool will have nothing on us sir! You'll always be just a couple of minutes from the corner pub. Anything else you need you can just hop on and off the streetcar to get it in a jiffy!"

Naturally once Mr. Campbell's understandable reservations had been overcome he was sold, and bought a house in the process. He was overjoyed to be able to buy a freestanding home for him and his family, something only the very rich of Liverpool could afford. All of the promises made came true more quickly than he imagined possible, with the single exception of the four story buildings to be proud of. Rather than ten years that would take another 80. First, the great depression slowed economic activity then, WWII redirected economic activity to the war effort. By the 1950s the economic pendulum had swung toward suburban development fueled by increasing car ownership. It was not till the 1990s that these streetcar neighborhoods would see the vision of four storey buildings lining both sides of the street realized.

Streetcar City as a unifying principle

The Streetcar City principle is not about the vehicle. It's about a sustainable relationship between land use, walking, and transportation. Streetcar Cities can exist without steel wheeled transit, but they can't exist without frequent and convenient transit that serves the local district. The Streetcar City principle gives us a shorthand way to signify a uniquely North American form that met and still meets many of the emerging principles for sustainable communities which we are all struggling to apply. The streetcar city principle orders and includes three others. The streetcar city that Mr. Campbell experiences necessarily has an interconnected streets system, different housing types in the same area, and a five minute walking distance to commercial services and transit.[4]

Basic structure of the Streetcar City

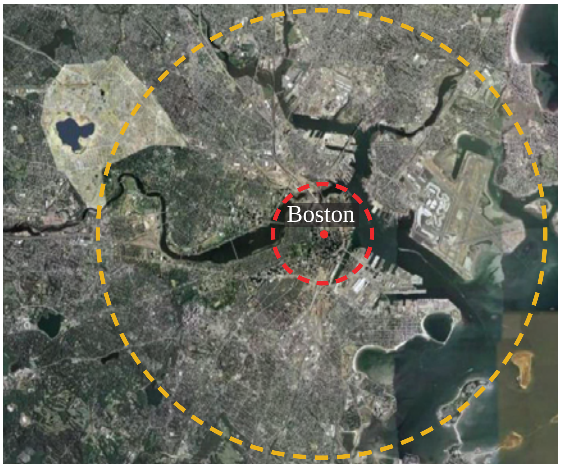
Streetcar cities, like Cleveland, Minneapolis, Seattle, Los Angeles and Vancouver have certain things in common. They are all laid out in a gridiron, with streets orienting to the cardinal axis. The grid is a subdivision of the original 40 acre blocks, commonly subdividing the 40 acre "quarter quarter" sections into 8 equal 5 acre blocks (inclusive of street space). Most homes are located within a quarter mile or five minute walk to the nearest streetcar stop, which means that ideally streetcar arterials were located every one half mile or every eight short blocks. In certain instances the streetcar arterials would form a grid of one half mile squares. More commonly a district might be better served by service in the east west direction on the half mile grid than in the north south. Commercial services occupy the ground floor of street fronting building along the line of the streetcar. This linear commercial oriented public realm is a unique feature of the Streetcar City which will be examined at length below.

4. Handy (1993) found that residents living in traditional neighbourhoods made 2-4 more walk/bike trips per week to neighbourhood stores than those living in nearby areas that were served mainly by auto-oriented, strip retail establishments. Ewing et al (1994) found that sprawling suburban communities generated almost two-thirds more per capita vehicle hours of travel than the 'traditional city.' Neighbourhoods that have gridded streets, convenient transit access and destinations such as stores and services within walking distance result in shorter trips, many of which can be achieved by walking or biking (Hess & Ong 2002). Streetcar suburbs tend to have these attributes therefore reducing vehicular travel and allowing for higher than normal public transit service (Hess & Ong 2002).

Figure X. The grid overlay makes it clear that urban blocks were cut from the original agricultural pattern. The unaltered agricultural pattern in Richmond near the bottom of photo still retains this original pattern.

Figure X. Historic Los Angeles with streetcar routes

Figure X. Historic Seattle with streetcar routes



Zone of mostly attached walk-ups (1 mile)
Zone of mostly detached ground oriented streetcar city neighbourhoods (4 miles)

5. Despite dramatic technological innovations, the amount of time that Americans spent commuting to work remained relatively constant, at approximately 20 minutes, from the 1840s through to the 1990s (McLynn & Spielberg 1978). However, in the 1990s the average commute time began to increase and is now up 18 percent from its historic norm with almost 10 million Americans driving more than an hour to work, an increase of 50 percent since 1990 (Siegel 2006).

6. Historically, walk up tenements allowed for compact, high density, walkable cities. Ancient Rome reached urban densities of 95,000 people per square mile of built up land while Manhattan reached a peak of 130,000 around 1910 (Pushkarev & Zupan 1977). Renaissance Florence had a more typical population density of around 28,800 per square mile and from the city centre one could walk to the city edge in 15.5 minutes (Pushkarev & Zupan 1977). In 1880, 45 percent of all adult male workers employed in Philadelphia lived within one mile of the central business district and 96 percent lived within six miles (Gin & Sonstelie 1992). Historically, people had much less indoor housing space than we do today so higher average population densities could exist while the density of structures remained relatively low (Pushkarev & Zupan 1977). However, allowing for modern space requirements (dwelling units ranging from 1,000 – 2,000 square feet with one parking space and 100 square feet of open space per dwelling), Ellis (2004) found that four story walk-up townhouses could still reach densities of 30-40 dwelling units per acre or 19,200-25,600 per square mile. The benefits of this type of development have been studied by Cervero & Kockelman (1997) who found that compact, mixed-use, pedestrian-friendly designs can 'degenerate' vehicle trips, reduce vehicle miles traveled per capita and encourage non-motorized travel.

7. An example of the classic four-story walk-up city is the Beacon Hill district in Boston. Even today the built form of this neighbourhood supports a density of approximately 40,000 people per square mile (Beacon Hill Online). In comparison, streetcar suburbs in Cleveland historically supported population densities of around 2,000-5,000 people per square mile demonstrating the approximately 16 fold drop in density permitted by the streetcar access (Borchert 1998).

Streetcars made detached housing possible.

Much has been made of the American Dream of owning your own home on its own lot. The Dream was presumably realized after WWII when the auto oriented suburb was born. But the dream was realized two generations before in the Streetcar City. With the emergence of the streetcar, the radius within which urban North American's could operate expanded dramatically. Prior to the streetcar, the radius of the average persons activities were proscribed by walking distance. Since the time of the Romans the time spent getting to work every day has been about 20 minutes on average.[5] You can walk about a mile in 20 minutes, thus the distance between work and home in cities from the time of Rome to the early development of Boston and Cambridge was one mile. As cities became more and more active, the need to put more and more people within easy compass of work led to cities of higher density. The classic "four storey walk up" city emerged in the time of Rome and persisted till the mid 1800s.[6] This is a city of roughly 30 to 60 dwelling units per acre, with a floor area ratio (FAR) of greater than 2, with a population that could easily exceed 60,000 people a square mile. In such cities single family detached homes were extremely rare. The vast majority of working class and middle class residents in such cities lived in apartment style structures while the rich lived more lavishly but still in high density townhouses – Boston's Beacon Hill district is a good example.

With the advent of the streetcar twenty minutes got you much further. Using an average speed of ten miles per hour inclusive of stops and intersection waits of 10 miles per hour, the distance traveled in twenty minutes increases from the walking distance one mile to the streetcar distance of 4 miles. This fourfold increase in distance is actually much greater than it seems when you consider that this increases by 16 times the area one can cover in 20 minutes from one square mile to sixteen. Thus the same 60,000 people that were compressed into one square mile could now be spread over 16 (under 4,000 people per square mile) allowing much lower density housing while still maintaining easy access for workers across the service area. For the first time, the urban middle class could buy detached homes.[7] Most streetcar city residential districts were therefore comprised mostly of single family homes, the bungalow style predominating. The Streetcar City form allows detached housing within walking and short transit distance of jobs and services over very large metropolitan scale areas. If our challenge is to reintroduce walking and transit into North American life, while not ignoring the desirability in the minds of most homebuyers for ground oriented detached dwellings, then the Streetcar City form is a proven prototype.

Forty percent still live there

About 40% of North America's urban residents live in districts once served by streetcar.[8] As such this same population lives in districts where options to the car are still possible. Most of these districts are still pedestrian and transit friendly, although with rare exception the streetcar and interurban lines that once served them have been removed – Toronto a rare exception to the rule. While there is much debate about what precipitated the removal of North America's streetcar and interurban systems, one thing is beyond debate. The U.S. courts convicted "National City Lines" for conspiring to intentionally destroy streetcar systems for the purpose of eliminating competition with rubber wheeled vehicles. While it seems impossible to us today, Los Angeles once had the largest and most extensive system of streetcars and interurban lines in the world. This system was completely dismantled by National City Lines, a "transit" company owned outright by GM, Firestone, and Phillips Petroleum. In 1949 GM was convicted of anti-trust violations for this practice, but by then it was too late. The streetcar boulevard system was irreparably damaged while an enormous and, in the minds of many, eventually fruitless effort to lace the LA region with freeways was underway. Now no hint of this original fabric can be directly experienced. Only by perusing the old photos can one sense the extent of the destruction.[9]

Linear not nodal

Linear public space is the distinguishing feature of the streetcar city. This is highly unusual and not generally appreciated. Most planning and urban design strategies see cities as places comprised of key places – crucial points in the landscape of the

Figure X. The last streetcars burn in Minneapolis, 1954
Source: Minneapolis Collection, M3857

Figure X. LA streetcars awaiting their fate, 1965
Source:Security First National Bank Historical Collection

8. In 2000, 80.3% of the total population in the United States lived in Metropolitan Areas (MAs): 30.3% in central cities and 50% in suburban areas (US Census Bureau 2000). This means that 60% of the total metropolitan population still lives in central cities. Central cities are defined as the largest city in a Metropolitan Area (MA) with additional cities qualifying if specified requirements are met concerning both population size and employment to residence ratios of at least 0.75. Suburbs are the areas inside a MA but outside the central city (US Census Bureau 2000). Central cities have substantially higher densities than their suburbs and are the closest approximation to traditional streetcar cities for which census data is available.

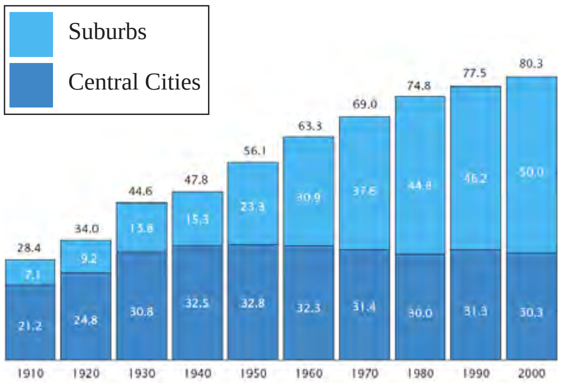


Figure X. Percent of Total Population Living in Metropolitan Areas and in Their Central Cities and Suburbs:1910 to 2000
Source: US Census Bureau, dicennial census of population 1910 to 2000

9. National City Lines (NCL) was organized in 1936 "for the purposes of taking over the controlling interest in certain operating companies engaged in city bus transportation and overland bus transportation" (Bianco 1998). In 1939, when NCL needed additional funds to expand their enterprise they approached General Motors for financing. GM agreed to buy stock from NCL at prices in excess of the prevailing market price under the condition that NCL would refrain from purchasing equipment not using gasoline or diesel fuel (Bianco 1998). Although it is not unlawful to make such requirements contracts it is this contract that resulted in so much controversy over GM's relationship with NCL and the charges of a conspiratorial relationship that brought about the destruction of North America's streetcar system. GM and their affiliates were never charged for replacing streetcars with motorized buses even though by 1949 they had been involved in the destruction of more than 100 electric transit systems (Snell 1973). What they were charged with was conspiring to eliminate competition in the sale of motor buses and supplies to National City Lines. They were convicted: GM was fined $5,000 and its treasurer was fined $1 (Bianca 1998).

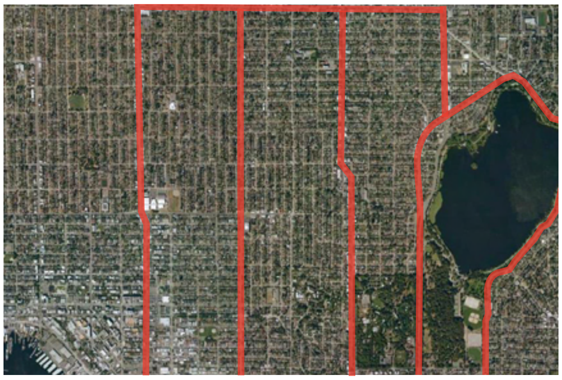


Figure X. Original streetcar routes highlighted in the University District of Seattle WA.

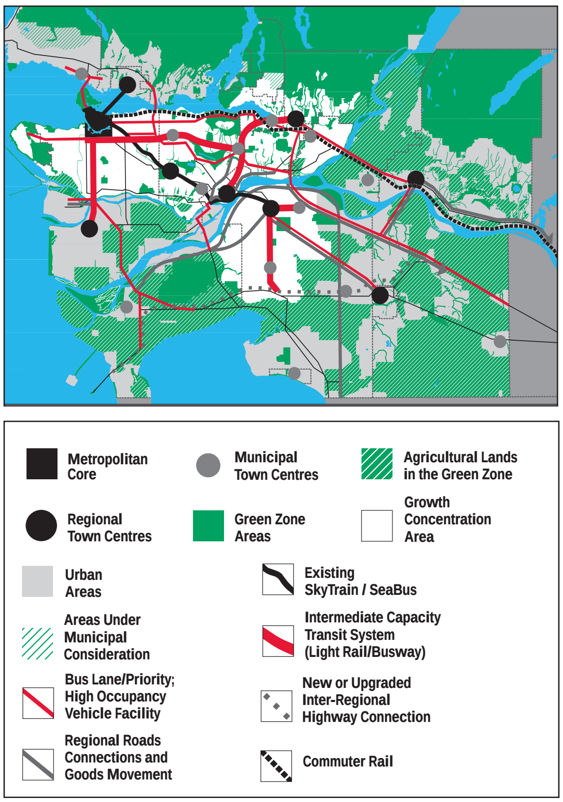


Figure X. Livable Region Strategic Plan: Transportation and Town Centres

10. Metro Vancouver's Livable Region Strategic Plan calls for regional town centres to "accommodate a large share of the region's future higher density commercial and residential growth" (GVRD 1999). However, between 1990 and 2000 the regional town centre's share of the office market actually declined from 11 percent to 10 percent while business parks' share grew from 20 percent to 30 percent (Royal LePage Advisors 2001). In 2000 half of the new office space in the Vancouver region was located in business parks outside of town centres (Memon et al. 2006). Taking a closer look at the distribution of business parks in Metro Vancouver we see that they are often located close to residential areas, services and transit. Instead of being inherently disconnected from the urban fabric it is the physical site design and single use zoning that frustrates connectivity, explodes distances between amenities and generally makes for an unwalkable, auto-dominated environment (Condon et al. 2006)

metropolis. The assumption that cities are made up of key centers and destinations deeply informs the planning, urban design, and economic development disciplines. For them, preserving and creating functional nodes is most often the goal. For example, the Vancouver region is justifiably famous for its Liveable Region Strategic Plan (LRSP), the plan to create complete communities linked by transit and protect the green zone. But the plan fails to mention the role of corridors at all. This may not seem like a significant disagreement, except it led to a transportation strategy primarily focused on equipping the widely spaced "Regional Town Centre" nodes with rapid transit connections. The plan was mute on the role of districts between the regional town centers, certainly more than 80% of the urban landscape.

The LRSP set aggressive targets for attracting housing and jobs into the town centers however. Housing targets were generally met for these nodes, and the region is rightfully famous for this achievement. But in its own reports the Greater Vancouver Regional District (GVRD) admits "failure" to meet regional town center job targets. Without both jobs and housing in the nodes only one "trip end" was close to transit, the housing end. The job end was still somewhere else.[10] Thus the strategy to connect the town centers with rapid transit links was compromised. Thus it was assumed the plan had failed in a critical way. The Province now threatens to over invest in freeway expansion to "fix the failed plan", noting that jobs were highly dispersed and thus not reachable by the new transit system.

But the jobs did not escape. They ended up in the spaces in between the town centres, close to the corridors. A strategy that had acknowledged the corridors as at least as important as the nodes would have likely led to a more balanced transit strategy, with buses and a rebuilt streetcar system (one was briefly proposed in 1995 for the Vancouver region but abandoned

Figure X. Four business parks in Burnaby show the characteristic patterns of large lots, single use zoning, and cul-de-sacs that characterize these developments. Distances within and between the parks are long and unlikely to be undertaken on foot.

11. In 2006, 73 percent of all transit trips in Vancouver were made by bus and 24.5 percent were made by skytrain (Translink 2006). The new 99 B-Line Service, along with implementation of the U-Pass, have led to dramatic increases in transit ridership and accounts for 73 percent of all new transit riders to the University of British Columbia (Walter 2000). In 1999 this accounted for 8665 total daily riders along the Broadway Corridor (Walter 2000).

12. In the past ten years population and employment in Vancouver has grown steadily, resulting in a 23 percent increase in trips to Vancouver (Memon et al. 2006). However, in contrast to the rest of the region where auto modes are increasing, new trips to and within Vancouver have increasingly been accommodated by transit, bike and walk modes resulting in an overall decrease in the number of vehicles entering and leaving the City by 10 percent (Memon et al. 2006). During the peak AM period (7am-9am) in 2004 there were an average of 140,000 commute trips into Vancouver, 250,000 internal trips and 70,000 commute trips out of Vancouver (Memon et al. 2006). From a regional perspective however only 19 percent of vehicles crossing the Port Mann Bridge (a notorious congestion area) are bound for Vancouver while almost 32 percent of these trips are destined for the Coquitlam area (Rock 2004). According to the Gateway Program Engineer (2006) 65 percent of all users of the Port Mann Bridge have origins or destinations outside of the Growth Concentration Areas, highlighting the failure of employment centres to organize themselves around transit hubs.

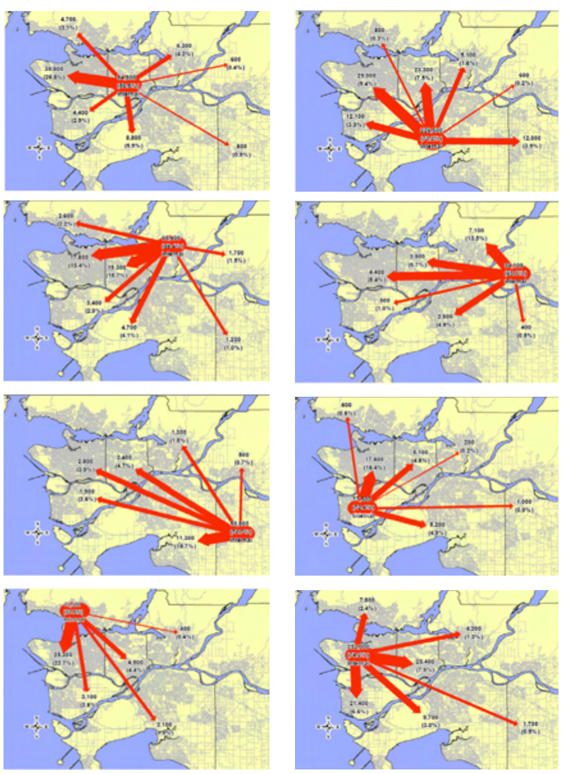


Figure X. Commute patterns for daily trips by origin, Vancouver (Translink 2004)

13. For a detailed look at the shift of employment to the suburbs see: Glaeser, Edward L. and Matthew E. Kahn. 2001. "Decentralized Employment and the Transformation of the American City." NBER Working Paper 8117.

for elevated subway Skytrain technology) getting their fair share. Instead billions were invested in a heavy rail system, the Skytrain, while many complained the bus system, which carries 80 of all trips in the system, was drastically under funded.[11]

Web vs Hub and Spoke

Concentric hub and spoke Patterned on New York and London

This discussion of the Streetcar City generates skepticism for many. Most discussions of transit made by environmentalists and their brethren have concerned the need to move people from their cars to transit, and have focused mostly on the car trip from the suburb to the center. The presumption, now quite outdated, is that people live in suburbs and commute to the center city for work. This trip now constitutes a minority of regional work trips.[12] Much more common now are trips to other job locations throughout the metropolitan area. This more homogeneous distribution of jobs is seen by transit planners as a failure to be corrected through planning policy and transit investments. The supposed "failure" of the Greater Vancouver Regional Districts Livable Region Strategic Plan, discussed above, is one particularly vivid example of this fixation. Metropolitan areas throughout North America have attempted to preserve the job site dominance of center cities against these centrifugal forces. But in most North American cities with the exception of New York the brief post war period where jobs stayed in the center while residential functions moved to very distant suburbs was the exception rather than the rule.[13] This massive region wide separation of activities therefore constitutes the exception rather than the rule. Unfortunately planners and advocates for both new highways and transit, folks who believe themselves on the opposite sides of a holy divide, both assume this exceptional status is a permanent condition of metropolitan North America. They both promote massive infrastructure investments intended to move people from where they presumably live, at the outside edge of the metropolitan region, to where they presumably work, at the center of the metropolitan region. Commuting statistics for most regions show that this is false. In the Vancouver region

14. Source: Travel Characteristics of Traffic on the Highway 1 Corridor. From Clive Rock, Director of Strategic Planning and Policy. To GVTA Board of Directors. July 2, 2004.

15. When comparing the map of Vancouver's historic streetcar lines and the current transit map of the same area one can clearly see how the motorized bus routes closely mirror the routes and major corridors set out by the streetcars. To a large extent these bus routes maintain the traditional streetcar grid.

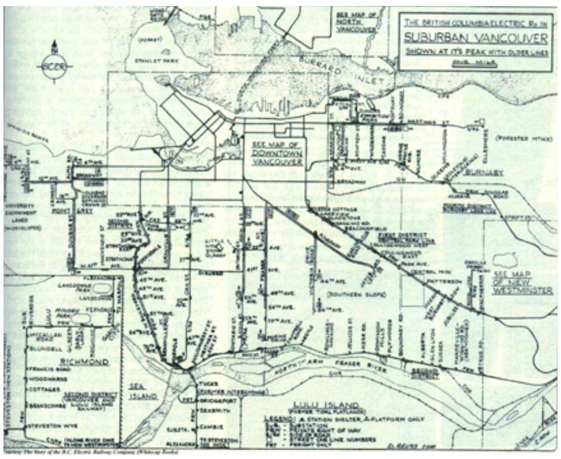


Figure X. Vancouver's historic streetcar lines
Source: *The Story of BC Electric Railway Company* (Whitecap Books)

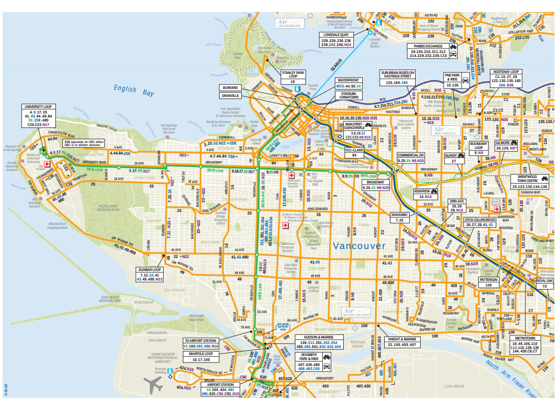


Figure X. Vancouver's current bus routes
Source: Translink

only 19% of trips crossing the Port Mann bridge from Surrey are destined for the center city of Vancouver. [14] The other 80% are commuting generally from the east to the west, toward Vancouver, but occupy job locations in the first and second ring suburbs. Gradually these first and second ring suburbs are adding jobs to the point where they have nearly as many jobs as workers. At this point are they no longer suburbs but cities in their own right? If so what does that say about the logic of continuing to invest tens of billions of dollars in systems designed for trips that no longer exist.

Streetcar city was more grid

If we accept this organic evolution of metropolitan regions towards a more even distribution of jobs we can look with new interest at the Streetcar City model, and see what it can teach us. Streetcar City transportation systems were grids, not hub and spoke systems. Movement in the system was not to once central location or effectively served by systems where all transfers had to be made at a central hub. Rather, movement was along parallel north south or east west arterials. You could get anywhere in the system with a two seat ride and a five minute walk at both ends of the trip. In Streetcar Cities each part of the city was more or less equally served and destinations were always by the shortest possible route (given the natural rectilinear constraints of the gridiron city plan of course). Busses that have taken the place of demolished trolley lines in most gridded cities still work this way and still enjoy advantages that are a legacy of the Streetcar City form.[15]

The lesson for older parts of the region with the original Streetcar City fabric still in place should be to re-enforce that structure with transit investments to shore up the function of these arterials, shifting investment here and away from hub and spoke systems.

The lesson for the suburbs should be to examine the fabric of the transporation network in those regions against the new evidence of the wide distribution of jobs for clues about how a revived Streetcar City type strategy might be a wiser investment than continued over investment in a obsolete hub and spoke system. This is particularly important if one accepts that "complete communities" should be a feature of any sustainable city. Complete communities are communities where one needs to travel far less during the average day than we do now – cities that reverse dramatically our need to travel by whatever means except possibly by foot. It seems unlikely in the extreme that we can ever achieve the massive reductions in energy use required to bring global warming under control, to cite just one aspect

Figure X. "Light" rail Portland Max vehicle opperating like streetcar in the forground with a true light rail streetcar in the background.

Figure X. MAX line, Portland
Available under the Creative Commons Attribution 2.5 License

of our linked sustainability crisis, if we accept the inevitability of residents in regions making daily trips half way across the region in thirty minutes or less, and invest in systems that make such trips possible. Both highway and transit advocates fall into this trap. Trips by transit are not free. A passenger mile in a bus or commuter rail takes less energy than an average car but about the same as in a prius. It won't help us to get everyone onto transit unless we can find a way to radically decrease the average daily demand for motorized travel of any kind. Community districts that are complete and favor short trips over long ones seem an obvious part of the solution. Inexpensive short haul transit vehicles, like streetcars and of course busses, are likely features of a low energy solution.

Buses and streetcars.

When National City Lines disassembled streetcar systems in Los Angles they marshaled strong arguments in support, arguments still leveled against streetcar systems when they are proposed. Streetcars are inflexible. They are on rails so if one gets stuck the whole system gets stuck. Streetcar vehicles cost more than busses. Busses don't need overhead wires to run them. Buses do the same job as streetcars but do a lot more too.[16] These arguments are often sufficient to end the matter. But lets approach the question from a different angle. Its not a question of busses or streetcar really. It's a question of what kind of rail transit makes the most sense.

Figure X. Dallas streetcar

There is general agreement that light rail systems are a good thing, and that they should be a major part of any region's transportation expenditure. Recent US transportation bills have allowed the use of gas tax for transit lines, resulting in new rail systems for places as unlikely as Dallas. Almost all of this new expenditure for rail systems has been made on systems expected to move riders from the edges of the metropolitan area to the center in thirty minutes of less. To call these systems "light" is a misnomer. They are heavy rapid transit systems that cost many billions to construct. Portland's MAX system, one of the earliest and according to most one of the most successful of these commuter systems,[17] operates like a large streetcar in the center city, moving at slower speeds on crowded streets. Once out of the downtown it operates as a grade separated system with a dedicated right of way, widely spaced stations and travel speeds of up to 60mph. The system had to be built this way. It was the only way to satisfy the

16. When National City Lines disassembled the streetcar system in Los Angeles they used predominantly economic arguments to support their actions. They argued that initial capital costs were much higher and that the cost of operating buses per vehicle mile was at that time half the cost of operating streetcars (Bauer 1939 as cited in Ortner & Wachs 1979). With fuel costs rising, this is calculus is certainly different today of course.

17. Portland's Metropolitan Area Express (MAX) system is one of the most successful light rail systems in North America. According to the American Public Transportation Association's Ridership Report (2007), Portland's MAX system accommodates 104,300 daily trips and is the United State's second most ridden standalone light rail system, second only to San Diego. Cervero (1998) writes that Portland has made a "stronger commitment to integrating transit and urban development" than any other city in the United States and that "if any American region is poised to become a great transit metropolis during the twenty first century, it is metropolitan Portland."

Figure X. Streetcar in Portland's revitalized Pearl District
Photograph by Scott Harrison

primary performance objective for the system: get riders from the edge of the metropolitan region to the center in a half hour, or at speeds that compete with the car. Regional authorities typically assume that the role of rapid transit is to operate at speeds comparable to the car. This is a race that transit can never win before bankrupting the civic purse.

Portland style MAX technology costs approximately 100 million dollars per two way mile to build. Fully grade separated systems like the Vancouver Skytrain system cost twice as much: 200 million or more per two way mile. In the mid 1990s, Tri-Country Metropolitan Transportation District (TriMet) planned a north south MAX line to compliment the existing east west line. The new line would have run from Downtown Portland, serve the north side of the city, before connected across the Columbia river to the City of Vancouver, Washington. Voter approval via a referendum was required to authorize the local cost share. The bond measure was narrowly defeated, constituting a major setback for transit in the region.[18] Officials in Portland were initially inclined to give up, but didn't. They still needed a system to serve the north part of the city so they cast about for more affordable alternatives. What they found was modern streetcar technology. Europe had never abandoned streetcars and many companies still manufactured them. A Czech company (get name) was able to provide the components of a system that could be installed, including rolling stock, for 20 million dollars a two way mile – only one fifth the cost per mile compared to MAX technology and one tenth the cost of Skytrain. Why so cheap? Car size was the same as Skytrain so it wasn't that. The system is cheap because while it can run in dedicated right of ways at speeds of 50 mph it can also very easily run on existing street rights of way. It can either share lane space with cars as it does in Portland or move faster on dedicated lanes in the center of streets as does the Green Line in Boston. The vehicles are so light that streets and bridges do not need reconstruction to accommodate. On regular streets all that is needed is a 12" concrete pad within which to set rails. Otherwise the street is not disrupted, nor are the businesses that may line it.

In Europe streetcar or tram systems are being expanded much faster than heavier rail systems,[19] gradually replacing busses on heavily used urban arterials. They provide a much smoother ride than busses for elderly. With an aging demographic where those over 65 years old will soon constitute over 33% of the population, a 200% increase over today,[20] this is a key factor. Body balance is very compromised as we age. Unsteady rides and buses that are hard to mount and stand in are increasingly difficult after age 55 and almost impossible over 70. Low floor streetcar are mountable at grade and are free of rocking motion.

18. In 1996 Oregon voters rejected a $375 million transportation package that would have funded the north-south light rail project as well as a 9 mile extension from Vancouver to Hazel Dell by a vote of 53 percent to 46 percent (Metro 2007). Although the measure failed state-wide, it was approved by a majority of voters within the TriMet service area (Metro 2007).

19. The majority of European cities rebuilt or upgraded their streetcar systems following World War II in response to "lower automobile ownership, a lack of domestic petroleum resources, plentiful electricity and a desire to not allow automobile usage to disturb the traditional economic and social patterns of these centuries-old cities" (Gormick 2004, p.v). A few large cities like Stockholm, Rotterdam, and Milan built heavy rail but most decided to restore or upgrade their streetcar services instead (Black 1993). In 1975 there were 310 cities in the world with streetcar/LRT systems in operation including most West European nations and Japan (Diamant et al. 1976). Great Britain and France were two notable exceptions to this trend in Europe. Very few tram lines survived in these countries after WWII however, more recently many cities in the United Kingdom and France are reintroducing streetcars from scratch, having had no light rail or tramway for more than a generation (Hyden and Pharoah 2002).

20. In the year 2006 the following percentage of citizens were over 65 years of age in each country: Japan (20.8 percent); Italy (19.7 percent); Germany (19.3 percent); France (16.2 percent); United Kingdom (16 percent); Canada (13.7 percent); Russia (13.7 percent); and the United States (12.4 percent) (Martel & Melenfant 2007). It is projected that 30 percent of Canada's population will be over 65 years of age by the year 2056 (Statistics Canada 2005) and that by 2050 those ages 60 and over will make up 22 percent of the world's population: 33 percent in more developed regions, 21 percent in less developed regions, and 12 percent in the least developed countries (Mirkin & Weinberger 1998).

Streetcars are always electric and thus don't pollute. Finally and most compellingly, they don't really cost much more than busses. Vancouver recently purchased a new fleet of trolley busses, eclectic vehicles that have been used on streetcar streets since the rails were removed in the 1940s and 50s. Vancouver's rapid bus system cost $4.3 million per mile[21] and features articulated buses with a maximum load of 80 persons per bus[22]. With a maximum load of 156 passengers per vehicle[23] streetcars can carry nearly twice as many passengers as articulated buses at a cost of $26 million per 2-way mile.[24] While more expensive it is nothing like the quantum leap in cost between busses and heavier rail systems.

Portland and investment.

Most discussions of streetcar focus solely on transit issues, but the implications are much wider. Streetcars stimulate investment and busses don't.[25] This has been powerfully demonstrated in Portland where the introduction of a modern streetcar line spurred high density development that helped the City of Portland recoup construction costs through significantly increased tax revenues. Between 1997 and 2005 the density of development immediately adjacent to the new streetcar line increased dramatically. Within two blocks of the streetcar line $2.28 billion was invested, representing over 7,200 new residential units and 4.6 million square feet of additional commercial space; even more impressive, new development within only one block of the streetcar line accounted for 55 percent of all new development within the City's core.[26] To put this in perspective, prior to construction of the new streetcar line land located within one block of the proposed route captured only 19 percent of all development. Most attribute this impressive increase in investment to the presence of streetcar. Developers for the new South Waterfront development at the other end of the downtown from the Pearl District would

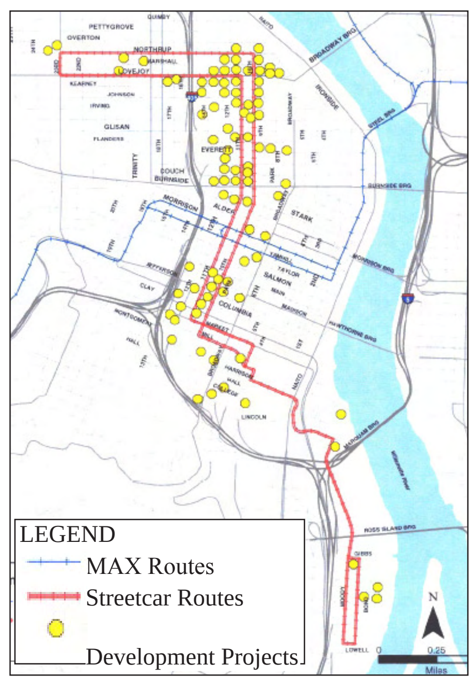


Figure X. This map of development projects along the streetcar alignment suggests that the lighter streetcar technology was a greater spur to development than the heavier MAX light rail Source: Portland Streetcar Development Oriented Transit, January 2008, p. 7

21. Breakthrough Technologies Institute; cost includes vehicles, the median busway improvements, station shelters, automatic vehicle location system, transit signal priority systems and a % of a new bus depot.

22. IBI Group. 2003. Bus Rapid Transit Evaluation Study. Prepared for Translink.

23. IBI Group. 2006. Streetcar and Local Bus Comparative: A technical memorandum for the City of Vancouver's Downtown Streetcar Project Update.

24. The average cost of new light rail construction in North America is $35million/mile, excluding Seattle whose $179million/mile price tag is well outside of the norm (Light Rail Now 2002). This calculation includes new streetcar systems which are significantly less expensive. Portland's modern streetcar line was constructed for $12.4 million/mile (although some sources have it at $16.4 million/mile (Light Rail Now 2002)), Tampa, Florida's was built for $13.7million and the streetcar line in Little Rock, Arkansas was built for $7.1 million/mile (Weyrich and Lind 2002). Existing systems show us that new light rail systems can be built well for $20 million/mile and streetcars can be built for $10 million/mile. When compared to bus service streetcar's have higher capital costs for streetcar infrastructure and vehicles. The typical price for a modern streetcar is in the range of $3 to $3.5 million while a 40-foot transit bus costs between $0.4 to $0.5 million and articulated buses range between $0.6 and $0.9 million. These costs can potentially be offset by increased efficiency in operating costs. In most cases, the operating cost per boarding rider for light rail and streetcars is significantly lower than buses, primarily due to their higher capacity. For example, the operating cost per rider trip for buses in St. Louis is $2.49 while for light rail it is only $1.32 (Lyndon 2007). Streetcars also have a service life of 25 years while transit buses only have 17 years (City of Vancouver 2006).

25. Cervero (2007) cites the streetcar system as a major driving force in the development of the Pearl District in Portland which now has an average density of 120 units per acre, the highest in Portland. The streetcar has stimulated housing and transportation in the area as well as an estimated 1.3 billion dollars in investment (Ohland 2004).

26. Hovee & Company, LLC. 2005. Portland Streetcar Development Impacts. *In* Portland Streetcar Loop Project Environmental Assessment, January 2008.

not proceed before the city guaranteed to extend the streetcar line to their site. The developer for the South Waterfront also spearheaded development of the Pearl District. They were quite certain that streetcar was a crucial element for financial success. If the free market is telling us anything at all in this case it is that the economics of streetcar, when the value of new investment is included, is much more cost effective than an investment in rubber wheeled diesel busses.

Does it have to be streetcar?

Figure X. Bus Rapid Transit on the Broadway corridor in Vancouver, BC

There are examples of streets that operate effectively as streetcar streets without the streetcars, demonstrating that the concept is about more than vehicle choice. Broadway in the city of Vancouver is an example. Broadway is the dominant east west corridor in the city, running from its eastern border at Boundary Street to its western border at the campus of the University of British Columbia. Broadway has always been a good street for transit, even after the streetcars were removed. All of the density and access features described above are found there. Residents who live near Broadway can survive without a car. Many of the residents along the corridor are students at UBC, who have always enjoyed a one seat ride to school on busses with three to five minute headways. More than half of all trips on the corridor now are by bus, over 60,000 passenger trips per day.[27] Very frequent bus service has re-enforced the function of the Broadway Streetcar Street corridor even without the streetcar in place. Walkable districts, sufficient density, three minute headways, hop-on-hop-off access to commercial services, and five minute walking distance to destinations at both ends of the trip all contribute synergistically.

Gradually restoring the streetcars to Broadway is eminently sensible. This will reduce pollution, better accommodate the infirm and the elderly, add capacity, provide everyone a more comfortable ride, and attract investment where you most want it. For these reasons the City of Vancouver is planning a streetcar line for Broadway. Unfortunately this contradicts the regional transit authority’s preference for heavier “rapid” transit, meaning that Vancouver, like Portland before it, would have to start its own city transit authority to build and finance the project.

Conclusion

The Streetcar City Principle is about more than just the car. It’s about a balance between density, land use, connectivity, transit vehicles, and the public realm. The Streetcar City is compatible with single family homes yet can be served by transit. It assures that walking will be a part of the everyday experience for most

27. Leicester, G. 2006. Implementation of Transit Priority on Broadway Corridor. Prepared for GVTA Board of Directors.

residents and eliminates the imprisonment of the suburban cul-de-sac for children and early teens. It has been shown to induce substantial shifts away from auto use to transit use and can conceivably be introduced into suburban contexts.[28] It is compatible with the trend to increasingly dispersed job sites and seems to be the form that best achieves “complete community” goals. The Streetcar City principle, whether manifest with or without steel wheeled vehicles, is a viable and amply precedented form for what must by 2050 become dramatically more sustainable urban regions. Other sustainable city concepts that presume extremely high density urban areas linked by rapid regional subway systems seem inconceivably at odds with the existing fabric of both pre war and post war urban landscapes. At the other extreme, assuming that some technological fix like the hydrogen car will allow us to continue sprawling our cities infinite future seems even more delusional. Part of the therapy for the sickness of our cities must be a clear eyed recognition of the status of the physical body of the city as it is, and a physical therapy calibrated to its specific capacity for a healthier future. The Streetcar City principle is intended to both provide simple insight into our condition, and a clear set of strategies that have proven themselves for decades.

28. Litman (2006) found that “cities with large, well-established rail systems have significantly higher per capita transit ridership, lower average per capita vehicle ownership and annual mileage, less traffic congestion, lower traffic death rates, lower consumer expenditures on transportation, and higher transit service cost recovery than otherwise comparable cities with less or no rail transit service.” Recent studies have found that 30 percent of residents moving into Portland’s new transit oriented development own fewer cars than they did at their previous home, and 69 percent use public transit more often than they did in their previous community (Podobnik 2002; Switzer 2003). It is important to note that the benefits of transit oriented development don’t come solely from the construction of a streetcar system. When applied to low-density suburban developments modern streetcars are doomed to low ridership and cost recovery (Gormick 2004). Reforming land use and increasing density prior to or in concert with the construction of streetcar lines is essential if the full benefits of the system are to be realized (Gormick 2004).

Chapter 3: An Interconnected Street System

Interconnected street systems vs. dendritic street systems.

Street systems either maximize connectivity or frustrate it. North American neighborhoods built prior 1950 were rich in connectivity, as evidenced by the relatively high number of street intersections per square mile typically found there. Gridiron streets systems are the most obvious and most common example of interconnected street networks.[1] Gridiron streets systems provide more than one path to reach surrounding major streets. In most gridiron street networks only two types of streets predominate: narrow residential streets and urban arterial streets that in this book for reasons explained in chapter 2 we are calling "streetcar arterial" streets.

On the other end of the spectrum are the post WWII suburban cul-de-sac systems where dead end streets predominate and offer only one path from home to major surrounding streets. This second cul-de-sac dominated system can be characterized as *dendritic* or "treelike". Streets in this system all branch out from the main "trunk", which in North American cities is usually the freeway. Attached to the main trunk of the freeway are the major "branches", which are the feeder suburban arterial streets or minor highways. These large branches then give access to the next category down the tree, the collector streets or the minor branches in the system. Collector streets then connect to the "twigs and branch tips" of the system, the residential streets, and dead end cul-de-sacs.

This dendritic system has become a ubiquitous feature to urban districts built since 1950.[2] The complex industry that creates new communities is so thoroughly committed to the dendritic street system that alternative thinking is no longer supported. Most municipal and regional transportation planners and engineers speak only in the language of the "street hierarchy", or the hierarchical categorization of streets. This is the language now used to describe this "tree like" dendritic concept and it is almost impossible to easily dislodge. Jurisdictions have rules tied to this street hierarchy taxonomy. Here is only one example of how this works: the Salem OR Planning department requires new developments to assign categories from this hierarchy to all the streets in a subdivision proposal before it can be approved.[3] In 2003 the proponents for a sustainable new community at the former Fairview State Training Center in Salem argued that their interconnected street system proposed was essentially without a flow concentrating hierarchy, but rather was designed

1. A gridiron street system typically has a greater number of intersections than a dendritic street system.

Figure X. This typical sq km in Vancouver, British Columbia has 66 intersections

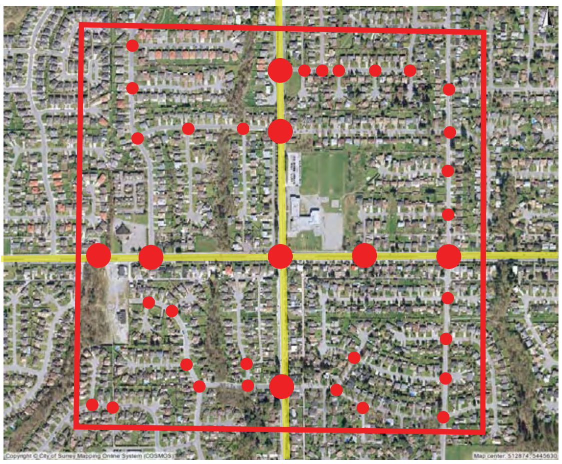


Figure X. This typical sq km in Surrey British Columbia has 36 intersections

2. The street hierarchy was first elaborated by Ludwig Hilberseimer in 1927 and has since prevailed as the dominant model for suburban development (Ford 1999). Between 1930 and 1950 residential street standards became institutionalized by the Federal Housing Administration (Southworth & Ben-Joseph 1997) and by the late 1950s the "normal" suburban street network was dominated by cul-de-sac streets within vast areas of single use residential zoning (Ford 1999).

3. According to Salem's Subdivision Land Use Application, streets in proposed developments must be designed to provide safe, orderly and efficient circulation of traffic in conformance with the Salem Transportation Plan. A key objective of the Salem Transportation Plan (2007) is to "develop a comprehensive, hierarchical system of streets and highways that provides for optimal mobility for all travel modes." This is to be achieved through the creation of a street network made up of: peripheral arterial streets linking outlying districts to each other and the central core area; collector streets that connect local traffic to the arterial system and; local streets that provide property access and neighbourhood circulation (Salem Transportation Plan 2007). Based on traffic type and volume, all streets are classified under the Street Classification System which then determines the specific design characteristics of the street. This is a community that otherwise encourages alternatives to the

car and sustainability. The contradictions between the street regulations and the broader sustainability goals are not recognized here in Salem, Oregon or in most other jurisdictions in North America.

4. Recollection of author who participated in these meetings.

Figure X. Brookside Elementary School in Surrey BC is located in the middle of a superblock, far from the high traffic arterial highlighted above. The closest bus stop is more than half a kilometer from the front entrance of the school.

Figure X. An example of an overbuilt arterial intersection. A solidary pedestrian risks the crossing while a bicyclist fights for position with cars at the intersection.

5. Allen, Eliot. 1996. Benefits of Neotraditional Development. Criterion Engineers and Planners, Portland, Oregon.

to distribute traffic throughout the network. Unfortunately city planners and engineers did not have the discretion to accept this argument, feeling that their own policies made a categorization unavoidable. Having failed, the proponents reluctantly identified the community's proposed "High Street," where shops and community facilities like libraries and schools were proposed, as the "arterial." Unfortunately this designation triggered a reaction at the school district where one of their policies prohibited elementary schools located on "arterial" streets. Here too the school officials felt that they had no discretion in the matter and could only accept a plan where the school was placed less accessibly on a "quieter" part of the site. They recommended putting the school at the end of a cul-de-sac, with ample space for "mothers to drop of their children in cars every morning". At no point did they take the master plans imperative that the school should be "centrally located to make walking convenient and to make the school the symbol of the community" seriously.[4]

A second example: In 1998 the City of Surrey BC, partnered with the UBC Design Center for Sustainability to design a new "sustainable community" based on principles similar to the ones in this book. An interconnected modified grid system was designed. As part of the process the consultant transportation engineer was required to model the performance of the system. Even though all charrette participants understood and supported the logic of the interconnected grid, including the consultant engineer, she had to artificially assign a hierarchy to the road system or the traffic flow software simply would not run! Thus even the modeling software only acknowledges one kind of system, the dendritic.

Why is the dendritic system a problem?

The basic problem with the dendritic system is that all trips collect at one point, usually the major intersection of two suburban arterials or the on ramp to the freeway. With all trips in an area feeding to one point that intersection will typically receive up to 4 times more trips than would an equivalent intersection in an interconnected system.[5] With all of these trips forced through one pinch point, congestion is inevitable unless Herculean road expenditures are made. But huge expenditures for suburban intersections are now routine, with nine or ten 13' lanes and 200+ foot wide right of way intersections very commonplace. While many of these intersections admirably handle the turning motions and through trips for 60,000 or more car trips a day, they are almost impossible to cross on foot, particularly for the infirm. One study of pedestrian deaths in the Orlando area identified just such a landscape as a pedestrian death hotspot, the worst in the region.[6] Apparently many customers were foolhardy enough to try to trek on foot from the Ground Round to T.G.I.F across the 10 lane arterial street that separated them, and there met their end. It would have been infinitely more intelligent to drive.

Transit systems seldom work well in such places either, since the bus stop drop off point at the intersection is still hundreds of yards away from the bus riders destination, separated from the street by hundreds of yards of parking lot.

Major streets within interconnected street systems often work quite differently than in suburbs. The contrary example of the Broadway corridor in Vancouver BC is instructive. This corridor carries 60,000 trips a day. Were it redesigned to suburban standards, Broadway would require at least nine travel lanes, including three turn lanes.[7] It operates with only four through lanes, no turning lanes, and two parking lanes. The parking lanes are used for through traffic during rush hours, a double use of a lane that is common in older communities but unheard of in new ones. Left turns are restricted at many intersections to keep traffic moving smoothly. The lanes are a relatively narrow 11', with a consequent curb to curb crossing distance of 66 feet, less than half the distance of the comparable suburban intersection, in a total ROW of 90 feet building front to building front. Crossing times for pedestrians, even the infirm, are reasonable over this distance. The remaining space is taken up by 17' wide sidewalks serving a continuous line of store fronts. The surrounding grid of streets provides alternative options when this intersection is congested, alternatives that do not exist in the suburbs. Drivers frustrated from making lefts always have the option of using the adjacent street grid to position their car on a perpendicular intersection and achieve their destination that way.

Big boxes

A second consequence of dendritic street systems which, depending on your point of view about big box commercial may be seen as a negative is this: dendritic traffic networks that

6. Between 1994 and 2003 pedestrian fatalities declined by approximately 12.8% which sounds encouraging until you realize that the percentage of commuters who walked to work has declined by 24.9% (Ernst, 2004). In fact, walking is by far the most dangerous mode of travel per mile. In 2001 the fatality rate per 100 million miles traveled for public transit riders was 0.75, for drivers and their passengers it was 1.3 but for walkers it was 20.1 (Ernst, 2004). Since the end of the 1930s, guidelines published by the, Federal Housing Authority (FHA) on neighbourhood design have prescribed large-scale developments based on road hierarchies and superblocks whose interiors preclude all but single-family homes and schools (Miles-Doan & Thompson 1999). In their 1999 case study of pedestrian injuries and deaths in Orange County, Florida, Miles-Doan and Thompson argue that "the institutional neglect of pedestrian safety along arterial roads stemming from the historic evolution of the planning profession has serious consequences" for pedestrian safety. They found that incidents of pedestrian injury and death cluster themselves outside of neighbourhoods, along arterial roadways with strip commercial development. Ernst (2004) found that Orlando is the most dangerous metropolitan area for walking with 3.15 deaths per 100,000 people despite the fact that their walk-to-work rate of 1.3 percent is well below the national average. In comparison, Boston has a death rate of 1.02 but a walk-to-work rate of 4.0% making it one of the safer large metropolitan areas (Ernst, 2004). Miles-Doan and Thompson (1999) state that "the long-range solution to the arterial road safety problem begins with reevaluating the planning practice of designing urban arterials as traffic-moving facilities and nothing else." Typically, pedestrians who want to cross arterial streets need to contend with several lanes of traffic making a variety of movements at street intersections. The City of Orlando Transportation Planning Bureau (2002) found that when these discouraging conditions are minimized, by reducing road width, the number of pedestrians crossing the street increased by 56 percent.

7. Contemporary suburban street patterns are characterized by wide spacings of arterial streets that typically provide six through lanes, right turn lanes, and single or dual left turn lanes (Levinson 1999). In his report *Traffic Circulation Planning for Communities*, Marks (1974) specifies that arterial streets should be spaced one mile apart, accommodate 10,000-30,000 vehicles per day, feature 4-6 lanes with a physical median, turn lanes, signalized pedestrian crossing and have considerable building setbacks. On-street parking is prohibited and pedestrian use is meant to be minimal.

force all trips to one point create a commercial circumstance that favors big box developments over other more neighborhood scale developments. When trips through a certain intersection reach a certain number of tens of thousands per day the major big box chains take an interest. Their store location formulas depend almost entirely on a combination of two factors: 1) the income range of families in the “service area’ as taken from the census data and, 2) the number of trips per day through the intersection adjacent to the site they are considering. [8] The service area calculation is based on the distance from the store customers might be drawn, based on a reasonable assumption of how long they might be willing to drive to get there (lets say twenty minutes). Obviously the more the public spends on a smooth flowing auto oriented infrastructure the longer is the radius line for the service area, the more the potential customer base, the bigger the store and parking lot should be! In this way it can be seen that ever greater expenditure on suburban road infrastructure leads logically to ever larger stores that capitalize on this public expenditure. As this process unfolds and other stores make similar decisions the gravitational forces these stores exert on the system lead inevitably to congestion, as whatever capacity the system provides is used up by the decisions of big box corporations. Interestingly, Home Depot Corporation has recently changed the way it calculates store locations and size, moving to a smaller stores more frequently located in the urban landscape. Why? Because increasing congestion in North American cities is shrinking the distance consumers can dependably drive in twenty minutes, and as it shrinks the Home Depot “big” box is shrinking as well.[9]

8. Hahn (2000) looked at two case studies of agglomerated big box retailer developments that were thought to be representative of the industry as a whole and found that in both cases the developer chose a location adjacent to a high traffic intersection and in an area where the average household income was above the national average.

9. ***My research indicates that this decision was more about exploiting untapped urban markets rather than in response to congestion – discuss with PC

Dendritic systems and gated communities

Whatever ones opinion of “gated communities”, they are highly compatible with dendtitic systems and generally incompatible with interconnected systems. Dendritic systems by their nature require developments to occur in pods with usually only one access point into surrounding collectors or arterial roads. Since these arterials are usually unattractive and pedestrian unfriendly “car sewers” (in the words of William Kunstler), there is no incentive to connect to them in ways that go beyond the necessary car link. In such an environment it is eminently logical for developers to mark the transition between the unattractive world of the arterial and what they intend as the much more attractive world of their development. The decorative and entry controlled gate is the typical response. This gate serves less to insure safety than to mark a congenial and attractive inside from the threatening and often very unpleasant exterior of the suburban arterial. Social critics often remark on the insularity

Figure X. Atlanta National Gated Community, Alpharetta, Atlanta, GA

10. Kunstler, J.H. 1993. The *Geography of Nowhere: The Rise and Decline of America's Man-Made* Landscape. New York: Simon & Schuster.

Kunstler, J.H. 2005. *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century*. New York: Atlantic Monthly Press.

Figure X. Seagate is the oldest gated community in New York and features an interconnected street network and relatively high density.

Figure X. It's easy to see why people living in the cul-de-sac development prefer it to the busy arterial environment created as a result of the dendritic street system.

Figure X. From the air one can easily see the difference between heavy traffic arterials and light traffic cul-de-sac

and inherent inequity of gated communities but seldom link their emergence with the dendritic street network which makes them inevitable.[10]

On the other hand, interconnected systems leave development increments that are usually too small for gated communities. Examples DO exist but tend to be of a small scale and therefore less appropriately subject to the criticisms leveled at typically much larger projects in suburban dendritic street systems.

But people like cul-de-sacs!

It is often said in defense of dendritic systems that people like the safety and the much reduced traffic flows in front of their houses on cul-de-sacs, and cite this as an overarching justification for the dendritic system we here discuss. While the evidence of that is not universal there is no doubt that many people do prefer the dead end street for these reasons. It is also understandable that given the hostile environment that characterizes the arterial and even collector streets in dendritic systems it is quite reasonable and rational to want to be as far upstream from these traffic impacts as possible. Unfortunately it is just not possible to design these urban landscapes such that everyone lives at the end of a cul de sac. An achievable number might be in the order of 25% of all people living on streets that serve fewer than 100 homes and their 12 trips per family a day by car (for a total of 1,200 cars past your window or one every 40 seconds). People living on other streets further down the system will be subjected to more and more trips. Thus those unfortunates who reside far downstream of the cul de sac will have to tolerate many more cars past *their* homes than would the average resident living within an interconnected street system. Thus the advantages of the cul-de-sac are paid for to the penny by residents less fortuitously situated, proving yet again that there is no such thing as a free lunch.

Why is the interconnected system better?

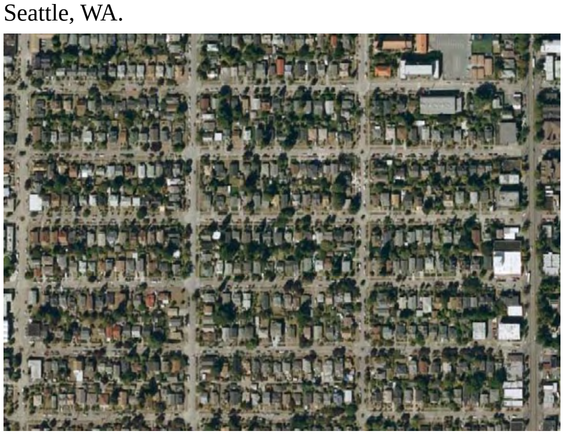
Interconnected street systems allow trips to be by the shortest possible rather than by an artificially lengthy and circuitous route. Five minute walking distances thus cover much more ground in interconnected street system contexts, easily as much or more than twice as many total acres, making it much easier to provide the services or recreational amenities they need inside this walking distance radius. If an intersection in an interconnected system is congested it allows for "rat running" through the parallel residential streets, obviating what would otherwise be the need for expensive intersection widening and associated expensive property takings. While residents don't like "rat running" it occurs only during times of peak congestion, can be slowed, and is much less damaging to neighborhood quality and much less expensive than prohibiting rat running while adding lanes to main intersections. Interconnected street systems are also safer for pedestrians. A landmark study by Peter Swift[11] determined that pedestrian injuries were four times more likely on wide suburban streets than on typically narrower urban streets (street width issues are discussed below). Finally, it must be admitted that arterials in interconnected systems must be designed for slower speeds than in dendritic contexts. This is because frequent intersections are an elemental feature of interconnected systems and the streetcar arterials that serve them. This frequency of intersections requires that the streets be designed for lower average speeds and that stops be more frequent. Thus under ordinary circumstances a suburban arterial will deliver drivers faster to their destinations than will a more traditional streetcar arterial street. This point is discussed further under the streetcar city rule below. Here suffice it to say that slower average speed in a system that resists congestion and is compatible with urban uses is probably a good thing, not bad. As mentioned above, the Home Depot decision to downsize their stores is instructive. As speeds are slowed in a system, the scale of enterprises scales down with it. If our objective is to reduce distances between desire points it would seem that a strategy which allows for smooth flow but not necessarily fast flow has a certain utility value.

11. Residential Street Typology and Injury Accident Frequency. Swift & Associates, Longmont, CO, Peter Swift, Swift and Associates, Longmont, CO., 1998.

Four types of interconnected street systems.

Not all interconnected streets systems are grid patterns. In addition to the grid there are at least three other identifiable and distinct but still interconnected systems: the radial system, the informal web, and the warped grid.

Figure X. These classic block sizes in Vancouver, BC are the same dimensions as the blocks shown below in Seattle, WA.



The Gridiron

As the name suggests the gridiron pattern is the highly uniform grid pattern of straight streets at ninety degree angles usually aligned with the cardinal axes. The pattern is most common in the US and Canada in cities laid out between 1850 and 1950. This block pattern is best understood as a finer grain subdivision of the larger agricultural 40 acre quarter section. Typically one 40 acre quarter section would be subdivided into two 640 foot segments in one direction and four 320 foot segments in the other, resulting in 8 blocks of 5 acres each. This pattern has two principal advantages over all others. It automatically aligns all intersections perfectly at even right angles and can be extended infinitely in all directions as the city grows. It is often criticized as dull but can be extremely dramatic in some circumstances. Manhattan and San Francisco are two good examples. It is also easy to get oriented in a grid system and provides vistas to distant parts of the city or region down the uninterrupted visual corridors of the street.

Figure X. Radial street layout in Washington, DC

The radial system

Washington DC is the best North American example of this pattern. It is a highly interconnected system but with streets that do not align with the cardinal axes. Rather in this system the major streets typically radiate from significant squares or public monuments. Orientation is not to the north south east or west but to key landmarks in the urban fabric. Blocks are not cut evenly from the fabric of 40 acre quarter quarter section in this pattern, but are nevertheless typically close in size to the 320 foot by 640 foot module of the gridiron. It is undoubtedly a dramatic pattern and can function as well as the gridiron. However, moving traffic and pedestrians through complex intersections where more than two main arterials intersect can be difficult.

Figure X. Informal web street layout in Cambridge, MA

The informal web

Boston and Cambridge Massachusetts are two characteristic North Amercian examples of this pattern. This pattern is the legacy of an early North American rural road pattern common prior to the Ordinance Survey method of subdividing the North American landscape. In the absence of the organizing grid of 40 acre squares, earlier Noth American cities organized themselves around a web of streets that connected key villages and crossroads, thus laying down the main bones of a web of major streets that connected locations via whatever angle happened to be required. The spaces between these major connections were eventually filled in with generally rectilinear blocks, again in the natural increment of between 250 and 350 in width and 400 and 700 feet in length. Navigation in such a system is not via the cardinal axes of from one monument to another, but, as in the case of Boston/Cambridge, from one city "square" (they are seldom square) to another: from Kendall Square to Inman Square to Harvard Square to Scolly Square etc.

The warped grid.

Grids don't need to be rectilinear and aligned with the cardinal axes to be grids. The grid can be twisted and warped so the streets curve, usually to match the contours of the landscape. When twisted and warped like this blocks will naturally vary

Figure X. Warped grid street layout in Riverside, IL

Figure X. This superblock in Hollywood, Florida is one square mile with only two entrances from the surrounding streets.

somewhat in size. Warped grids create more opportunities for dramatic landscape features than gridirons. This form is usually associated with the romantic period in North American city design with Frederick Law Olmsted as its most significant proponent. No complete North American city is designed this way unfortunately. However most cities have at least one district done in this style dating from the period between 1860 and 1930 when this style was popular. Riverside Illinois by Olmsted is the most famous of these.

Block size

The land left inside surrounding streets is called a block. Traditional cities have blocks of about 5 acres including street space and between 3 and 4 if one only counts the developable land outside of the right of way. Exceptions exist all over the place of course, notably Manhattan with its much smaller 200 foot wide by 500 foot long blocks of less than 3 acres each, and Portland with its extremely small but very walkable blocks of only 200 foot square, or just less than one acre each.

At the other end of the size spectrum is the suburban “super block”, a large block who’s attributes are a bit harder to describe and understand. Super blocks are always very large but frequently 40 acres (again, the legacy of the original subdivision of the North American landscape into one mile sections, half mile quarter sections, and quarter mile quarter quarter sections). Super blocks can even be as large as one square mile, the norm in Phoenix and much of Florida. Whether they are quarter mile or full mile or some size in between they are still defined as the land inside a surrounding road. Developable land inside such large blocks most often needs additional streets to access interior parcels, thus they are usually equipped with penetrating branching dead end road networks that could connect across the block but don’t. As discussed above, every parcel inside a super block typically has only one point of access to the surrounding street system. In the case of Phonix all of the streets on the one mile grid serve a variety of essentially gated complexes inside the one mile squares. The result is a city where the through streets on the one mile grid are all heavily loaded with traffic and generally incompatible with pedestrian friendly commercial uses. They simply accept too much traffic load from the interiors of the one mile superblocks they serve.

Plusses and minuses

Superblocks have the advantage of excluding through traffic across the block, provide more options for parcel configurations inside the block, and require less road length to serve parcels than gridirons. This is why they have been increasingly favored

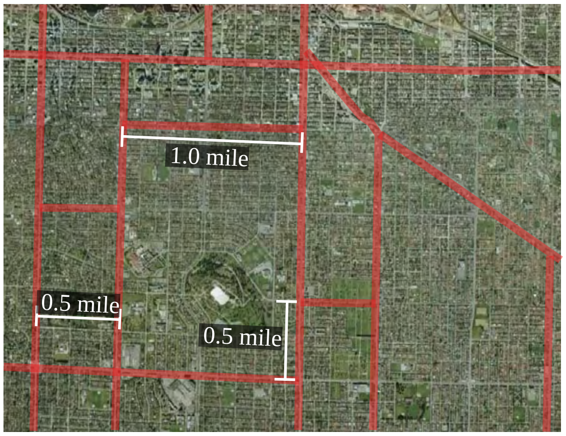


Figure X. “Streetcar” arterials in Vancouver, BC

On-Street Bike Route
Off-Street Bike Route
Local Streets
Future Bike Route

Figure X. The bike system in Vancouver, British Columbia

since 1950. On the other hand they prohibit through movements across the block and thus force traffic onto arterials and overload arterial intersections, prevent congestion flows from exercising any optional routes, make pedestrian trips frustratingly indirect, provide bicycles no option but to compete for road space on the arterials with cars and trucks, and degrade the value of parcels fronting arterials for pedestrian friendly commercial use consequent to the excessive through traffic usually found there.

Traditional smaller urban blocks are much more permeable for both car and pedestrian traffic and allow for more frequent “streetcar” arterials (Vancouver for example has a streetcar arterial every half mile on average, which means that you are never more than a five minute walk from a commercial “streetcar street”). The distribution of traffic and the more frequent provision of streetcar arterials within walking distance makes this form inherently more compatible with a strategy to promote transit, biking and walking. For example, bikers who are not enthusiastic about keeping pace with traffic on the arterials can take advantage of the parallel street network for a safer and slower ride without sacrificing directness. Vancouver has a very successful bike network of designated bike streets that typically run parallel to the streetcar arterials. On the other hand traditional blocks have the perceived disadvantage of allowing through traffic past all residential lots and require more road length on average to access and serve lots than in superblocks.
Also, fixed grids limit the ways that parcels can be configured much more than do
superblocks.

Which is better? If sustainable community design is the frame of reference when choosing between the superblock or the urban block option the choice is obvious. The imperative to provide options to the car provokes a clear choice for the smaller urban block.

Parcel Size

It may be obvious but bears emphasis. Block size determines the range of parcel sizes possible. In most North American cities this is so commonplace that it seldom gets mentioned. But it is remarkable that in cities like Seattle or Vancouver every single land use has somehow been fit into parcels inside traditional 640 x 320 foot blocks with lanes leaving development parcels that are, at the most after ROW and lane space are subtracted 550 x 120 feet or less than 3 acres in size. Thus 40 story towers and single family homes and everything in between have been fit onto the exact same block. So while block size will limit the

Figure X. Typical block structure in Kitsilano, Vancouver

Figure X. Typical block structure in downtown, Vancouver

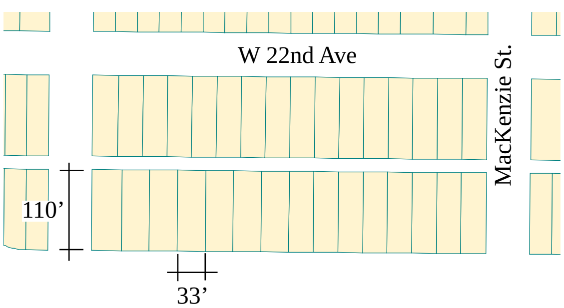


Figure X. This typical block in Vancouver yields 32 lots with the standard size of 33’x110’
Source: VanMap

12. This study is available online at: http://www.jtc.sala.ubc.ca/projects/ADS/HTML_Files/ChapterTwo/matrix_us_2.htm

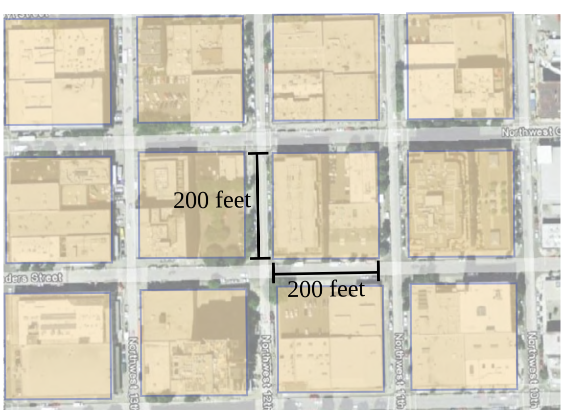


Figure X. Portland, OR is known for it’s 200’ x 200’ block size

range of parcel sizes and types it is astonishing to see how many different ways they have been designed and utilized.

Single family home parcels

The most pressing issue in sustainable urban design is probably the single family home parcel. This parcel type has been the driver for many if not most of the symptoms of illness described in chapter one. Some have argued that the single family home is anathema to sustainability and should be eliminated entirely. Yet the market for single family homes remains very strong and it is unlikely that this will shift dramatically barring precipitous economic crisis in North America. Fortunately there are ways to configure the single family parcel that is compatible with sustainable community design and that is the small lot. Traditional streetcar cities were largely organized around the single family home lot. Most parcels in Vancouver are single family home lots in neighborhoods that are pedestrian friendly and where options to the car exist. The secret is the 3,500 sq ft. lot with a 33 ft. frontage. Virtually all lots in Vancouver are 33x110’. At this size the lot yield is about 32 lots per block. At this size the gross density of the block would be approximately 6 to 7 parcels per acre. Since duplexes and secondary suites are allowed throughout the city, the gross density in dwelling units vs. parcels is over 10. Our analysis of two traditional Vancouver blocks, blocks that appeared to be all single family homes, actually had a density of over17 units per acre.[12] The secret was that most of the homes actually had a hidden secondary suite and some of the homes contained three units. By using small lots for detached homes it is easily possible to preserve the single family home option, and certainly the single family home “feel” of the street, and still create sustainable communities. Single family home lots can be as small as 2,500 sq ft if the footprint of the new home is small and the home is high rather than wide or deep. This issue is discussed further below under the “different dwelling types on the same street” principle.

Ideal block and parcel size

Various arguments have been forwarded favouring the small “Portland Block” for its abundance of corner opportunities and its walkability. The longer “Manhattan Block” has been promoted for similar reasons. However, those two blocks have very shallow parcels, never deeper than 80 feet, tightly constraining the building form options available and making it impossible to provide lanes in the middle of the block for service and secondary access. For this reason Portland residential neighbourhoods are afflicted with driveways that cross sidewalks every house lot, compromising the safety and

Figure X. Manhattan blocks are 4 times as long as blocks in Portland


Figure X. The smaller block size in Portland, OR favours single building blocks


Figure X. The larger block size in Vancouver, BC allows for more diverse design solutions

comfort of the sidewalk and eliminating at least a third of on street parking spots. In downtown Portland, lacking lanes, all loading and delivery must compete for space with pedestrians on the sidewalks. The same is true in Manhattan. Conversely, in Vancouver and Seattle, where blocks are the more common 640 x 320 foot increment, parcels can be over 110 feet deep, even after subtracting 20 feet for the rear lane. These somewhat larger blocks have provided suitable footprints for the proliferation of new condominium high rise buildings for which Vancouver is now famous. Ideally these towers should be between 60 and 80 feet square. Any smaller and they are diseconomic, any larger and they are too fat to get natural light into the core of the building (not to mention ugly). The point tower on the podium base pioneered in Vancouver would not have been possible on a smaller block, or larger blocks for that matter. Indeed, in Portland where new tower developments are now coming on line, the smaller block is creating a trend toward single building blocks, were a whole block is occupied by one podium building of about 150 feet on a side and a usually somewhat fat tower in the middle of the base. While some good results are possible with this form it tends to predetermine design outcomes more decisively than the larger Vancouver block and would in time lead to a city of single buildings surrounded by a square of streets; probably not a good thing.

In residential areas, the larger Vancouver block allows for a rear lane to keep driveways from crossing sidewalks and allowing the front façade to be free of garage doors. Narrow lot homes have many advantages but most of them are compromised if half or more of the frontage is given over to garage doors. The phenomenon of the “snout house,” a house that is all garage and no façade to the street, is common in California for this reason, where small lots are popular but rear lanes are not.


Figure X. A snout house is characterized by a protruding garage that takes up most of the street frontage, squeezing out front yards and making it hard to find the front door. Source: Dolores Hayden’s “A Field Guide to Sprawl” / Photograph by Jim Wark


Figure X. Cleveland: 24’ curb to curb width


Figure X. Nashville: 24’ curb to curb width


Figure X. Seattle: 24.5’ curb to curb width


Figure X. Vancouver: 26’ curb to curb width

Finally, the deeper lot allows many creative options for the site, including front to back duplexes and lane houses, and/or generous rear yard gardens. Finally, why not bigger than this? If blocks were 400 feet wide rather than 320 feet you gain rear yard space but lose yield. While possible to use the deeper lots in a way that achieves a threshold density of 10 dwelling units per acre, it is not easy. Too many of the units end up away from the street in back yard conditions. The other option is to narrow the lots thinner than 33 feet to gain back this yield and keep the units on the street. But when accounting for necessary side yard setbacks of at least 4 feet on each side (for access and fire) the 33 foot lot only has 25 feet to work with. Dropping the lot much below 33 feet means buildings quickly become too thin to create efficient floor plans.

This complaint does not account for block length however. Why not longer than 640 or shorter for that matter? Here there is more flexibility. The breaking of the quarter mile into two even increments makes a certain intuitive sense and has proven itself to be walkable in many North American settings, but it is by no means a universal increment. One can reduce the length down to 400 without tremendous loss in land use efficiency or up to 800 before the blocks become a very serious barrier to easy pedestrian movement or starts to compromise the overall permeability of the system.

Road Width

Now for the nub of the matter, road width. Prior to 1940 most residential streets in North America were less than 28 feet measured curb face to curb face. Most of these streets allowed parking on both sides of the street in seven foot wide parking lanes. This left only 14 feet of travel lane in the middle to handle two way traffic. The typical car is about six feet wide, so two cars approaching from opposite directions are going to have to go damned slow if cars are parked on both sides of the street to avoid hitting each other. This presumably unsafe condition motivated a change in standards after 1950 typical curb to curb width became 34 feet, comprised of two 10 foot travel lanes flanked by two seven foot wide parking lanes. This width allowed free flow of two way traffic without the need to slow down when cars approached from opposite directions. As time passed, many municipalities decided it would be a good idea to widen residential streets even more, allowing additional space for parking and travel ways such that 40 foot wide suburban residential streets are found in many parts of North America.

There have been a number of unanticipated negative consequences associated with this trend. Most surprising is that streets that were made wider to be safer turned out to be much more dangerous. A study by Peter Swift associates, *Residential Street Typology and Injury Accident Frequency,* found that wide suburban residential streets were associated with four times more pedestrian deaths per unit population than were narrower traditional urban streets. How can this be explained? The answer appears to be induced speed. Pedestrians hit by cars traveling 35 miles per hour are ten times more likely to be killed than pedestrians hit by cars traveling 20 miles per hour. Wider suburban streets designed to allow two free flowing two way traffic and generous parking strips signal drivers that it is ok to travel at speeds much higher than narrower traditional streets.[13] This phenomenon is even more extreme when one considers that the parking strips on most suburban streets are rarely used since these landscapes also include generous driveway space. Thus drivers are provided with as much as 40 feet of clear width to command when driving. Even when these streets are posted with 20 mph speed limits, as they often are, it takes a tremendous act of will to slow to that apparent crawl when the freeway scale generosity of the road width invites speeds twice that fast.

It took decades for the engineering community to begin to come to grips with this phenomenon and to coin a term to describe it.[14] The term is "side friction". Traditional urban streets have "high side friction" because the travel way is too narrow for passing oncoming cars at speed, the abundance of parked cars on both sides, the trees in the boulevard, the pedestrians on the sidewalks that one may or may not be able to see behind the cars and trees, all of these things conspire to create an atmosphere of uncertainty and caution in the mind of the driver. Thus the driver responds by driving slow, no matter what the posted speed.

Alternatively, wider suburban streets have "low side friction." There the travel way is generous enough to pass oncoming cars at speed, parked cars are rare providing an even greater enticement to move quickly, and nothing is hidden from the drivers field of view by trees etc. – all of these things conspire to psychologically license the driver to feel safe at speeds much higher than those posted. Increased pedestrian fatality is the result.

Fire access

But pedestrian and auto safety was not the only motivation for wider streets. Fire access was a powerful motivation as well. The average size of North American fire equipment has been steadily increasing. It is common for ladder trucks to require 15

13. Peter Swift, Residential Street Typology and Injury Accident Frequency (Longmont, CO: Swift and Associates, 1998).

14. The first mention of the term "side friction" seems to be in 1936 in a paper for the Highway Research Board (Barnett et al. 1936). Sources in the 1940s and 1950s continue to use it within a highway context (Barnett 1940; Holmes 1958) however, understanding how the concept applied to residential streets took far longer.

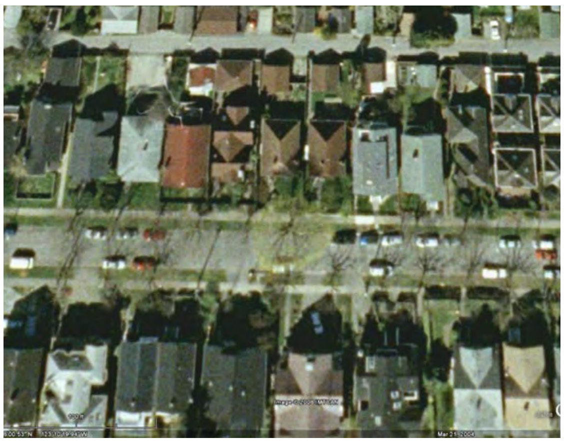


Figure X. Narrow, "queuing" streets create conditions with high side friction (top) as compared to a suburban street with low side friction (bottom).

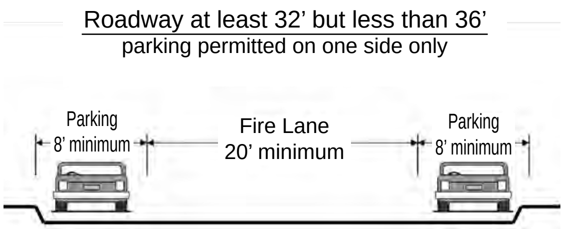


Figure X. A typical Emergency Access standard with 36' (11 m) curb to curb width (source: Ontario Fire Department, California)

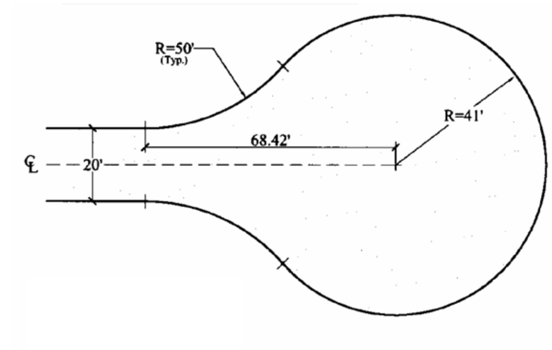


Figure X. A typical Emergency Access standard for cul-de-sacs takes up approximately an 1/6 of an acre (source: San Joaquin County , California)

15. Dedman (2005) writes in an article for the Boston Globe, "Few communities in Massachusetts are adding firehouses to serve new subdivisions" resulting in slower response times, which frequently result in deaths. Communities of all income levels are facing these problems."

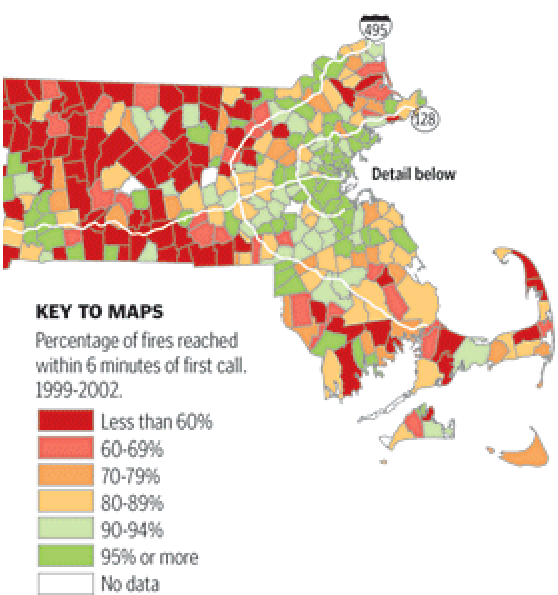
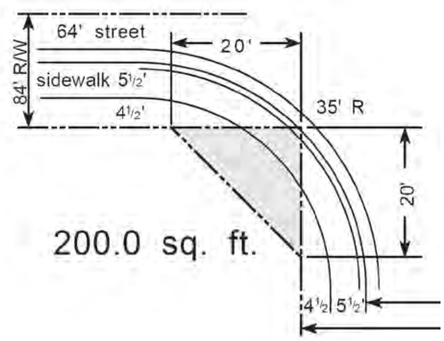
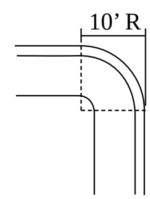


Figure X. Shows the emergency response times in the Boston Metropolitan area.
Source: Boston Globe analysis of National Fire Incident Reporting System data
Graphic: GLOBE STAFF/ David Butler, Bill Dedman

or even 20 feet of street width to set up stabilizer arms extending from the sides of trucks. Concerns about the need to speed to the scene of a fire can lead to demand for 13 foot wide travel lanes in both directions on even short cul-de-sac roads that serve only 20 to 30 homes. A similar concern about cornering at speed can lead to standards for corner curb radii so generous as to seriously lengthen pedestrian crossing distances at intersections and thus compromise their safety.



A typical arterial curb radius in a hierarchical street network is 35'



A typical neotraditional curb radius is 10'

Ironically but sadly predictably the increase in these standards has not led to enhanced safety. The same Peter Swift study found no difference in fire related fatalities when comparing districts with narrow streets to those with wider ones. More depressing still were the results of a study on fire response times in the Boston Metropolitan area. In this study it was found that response times became higher as one moved away from the urban core, in exactly those same suburban communities where wider streets were required. It seemed that whatever the benefit of wider streets for fire safety, it was far outweighed by the difficulty of getting quickly and directly to the fire via circuitous dendritic road systems, and the impossibility of funding enough fire stations within a short distance of all homes in communities with very low density sprawling residential development.[15]
In other words, in urban areas a service area for a fire station serving 20,000 people might be one square mile. In suburban areas the same population might be spread out over twenty times more land, and thus the fire station serving the area would on average be many times further away from homes. This of course suggests a larger contributing symptom to the disease of our unsustainable metropolitan areas. Fire officials, like other officials, are only allowed to comment very narrowly when projects are considered. Fire officials are typically called upon only to speak to issues road width and design, and seldom if ever on larger issues of density and interconnectivity – issues which seem more significant when the evidence is examined.

Figure X. An example of a queuing street with on-street parking and a narrow through lane

16. Looking at neighbourhoods of varying age in five study areas (Maricopa County, Arizona; Orange County, Florida; Minneapolis-St. Paul, Minnesota; Montgomery County, Maryland; and Portland, Oregon), Knapp et al. 2004 found that lot sizes rose between 1940 and 1970 and then fell continuously, reaching an all time low in 2000. Hubble (2003) found similar trends in Las Vegas where the average lot size for a new home fell 500 square feet in the last two years. In 2001 only 13% of new residential lots were smaller than 4,000 square feet, however, in 2003 this number had doubled to 26% (Hubble, 2003). According to the US Census Bureau's American Housing Survey the median lot size fell 26% between 1995 and 2001(US Census Bureau).

Figure X. The aerial photograph taken in Surrey, BC shows shallow lots with large frontages dominated by driveways

Figure X. The aerial photograph taken in Kitsilano shows deep, narrow lots with lane access

Queuing streets

Thus it seems that the traditional 26’ to 28’ street in an interconnected system was better after all. This kind of street is now called a queuing street, a somewhat misleading name that tries to signify the “taking turns” way that one or the other approaching car will typically pull over into an empty parking space to allow a more generous space for the other to pass. This natural street calming strategy, coupled with short blocks and frequent stop signs, is a more effective traffic calming strategy than speed bumps. It saves pavement, and makes for a much more attractively scaled pedestrian friendly streetscape. A recommended ROW for a sustainable queing street, capable of handling a large number of car trips but at speeds compatible with pedestrian and bike safety is as follows: 6’ sidewalk, 10’ tree boulevard, 7’ parking, 14’ travel way, 7’ parking, 10’ tree boulevard, 6’ sidewalk. All of this fits within 60’, which happens to be the most common ROW width found in streetcar city residential districts. Some narrowing can occur in the tree boulevard and sidewalk but it is not recommended. Developers will justifiably be anxious to reduce total width as this extracts from developable salable lands. But these pedestrian support and ecological elements are as important as the travel way for reasons discussed below under infrastructure.

Lanes and Alleys.

Most North American cities built primarily between 1850 and 1950 have blocks equipped with rear lanes or alleys (I will use the single term rear lanes or lanes to refer to these). After 1950 when lot frontages increased from 33’ to 50 or more feet they were no longer needed. There was plenty of space out front to get the car in and still have a space for the house façade. There were other reasons too. Lanes were considered unfashionable to buyers and developers were understandably unwilling to pay money to provide two public access ways, the street and the lane, to every parcel. This logic prevailed until recently. The average house lot size in typical middle class subdivions had been steadily shrinking back toward the original standard 3,300 square foot lot.[16] The lane makes sense again. When lots get this small there are only two choices. They can be configured wide and shallow with frontages over 45 feet but depths of only 73 feet. This leaves room on the façade for the one or two car garage but precious little for the back yard, putting rear windows of houses within 40 feet of each other. The other problem is that driveway curb cuts will occur every 40 feet and be about 20 feet wide meaning 50 percent of the front yard space will be driveway, that driveways will cross sidewalks half the time, and that half of the on street parking spaces will be lost to curb cuts.

The other option is the narrow deep lot with a lane. A 33 foot 3,300 sq. foot lot is 100 feet deep. This lot requires a lane to avoid the “snout house” effect, where streets are all garage doors and no facades. Installing the lane steals 20’ from the mid block of course; but it eliminates the need for driveways of any kind and therefore does not add to the total amount of pavement required per block, however it adds to the *developer’s* costs. Typically street infrastructure is installed by the “horizontal” developer who buys the land, subdivides it, and sells off lots to the “vertical” developer or the house builder. If lanes are installed they are a cost to the horizontal developer. If not the cost of the necessary driveways is off-loaded to the vertical developer.

It is very difficult to work through the geometric and cost and amenity trade-offs associated with lanes for these and other reasons. Fear of crime is often cited as a reason to avoid lanes, even though we find no correlation between crime rates in lane served areas of Vancouver and those without. Municipalities are often adverse to lanes, feeling that it is hard enough to take care of streets without the added responsibility of publicly owned lanes. For this reason many developers who see the attraction of lanes but have fought a losing battle with municipalities will throw up their hands and privatize the lanes, and even all the streets, managing them through a neighborhood association. The neighborhood association has neighborhood wide taxing authority (in the form of required association fees enforceable via liens on property) and responsibility for maintenance of all common infrastructure. The general trend, particularly strong in the US, towards tax cutting measures in cities, has forced municipalities to off-load as many costs as possible. Typically any digression from standard street designs will trigger an opportunity for municipalities to suggest developers privatize streets, shifting responsibility to the homeowners in the development for their perpetual maintenance. Whether the privatization of urban public realm infrastructure is a good or bad thing is debatable (the author believes it is anti democratic), that debate lies beyond the scope of this book. The important point here is that any discussion of lanes in municipalities that don’t presently allow them is likely to trigger a move to privatize the system, and that citizens and devloepers should be prepared for this. It constitutes a huge disincentive to more healthy urban infrastructure and is yet another in an all too lengthy list of cultural impediments to healthy change.

The corner

Like all elements of street design, intersection design is far more complex and contentious than one at first imagines possible. But to radically oversimplify, the challenge is to reconcile the issue of moving large vehicles around corners with the need to safely and comfortably get pedestrians across them. The two are in conflict. Fire safety and school bus vehicles, the vehicles that will most often be invoked when setting performance standards for turning motions, have long wheel bases and thus corner more easily when there is a wide radius curve to navigate round. But wide radius curves at corners shave off sidewalks right where you need them most, where people need to stand and look before crossing. Most jurisdictions apply minimum standards for turning radius based on the needs of fire trucks and school busses rather than the needs of pedestrians. As with any other standard, turning radius requirements are seldom absolute, even though they are often presented as if they had legal standing. Municipalities are free to set their own standards even if they digress from practices adopted by the majority of other municipalities if they have a reasonable rationale and their decision has been exercised in an atmosphere of due diligence.[17]

17. Local levels of government generally have a great deal of input when it comes to the adoption and implementation of design standards. In Oregon for example, land use laws allow local governments to establish local subdivision standards for street widths that shall "supercede and prevail over any specifications and standards for roads and streets set forth in a uniform fire code adopted by the State Fire Marshall, a municipal fire department or a country firefighting agency" (Neighbourhood Streets Project Stakeholders 2000). Organizations like West Coast Environmental Law advocate and empower local governmental agencies to adapt their standards and guidelines to be more in line with social and environmental perspectives (West Coast Environmental Law 2002.

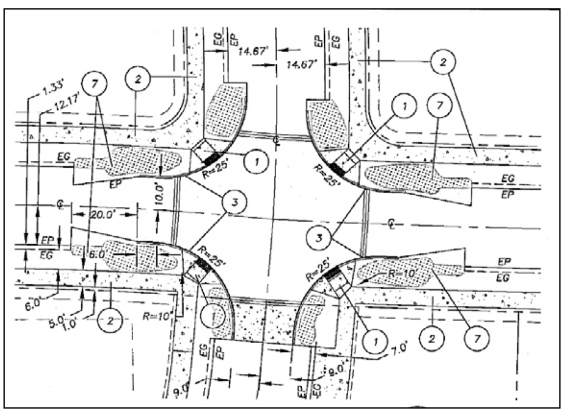


Figure X. Engineering drawing from Pringle Creek development showing "neck downs" (copyright WH Pacific Inc.)

One very effective way to satisfy both the fire truck turning demand with the pedestrian safety demand is by using "neck downs". Since cars are always prohibited from parking near intersections this space can be given over to sidewalk and boulevard uses. Curbs are extended further towards the center line of streets eliminating the parking bays and allowing for 20' curb face to curb face distance used exclusively as two way travel lane. Changing to a two way travel lane from the 14 foot queuing street is required to allow space for turning or approaching cars to easily fit next to a car that may be waiting at the stop sign. Thus the recommended cross section at the neck down would be 6' sidewalk, 14' boulevard, 20' travel way, 14' boulevard, 6' sidewalk for a total of 60'. The much wider boulevard provides a more generous area to shave back with the radius curve that might be required by fire trucks or school buses. It also pushes the pedestrian safety zone further out to the center line of the street and shrinks the crossing distance to a mere 20'. Streets with neckdowns cost more than streets without them unfortunately. Additional cost is for the extra curb if supplied and the frequent need to double up on storm drain inlets. If neckdowns are absent, proponents of sustainable design should be sure that engineers remember the existence of the parking lane and that measurement of the radius curve is not from the edge of the curb but from the edge of the travel lane. Figure X to the left provides one common configuration for a residential street with neckdowns in place with a radius that has been tested against the longest school bus wheelbase known to man. Of course School buses are both a symptom of the problem (no one walks to school) and a geometric demand that makes it worse (everything must be designed to conform to their monstrous proportions). But here suffice it to say that the school bus issue is just one more example of how intricately nested are all of the elements that conspire to make our new communities unhealthy, and terrifically resistant to change.

Conclusion

It's a simple idea and easy to grasp. Interconnected streets good, dendritic streets bad. What gets complicated is unpacking all the unhealthy habits that conspire to block a logical return to interconnected worlds and neighborhood health. The interconnected street system is the very armature of a healthy urban landscape. Preserving interconnectivity in areas where it exists and finding ways to build it into areas where it has been frustrated should always be part of the therapy. In already built up suburban areas where the network of disconnection is firmly entrenched, this can seem impossible. There the best and in some cases only opportunity for new connectivity is in shopping center redevelopment; but the importance of this one move should not be discounted. Urbanizing these important social and commercial destinations can go a long way to restoring health. Lifestyle malls where people can walk have become tremendously popular, precisely because people are starved for walking opportunities in these auto dominated worlds. In new suburban developments of 40 acres interconnectivity should be a first principle, even if this results in a small island of connectivity in a sea of dendritic pod development. Many New Urbanist projects hold firm to this principle even though the value of internal connectivity is limited in such a context, and good on them.

Working at the policy end is more effective. Portland Metro Planning Council is working hard to impose an interconnectivity standard requiring a through street at least every 600 feet.
The brilliance of this standard is its simplicity. It represents a measured and reasonable requirement from the public sector, insuring the public good is represented while not unduly proscribing the actions of the development community. It would lead inevitably to some set of patterns that would emulate the function of the traditional North American 640 x 320 foot block (a 640 foot minimum would have been a bit better given the sectioning of that landscape; but that's a detail). Finally it creates a policy framework where individual projects with interconnected internal systems can be integrated into an interconnected whole.

Chapter Four: Five minute walking distance to commercial services and frequent transit.

The walk to the store

North Americans will walk only if it's easier than driving. The break point for walking trips seems to be the five minute walk,[1] which is approximately one quarter mile or 400 meters. Most people think that walking five minutes is easier then firing up the car, pulling it out of a parking space, negotiating streets, finding a place to park, and exit. Humans are incredibly sensitive to the minor benefits and costs of choosing one mode over the other, no matter how short the trip. Naturally some people will choose to make longer walks, while others will opt for the car even if the walk is ridiculously short, but the average is five minutes. Certainly people in other cultures where they do not have ready access to the car will make longer walk trips. They have no choice. But in our culture five minutes is about the maximum we can expect, no matter how much we wish it otherwise.

But the five minute rule is meaningless if there is no place to walk to. Many projects build in nature and walking trails as a means to provide walking destinations, but while these trails may be used every day by people who are in the habit of walking and jogging for exercise, the average person will use them much less regularly. For the average person the most compelling destination for regular walking is to the corner store. If a convenience store is located less than a five minute walk from home the average person will walk there many times a week to pick up bread, eggs, milk, newspapers and, dare we say, cigarettes and lottery tickets as well. In suburban sprawl locations, the five minute rule holds, but in a very different way. There you will usually find "gas and go" stores distributed evenly throughout the suburban matrix, but at five minute *drive* distance; these stores are usually inaccessible by foot, further exacerbating auto dependence in these landscapes.

If the basic corner store is joined by video rentals, bakeries, taverns and cafes then all the better. It is that much more likely that walking will be a daily part of life for nearby residents. If conditions are perfect and these stores are joined by coffee shops, hairdressers, hardware stores, used book stores, fruit and vegetable stands, pizza shops, accountants, dentists, and the local Subway sandwich shop. When commercial areas reach the point at which most of your daily commercial needs can be met within walking distance, not only do you walk more but you use

1. A pedestrian shed, or catchment area, is determined by the distance most people will typically be willing to walk and is generally defined as a five minute walk to the centre of each neighbourhood, creating a unit of approximately ¼ mile (Watson et al. 2003). Studies at the Port of New York Authority bus terminal found that a 5-7 minute walk is typically the maximum amount people will walk although this varies somewhat depending on the trip purpose, walking environment and available time (Watson et al. 2003).

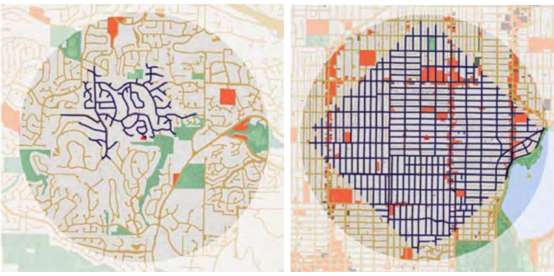


Figure X. The shaded circles above indicate a 10 minute walking radius as the crow flies. The blue lines indicate a 10 minute walking radius that follows the street network. As you can see the area that can be reached within a 10 minute walk in a dendritic street netowrk is substantially smaller than what can be accessed in the same amount of time in an interconnected street network.

The corner store below is located within a five minute walk of residences in a more densely populated neighbourhod. The gas station on the other hand is located within a five minute drive in a low density subdivision.

Figure X. Corner store

Figure X. Gas station

the car significantly less. Residents of Vancouver, where most residents can satisfy their daily commercial needs on nearby streetcar arterials, use their car s 30% less than do residents of South Surrey/Langley, BC, a newer car oriented community. Residents of Vancouver also own fewer cars, 1.25 per family compared to1.7 per family in Surrey. B.C.[2] Access to commercial services and frequent transit seems to explain these differences, as average family income in the two communities is nearly the same.

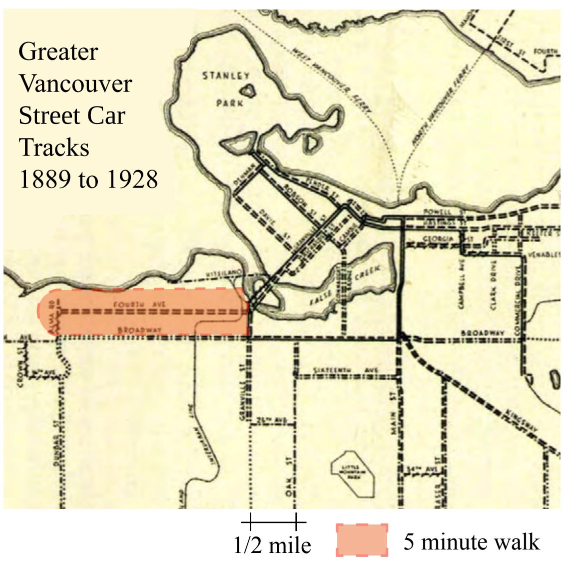
Among sustainable community advocates the five minute walk rule has become axiomatic. However, it is usually imagined and applied as a walking distance radius or circle surrounding some fixed commercial point. This is indeed the way it works if there is only a small commercial node with one or two stores, but in Vancouver and other Streetcar Cities the situation is different. In vibrant Streetcar Cities, commercial activates spread along the streetcar arterial until in many cases they form a continuous frontage of commercial establishments many miles long. When this occurs the five minute walk is no longer a circle but rather a continuous band that extends ¼ mile perpendicular in both directions to the streetcar arterial. The basic pattern for Streetcar Cities is a grid of streetcar arterials spaced at half mile intervals.[3] This means that everyone will be within a five minute or quarter mile walk of some streetcar arterial, and often able to choose between two. These long linear commercial corridors comprise the bulk of public realm spaces in streetcar cities. This linear public realm, so characteristic of most North American cities, has implications for our understanding of their qualitative aspects – their “sense of place”.

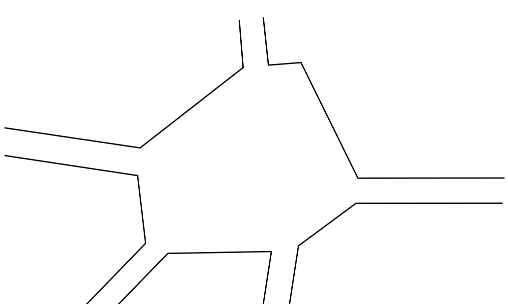
Sense of place in corridors

It is not unkind to say that North American planners and urban designers have been very focused on identifying places worthy of preserving, and in fostering new places worthy of caring about. Naturally they identify a location here and a location there for their attention, and apply the best teachings of Kevin Lynch and any of a number of other planning theorists to these crucial locations. It seems likely that their training and good intentions have made it difficult to cherish the seemingly undifferentiated linear corridors that are such a humble and ubiquitous datum for our experiences in most gridded cities. It may be that this inattention to the meaning and value of the corridor came from the careful study of older European and east cost cities whose web of streets usually focused on key “five corner” intersections or squares as in Kevin Lynch’s Boston.[4] Whatever the motivation, it is indeed surprising how little attention has been

2. According to Metro Vancouver’s Livable region Strategic Plan 2000 Report, 22% of households in Vancouver don’t own a car and only 26% have two or more cars while in Surrey and Delta only 5% of households don’t have a car and 52% have two or more. In January 2000 there were 1,172,866 vehicles licensed in the GVRD and an overall rate of car ownership of 1.5 cars per household across the entire region (Metro Vancouver 2000). Between 1995 and 2005 the rate of vehicle ownership per household in the GVRD has remained relatively stable at 1.5 however there is significant variation within the region (BC Stats; ICBC). The Burrard Peninsula (including the Cities of Vancouver, Burnaby, New Westminister, Port Moody, Coquitlam, and Port Coquitlam) has maintained a lower rate of vehicle ownership per household at approximately 1.25 while the rest of the GVRD, including the Cities of Abbotsford, Delta, Langley, North Vancouver, Pitt Meadows, Richmond, Surrey and White Rock, fluctuates around 1.7 vehicles per household (BC Stats; ICBC). South Surrey/Langley residents took about the same number of trips as residents in Vancouver but 88% were by automobile (Canadian Facts 2000a) as opposed to 58% in Vancouver (Canadian Facts 2000b).

3. Figure X. below shows the historic grid of streetcar arterials in Vancouver, BC distributed in regular intervals. A five minute walking distance is indicated along 4^{th} Avenue in Kitsilano. As you can see the majority of the Vancouver is within a 5 minute walk of a historic streetcar arterial.





4. “Five corner” intersection: Lynch, K. (1960) “The Image of the City” MIT Press.

The images below show the experiential diversity along the Fourth Avenue in Vancouver.

4th Ave @ Bayswater St.


4th Ave @ Balaclava St.


4th Ave @ Trutch St.


4th Ave @ Blenheim St.


4th Ave @ Waterloo St.


4th Ave @ Collingwood St.


4th Ave @ Dunbar St.


4th Ave @ Alma St.

5. See: Norberg-Schulz, Christian. 1980. *Genius Loci, Towards a Phenomenology of Architecture* Rizzoli, New York and Alexander, Christopher. 1977. *A Pattern Language: Towns, Buildings, Construction* Oxford University Press, USA.

paid to this especially North American urban form: the linear commercial corridor or the streetcar arterial. If one accepts the proposition that suburban auto oriented areas are virtually devoid of public realm space, then streetcar streets were and still are the most commonly experienced and widely distributed urban public realm space in North America.

What appears to outsiders to be miles of undifferentiated shops appears quite different to those who use these corridors every day. Local users do not experience the relentless miles of the corridor but rather the transition from their residential block to the more active arterial. Along the way they might pass the community school, a number of gardens, some townhouses on the block closer to the corridor, and then the streetcar arterial itself. Once at the arterial they turn either 90 degrees right or 90 degrees left to take advantage of services on the two or three blocks in either direction. Thus their sense of the place is determined by their walk to the arterial and their eventual familiarity with the blocks immediately in either direction. People who live two or three blocks away in one or the other direction will have a similar and overlapping, but not identical experiences. Some of the shops they use will be the same, others different. Some of the people they encounter frequently will be the same, others different. In this way corridors are quite unique and different than centers. They allow for shared and similar experiences but experiences that gradually change depending on where you reside along the corridor. Vibrant streetcar streets are experientially very rich, with busses or streetcars arriving and departing every few minutes, familiar shopkeepers sweeping sidewalks, denizens of ethnic social clubs arguing on sidewalks, school kids duck walking to the local library branch, and teens showing off to the opposite sex. They offer a unique dialectic between of the freedom of action allowed by the apparently infinite length of the corridor and the proxemic familiarity that characterizes the best of village environments. More can and should be said about these undervalued and academically overlooked spaces, but for our purposes it is only necessary to establish an argument in support of their experiential quality, as the Streetcar City principle must work in both practical and experiential terms to be of value. This discussion of the experiential value of the corridor is not intended to supplant the articulate explorations of the sense of place attributable to urban *centers*, just to give *corridors* equal standing. Rather than repeat all the eloquent arguments of Norberg-Schulz, Christopher Alexander and others, [5] they are simply included by reference and accepted as equally valid.

Transit

Transit has a synergistic relationship with walking distance commercial. If the solitary corner store has a bus stop outside, both the store and the transit service are enhanced. The store is enhanced when bus riders pop in to buy a newspaper before jumping on the bus. The transit service is enhanced because riders can now use the trip to the bus to do more than one thing – ride to work and pick up the paper, ride back from work and pick up milk – making the bus that much more attractive. The more commercial functions at the stop the better, as this makes it more even more possible to "trip chain," meaning performing more than one errand on the same trip.

On streetcar arterials trip chaining is even easier. Riders can hop off the bus or streetcar to stop at the pharmacy, the toy store, the radio shack, or the wine shop, then hop back on to continue their trip home. In this way, stores located along highly functional streetcar corridors gain customers from both the pedestrian walking and transit users passing on the corridor.

Bus or Streetcar Headways

For many transit authorities the seven minute headway is the Holy Grail. At headways of seven minutes or less, meaning a bus or streetcar stopping at a stop every seven minutes or less, users no longer need to consult schedules. They know that their wait will be four minutes on average, sometimes less sometimes more, but never more than seven minutes. These waits are insignificant in the minds of most riders, making it that much more likely they will use transit.

In suburban areas of Vancouver the transit authority has successfully provided bus service within a five minute walk of almost all homes (thanks to the legacy of the agricultural grid and its quarter section roads on the half mile interval). Thus the five minute access to transit is accomplished, but unfortunately not the seven minute headways. In auto oriented areas of the region transit ridership captures only a few percent of all trips. Most destinations require one or two transfers, thus taking many times longer than car trips, while destinations such as shopping malls are notoriously unfriendly for transit customers on arrival. With so many disincentives for transit built into the suburban dendritic street system it is no surprise there are so few customers. With so few customers to serve, transit officials are hard pressed to provide buses more frequently than every half hour, with buses only every hour common on many routes. At these headways users must organize their whole day around the schedule of the bus, not just on their departure trip but also on the return. Long headways combined with long multi seat trips and pedestrian unfriendly destinations make it unlikely that anyone with a car will choose transit, and they don't. The large majority of transit users in most suburban areas are the infirm, the young, and those too poor to own a car.[6]

Conversely in Streetcar Cities this kind of entropy toward failure is reversed. Features of the landscape conspire to re-enforce pedestrian and transit use, making it more and more likely that residents will choose transit for its convenience and economy resulting in a more efficient transit system, more revenue for the transit agency, and a compelling justification to reduce headways on the corridor even more. But the key factor in this success, one that we have yet to address, is density.

Residential Density

It is now accepted that the higher the density in a service area the more likely it is that residents will use transit. Evidence for this comes from analysis of real places. Almost everyone in high density Manhattan uses transit, almost no-one in low density sprawling Phoenix does.[7] In places in between like Vancouver and Portland, places that include high density areas and low density areas you get a mix. Thus there seems to be a direct correlation between density and transit use. More subtle causations like the role of interconnected street networks in enhancing access to transit, the even distribution of commercial services along streetcar arterials as discussed above, and the overall pattern of origin and destination obviously play a role but have proven more difficult for scholars to definitely link to ridership.

Nevertheless it can safely be said that a threshold density for a viable transit system, meaning one offers real options rather than simply being transportation of last resort, is ten dwelling units per gross acre (gross acre meaning calculation for density is inclusive of street right of way).[8] If the average density of a very large area, say greater than 10,000 acres or 15 square miles, is 10 dwelling units per acre or more, and if this area is balanced with one job per household, and if there are convenient transit connections to the larger metropolitan region, and if a full range of commercial services available in the district, then transit may be able to provide an option to the car. That's a lot of ifs. Fortunately many Streetcar City areas already meet these criteria and suburban areas, as they mature, are increasingly approaching those thresholds as well. Most North American suburbs start out with average densities of between 1 and 4 dwelling units per acre

6. In the United States there are two major groups of transit riders: downtown commuters and those who are too young, too old, too poor or physically unable to drive (Garrett & Taylor 1999; Wach 1989)

Figure X. Lonely bus stop

7. Based on data from the 2000 census, the commuter public transit rate for Manhattan, New York for workers over 16 years of age was 59.6 percent while in Phoenix this number was only 3.3 percent (US Census Bureau 2000).

8. According to Pushkarev and Zupan (1977) demand densities for minimum bus service of half mile parallel route spacing and hourly bus service can be attained at 4.5 dwelling units per acre. At 7 dwelling units per acre this service can be sustained at 30 minute intervals, and at 15 dwelling units per acre 10 minute bus service is possible. Densities of 7 to 30 dwelling units per acre are necessary to support and sustain significant transit use of 5-40% of all trips. Increasing from 7 to 30 yields a significant increase in transit use and a reduction in automobile reliance. Dittmar and Ohland (2003) state that transit agencies in the United States generally use a planning criteria of 7 dwelling units per acre to support basic bus service. The Institute of Metropolitan Studies (1994) found that although 7 dwelling units per acre is the threshold for offering service, there is a substantial increase in transit use at ten dwelling units per acre.

gross. Newer suburban areas in many parts of the nation, Las Vegas for example, are higher at about 7 dwelling units per gross acre.[9] Other metropolitan areas are finding ways to add density to previously built low density areas. Vancouver and Portland for example are adding density and jobs to formerly car dependent areas in numbers that make it possible to provide additional transit service and anticipate viable commercial services in walking distance in locations that could not previously support them.

The ten dwelling unit per acre is usually an accepted figure for busses. For streetcars or trams the accepted figure is closer to twice that.[10] Densities of 17 to 25 du per gross acre are not uncommon in Streetcar Cities and not unachievable in new communities. Also, as discussed in the chapter on Streetcar City, there are other reasons for investing in streetcar than ridership which may make streetcar an intelligent economic development strategy at average densities between 10 and 20 dwelling units per gross acre.

The greatest opportunity for making suburbs more sustainable is along strip commercial corridors. While wholescale alterations of the dominant single family fabric are not conceivable in most suburban communities, the gradual intensification of low density commercial strips is. These vast areas that typically have a residential density of close to zero could easily accept redevelopment where the residential component could be 40 dwelling units per gross acre or more. Conversions of this type are already widespread in the Vancouver and Portland areas.[11] As

In 2006 the Design Centre for Sustainability led a region-wide initiative to produce a long-range urban design vision for the Greater Vancouver region. This was accomplished through public forums, stakeholder workshops and local area design charrettes; the outcome was a design scenario of how the region might look in 50 years. A portion of this future vision is shown above (right) next to an aerial image of the current conditions (left). For more information on this project see: http://www.sxd.sala.ubc.ca/

9. Currently the density of Las Vegas' suburbs peaks between 5 and 6 dwelling units per acre (US Census 2000) but a new higher density community being built in the CDP of Summerlin will have a density of 7 dwelling units per acre (Robinson 2005).

10. The research doesn't support the assertion that light rail requires twice the density:

Pushkarez and Zupan (!997) found that 7 to 15 dwelling units per acre can support moderate levels of convenient transit of all type including light rail which is reasonably sustained at 9 to 12 dwelling units per acre. Cercero (1984), Calthorpe (1993) and Lowe (1992) all cite 9 to 10 dwelling units per acre as the minimum density to support light rail.

11. In Surrey, BC Bosa Properties is converting a suburban strip mall into a high rise urban village called the Semiahmoo Town Centre. This development features mixed use, pedestrian-friendly streets and high residential densities.

- Commercial
- Mixed-use/ Retail at grade
- Mixed-use/Commercial at grade
- Mixed-use/Residential at grade
- Residential
- Park

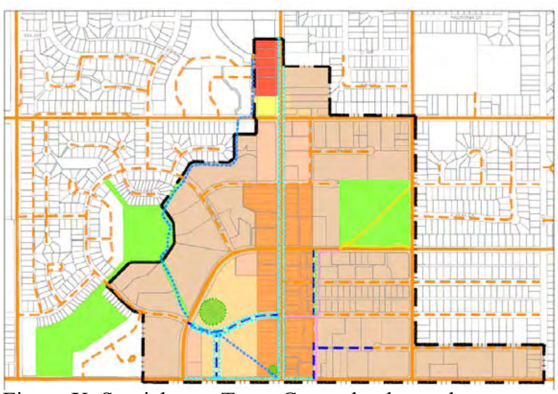


Figure X. Semiahmoo Town Centre land use plan

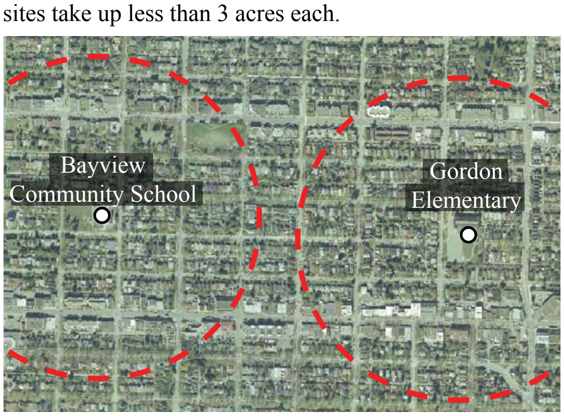
Figure X. Aerial image of Semiahmoo Town Centre site these developments proliferate along suburban strips they start to behave like streetcar arterials, allowing residents to access other parts of the corridor by transit, and as such providing transit authorities with sufficient justification for reducing headways. Strip commercial zones often occupy between 8 and 15% of developed land in the suburbs. Were ten percent of this land developed at 40 dwelling units per gross acre it could move average densities from 6 dwelling units to 10. And would likely be more effective at increasing walking and transit use than that implies since all the new residents would be within one or two minutes of commercial services and a bus stop.

12. Below is an aerial image of a new school site built in a sprawling suburb near Boise, Idaho. The site takes up over 32 acres.

The walk to school

In many suburban locations the neighborhood school is indistinguishable from the shopping center, a sprawling one story box set behind a parking lot and a bus drop off, attached to the arterial via the umbilicus of the cul de sac. With more and more school kids getting to school by bus the necessity to scale schools in relation to the population within a walking distance circle, formerly assumed to be ten minutes or less, has been eliminated. Absent this restraint various school districts have been attracted by the siren song of "economies of scale" to authorize larger and larger elementary schools. In the Boise region some districts won't consider schools on sites less than 40 acres.[12] If this were the standard when Streetcar Cities were laid out fully 30% of all land would be occupied by elementary schools.

13. The image below shows an example of smaller school catchment areas in Vancouver, BC. The red circles indicate a 700m walking radius. These school sites take up less than 3 acres each.



As in many things the Streetcar City pattern is instructive. A school would be provided for each 160 acre half mile square, each square surrounded by streetcar arterials. The school was almost always located in the middle of the square, meaning no child was more than a six minute walk from the school and no child had to cross the arterial to get there. With a residential density of at least 10 dwelling units per acre (and larger family sizes than now) those 1,600 units usually produced enough kids to fill two class rooms for each grade 1 – 7. This meant that schools had about 400 kids in them, a school size now considered "small" but that the Small Schools Foundation considers ideal. The principal of the Bayview School in Vancovuer's Kitsilano district knows the names of all 400 students, and the kids know the names of almost everyone who goes there too. Over the 400 student size establishing this kind of close educational community becomes increasingly impossible. A school for 400 students should ideally fit into one 4 acre block.[13] This likely means a school that is tall rather than spread out. Traditional schools were three stories served by stairs. This is still an efficient form. Elevators for handicapped can be installed at less cost than the building and land costs of sprawling one story schools. A three story school for 400 will have a footprint under an acre leaving three acres for recreation, enough for a large playground and a soccer field. Whatever parking is necessary should be accommodated on surrounding streets. The full perimeter of the block is usually more than ample for this purpose.

A 4 acre site will be a very hard sell with most school districts. The habit of large sites is so strong it won't be easily overturned. The compromise is the two block site of 8 acres. The negative consequence of a two block site is that it marginally impedes interconnectivity and removes an additional 3 to 4% of land otherwise available for housing or services within the five minute walk circle, increasing the difficulty in achieving sustainable densities with the detached housing forms so heavily favored in many metropolitan areas.

Conclusion

All of our efforts to get people out of cars and on their feet will be fruitless unless we can make walking easier than driving. And this is only possible if the things we need and want every day are within a five minute walk. If this five minute walk brings us to zones where busses and streetcars abound then it becomes equally convenient to hop on and hop off regularly, until at some point life without a car seems like not such a bad idea. None of this works without a balance between density, street network, frequent bus and streetcar headways, and even sensible locations for elementary schools. Miss one of these components and you compromise the others. Streetcar City models provide many lessons for reapplying to other newer contexts, and impel us to protect these features in landscapes where they are threatened. Creating new and retrofitting old communities for walkablility and options to the car will be the challenge of our time. The various monumental pathologies identified in the first chapter have their source in what seems like a humble decision. Should I drive to get that loaf of bread or walk? That decision amplified and repeated by many millions results in impossibly overloaded freeways and ridiculously expensive and unsustainable patterns of movement. Reconstructing our urban landscapes around the five minute walk is a key part of restoring health.

Chapter Seven: Lighter, Greener, Cheaper, Smarter Infrastructure

Introduction

North American road and utility infrastructure appears to have been intentionally designed to destroy the ecological function of the land that supports it, and to bankrupt homebuyers and taxpayers through its cost to install, maintain, and replace. Since the end of WWII, the per dwelling unit costs for providing, maintaining, and replacing infrastructure (defined here as the physical means for moving people, goods, energy, and liquids through the city) has increased by nearly 400% according to some estimates.[1] Most of this per capita increase has been the consequence of ever more demanding engineering standards for residential roads, coupled with the gradual increase in per capita land demand over the decades prior to 1990, a necessary consequence of universally applied sprawl patterns throughout the North American continent. The first costs of these ever more odious engineering standards and ever more exclusive zoning regulations was often invisible to the taxpayer, buried as it is within the costs of the original home purchase. These costs become more obvious to the taxpayer after two generations, when the costs associated with the necessary replacement of infrastructure fall not on the home purchaser, but on the property tax payer.[2] First ring suburbs built during the 50s and 60s, now face major costs for overhauling an overextended system of roads and pipes, and because of low density development, have an inadequate number of taxpayers to pay for it.[3] Faced with rising property taxes and falling level of services, residents of first and second ring suburbs are often simply opting out, leaving behind these communities for the greener fields of the third and fourth ring suburbs, or even exurbia, where these impacts lie a still comfortable two generations away. The crushing liability for oversized infrastructure falling on too few taxpayers is another element of the “doughnut hole cities” phenomenon (freeway oversupply is the other). It provides strong financial incentives for residents to move further and further away from the geographic core of the region and further and further away from jobs and services.[4]

Beyond the cost consequences, there are the environmental impacts. Every dollar’s worth of pavement produces a measurable increase in environmental impact, not because pavement is inherently polluting, but rather because it so fundamentally alters how water is delivered to receiving waters when it rains: water that should go into the ground goes into a pipe instead, utterly transforming watershed performance. The cure for the sickness inflicted on watersheds consequent to urban

1. By compiling the various costs associated with infrastructure construction, operation and maintenance, Condon and Teed (1998) estimated that the total per dwelling unit infrastructure costs for a Status Quo Development scenario were $23,520 while the Sustainable Alternative Development was only $4,408, a fifth of the cost of the Status Quo Development. Savings in the Sustainable Alternative Development came primarily from reducing road widths, allowing gravel lanes with utility poles and efficiencies in placement and utilization of utility hookups (for more information see: http://www.jtc.sala.ubc.ca/projects/ADS.html). CMHC (1995) found similar infrastructure savings between a conventional suburban development pattern and a mixed use, more compact development planned according to the principles of “New Urbanism.” They found that initial capital costs of infrastructure were approximately $5,300 cheaper per dwelling unit in the alternative plan, operating and maintenance costs were $3,700 less, and infrastructure replacement was over $2,000 less totalling $11,000 life-cycle savings (CMHC 1995).

2. Sprawling development increases the cost of building and maintaining roads, sewers, schools and other public facilities for a number of reasons, including: the initial capital costs of new infrastructure in greenfield developments, the increased distance between developments increases the length of roads, water pipes and sewer lines and facilities must be more dispersed in the landscape without being able to take advantage of efficiencies from economies of scale (Meredith 2003). In Canada, more emphasis has been placed on building new infrastructure rather than maintaining existing facilities (Vanier and Danylo 1998). In a report released in 2007 the Federation of Canadian Municipalities (FCM) found that close to 80% of Canada’s infrastructure is past its service life and the price of eliminating the municipal infrastructure deficit is $123 billion (Globe and Mail 2007). In the city of Memphis, urban sprawl has contributed to the increased costs of operating basic infrastructure in real dollars from $466 per capita in 1990 to $637 per capita in 1999 (Ciscel 2000). As urban centres are left with aging and deteriorating infrastructure properties are abandoned and property values and tax revenues go down depriving the municipality of the money needed to maintain, repair or replace existing infrastructure (Hirschhorn 2001).

3. Although the total infrastructure costs for the entire site were greater, the per dwelling unit costs in the sustainable alternative ($4,408) were significantly lower than the per unit infrastructure costs in the status quo development ($23,520) (Condon and Teed, 1998). These cost savings are attributable to a more compact urban form and higher residential density (Sustainable Alternative Development 17.7 du/acre; Status Quo Development 3.9 du/acre).

4. In Hirschhorn’s Traditional Circular Model of Sprawl (2001) higher taxes and decaying infrastructure do as much to push the nonpoor out of urban centres as the cheap outlying land, new infrastructure, low property taxes and attractive open space pull them to the suburbs. Urban centers are left with aging and deteriorating properties, facilities and infrastructure as property values and tax revenues decline (Hirschhorn 2001).

Change in Total Population by Census Tract
Neighbourhood Areas, 1990-2000

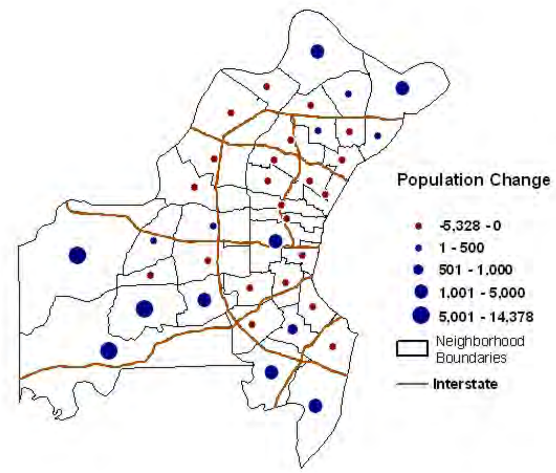


Figure X. Shows the doughnut hole effect in St. Louis as the population moves from the centre city to the suburbs. Source: USDC Bureau of the Census, Census of Population and Housing [1990 STF3; 2000 SF3] Prepared by: Office of Social and Economic Data Analysis

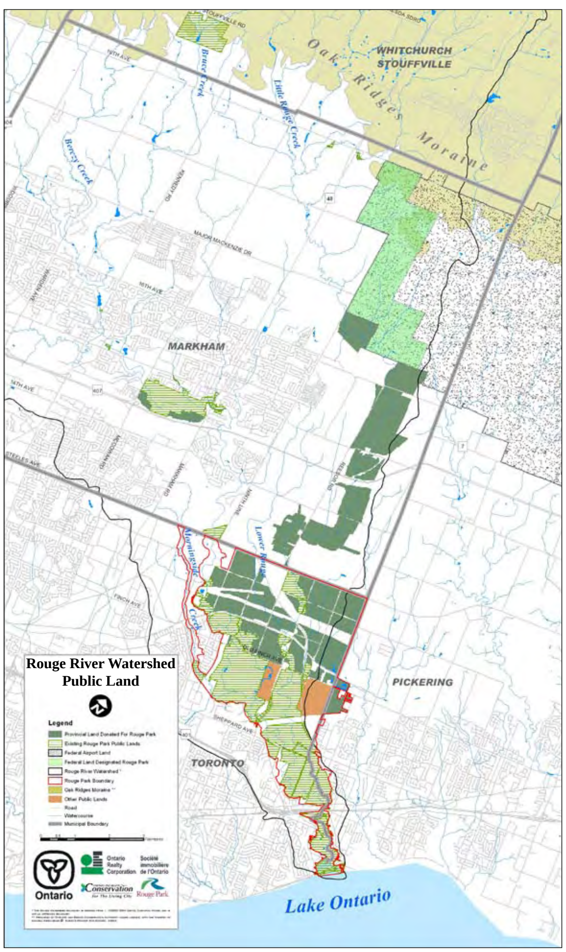


Figure X. Shows the extent of an urban watershed in Ontario, Canada.

development is to spend *less* on infrastructure not more – less pavement, fewer pipes, fewer gutters. The idea of spending less money not more is a crucial one. Environmentalists often demand costly government responses to environmental problems, be it the purchase of a nature reserve on the one hand, or a new storm water treatment facility on the other. They also often call on regulators to reduce project density or eliminate large areas of subject sites from development reducing yield and thus reducing economic return to proponents. This zero sum game allows development proponents to argue that preserving natural systems will add cost to the project, costs that must be ultimately passed on to families struggling to purchase a home. The environmental arguments leveled most often against new development are in many cases counterproductive. Arguments to keep density low simply shifts the demands for those housing units to other sites on similarly sensitive lands further away from jobs and services. The demand for natural preserve areas salvages fragmented pieces of a disintegrated natural system, cut off from the natural connections necessary to maintain ecological integrity. There are practical alternatives to unproductive pitting of environmentalists against development. Infrastructure exists that costs less than what we are currently requiring and that works with Nature's systems not against them. This is infrastructure that capitalizes on nature's services while minimizing the weight, extent, and cost of the "hardscape", the streets, walks, lanes and drainage ways of the site. Such infrastructure can significantly reduce cost while dramatically shrinking environmental impacts. How this can be accomplished is described below.

The Site is to the Region what the Cell is to the Body.

It seems obvious but bears repeating. *The site is to the region what the cell is to the body, and just as the health of the individual human cell has everything to do with the health of the human body, so too does the ecological function of the individual site have everything to do with the ecological health of the region.* Site scale elements, when multiplied thousands and even millions of times throughout vast metropolitan regions, do more than *influence* regional environmental systems, they *constitute* regional environmental systems. The most obvious and important regional environmental system is the watershed. Of all the varied influences of the city on environmental function, the influence of urbanization on watershed function is the most profound.

Natural Watershed Function

In most North American natural landscapes, the vast majority of rain water that falls on the ground is infiltrated by the soil or absorbed into plants. Plant roots draw rain water from shallow soils, then send it back up into the sky through the leaves (a

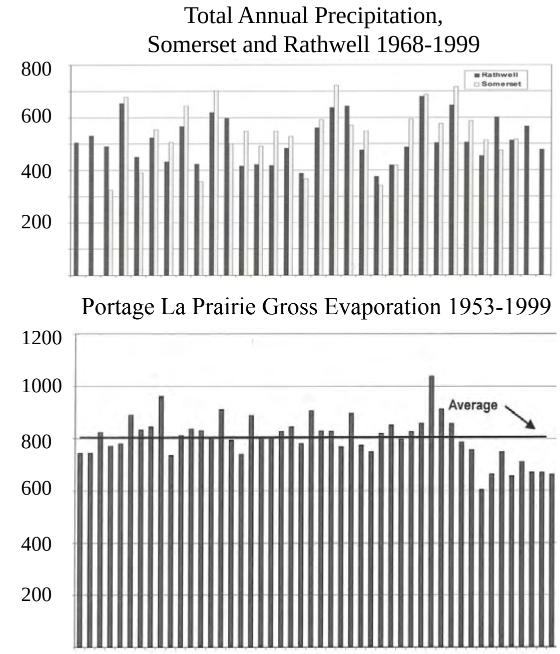


Figure X. The two charts above show the annual precipitation and evaporation for a prairie region in Manitoba, Canada. The average annual gross evaporation is approximately 800 mm (31.5 in.) while the annual precipitation is closer to 500 mm (19.5 in.).

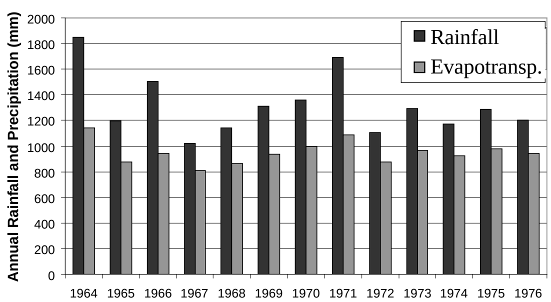


Figure X. Shows the total annual precipitation and evapotranspiration of a mostly forested watershed in the Pacific Northwest. Here, precipitation is significantly greater than evapotranspiration.
Source: Amatya and Trettin 2007

Figure X. The extent of glaciation in North America during the Pleistocent times (Minnesota University)

process called transpiration). The water that the plants don't need or can't absorb flows through the soil to be stored in the water table or drained from the soil via a nearby stream. The relative ratio of water transpired vs. water absorbed varies from place to place and from season to season. For example, during the dry season in certain prairie landscapes, plants can commonly transpire more water than they receive. Thus the plants draw not only from the supply of new rain but also from moisture stored in soil over the winter and early spring. Conversely, in coastal Pacific Northwest temperate rainforests, the average percentage of rainwater that is returned to the atmosphere as evaporation and transpiration throughout the year is about 45% while infiltration accounts for the rest. However, during the winter when it rains the most it is too cold for much photosynthesis and thus transpiration to occur. Consequently, during winter nearly 100% of the winter rain that falls on the forest floor is absorbed by the tree detritus and the soils below. As more water falls, soaking the soils, some of the excess seeps into deep water aquifers where it might be stored for an indefinite, or almost infinite, amount of time; however the majority of this water seeps a few inches or a few feet below the surface until blocked by a harder soil, called glacial hardpan, the legacy of the most recent period of glaciations. The importance of this impeded flow is discussed below.

Ten thousand years ago, all of Canada and many parts of the US were covered by a sheet of ice many miles thick. The motion and weight of this ice mixed and compressed soils and rocks to form an unstratified (all mixed up) concretized (very hard) layer that is often quite close to the surface. All of Canada, Minnesota, Iowa, Illinois, New England, New York State, and Michigan were covered by the glacier and thus have soils who's characteristics derive from this event. Parts of Wisconsin, Pennsylvania, Ohio, Indiana, and Washington State including the Puget sound were also covered and were left with "hardpan" soils in the glaciers wake. When rain water hits the hardpan layer it most often migrates horizontally over the surface of the hardpan but still underground, until it emerges in the banks of a nearby stream. The characteristic dense and fine grained lacework of streams common to these landscapes is the consequence of this relatively recent glacial event. Aquatic creatures that inhabit these streams, particularly spawning and rearing salmon, have acclimated themselves to this hydrological framework during the ten millennia since the glacial recession. Water that falls on these watersheds is absorbed by the soils and delivered to nearby streams, seeping slowly horizontally over the surface of the hardpan. A drop of rain can take weeks, or in some cases months, to get to the stream. When this water arrives at the stream it trickles down the stream banks, scrubbed clean by the filtering particles of soil and cooled by the constant temperature of the earth. The heavier the soil the cleaner is the water and the more gradual it is delivered.

What of the other parts of the continent? Soils in other parts of the continent have a more complex and older genesis, some the result of wild volcanic events so far in the distant past that the glaciations occurred only yesterday in comparison. Nevertheless, it is fair to say that in any landscape where there are frequent streams which tend to flow consistently even during periods of extended drought you are in an area of impeded flow to deepwater aquifers, resulting in horizontal interflow which feeds streams a steady supply of clean and cool waters.[5]

The capacity of soils to deliver water to deep aquifers and water tables vs. trapping it as interflow is unevenly distributed over locations. The performance of any acre of land can vary wildly from the acre next to it, particularly in glaciated landscapes. Because of the highly erratic actions of the glacier during its various stages of melt and advance, one acre of land can be the locus of a deep lens of sand left by a particular kind of outwash off the surface of a melting ice sheet, while on the acre immediately next door the soils are a dense and almost completely impervious concretized mass of very heavy clayey soils. Thus infiltration devices installed for even a very small subdivision can work splendidly in one yard and fail in the next. Nevertheless, as a general rule these averages hold true enough to form a useful assumption for planning sites, prior to more detailed investigations as part of any building program.

Streamside vegetation also plays an important role in preserving fish habitat. Streamside vegetation holds soils in place, retains nutrients in the channel, prevents water from overheating and ensures a steady food supply of insects and forest detritus for fish. Some studies indicate that at least thirty meters of streamside vegetation on both sides of any given watercourse is required in order to maintain a healthy riparian corridor.[6] Such a canopy cover of riparian vegetation shades streams and helps to maintain cold water in streams. Insects that reside in this vegetation also provide a constant source of food for fish. Fallen trees and branches provide cool resting places for fish as well as protection from predators. Roots and fallen trees reduce the energy of flowing water, which in turn helps to secure stream flow and to stabilize stream banks. Riparian plants bind soils in place and trap moving sediment, actually replenishing healthy soil and reducing erosion. During times of rising floodwater, vegetation filters surface runoff and slows overland flow. Slow-moving water then has more time to soak into the soil. In healthy, well managed watersheds, stored groundwater is released back into the stream during periods of dry weather.

5. During and after a rain event on glaciated soils precipitation infiltrates the soil, percolating downward until it reaches a layer of less-permeable soil or rock material that restricts the downward flow causing the water to move laterally along this layer, eventually discharging into a surface water body (Ward et al. 2004). This lateral movement, called interflow, maintains the streams baseflow during the sometimes-lengthy period between storms (Ward et al. 2004). In the glaciated midwestern United States most present-day groundwater flow is restricted to shallow aquifers that help to maintain this baseflow (Person, et al. 2007).

Figure X. The fine lacework of streams in Tennessee shows interflow at work in an unglaciated landscape..

6. Erman et al. 1977; Steinblums 1977; Rudolph and Dickson 1990; Chen 1991; Spackman and Hughes 1994 and Ledwith 1996 found that a minimum buffer of 30 meters (100 feet) is necessary to avoid significantly impacting riparian environments. To maintain processes such as sediment flow and contribution of large woody debris this 30 meter buffer may be increased to 60 to 80 meters, or the average height of one site-potential (ie. maximum height of native riparian forest trees) tree (Broderson 1973; Beschta et al. 1993; Thomas et al. 1993).

7. The United States Environmental Protection Agency and Environment Canada define benthic invertebrates as "animals with no backbone or internal skeleton that live on the bottom of lakes, ponds, wetland, rivers, and streams, and among aquatic plants." Many benthic invertebrates are actually the larvae of insects such as stoneflies, mayflies and caddisflies that live on land as adults but lay their eggs in aquatic environments (Yukon Place Secretariat 2007). These species, in both their larval and adult forms, are an important food source for aquatic and terrestrial vertebrate consumers such as fish, turtles and birds (Covich et al. 1999). In addition, they transform organic detritus from sedimentary storage into dissolved nutrients that can be mixed into overlying waters and used by rooted plants and algae to enhance primary productivity (Covich et al. 1999).

Figure X. The Cuyahoga river caught fire several times, once in 1936 and again in 1952 (shown above)
Photo credit: United Press International

8. For more information on Water Legislation in the United States visit: http://www.epa.gov/water/laws.html

9. Much like the United States, Canada's water legislation has focused primarily on issues of water quality and the control of pollutants rather than issues of water quantity and changes to the hydrological cycle. During the 1970s Canada's management approach could be characterized as reactive and while it arguably had some successes with highly visible forms of pollution and other conventional water issues it failed to tackle more complex and pervasive forms of water degradation (Environment Canada, 1987). Federally, the Canadian Environmental Protection Act establishes a regime for identifying, assessing and controlling toxic substances and is administered largely by Environment Canada. Environment Canada also administers the Canada Water Act, enacted in 1970, which provides the framework for joint federal-provincial management of Canada's water resources. For the most part, waters that lie solely within a province's boundaries fall within the authority of that province whose legislative powers cover flow regulation, authorization of water use development, water supply, pollution control, and energy development. Although BC recently passed its Ground Water Protection Regulation in 2004, the focus was on groundwater quality not quantity (Douglas, 2006). The BC Liberal's new Riparian Areas Regulation (RAR) significantly weakens the Streamside Protection Regulation (SPR) enacted under the NDP. For example, the SPR set minimum standards for building setbacks on fish-bearing streams while RAR allows the developer to hire a professional to determine the setback while giving local governments more flexibility in choosing whether or not to implement protective measures for Streamside Protection and Enhancement Areas (SPEAs) (WCEL).

Even the riparian vegetation of non-fish-bearing parts of a stream system plays a role in fish habitat. Upstream areas and their intermittent streams (streams with flowing water only during wet seasons or during the period after rains) provide food for fish in the form of insects and forest detritus. They also help to maintain the quality and quantity of water flowing downstream.[7] These intermittent portions of streams are extensive throughout any stream laced watershed, which makes them impossible to completely protect when development occurs. To do so would so reduce project yield as to make development impossibly expensive while encouraging low density sprawl. Some have suggested that the solution is to build very few but very tall buildings widely spaced. While this might meet the performance criteria for stream protection it would contradict other principles for healthy sustainable communities. Fortunately there are ways to protect and recreate upstream function by incorporating an understanding of natural processes into the design strategies for site development infrastructure.

Water Quality and Water Quantity

Water Quantity, not Water Quality!

Throughout North America the conversation about watershed health has been inordinately focused on water quality, the degree to which water discharged into receiving waters carries pollutants, as opposed to water quantity, the degree to which urbanization alters the rate and amount of water discharged into receiving waters. This is a legacy of the first North American environmental movement when national concerns about polluted water and air (sparked by many notable events including the combustion of the Cuyahoga River, Cleveland Ohio, in 1969) led the US to pass the "Clean Water Act of 1972".[8] Thirty five years later, the Clean Water Act is still the only regulation governing US waters, and all 50 states have to a greater or lesser extent aligned their policies with it in the intervening decades. The original act clearly obligates states and lower levels of government to protect America's waterways, with a goal of keeping all US waters "swimmable and fishable" if not drinkable. But the Act was mute about the damage wrought on American waterways by alterations in the quantity of water that moved through its rivers and streams. At the time the act was passed very little was known about the devastating consequences to streams consequent to alterations of the rate, amount, and temperature of urban water discharged into them.[9] In the decades since the original act was passed it has been updated but its essential focus on "water quality" has never changed.

Only recently have we learned that streams, the waterway type that covers and drains the lions share of most North American watersheds, are far more susceptible to water quantity changes than to water quality changes.[10]

Where We're Doing Wrong

In the Pacific Northwest of the US and Pacific Canada, the water quantity changes brought about by urbanization have produced a crisis. By 1999, the US Fish and Wildlife service, acting in conformance with Endangered Species Act of 1973 mandates, listed five species of Pacific salmon as endangered.[11] This triggered a requirement for other jurisdictions in the states of California, Idaho, Oregon, and Washington to respond in a way that ensured no further harm to these species. Unfortunately among the harmful activities that impacted fish, urbanization was second only to forestry on the list.

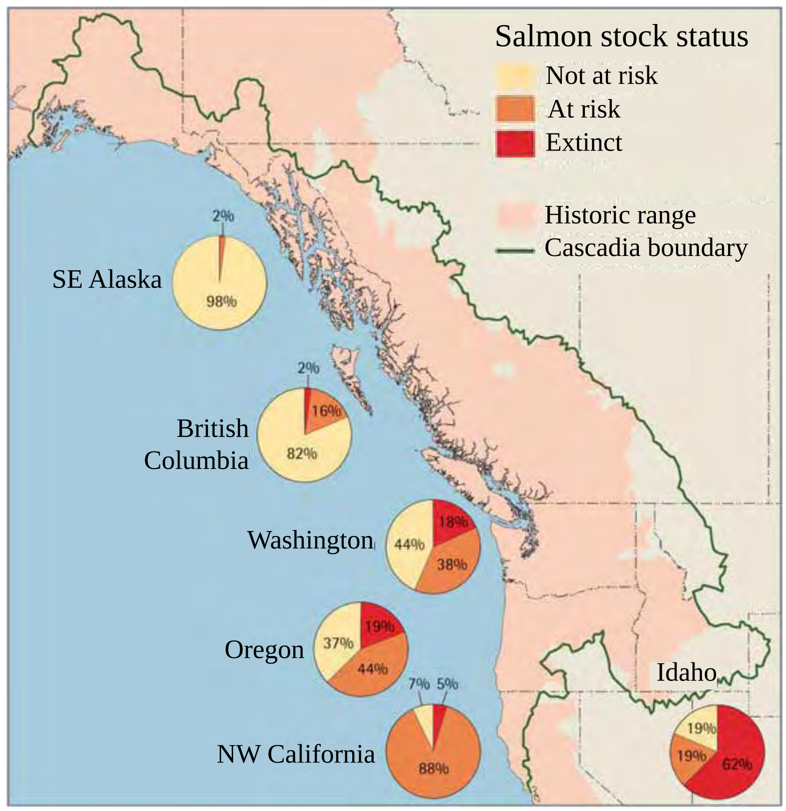
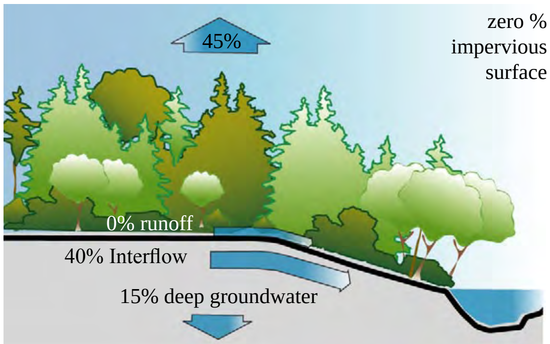


Figure X. This map shows how the percentage of threatened or extinct wild fish stocks increases towards the Cascadia's southern tip where human impacts are greatest (Source: Ecotrust)

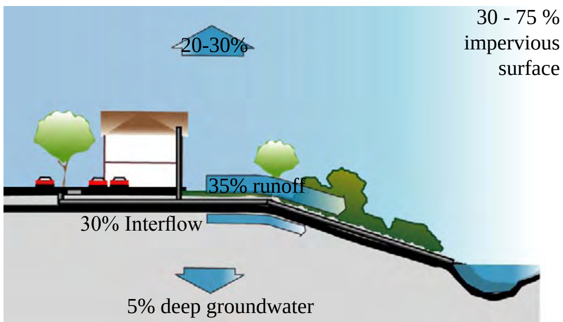
How is it that a land use that covers less than ten percent of these states could be so damaging? One reason is that when people build cities they tend to choose the same places that salmon spawn and rear. Spawning and rearing occur on stream runs that are between 2% and 5% gradient. These gradually sloping but not entirely flat streams occur in gradually sloping but not entirely flat landscapes: exactly the landscapes that are appropriate for building cities. The second reason is how profoundly urbanization, even at suburban densities, alters

10. The increase in impervious surfaces associated with development together with traditional channel and pipe stormwater management systems deliver stormwater to receiving waters much faster and in far greater volumes than under natural conditions. Water that under natural conditions would have infiltrated into the soil and traveled slowly to receiving waters via interflow, significantly contributing to stream baseflow during dry periods, is instead delivered all at once via pipes in the period immediately following the rain event. This increase in flow volume and peak flow rates erodes stream channels and increases the risk of flooding (Stormwater Planning 2002). Eroded material creates turbidity which degrades aquatic ecosystems and is harmful for fish health and reproduction (Stormwater Planning 2002). According to Booth (1991), increased runoff associated with urbanization is responsible for catastrophic expansion of stream channels, increased flooding, erosion and sedimentation in low-lying areas, and the subsequent decimation of aquatic organisms. Modifications of the land surface, specifically the elimination of vegetation and the proliferation of impervious surfaces, results in the loss of water storage in the soil column and drastically alters flow patterns so that the largest flood peaks double or more and frequent storm discharges can increase by as much as ten-fold (Booth 2000). The high velocities associated with increased peak flows increase erosion and can wash salmonid eggs from their beds, displace newly emergent alevins and fry and limit the migration of adult fish. Increased erosion leads to increased sedimentation that clogs salmonid spawning gravel, depriving oxygen to the fish eggs (Vronskii and Leman, 1991) and the removal of metabolic wastes (Havis et al., 1993). Impervious surfaces reduce the retention of water in the soil and the amount of groundwater recharge resulting in low summer base flows that can cause fish mortalities due to reduced velocity, cross-sectional area and water depth (Williamson et al. 1993). Water quality is impacted when stormwater containing hydrocarbons, heavy metals, nutrients, pesticides and bacteria is delivered directly to the stream via pipes instead of being cleaned by infiltration and delivered to the stream via interflow through the soil column. Stormwater flowing over large paved surfaces on a warm day raises the temperature of the water to levels that can be harmful for cold-water fish like salmon and trout. Finally, the capital costs of land development with traditional piped systems can be a significant cost to local government and developers and ultimately can undermine the affordability of housing (Stormwater Planning 2002).

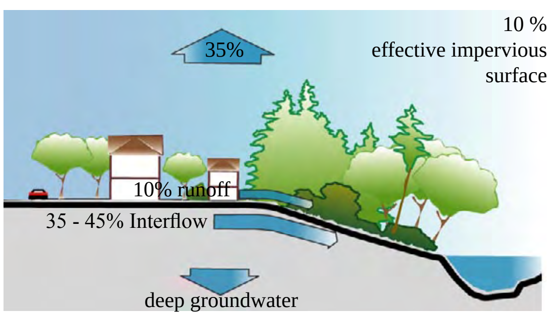
11. Between November 1991 and October 1999, 20 distinct population segments of five salmonid species were listed as endangered under the Endangered Species Act (Buck and Dandelski 1999).



Pre-development hydrology: In a naturally functioning watershed in the Pacific Northwest, 45% of rainfall is lost to evapotranspiration, and 55% infiltrates the soil, feeding streams through subsurface interflow and replenishing the deeper groundwater aquifer. There is essentially no runoff.



Post-development (Conventional): Here runoff imcreases dramatically from close to 0% to 35% while evapotranspiration drops from 45% to between 20 and 30%. Only 35% of rainfall infiltrates the soil to replenish streams and deeper groundwater aquifers.



Post Development (Alternative): Development that limits impervious surface area achieves a much higher rate of infiltration than conventional development. Narrower streets, smaller building footprints, and riparian vegetation with continuous tree cover work together to mimic the natural hydrology of the site. Runoff is limited to 10% of the total rainfall.
Source: Site Design Manual for BC Communities (2003)
http://www.jtc.sala.ubc.ca/projects/DesignManual.html

12. In Vancouver, BC there were once over 50 salmon and trout bearing streams but today that number has dwindled to only two: the Musqueam Creek and its tributary, Cutthroat Creek, both of which run through Pacific Spirit Regional Park (Kirkby 1997). Recently efforts have been made to restore salmon habitat to waterways such as Spanish Banks Creek where coho and chum salmon fry are have been released in an attempt to develop a viable population of returning fish (Urban Streams).

watershed performance. When an area urbanizes, conventional storm water practices require the installation of a storm water infrastructure over potentially vast percentages of salmon habitat. This storm water infrastructure functions in a way that is 180 degrees contrary to the way natural landscapes perform. Rather than holding water in the soil where it can be cleaned and delivered via interflow over days, weeks, or even months, a network of pipes is installed to insure that the same amount of water is delivered to the stream within a few hours or even within minutes of a rain event. Thus water that was previously slowly metered out by the soil, clean and at the temperature required for fish health, is flushed in amounts that can be tens of times more gallons per minute then pre development rates. This “fast flush” off urbanized landscape produces many serious consequences; destruction of stream banks is the most damaging of these, precipitated by these sudden unaccustomed deluges. Stream banks that have taken 10,000 years since the recession of the glacier to stabilize are suddenly asked to accept ten or twenty times more water than they can accommodate. The result, unsurprisingly, is erosion of the stream channel, and the delivery of those silts to lower parts of the watershed. Unfortunately it is these very places that the salmon favor for spawning and rearing - gravel beds in stream locations with gradients between 2% and 5% - that all that unstratified glacial muck gets dumped.

Figure X. A typical stormwater outfall seen here at a time of low flow. During high precipitation events the force of the water is enough to move boulders.

Figure X. Shows the consequence of urbanization on stream banks. Larger volumes of water delivered to streams in the hours immediately after storms can devastate stream banks and effectively sterilize stream ecology.

As a consequence of the disruption to urbanized watersheds, the fish-bearing capability of virtually all of our urbanized stream systems has been destroyed. In the City of Vancouver alone, only two of the original sixty salmon-bearing streams still provide habitat.[12]

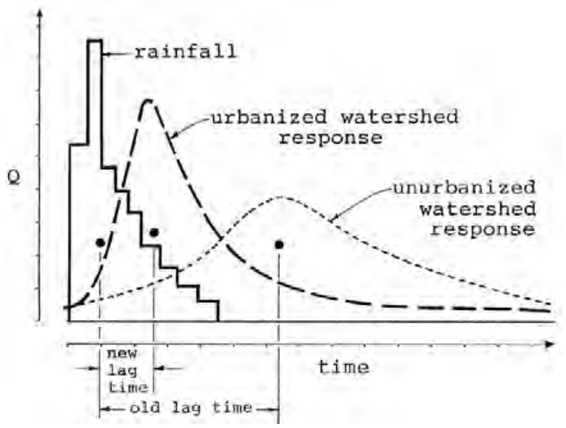


Figure X. Shows a schematic representation of changes in peak stream flow due to urbanization. The lag time between rainfall and peak flow can be significantly reduced as the watershed run-off characteristics are changed by urbanization (Source: J. David Rogers 1997)

13. To see the breakdown of impervious surfaces for low density residential developments visit: http://www.jtc.sala.ubc.ca/projects/ADS/HTML_Files/ChapterTwo/matrix_us_2.htm. Status quo development with a density of 4.4 dwelling units per acre was found to have 54% Total Impermeable Surface (TIA) while traditional development with a density of 13.4 dwelling units per acre had 51% TIA (Condon et al. 1998).

14. Horton overland flow (HOF), commonly known as runoff, occurs when precipitation falls on soil faster than the soil can absorb it. It is most common in regions with periodic, intense rainfall, limited vegetation, and thin soils. Where rainfall intensities are generally lower than the rate at which soil can absorb it, all of the precipitation is infiltrated where it first lands, resulting in surface runoff rates of essentially 0%. The coastal regions of the Pacific Northwest, with their gentle rainfall and lush vegetation, provide an excellent example of these conditions. In these regions rainfall is infiltrated into the soil and moves downslope below the ground surface at substantially slower rates than HOF. [Summarized from Booth 2000]

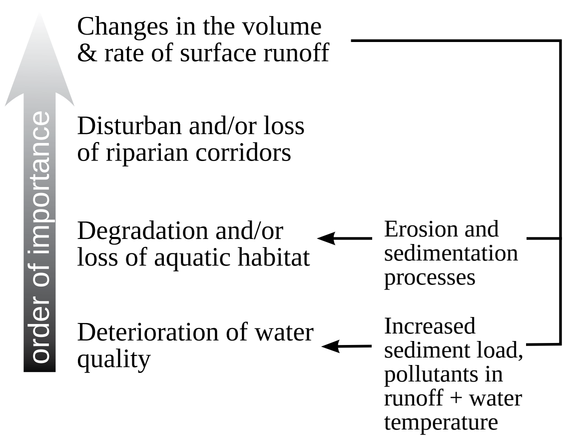


Figure X. Shows the factors that limit the ecological values of urban streams. In addition to being the most important factor in the degradation of aquatic ecosystem values, changes in the volume and rate of surface runoff also contributes significantly to the degradation of aquatic habitat and the deterioration of water quality.

Impervious Surfaces

Impervious surfaces don’t kill fish. Pipes kill fish.

It’s not the impervious surfaces that kill fish, it’s all the pipes that drain them. Under conventional circumstances, every hard surface in the city is directly connected to the stream with a hard pipe connection. Many municipalities require that roof drains be connected from residential structures via hard pipe connections to street storm drains. This is true even when there is ample yard area to more cheaply accept roof drainage via downspouts. Similarly driveways and sidewalks are drained directly to streets where their discharge is gathered in storm drain inlets that lead to pipes. These pipes in turn lead to bigger pipes and eventually into streams. What this creates is a watershed where in what are usually considered low density and relatively green suburban locations, every other foot of land is directly piped to streams. Since most of this water drains from exposed surfaces that may have been heated by sunlight in the hours before the rains, water draining from these surfaces can be tens of degrees warmer than waters entering streams from more natural avenues.

It can be surprising to discover that even in low density developments of 4 dwelling units per acre, between rooftops, driveways, patios, sidewalks, and most importantly streets, over 50% of the surface area can be covered with impervious surfaces.[13] Note that 35% of all water that falls on such a low density site is channeled as “runoff” directly and quickly to streams via hard pipe connections to storm drain systems. Runoff is a category of drainage that does not even exist in natural forested landscapes.[14] As areas urbanize runoff suddenly emerges as the dominant way that water leaves the site. Evapotranspiration rates while still significant fall to between 20 and 30% from over 45% in pre development landscapes, while interflow and deep infiltration drops to 30% from over 50% in the forest. This change may not seem extreme until you consider that all of the 35% of total rainfall that is drained as runoff is directed to the stream in the hour or two immediately after the storm event, delivering tens of times more water to the stream during those hours than it can comfortably manage, often at temperatures many degrees too hot, and carrying varying amounts of suspended solids (dirt in layman’s terms, often seen as a grey fog in stream waters).

Relationship between impervious surfaces and fish kill

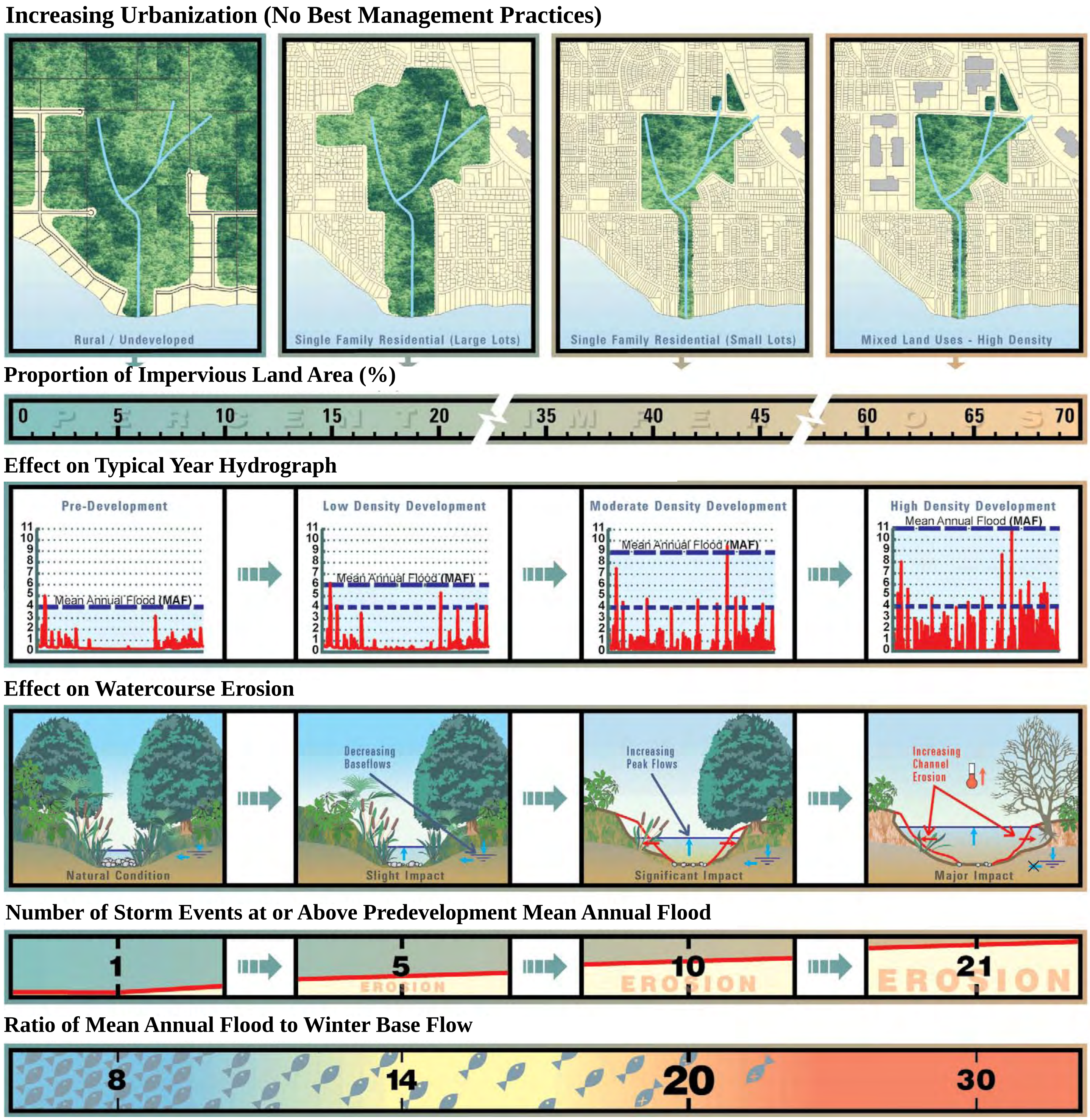


Figure X. Shows the impact of changes in hydrology on watercourse erosion and base flow relationships (without best management practices). It illustrates the progressive changes in hydrology that result when land use change alters the water balance and replacement of natural vegetation and soil with impervious surfaces reduces infiltration and evapotranspiration. Total runoff volume increases (as shown in red in the hydrographs) and so does the Mean Annual Flood (MAF).

Source: Graphics for Figure X and X were a collaborative effort of Kim Stephens, Bill Derry and Chris Johnston for the purposes of communicating scientific findings; and translated research done by Richard Horner and Chris May of the Center for Urban Water Resources Management at the University of Washington.

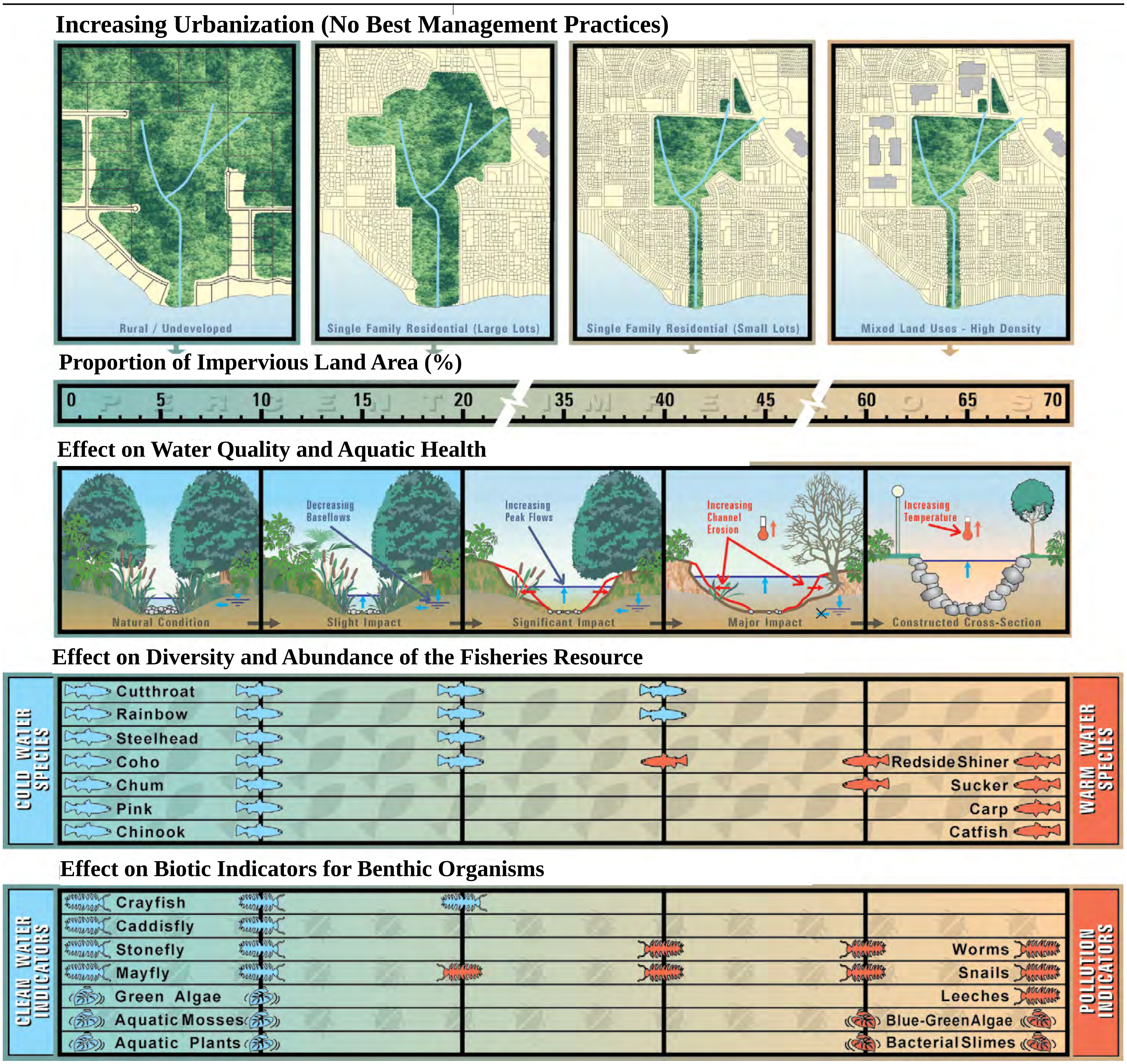


Figure X. Shows the impact of increasing urbanization on stream corridor ecology (without best management practices). Increasing impervious area and decreasing riparian corridor integrity increases runoff volume resulting in watercourse erosion, degradation of the stream channel and ultimately the progressive decline in stream corridor biodiversity and abundance of cold-water fish and clear water indicators.

It only takes a small amount of pavement in the watershed to kill fish. In the Pacific Northwest, an analysis of a multitude of urban streams revealed that fish counts in urban streams began to fall off when only 10% of the urban watershed was covered in pavement and rooftops.[15] When reaching impervious surface rates of 30% and above, the minimum coverage conceivable for even low density suburban development the news is even worse. At this level in most cases fish populations have collapsed and salmon runs have been extinguished. At streetcar city densities of 10 to 20 dwelling units per acre gross density you can, with

15. As a watershed nears, or exceeds, 10% impervious cover stream health deteriorates rapidly. Studies have found that there is a decrease in large woody debris (Booth and Jackson 1997), a decline in channel stability and fish habitat quality (Booth 1991), a significant decline in wetland aquatic macroinvertebrate community health (Hicks and Larson 1997), sharply lower insect (Jones and Clark 1987), macroinvertebrate and fish diversity (Klein 1979), higher rates of fish egg and larvae mortality (Limburg and Schmidt 1990) and steep decline of biotic integrity (Steedman 1988). To protect sensitive stream ecosystems, such as those supporting fish populations, watershed imperviousness should not exceed 10% (Limburg and Schmidt 1990).

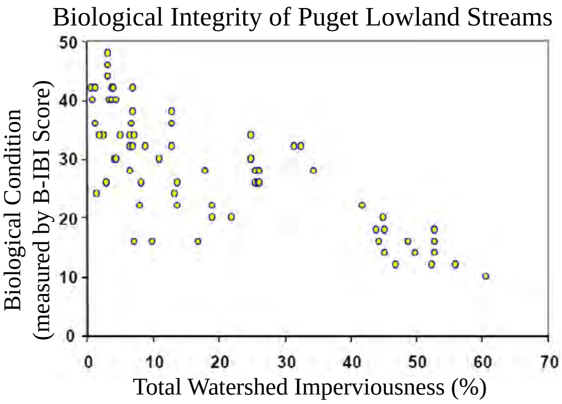


Figure X. The chart above, (from Booth 2000) shows a compilation of biological data on Puget Lowland watersheds reported by Kleindl (1995), May (1996), and Morley (2000). "The pattern of progressive decline with increasing imperviousness is evident only in the upper bound of the data; significant degradation can occur at any level of human disturbance (at least as measured by impervious cover)" (Booth 2000).

substantial effort, keep up to 50% of the site pervious; but these statistics suggest that such effort is for naught. Judging by this work, at 50% impervious levels no fish have survived. And it is not the pollutants in the streams that kill the fish. Chemical pollution in streams becomes a serious problem at impervious levels over 50% of the watershed. At this level enough chemical and particulate matter flows in streams to clog and poison the gills of the crustiest Coho. But in fact Mr. Crusty is long gone by this point; killed years before when the disruptions caused by development in his watershed had altered water quantities, temperatures, and flow rates enough to utterly destroy his habitat. But it is not the pavement that kills the fish it is the drains that drain it, as discussed below.

Storm Sewers

Storm sewer history and cultural tradition

The basic architecture of storm drain systems has not changed since the Cretan Minoans installed the first system over 4,000 years ago. For all but the last fifty years of that history the storm systems have carried both rainwater and sanitary discharge from toilets (known as black water) in the same pipe. Treating storm water as "waste" equivalent to human waste has developed a cultural ethos and a storm water technology focused entirely on removing this "hazard" as quickly and completely as possible, and not at all on understanding and working with natural processes. With storm and sanitary waters mixed in the same pipe these mixed waters were indeed dangerous and needed to be kept separate from humans.[16] Only in the last 50 years have the storm and sanitary systems been separated, and thus only recently can we consider these systems and the water they contain appropriately. Of all the impediments in the way of change the tendency to see storm water in terms of its potential for disaster is the worst. Methods used for sizing storm water pipes have not changed in the hundred plus years since the "Manning Formula" came into common use. This formula calculates the amount of water that might fall in the various parts of a drainage area and how long it will take it to reach a discharge point. The volumes assumed are derived from an assumed extreme storm event, typically the largest storm you might expect in any five year period, called the design storm return frequency. Storms that dump 10 inches of water on a site during 24 hours are commonly used as a basis for this in many parts of North America. Some jurisdictions use even more conservative design requirements, applying the 100 year design storm return frequency – typically a few inches per day more than the 5 year return storm. It follows of course that systems designed solely to quickly move waters from catastrophically large storms to off site streams will move waters from smaller more frequents storms to receiving streams

16. A Combined Sewer System (CSS) is a wastewater collection system that collects and conveys sanitary wastewater (domestic sewage from homes as well as industrial and commercial wastewater) and storm water through a single pipe (EPA 2004). During times of low, or no, precipitation wastewater can be pumped to treatment facilities however when collection system capacity is exceeded during precipitation events the systems are designed to overflow, discharging sanitary wastes directly to surface waters (EPA 2004). In the United States there are 746 communities with combined sewer systems, these communities are regionally concentrated in older communities in the Northeast and Great Lakes regions and are responsible for the release of an estimated 850 billion gallons of untreated wastewater and storm water (EPA 2004). This wastewater contains raw sewage, pathogens, solids, debris, and toxic pollutants (EPA 2004). The major causes of water quality impairment are associated with pathogens, organic enrichment leading to low dissolved oxygen, and sedimentation and siltation (EPA 2004). Catchments with combined sewer overflow effluent usually exhibit high coliform bacteria densities, especially after a storm (Gibson et al. 1998, Young and Thackston 1999). To mitigate combined sewer overflows municipalities can attempt to maximize the flow to the treatment plant and expand their existing facilities to accommodate these increased flows but expansion comes with a high cost as seen in the City of Tacoma, Washington where a partial upgrade of their activated sludge process would have cost $130 million (EPA 2004). Other options include reducing the inflow of rainwater into the system, separating the storm and sanitary systems and/or rehabilitating the sewer system components (EPA 2004).

with equal or greater rapidity, with great damage to receiving streams.

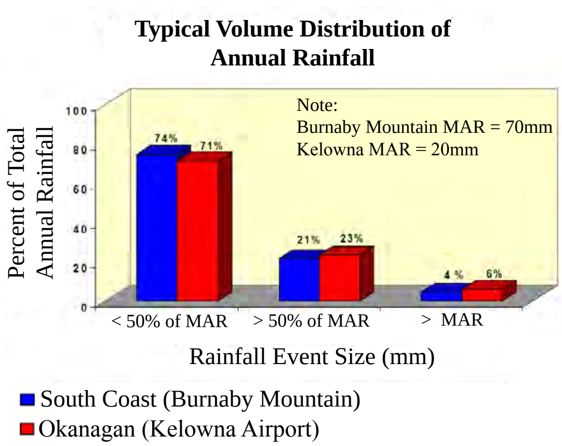
It's the small storms stupid

Four thousand years of focusing on the big storms prevents us from seeing the problem differently. From the point of view of the fish, it's not the big storms that matter it's the small ones. Fish can survive the rare cataclysm, it's the day to day disruption caused by the way small storms are treated that kills them. In all but a few parts of North America, the vast majority of storm events are small, generally under one inch per day. In most zones, storms under one inch in 24 hours (or one mm per hour) account for over 70% of all water that falls during the year.[17] The devastating consequences of stream health wrought by our storm drain systems can be fairly ascribed to our fixation, understandable but still a fixation, on the cataclysmic storm, and the design of our systems entirely around that rare event.[18]

Retention ponds

Some jurisdictions require retention ponds be installed just upstream of discharge points into streams, hoping thereby to mitigate the worst effects of conventional storm drain systems on receiving waters. Retention ponds were originally required to mitigate the potential floods caused by urbanization. In this function they are only partially successful and in some cases actually make floods worse by releasing waters during periods of crest when an earlier release might have been better. As for pollution benefits their efficacy is quite limited. It is generally assumed that retention ponds remove 50% of pollutants that would otherwise enter streams. Removing 50% of pollutants is like cutting your poison dose in half: instead of dying right away you die slowly and painfully. But this is not bad enough. Research suggests that in some cases retention ponds can even add pollutants to storm water, such that water emerging from the downstream side of the pond is more polluted than water on the upstream side (turbulence in the pond that stirs up previously settled pollutants appears to be the answer to this mystery).[19] Perhaps of more importance, retention ponds do nothing to enhance infiltration and thus very little to mitigate the distortions to the stream hydrograph consequent to urbanization. This is because it is physically impossible, or if not impossible incredibly expensive and space consumptive, to have a retention pond large enough and deep enough to hold the volume of water you would need in order to meter it out, not over 48 hours which is typically the maximum residence time in retention ponds post storm events, but over weeks and months to approximate the discharge rate of native soils. And even if you were willing to entertain the construction of a pond so large, you would still need

17. Small rainfall events are generally described as less than ½ the size of the Mean Annual Rainfall. This volume varies from region to region but in general accounts for approximately 75% of the total rainfall events in a given year. Water from small rainfall events should be captured from rooftops and paved surfaces and infiltrated, evapotranspirated or re-used at the source. Maintaining the natural water balance at the source is crucial for volume control which maintains baseflows, reduces erosion and flood risk and filters/cleans water. During large rainfall events (greater than ½ the size of the Mean Annual Rainfall) runoff from impervious surfaces should be stored onsite and released at a controlled rate. Only for extreme rainfall events (those that exceed the Mean Annual Rainfall) should it be necessary to provide escape routes for runoff with sufficient capacity to contain and convey flood flows. Generally extreme rainfall events happen only once and year, making up a very small portion of the annual rainfall volume. [Summarized from "Stormwater Planning: A Guidebook for British Columbia", May 2002 http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html]



18. Kunkel and Andsager (1999) studied extreme precipitation events of 1-7 day duration with recurrence intervals of 1 or 5 years. They found that precipitation from 7 day, 1-yr events (with thresholds ranging from less than 4mm/day in desert regions to more than 21mm/day along the coast) accounted for only 15% of the total annual precipitation in the United States. The contribution of 1- and 3-day 5-yr events accounted for an even smaller percentage (Kunkel and Andsager 1999).

19. Need work from research committee (Patrick)

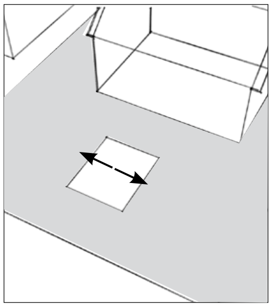
to provide a filtering mechanism that would emulate the cleaning function of soils, and a refrigerator to cool sun baked surface water to the temperature expected by aquatic stream species.[20]

"Total impervious surface" versus "effective impervious surface".

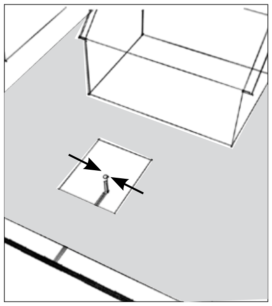
The recently discovered direct correlation between the amount of impervious surfaces in the watershed and the collapse of fish stocks in the streams has been important but depressing discovery. Unfortunately it has often provoked responses among some researchers, environmentalists, and policy experts that lead to more sprawl not less. The 10% total watershed impervious threshold, where fish stocks begin their steep collapse, has led many to suggest that new urban developments should not exceed a total maximum impervious surface level of 10% of the entire watershed. This would give you a maximum density of about one dwelling unit per two acres or less (possibly far less depending on the presence of commercial areas and major roadways in the watershed). Some, like Tom Holz of Lacey, Washington, have even gone so far as to suggest that no single family zones should be approved at densities higher than one dwelling unit per five acres accessed on a gravel road, with most new density absorbed by isolated tall towers linked by low impact elevated transit lines.[21] Faced with such extreme solutions many have despaired and concluded that healthy watersheds and walkable affordable communities are incompatible. When a choice is made in these stark terms certainly the fish will lose. Fortunately this does not have to be the case.

20. Water temperature determines the distribution, growth rate and survival of fish and other aquatic organisms through its influence on migration patterns, egg mutation, incubation success competitive ability and resistance to parasites, diseases, and pollutants (Armour 1991; LeBlanc et al. 1997). In addition, it influences rates of in-stream chemical reactions, the self purification capacity of streams and their aesthetic and sanitary qualities (Feller 1981). The highest average mean weekly temperature for coldwater, such as rainbow trout, book trout and salmon, coolwater, such as northern pike and yellow perch, and warmwater, such as catfish and bass, species are approximately 22°C, 29°C and 30°C respectively (Armour 1991). Mehner and Wieser (1994) found that on a restricted diet average metabolic expenditures were 1.56 times higher for perch at 20°C as opposed to 15°C and at 15°C, 47% of metabolizable energy was converted to body mass whereas at 20°C only 21% was available for growth (Mehner and Wieser 1994). The Q10 law states that the metabolic response of all organisms follows a general law of doubling with each 10°C increase in temperature but this is a conservative estimate for salmon where a decrease in internal temperature of 2.5°C was found to produce a 12-20% decrease in basal metabolic rate (Berman 1990). To put this in perspective, Pluhowski (1970) found that modifications of the hydrologic environment as a result of urbanization increased the average stream temperature in summer by 5-8°C.

21. Tom Holz chaired the *Salmon in the City* Conference held May 20-21, 1998 in Mount Vernon, Washington where he presented a paper with Tom Liptan and Tom Schueler, 'Beyond Innovative Development: Site Design Techniques to Minimize Impacts to Salmon Habitat,' available online at http://depts.washington.edu/cuwrm/research/sitc.pdf. More recently he has presented the concept of zero impact development to various City Councils throughout Washington State including Lacey, Sammamish, Tumwater and Shoreline.



runoff directed to lawn
Patio EIA 0%



runoff directed to drain
Patio EIA 100%

TIA and EIA

Much of the research that led to these depressing conclusions was conducted in watersheds where streets and rooftops were directly piped into streams, with great damage to the receiving waters. But it is conceivable for pavement to have little or no impact on receiving waters. For example, if you have a backyard of 1000 sq feet with a 100 sq foot paved patio, the impervious area of that backyard is 10%. This ratio of hard space to soft space is known as “total impervious area” or TIA, expressed in percentage terms. Presumably this patio contributes, when combined with all the other roads and rooftops and driveways in the area, to the destruction of the watershed. But what if the water that falls on this patio runs off into the soft grass around it, and what if the soil around the patio is porous enough to always accept this discharge. In this instance the influence of the patio on the watershed is zero. Conversely, what if the patio is equipped with a center drain, and that drain is connected to the street storm drain system, either by a hard pipe connection or via a drain that discharges at the curb or on the driveway or some other hard channel. In this instance the patio is “hydrologically connected” to the storm system. Water that falls on it has no opportunity to be absorbed by site soils. In this instance, 100% of the patio surface contributes to the decline of the watershed.

How can we then distinguish between the paved surfaces that are harmless, like the patio that drains into the grass, from the paved surfaces that are harmful, like the patio with the drain connected to the street drains? We can do so by distinguishing between the *total impervious area*, or the TIA, from the *effective impervious area*, or the EIA, of the site. In both cases described above the TIA of the yard is the same: 10% (total impervious area is a measure of pavement and rooftops and makes no distinction consequent to drainage method). But the patio that drained into the surrounding grass had no *effect* on the watershed. It therefore had an “effective impervious area”, or EIA, of zero. If all of the water shed by this patio infiltrates into the ground, then as far as the fish are concerned the pavement does not exist. It is this condition that we can and should shoot for. The following four rules provide the means.

Four Rules for Infiltration

Rule 1: Infiltrate, Infiltrate, Infiltrate

As in the business of real estate, when urbanizing or retrofitting existing urban areas for low impact on streams, there are only three rules: *infiltrate, infiltrate, and infiltrate.*[22] If all the rain or most of the water that falls on the site could go into the ground the pre development hydrograph is emulated. If this

22. An integrated stormwater management system seeks to maintain a site’s natural water balance by capturing rainfall at the source and returning it to natural hydologic pathways (which in the vast majority of landscapes are predominantly infiltration and evapotranspiration). This can be achieved through the adoption of Low Impact Development (LID) practices and source control. In addition to maintaining natural vegetation and reducing the compaction of soils, LID practices minimize the creation of impervious surfaces by building compact communities with reduced road width, building footprints and parking requirements. Source control involves preserving natural vegetation and stormwater features such as wetlands and riparian forests, preserving natural infiltration and evapotranspiration capacity through absorbent landscaping, infiltration facilities and green roofs and re-using rainwater for irrigation and indoor uses. Absorbent landscaping should provide 10-25% organic content in the soil and surface vegetation such as shrubs, grasses and trees that improve the infiltration capacity of the soil. Forests are generally the most effective landscapes for infiltration and evapotranspiration due to their deep rooting zones and high leaf density. Infiltration facilities provide on-site storage capacity through absorbent soil, sand or gravel, ponding, infiltration chambers or storage structures such as cisterns. The effectiveness of infiltration facilities depends on land use (impervious surfaces), soil type (infiltration capacity), the size of the infiltration area (as a percentage of the total site), rainfall characteristics, depth and type of the infiltration facility, and the water table depth. Green roofs can significantly reduce the volume and rate of runoff from buildings by using absorbent soil and vegetation to retain rainfall and facilitate evapotranspiration. Re-using rainwater at the source, especially for indoor greywater uses, not only reduces the volume and rate of runoff but also reduces the amount of water drawn from resevoirs and the cost of water supply infrastructure. [Summarized from “Stormwater Planning: A Guidebook for British Columbia”, May 2002 http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html]

can be fortified by a robust planting strategy for streets, yards, and, at certain densities, rooftops, then the pre development hydrograph can be nearly matched.[23] This is true no matter how much impervious surface there is. For example, it is possible to design a landscape where 100% of the site is covered with sidewalks, streets and rooftops. Such a site would have a TIA of one hundred percent but would also have an EIA of zero! This would be accomplished through holding water on rooftops and then infiltrating it under foundations and street sections. It would be costly to infiltrate all this water, requiring expensive infiltration chambers under all streets and walks, and high performance green roofs on all buildings; but it could be done. Of course infiltrating water on sites with less than 100% TIA is easier. Streetcar city districts at 10 - 20 du per acre are often still 50% pervious, providing ample soft areas to work with. The soft portions are largely the lawn and landscaped surfaces of yards and roadside tree boulevards.[24]

23. Research suggests that establishing urban forests that mimic native forests is key to more sustainable stormwater management. Although each region will have different sustainable design considerations relating to its particular hydrological and vegetative characteristics, some general guiding principles should still apply. Although the degree is variable between sites and seasons, most of the above-ground, surface and below-ground effects of urban trees and forests tend to reduce stormwater runoff amounts and peak runoff rates. The interception of precipitation by leaves delays precipitation reaching the ground and allows for some evaporation and absorption of this precipitation from the leaves or stem of the tree. When the leaf surface area exposed to the sun and wind is high, water loss from the leaves is high (Watson 1989). Leaf litter and soil with high organic content under vegetation can retain rainfall, reducing the amount and/or peak rates of runoff while the roots and trunk base of mature trees create depression on the ground where water can either be evaporated or infiltrated into the soil. Older trees generally generate more leaf litter and their roots create more and larger depressions. Organic material from leaf litter and other tree detritus tends to increase infiltration rates by increasing pore space and moisture holding capacity of most soils (Lee 1980). The overall effects of urban forests on stormwater runoff tend to be greatest during the growing season when most trees are in leaf and transpiration and evaporation rates are highest and have a relatively greater effect on small rather than extreme rainfall events. For example, a study in Sacramento, CA found that runoff reduction from interception alone averaged 15.2% for small storms (< 5mm/day) but only half that for large storms (>25mm/day) (Xiao 1998).

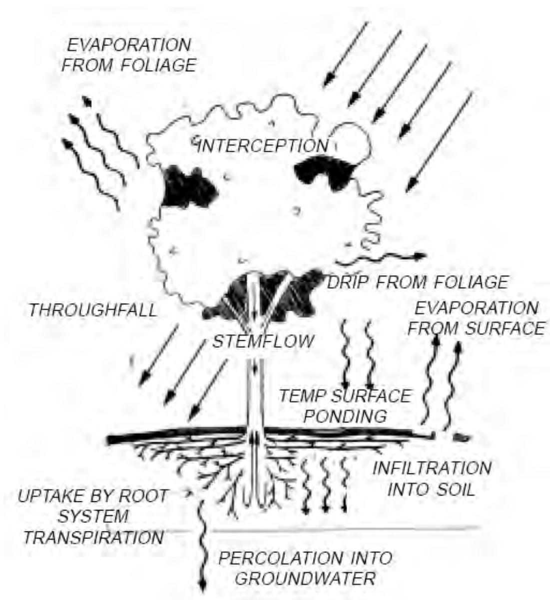


Figure X. Effects of urban forest on hydrological processes
Source: James Taylor Chair, Technical Bulletin 6, 2000

24. Condon, Patrick M. and Jackie M. Teed. 1998. Alternative Development Standards for Sustainable Communities. Available online at: http://www.jtc.sala.ubc.ca/projects/ADS.html

Rule 2: One inch per day

But how much of the rain must we infiltrate? Obviously infiltrating all of the rain should be the goal if we are to completely emulate pre development performance. Unfortunately in some parts of North America some storms dump more than ten inches of rain on the ground in a 24-hour period. These so called 100 year storms are the basis for storm water system design,

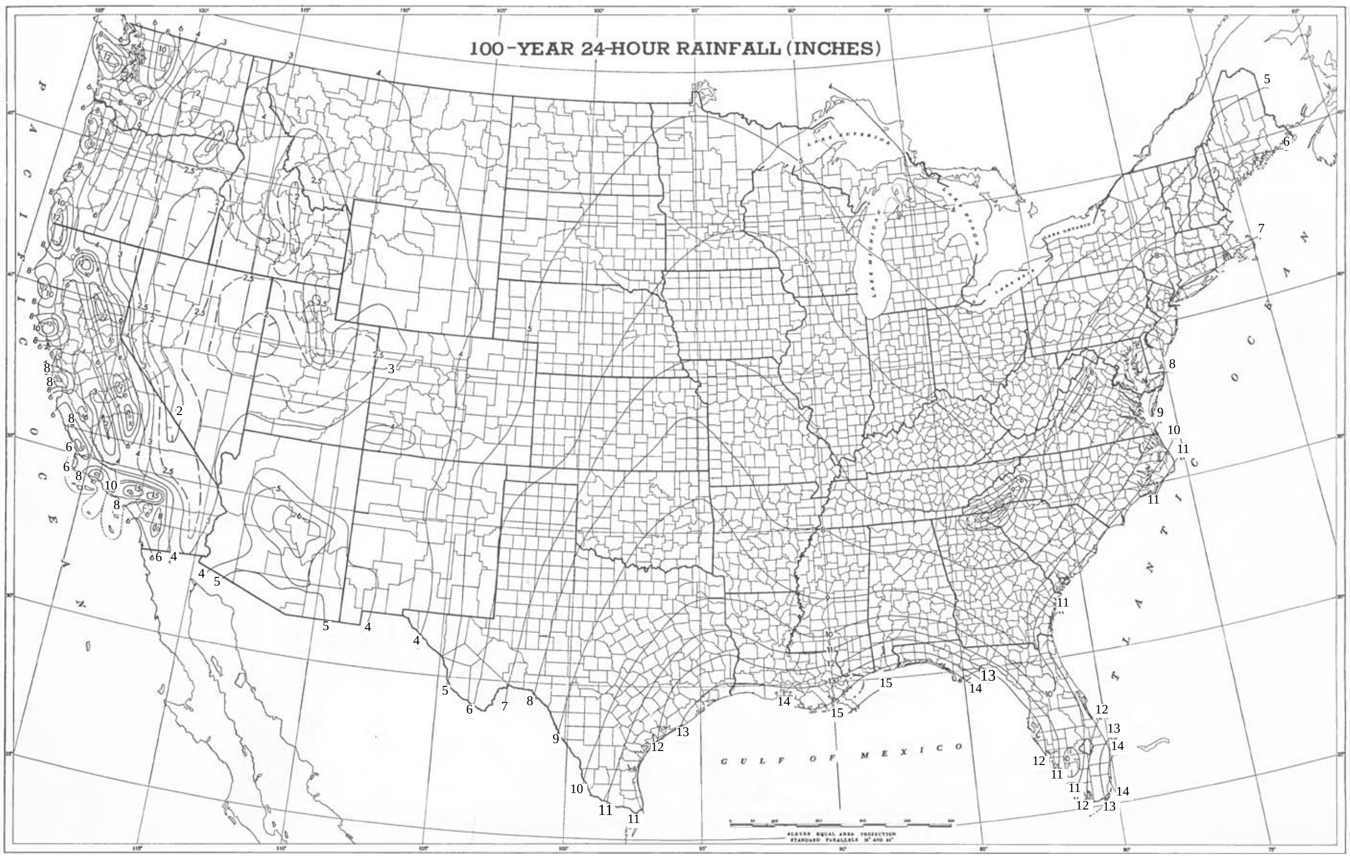


Figure X. 100 Year 24 hour rainfall (inches) in the United States. 100 year storm events range from 14 in/day in Florida to 2 in/day in Nevada. Source: Technical Paper 40 (Hershfield 1961).

should they be for infiltration systems? If soils are capable of infiltrating that much water in 24 hours the answer is yes, but few soils can do so. Fortunately aquatic species can manage the occasional large storm event, and for the most part so can the stream channel. The problem is not the big storm, which happens once in a while in natural environments too. The bigger problem is how urbanization fundamentally alters the behavior of streams under more ordinary circumstances - the 100 different rain events that you get during the ordinary year, not the one storm that comes every 100 years. Since the research suggests that watersheds start to degrade when impervious surfaces reach a threshold of 10% total imperious area (TIA), what if we were to design urban landscapes with a TIA of say 50% as if they were only 10% paved; i.e. design them such that the TIA is 50% but the EIA is 10%? It follows logically that if you could absorb 90% of all the water that falls on site, you would be emulating the performance of sites with a TIA of 10%.[25] If your objective

25. Limiting runoff volume to 10% of total rainfall should be sufficient to maintain baseflows, water quality and aquatic ecosystem health. Infiltrating rainfall feeds stream baseflow, removes many pollutants from stormwater and maintains the timing and volume of runoff thereby reducing the risk of flooding and stream channel instability. This can be accomplished by preserving or restoring natural vegetation along the riparian corridor and natural features such as wetlands, maintaining instream features such as channel complexity and spawning gravel and by controlling sources of water pollution from point and non-point sources. [[Summarized from "Stormwater Planning: A Guidebook for British Columbia", May 2002 http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html]

is to capture not all, but most, of the rain that falls on the site then obviously your best bet is to let most of the biggest and hardest to capture events go, infiltrating all the rest. But what size storms should you always capture to meet this performance threshold? For many landscapes in North America the answer is this: *capture all storms of less than an inch and the first inch of all larger storms.*[26]

Surprisingly this amount does not vary as much form one part of North America to another (the exception appears to be thunder storm and hurricane prone Florida).[27] An in-exhaustive analysis of Midwestern, Northeastern, Southwestern, and Cascadia landscapes suggests a range between .85 and 1.25 inches per day will achieve the 90% infiltration target. It may at first seem strange that a standard for the rainy Northwest is roughly the same as for the dry Southwest, but what matters here is not the total amount of rain in a year but the percentage of rain provided by small storms versus large storms. For all but one part of the continent the small storms contribute more total rain to receiving waters than storms over one inch per day.

Of the rules listed here in this section the one inch per day rule is the most important. Negotiations around storm water performance targets can often quickly bog down in the arcane language of civil engineering, with equations for time of concentration, complex grass swale turbulence, system friction, taking on a life of their own. Most of this language reflects a view of rainwater as a nuisance to be disposed of rather than something to be retained. No flow rate or pipe size calculations are needed for putting water back in the ground. It stays where it falls. Thus part of the value of the one-inch per day rule is its simplicity. It is memorable, easy to apply, and, most importantly, correct. Insisting on the one inch a day rule helps alter the frame of reference for storm water system design. It is even a simple yet scientifically credible rapier to cut through all the regulatory underbrush that blocks our path to more sustainable communities.

26. The majority of rainfall occurs at intensities of less than one inch per day.

Annual Rainfall Potentially Captured with a System That Can Absorb 1" (25.4mm) Every 24 Hours.

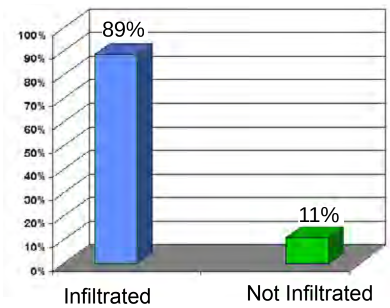


Figure X. In the Pacific Northwest a stormwater management system designed to absorb 24mm (1 inch) per day, will absorb almost 90% of all the rain that falls on a site. Source: Site Design Manual for BC Communities 2003

27. With most areas receiving at least 50 inches of rainfall per year, Florida is one of the wettest states in the US although it exhibits great annual variation often resulting in a year of flood followed by a year of drought (Black, 1993). South Florida receives 70% of its annual rainfall between May and November while North Florida receives less than 60% (Black, 1993). Thunderstorms are the main source of rain in Florida and peak in frequency and intensity in July and August except in South Florida where the storms continue into November (Black, 1993). Storm events with a 1-year reoccurrence and 24 hour duration range from 3.5 to 5 inches/day (Hershfield, 1961) meaning that in a typical year the largest storm event would account for up to 10% of the total annual rainfall.

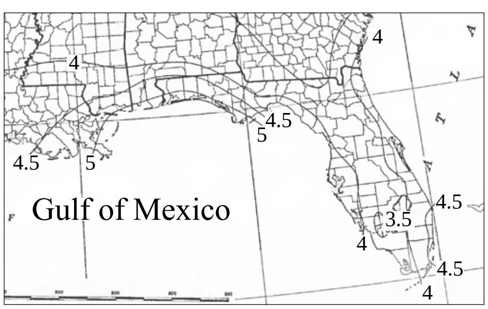


Figure X. 1-year isohyet for Florida (1-year storm ranges from 3.5 to 5 inches/day, among the highest in the US) Source: Hershfield, David, M. 1961.

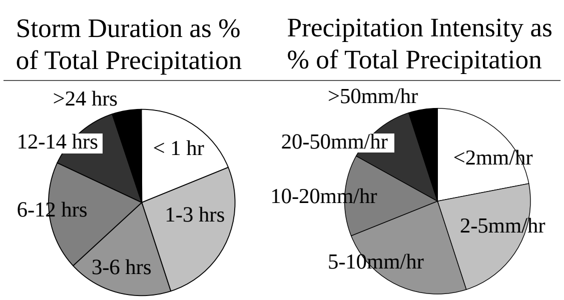


Figure X. Like Florida, the Southern Appalachian Mountains in North Carolina receive much of their precipitation in short term high intensity storm events (Neary and Swift, 1987).

Figure X. The Pringle Creek sustainable community in Oregon incorporates infiltration into streets, boulevards and yards.

28. True clay soils are actually quite rate. Most soils that are called clay simply have a larger than usual percentage of smaller soil particles

Soil Type	Typical Hydraulic Conductivity Range
Sands & gravels	> 50 mm/hour
Sandy loams	10 – 50 mm/hour
Silty loams	5 – 40 mm/hour
Clay loams	2 – 6 mm/hour
Clays	< 2 mm/hour

Source: Soil Texture Triangle: Hydraulic Properties Calculator, Washington State University (http://www.bsyse.wsu.edu/saxton/soilwater/)

Rule 3: Infiltrate everywhere

But the one inch a day rule only works if you can infiltrate on every inch of the site. But any developed site will have some areas that are less appropriate than others for infiltration. In our example streetcar suburb, all infiltration should occur on the soft lawn and boulevard areas that constitute fifty percent of the site. If these lawns can infiltrate the one inch per day that fall on them, and infiltrate the water that flows off of adjacent paved surfaces that constitute the other 50% of the site, then we will have met the target. Many soils can manage two inches per day without difficulty. It gets harder when you direct runoff to a more limited space. If you take the water that falls onto the impervious fifty percent of the site and for whatever reason direct it to a "rain garden" (a planted area designed to accept large amounts of water) that covers only 5 percent of the site, that rain garden will have to infiltrate the one inch that falls on it plus 10 additional inches. Eleven inches is a lot of rain. Very few un-amended soils are capable of this much. For this reason you must infiltrate everywhere: in every yard and every road verge not ignoring any opportunity to do so.

Rule 4: Heavy soils are good soils

Different soils have different capacities to infiltrate, but almost all soils are capable of infiltration at the 1 mm per hour or one inch per day rate. This point is key. Most civil engineers know a fair amount about soil infiltration, but they have very different performance assumption in mind when the subject is raised. For most engineers 1mm per hour is considered impervious soil, or "clay" soil.[28] The engineering community considers a soil to be porous when it has infiltration rates in the range of hundreds of mm per hour or more. This lack of common understanding between the value of ubiquitous slow infiltration for stream health, and the engineering community's assumption that infiltration is only possible in highly porous soils, creates extremely difficult implementation barriers. Long and careful discussion is required, usually in a charrette setting, to overcome these barriers. Proponents of infiltration strategies must be wary of this language difference and difference in understanding of the minimum soil conditions necessary for infiltration. From an engineering perspective only sandy soils are capable of storm water infiltration. From a broader sustainability perspective almost all soils are capable of infiltration, even heavy soils. Watershed performance, no matter what the soil, is dependent on the soils capacity to absorb and hold water. If a watershed soil is heavy it leads to a very precise regimen of interflow where waters will be retained in the heavy soils far longer than in sandy ones, be cleaned far better than in sandy ones, and lead to a landscape more frequently incised with small productive streams than in watersheds dominated by sand. In short the same things that make heavy soils difficult in the minds of many engineers are the very things that make watersheds biologically rich.

The two elements of the urban watershed: Parcels and streets.

There are only two building blocks to the urban region, private parcels and public rights of way. Parcels can be any size but are usually small, averaging less than an acre in most regions. Occasionally they are publicly owned, as in the case of schools or parks. The two basic conditions, parcel and right of way, can be discussed separately.

Green Infrastructure for Parcels

Building footprint

For watershed protection parcels should be designed to retain water in accordance with the four rules above. This is immensely simplified if 40 to 60% of the site is still soft. In residential landscapes this is usually lawn area. At the streetcar densities of 10 to 20 du per acre this is achievable if buildings are tall rather than spread out. Vertical buildings are important for other reasons as well. They increase yield on the development parcel and provide better visual containment for the street. A more compact vertical configuration is usually better for heating and cooling as well. Here, where our focus is on infiltration, the tall house with small footprint allows medium density dwellings to be compatible with preserving yard space for play, for gardens, and for infiltration.

Rooftops

At streetcar densities rooftops can cover about over 30 of the gross development site. Rooftops can be designed to retain water and transpirate it into the atmosphere while protecting the building from excessive heat in summer and premature failure of roofing materials or roof membrane. Roofs with a layer of plant materials, however elaborate or simple, are called green roofs. Many texts exist on the topic of green roof construction so no more technical detail is required here.[29] What *is* needed is to place green roof strategies in the proper relationship with parcel and street strategies, something that is rarely if ever done. Water can be retained on roofs and transpired on roofs but it cannot be infiltrated on roofs. Water in excess of amounts that can be stored and transpired must be drained to the ground. During rainy seasons like the Pacific Northwest winter, most of the rain that falls on a green roof will somehow run off to the ground.[30] In rainy winters green roofs are useful to slow the transmission of water to the ground but this is their only real benefit. In warmer climates and in climates where rain is more evenly distributed

29. For more information on green roofs see:

(1) Dunnett, Nigel and Kingsbury, Noel, Planting Green Roofs and Living Walls. Portland, OR: Timber Press, 2004;

(2) Liesecke, H.J., et al., eds., Guidelines for the Planning, Execution and Upkeep of Green-Roof Sites (English Translation). Bonn, Germany: FLL, 1995; and

(3) Scholz-Barth, Katrin, “Green on Top” Urban Land, June 2001.

30. In 2005 a study was conducted by the Centre for the Advancement of Green Roof Technology in Vancouver, BC to “investigate the performance and practical application of extensive green roof systems in Canada’s west coast climate” (Connelly et al. 2006). Green Roof 1 (GR-1) contained 75 mm of growing medium planted with sedums while Green Roof 2 (GR-2) contained 150 mm of growing medium planted with a mix of fescues and grasses. Although both green roofs delayed the start of runoff and reduced the peak flow and amount of runoff, the extent of these effects varied with the particular rainfall event and differed for the two green roof systems. In the dry season, mid-April to the end of September, GR-1 and GR-2 both performed well, retaining 86% and 94% respectively of the 242 mm of rainfall that fell during this time (Connelly et al. 2006). During the rest of the year however, only 18% and 13% of the 1266 mm of rainfall was retained resulting in an annual retention of 29% for GR-1 and 26% for GR-2 (Connelly et al. 2006).

Figure X. An industrial area in Seattle, Washington where rooftops cover the vast majority of the site with paved roads consuming the rest.

throughout the year green roofs have greater benefit. In North America green roofs are probably most useful in Gulf Coast areas and Florida where rain is reasonably well distributed throughout the year. Consequently in these areas irrigation is not required to maintain the cooling benefits of transpiring plants . As you move north and west from here their inherent value is reduced but not eliminated.

However, green roofs become more important for *storm water* control as building coverage rates increase increase. In certain industrial areas rooftops can cover 70% of the gross area (with paved roads consuming the rest). Absent significant vegetated ground areas to infiltrate on, robustly functioning green roofs can be crucial – especially if they are located in sensitive watersheds.

These cautions are provided to counteract the overly enthusiastic claims of many green roof proponents. Green roofs are in and of themselves of limited value unless integrated into a system of green infrastructure. When integrated into a system the relative costs and benefits of green roofs must be weighed against the costs and benefits of strategies applicable to the ground of the parcel, the street, or other public areas within the development site or neighbourhood. This contextualization of the green roof strategy is seldom done. Some jurisdictions are calling for a blanket requirement for green roofs while not requiring mitigation strategies for runoff from paved areas of the parcels. This constitutes a failure at the policy level to understand how the whole urban watershed system operates and where mitigation strategies might be most cost effective.

Parcels

From roof to yard

Once water comes off of roofs it should be spread out into soft surfaces as quickly as possible. For most types of residential structures this can be done at little or reduced cost by eliminating gutters in favor of long overhangs (cruelly overhangs are often impeded by setback requirements that count overhangs as part of he structure, disincentivizing this strategy). A drip line of crushed stone at the fall line will help distribute the water into lawn and underling soil.

Parcel grading is also significant. It has become traditional for lawn parcels to be graded fairly steeply out of fear of water returning to basements. Yet grades of greater than 2% can send water over lawns too quickly depending on storm event or soil conditions. Grades between 1% and 2% or even flat depressions are therefore recommended. Yards should be graded to avoid channeling flow but rather should spread flow as much as possible across all yard space. The obvious intention is to maximize the opportunity for roof drainage to come in sustained contact with lawn and landscaped areas and their underlying absorbent soils.[31]

31. In Massachusetts it is required that on-site infiltration measures be used to handle stormwater where suitable soils exist. The stormwater management system for the new Reebok headquarters in Canton, Massachusetts uses source control, structural and non-structural treatment methods, proper maintenance regimes, and stormwater Best Management Practices (BMPs) to maintain water quality and infiltration rates during construction and post-development. To date the Reebok stormwater system has successfully achieved 'zero net runoff' and natural drainage patterns have been retained and now act as natural stormwater management strategies onsite. The total system cost was $65,000 US dollars providing an effective, easy to install and economically feasible choice for infiltrating stormwater onsite. [Summarized from Technical Bulletin No.3 (August 2000), James Taylor Chair in Landscape and Liveable Environments http://www.jtc.sala.ubc.ca/bulletbody.html]

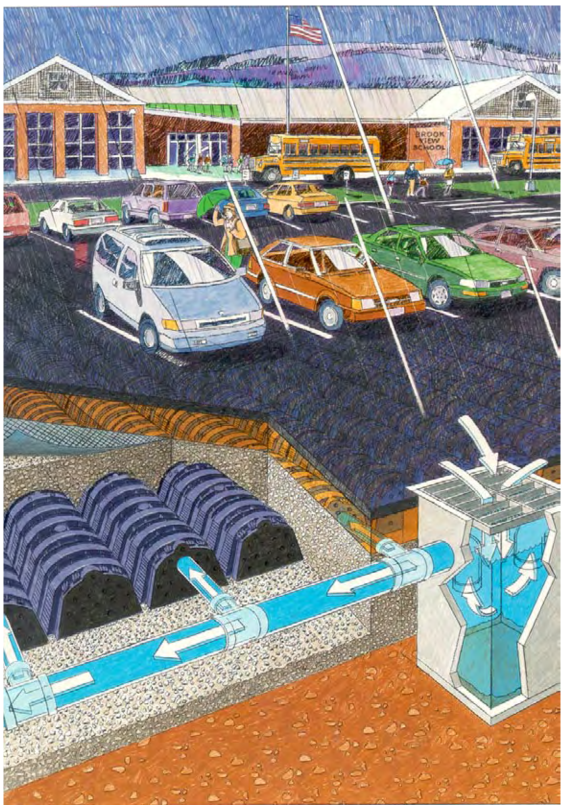


Figure X. Shows an infiltration gallery, similar to the one used for the Reebok headquarters described above, connected to a large, impervious parking lot.

The soils below

Ordinary site development practice destroys the capacity of site soils to infiltrate water. If development sites contain good topsoil it is often stripped and sold when ground is broken. One year later when construction is complete a much smaller amount is returned to the site to be thinly spread over severely compacted native subsoil, compacted by a year of heavy equipment traversing the construction site. Severe compaction crushes the void spaces from the parent soil, making it impossible for water to penetrate and rendering these soils incapable of supporting root growth. Lawn areas over such soils will not infiltrate water and after drenching rains will send most rainwater into adjacent streets as runoff, performing only slightly better than the concrete it abuts. We suggest a simple remedy comprised of two parts. Part one: Insure that soils around buildings remain uncompacted, then deep till this soil when construction is done. Part two: return at least as much topsoil to the site as was stripped and possibly more. As mentioned above, about 50% of a site will remain soft after construction is complete. If the site has six inches of decent topsoil pre construction then this stockpile should contain enough soil to return a foot of soil to all of the soft portions of the site. For many sites where subsurface soils are heavy this is likely the most effective strategy of all. Such a thick layer of highly porous and organically rich soil makes an ideal sponge to absorb and slowly release water into parent soils below. At

32. The East Clayton Neighbourhood Concept Plan is the first phase of the Headwaters Project, a real-life demonstration of sustainable development principles and performance standards in a community neighbourhood environment. For more information on the project visit: http://www.jtc.sala.ubc.ca/projects/Headwaters.html

Figure X. Topsoil, preserved from the initial site grading, is returned to residential lots at the East Clayton development in Surrey, BC.

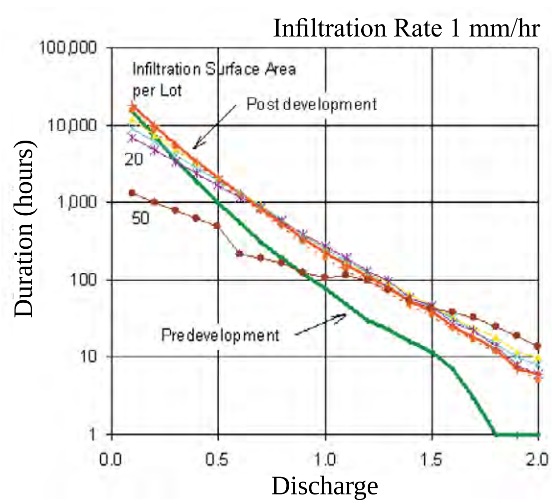
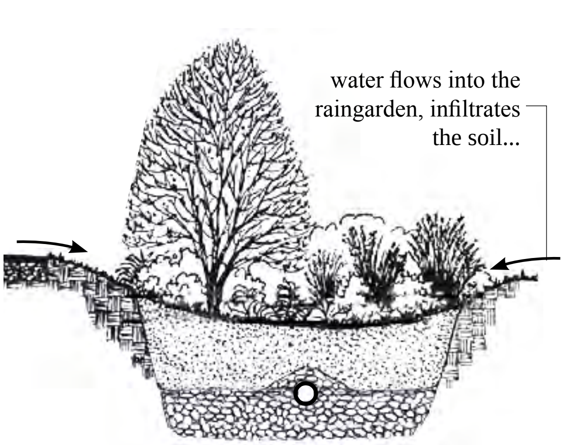


Figure X. Initial results of the 50 acre East Clayton demonstration development indicate that permeable areas and on-site infiltration devices are viable for stormwater management.
Source: ACT Phase E: Final Report (Headwaters Project)



...but when overloaded leaves the site via underdrain. During saturated conditions the filtering benefits of the root zone endure, but the benefit to preserving the pre development hydrological profile evaporates.

the East Clayton project[32] it was these extra deep topsoil layers that performed far better than expected. A requirement to double backfill the soft portions of the site up to a depth of 12 – 16 inches is therefore reasonable and far more cost effective than a green roof requirement in most locales. One foot of topsoil, assuming it is reasonably dry, can absorb approximately 3 full inches of rain, far in excess of the two inches required (remember that the overall target is 1 inch a day but that the site is only 50% pervious so each soft part of the site must absorb 2 inches in 24 hours).

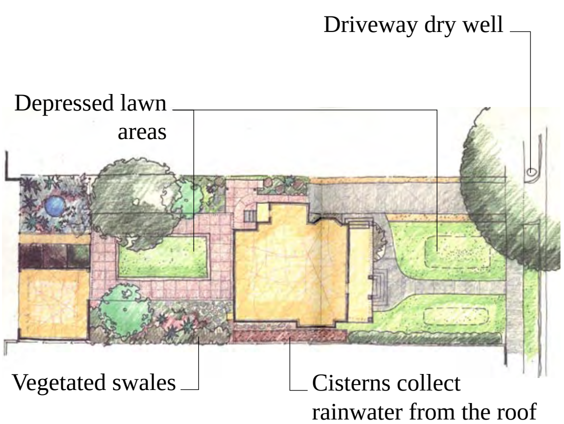
Raingardens

Raingardens have become increasingly popular as a low impact strategy. In a raingarden, water is directed over grass or directly from down spouts to planted areas designed to accept large amounts of water. These areas are often set an inch or two lower than surrounding grade to trap and hold water. Deep areas of amended soils are provided to absorb water and to provide rich areas for root growth. At their most elaborate they are equipped with underdrains and overflows connected to off site drains. Raingardens are inherently less effective than broad lawn areas for infiltration as they violate the infiltrate everywhere rule. When site water is concentrated in one place it puts an extreme burden on surrounding soils to absorb proportionately greater amounts of water. Heavy soils have a difficult time performing this way and thus the rain garden can get waterlogged, killing the plants if they are not resistant to constant flooding. Underdrains are often proposed as a solution but the drains compromise the original purpose of the rain garden. This is not to say they should not be employed, only that they should be secondary to ubiquitous infiltration on broad lawn areas. Hedge lines on the property line are of course the most effective rain garden design. It is necessarily long and thus covers a substantial percentage of the soft area of the parcel boundary, and are most commonly situated at the edge of large lawn areas they can capture any roof water that the lawn has been unable to infiltrate. Hedge lines on the property line are of course the most effective rain garden design. It is necessarily long and thus covers a substantial percentage of the soft area of the side, and situated at the edge of large lawn areas they can capture any roof water that the lawn has been unable to infiltrate.

Walkways

In many parts of North America, directing roof drainage across lawns will mean squishy conditions on grassy areas for many weeks in the year. This likelihood has impeded implementation of these recommendations in more than one jurisdiction.
The solution is to include paved walkways where needed. Unfortunately this can add to the TIA and possibly to the EIA

33. In the site plan below a single family residence in Los Angeles, California uses the landscape to work with, rather than against, natural cycles of water and waste. Rain falling on the building's roof is directed to depressed lawn areas or "sunken gardens" that retain rainwater until it can be absorbed into the ground. Only during rainfall events exceeding the 100-year storm does overflow need to be directed into the existing storm drain system. Rain that isn't directed into the lawn is collected and stored in two 1800 gallon cisterns that capture rain during the wet season and gradually release it for irrigation during the wet season. A roof wash unit collects the "first flush" water and sequesters it long enough to settle out the summer-long build up of dust and bird feces before the clean water decants into the cistern. These cisterns can also be used to regulate the flow of water during storms and reduce the risk of flooding. Vegetated/mulched swales slow the flow of stormwater, increases infiltration and filter pollutants while also providing an attractive and functional space that recycles greenwaste from the property. Runoff from the driveway is intercepted by a dry well which retains and cleans rainwater, giving water time to percolate into ground instead of carrying pollutants into the storm drain system. [Summarized from *Second Nature*, Condon & Moriarty 1999]



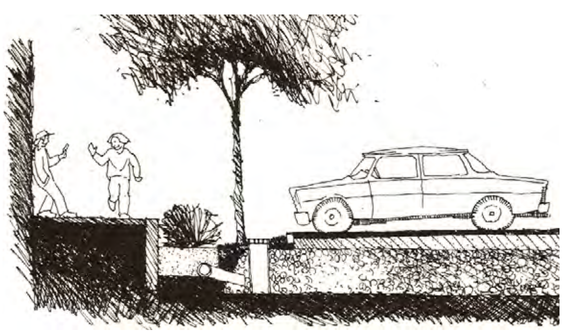


Figure X. Shows how the filter bed and the subsurface infiltratio basin work to treat and hold stormwater runoff from the large impervious parking area. The filter beds allow space for side-walks, trees and shrubs near the building whlie the plants contribute to the treatment of stormwater and reduce the energy-use for cooling during hot summer months (Condon & Moriarty 1999).

as well. Stepping stones are an effective low impact solution for occasionally used backyard paths. Stepping stones, like the patio solution discussed above, are by definition surrounded by soft pervious areas. In most soils it is likely that stepping stones will have an EIA of zero. Stepping stones flush with surrounding lawn or crushed stone beds are considered accessible under Americans with Disabilities act (ADA) rules where and when compliance is required.

For walkways that are more frequently used, such as the walkway from the front door to the sidewalk or from the back door to garage or lane, a continuous paved surface is required. Pervious pavement is an effective means to reduce EIA to zero for these surfaces, but it is often equally effective to simply cross pitch (slope slightly to the side) impervious concrete or asphalt into adjacent grass or hedges. These same rules apply to driveways, if and when required. Adjacent yard areas can be subtly dished with minor depressions to capture storm water, allowing puddles to form for short periods after severe storms.[33] This ephemeral feature is an enormously effective infiltration practice, and adds visual delight to the yard. Unfortunately allowing "standing water" on lawns for even a few hours defies most current conventions and biases against retaining rain water on site; in other words, we are afraid of puddles. This cost free strategy is therefore often difficult to implement.

Parking and Service Areas

At streetcar city densities of 10 to 20 du/acre parking lots should not be required. All recent city of Vancouver projects, commercial projects or residential projects over a gross DU per acre of 25 now have underground parking. Below this density parking is provided on streets, on lanes, or in garages. In consequence, there is generally no need for surface parking lots. However, if provided they too can meet the 10% EIA target in the following ways. Pavements can be pervious concrete or asphalt as described under roadways below. Alternatively parking lots can discharge into specially designed rain garden planters at parking lot edges or between bays. This second strategy requires highly permeable soils as the rain garden features will probably cover less than ten percent of the total surface area of the lot, and thus will be required to infiltrate ten or more inches per day to meet the overall target of one inch per day infiltration. If soil conditions are not this forgiving or if performance targets are high then infiltration under the lot via drain tiles or infiltration chambers may be required. This last strategy is especially effective when combined with rain gardens, as they clean silts out prior to delivering storm water to drain tiles. Unfortunately and obviously this is the most expensive strategy of the three discussed.

Right of Ways

Introduction

Rights of way are any publicly owned or publically accessible lands. In North America Rights of way are almost all streets and highways. Thus most of this discussion concerns these ubiquitous features of the urban landscape.

A street right of way (ROW) usually includes a paved street with verge areas astride it. Verge areas usually include some combination of sidewalks, tree boulevards, and/or road shoulder. ROWs are often much wider than the paved surfaces in them. For instance, the traditional streetcar city residential street ROW is 60 feet. Of this ROW less than half, or roughly 28 feet, is consumed by the paved street, measured from curb line to curb line. The remaining 32 feet is most often allotted to sidewalks and tree boulevards for both sides of the street. In most urban areas street right of ways consume between 25% and 40% of all land (depending on district street network type, existence or absence of rear lanes, and land use), making them far and away the most extensive and ubiquitous of all urban public land types. With so much of the site covered in public ROW it follows that street ROWs generate 40%, 50% or even more of the total district wide impact of impervious surfaces and storm drainage on receiving waters.

Figure X. Traditional queing street in Vancouver, BC. Parking is allowed on both sides of the 8.2m (27') wide paved way, which requires oncoming cars to take truns or "cue" on the residential cuing street. Sidewalks are provided on both sides of the street separated from the paved street by a 2.3m (7.5') grass and tree boulevard.
Source: Alternative Development Standards for Sustainable Communities, Condon & Teed 1998

Figure X. Pervious asphalt (top) and pervious concrete (bottom) are cheaper and more effective than pavers, allowing water to infiltrate through voids left in the paving when small aggregates and fines are eliminated from the mix.

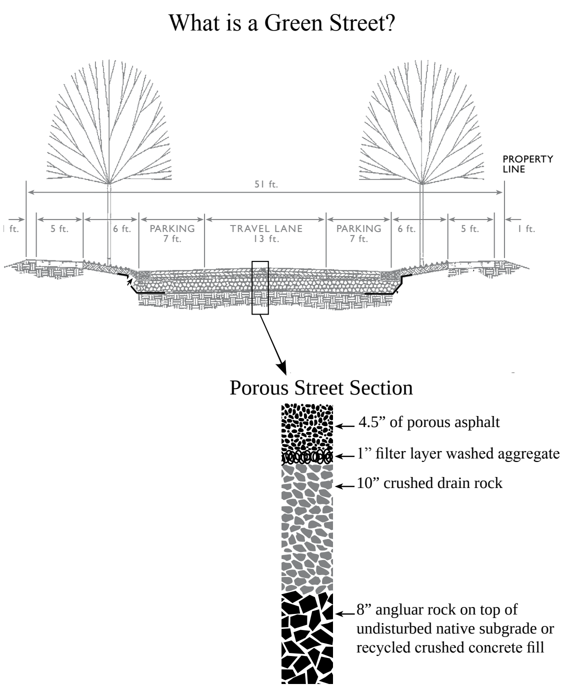


Figure X. A Porous Street Section
Source: Pringlecreek.com

Pervious or impervious

As discussed above, it's not pavement that kills fish, it's the pipes that drain it. If we want to save watersheds the key is abandoning our dependence on pipes to take water off the roads, and to find ways to get the water into the ground near or under the road instead. There are two basic ways to accomplish this: you can make all of the pavement in the road pervious so the water goes right down through it, or you can find a way to infiltrate the water in the soft surfaces of the verge. We discuss fundamental strategies for pervious pavements below, followed by a discussion of impervious streets that eliminate impact to receiving waters by absorbing water in verges.

Pervious Pavements

Much confusion exists about pervious pavements. For applications in North America there are really only two hard surface options that are both affordable and effective: pervious asphalt and pervious concrete. These pavements are fully capable of allowing 100% of even the largest storms to penetrate into the structural base below. What happens then is a different matter, discussed separately below.

Impervious unit pavers are often sold as a pervious pavement solution, with infiltration presumably occurring in the joints. They are not recommended for most applications. They are many times more expensive than pervious asphalt or concrete, and due to the limited area between pavers available for infiltration, tend to clog with silts (this occurs unless the units themselves are pervious, or the joints between the pavers are extremely wide). Unfortunately the unit pavers industry is well organized and markets its products extensively making strong claims to the contrary, while no industry exists to advance the use of simpler pervious asphalt and pervious concrete.

Pervious Pavement - Types and Characteristics

The two surface types, pervious asphalt and concrete, are very similar. Both pavements are identical to ordinary asphalt or concrete, except that the smaller aggregates (rocks in laymans terms) and fines (sands), which constitute a large part of mixes for impervious pavements, are absent. A typical size for aggregates in pervious pavements is ¾ ". Absent the smaller aggregates and fines, the liquid asphaltic binders of asphalt pavement or the cement of concrete pavements glues the large aggregates together, leaving ample void spaces between the ¾" rocks for water flow. Because pervious and impervious asphalt and concrete are virtually identical, costs and application techniques are similar as well. Visually the pervious surfaces have a somewhat rougher appearance but are as smooth or smoother than unit pavers and therefore do not pose a barrier or hazard to the handicapped. In short, anywhere that you can install ordinary impervious asphalt or concrete, you can install pervious asphalt or concrete for the same money, or close to.

Insuring that pervious pavements function well and last a long time is a somewhat different matter. Details of the road section below the paved surface must be reconsidered for enhanced infiltration, and care must be exercised during construction to insure that infiltration is not compromised.

Figure X. The pervious paving used at the Pringle Creek Sustainable Community in Salem, Oregon uses crushed basalt aggregates as a structural base which also acts as water storage.

Pervious pavement roadway structural section

Any roadway, or any paved surface for that matter, has two parts: The hard surface or pavement, and the earth below that holds it up. All well engineered and installed roadways need earth below that that is stable over time and structurally capable of holding up the pavement. Not all soils are. Clayey soils are particularly prone to deforming during freeze thaw cycles and thus are not used under pavements. “Gravel” is usually used instead, a mixture of fine and course sand particles and small and medium sized stones. This mixture does not deform or flow when weight is applied from above, as clay is prone to do, nor does it retain water long enough after rains for it to freeze solid, lifting and cracking the pavements above. These structural soils are more important in pervious pavement applications than in impervious applications because they have an additional requirement: they must store, infiltrate, and deliver rainwater within them.

Storing water in the section.

As discussed above, a useful rule of thumb is to infiltrate one inch per day of water over the whole site or 1mm per hour. If a roadway has no surcharge on it (i.e. no water directed to it from adjacent rooftops, driveways, or walks) then it must accept one inch of water somehow and infiltrate it into surrounding soils. If the roadway is accepting water from surrounding areas the amount of water it must store and infiltrate must be recalibrated up accordingly. Structural soils all have some capacity to store and infiltrate water, some more so than others. Ordinary gravel has tiny voids between the particles such that 10 to 15% of its total volume is available for storing water. Thus, to store one inch of water in the gravel would require a total cross section area of 7.5 to 10 inches. Other structurally suitable materials have even more void space. Crushed basalt aggregates of a uniform size can also be used as a structural base. Graded and washed stones commonly between ¾ inch and 1 ½ inches, used in place of gravel, have between 30 and 35% void space. Thus, to store one inch of water in a structural base of crushed basalt would only require three inches of area.

Figure X. The standing water seen here is actually the high water table revealed during the winter. The finished road surface is only a few inches above this point yet stays dry as water travels through the street section and surrounding soils via interflow, emerging in the banks of pringle creek almost visible in the distnce beside the trees. The surface of the creek is only a foot or two lower than the water table, but sufficient to draw down the water if interflow is not impeded.

Residence time

Storing the one or more inches of water in the base may not be required if the surrounding soils are extremely porous. In such cases water will flow immediately into parent soils, requiring no residence time and no reservoir function in the base. However, such soils are rare. More commonly there will be a need to hold rain water in the section for a certain amount of time, allowing it to gradually seep into surrounding parent soils. The heavier the surrounding soils the longer this might take, and the larger the required reservoir space might become.

Flow within the Section

Highly pervious structural sections will also allow water stored in the reservoir to flow along the section under the pavements. This can be a good thing, allowing rainwater to use the structural section below the pavement like an intermittent stream, facilitating the distribution of water on the site from saturated acres to acres that have better soils or more favorable water table conditions. If streets are steeply sloping this flow can be too fast, reducing the opportunity for rainwater to infiltrate into surrounding soils. In such instances various adjustments can be made. Installing a somewhat less pervious structural base intermittently along the street for example, or simply using impervious pavements for the parts of the site with steep roads, directing that water to the more shallow road gradients below.

What is not a problem

As in all things pertaining to sustainable communities, while the principles are easily accepted, the specific applications of these principles are controversial. No agreement yet exists in the engineering community about the practicality and durability of pervious pavements. These concerns are more extreme in the parts of the continent where winters are cold and freezes are frequent. The vast majority of these concerns are ill founded. The seminal collection of the research on this topic is contained in Bruce Ferguson's book, Pervious Pavements, and the reader is therefore directed to it for elaboration. Here suffice it to say that pervious pavements, if properly installed, do not crumble, and are safe. The first applications of pervious pavements are now over thirty years old and working fine, even in wintery New England. What prevents their use is an inertia built into the industry of paving roads and a fear of assuming liability for changes from accepted norms. Impervious pavement is the accepted norm, and municipal engineers are loath to depart from it for fear of something going wrong. Conventional pavements fail all the time, but because they are accepted "best practices" they are not freighted with risk to approving agents. Fear of risk is the single most intractable implementation barrier to more widespread use of pervious pavements.

34. Research conducted by the US Environmental Protection Agency found that the risks for groundwater contamination are significantly higher with subsurface injection than with surface infiltration (Pitt 2000). This seems to stem from the fact that most stormwater pollutants are more mobile in water than in soil. A large number of studies (see Bulletin No. 13 at http://www.jtc.sala.ubc.ca/bulletbody.html for details) have shown that shallow surface infiltration systems such as bioretention swales, vegetated buffers, and permeable paving are an effective means of removing the vast majority of residential-source stormwater pollutants, preventing their entry into groundwater sources (Condon & Jackson 2006: Bulletin No. 13 http://www.jtc.sala.ubc.ca/bulletbody.html).

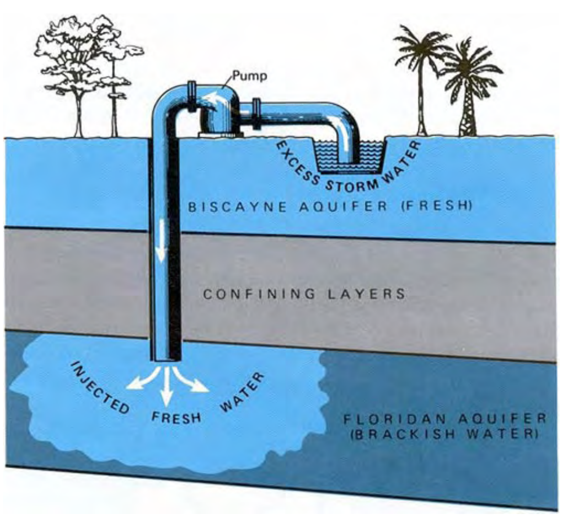


Figure X. This diagram of an injection well in Florida shows how excess stormwater is injected into the groundwater. Obviously such a device has the potential to quickly harm drinking water if regulations are not followed. The problem comes when infiltration streets are held to standards appropriate to this kind of injection system.

Figure X. Construction sites are dirty places, and dirt can quickly destroy investments in pervious pavements. At the Pringle Creek project streets were covered with filter fabric, as can be seen in this photograph, until the most disruptive phases of the site construction were complete.

Water Pollution

Pervious pavements clean pollutants out of urban environments better than pipe systems. The majority of pollutants found in urban environments adhere to dust particles and get trapped in the structural layers below the pavement. In pipe systems all of these pollutants are concentrated and delivered to the fish. Organic pollutants (largely those that come from hydrocarbons like dripping crankcase oil) are particularly well handled by pervious pavements.[34] It appears that the honeycombed structural base/reservoir is an ideal habitat for the bacteria that feed on hydrocarbons, converting them into benign discharges. The exceptions are the completely dissolved pollutants like salt and phosphate. These are not mitigated by the structural base or by surrounding soils, but neither are they more effectively handled by pipe systems. But another warning is in order here. In the US water that is considered "ground water" is more stringently managed than water that is considered "surface waters". In short, you are allowed to do nastier stuff to streams than to soil, even though the water going into the ground is likely ending up in the same place: downstream. The fact that people often drink ground water but not stream water explains the added concern. In most jurisdictions, deep ground water must be potable; no such requirement applies to streams. Ironically and tragically, it is for this reason that preserving watershed function using the strategies discussed herein is disincentivized in many jurisdictions. Happily, in many locations the ground water regulations are being reconsidered for the reasons discussed above; but the changes are slow in coming and geographically spotty. Infiltrating water at the surface is usually acceptable, but there is a grey line between surface infiltration devices and what many regulators call "injection wells". The deeper an infiltration device goes in the ground and the more elaborate is its engineering the more likely it will be declared an "injection well". At the Pringle Creek Community project, State of Oregon regulators approved the infiltration streets, but only after declaring that they could be considered injection wells. If they had been so declared it would have required all water entering them to be "pre-treated". Absurdly this could only be done by capturing and scrubbing rain water before it fell on the pavement. Happily agreement was reached when it was shown that the reservoir layer was relatively shallow and well above the seasonal high water table. This example is provided as a warning of what to watch out for when entering this regulatory maze.

Protection During Construction

There is however one very serious potential weakness with pervious pavements. They can get clogged. If massive amounts of heavy soils are dumped onto the pavements they can fill up and block all the voids in the pavement, impeding or blocking rainwater from flowing through it. In worst case scenarios they can also fill in the voids in the structural base, compromising the storage and infiltration functions as well. The amount of soil required to induce this catastrophic failure is so massive as to constitute a relatively minor concern, except of course during one period: construction. During construction new development sites are notoriously dirty, with silts pouring off torn up landscapes by the ton. If this dirt makes its way to new pervious pavement sections, the storm drainage system function will be compromised. To avoid this consequence requires extra care during site construction. This extra care translates into extra staff hours and consequently into additional cost. At the Salem, Oregon Pringle Creek Community, the contractors, who were contractually responsible for keeping the pervious pavement clean during construction, decided that it was safer to wrap all of the completed streets with filter fabric during the site construction phase, unwrapping them only when the dirtiest parts of the job were done – a very expensive proposition indeed.

Two factors make the added time and expense more acceptable: 1) developers are increasingly required to keep all construction generated silts on site anyway, so the costs for silt containment are already very high, and 2) pervious pavement systems should eliminate the need for any drainage inlet basins, pipes, curbs and other expensive elements of conventional storm systems. Savings from these items can be applied to the cost of the extra care required.[35]

Conveyance

In most cases, pervious pavements do not eliminate the need for conveyance systems. In most parts of North America, if the infiltration target is one inch per day, there will be 10 or 20 days a year when this amount is exceeded. On those days excess water that cannot be absorbed directly through the pervious pavement section must be conveyed to a receiving location. There are two ways to do this, one expensive, one cheap. The expensive way is to include a system of drain inlets in boulevards or street edges to accept and deliver these flows. The cheaper option is to allow these occasional flows to traverse the site overland. On the thirty-acre Pringle Creek site there are no storm water pipes at all. Large flows are conveyed at the edges of pavements, then across the surface of intersections, eventually to find their way to on site artificial wetlands and eventually, and very infrequently, overland to streams. Conveyance systems will be discussed in detail in the next chapter as they are rightfully considered as part of a system or network of human made features intended to emulate the natural network of tributaries in natural watersheds.

35. The United States is currently converting approximately 2 million acres of land from rural to urban every year (Coffman and Clar 2003). Using a conservative estimate of $1000 to $5000/acre to installing stormwater management technologies, the new construction alone costs between $2 and $10 billion annually (Coffman and Clar 2003). When the cost of annual inspections, maintenance, replacement and the cost of retrofitting areas that were developed prior to the existence of the Clean Water Act are taken into account the annual expenditure for stormwater management technology easily surpasses a trillion dollars per year (Coffman and Clar 2003). Urbanized jurisdictions are forced to maintain, inspect, and enforce thousands of miles of pipes and gutters, and tens of thousands of structures (Coffman and Clar 2003). As this infrastructure grows and ages most jurisdictions are reaching the point where they can no longer afford to adequately pay for the upkeep of their stormwater infrastructure (Coffman and Clar 2003). Through evaluating 17 case studies, the US Environmental Protection Agency (2007) found that in most cases significant savings were realized through Low Impact Development (LID) strategies (where small-scale stormwater management practices promote the use of natural systems for infiltration, evapotranspiration, and reuse of rainwater) as opposed to conventional stormwater practices (curbs, gutters and pipes). With few exceptions, total capital cost savings ranged from 15 to 80 percent when LID methods were used. Although it is difficult to directly compare maintenance costs against those of conventional stormwater management practices, some LID site designs, such as maintaining existing sandy soils for their drainage potential, cost nothing.

Figure X. Amble Greene project, Surry BC. Curbless streets allow rain water to flow unimpeded along the entire length into lowered boulevard. Infiltration for most storms occurs in the wide boulevard, enhanced by invisible infiltration galleries below.

Impervious Paved Infiltration Streets.

You can use impervious pavement on travel ways and still have pervious streets; in these instances rainwater is directing to street verges, verges specifically designed to accept and infiltrate rainwater. There are many ways to perform this trick but the following three illustrate the range of options.

Example 1. Amble Greene Community, Surrey B.C.
Most typical residential streets trap water between vertical curbs. Trapped like this, water that should be allowed to infiltrate collects in gutters and flows downhill until it reaches an inlet, leading to a pipe, leading to a bigger pipe, and finally dirty and hot, gets flushed into the stream. Any major metropolitan area contains thousands of miles of vertical curb, every inch of which contributes to the destruction of the watershed and constitute in the aggregate a bonafide environmental disaster. Removing curbs eliminates the problem. Without curbs to block it, rainwater can flow over the lip of pavement into grass or crushed stone verges/boulevards. Rural roads are still built this way, not to preserve watershed function, but because it is by far the cheapest way to build a road. By removing the curb and gently lowering the grassy tree boulevard, broad spaces are made available for infiltrating water. If verges are broad enough and soil conditions favorable enough, the one inch per day infiltration target can be achieved without soil or engineering enhancements. With this system verges need to perform double duty, infiltrating any water that falls on them as well as the water shed by the nearby roadways. As with rain gardens, this becomes increasingly challenging as the percentage of the ROW devoted to soft surfaces decreases. If 20% of the site is available for infiltration this means that each square foot of verge area will have to infiltrate not 1” but 5” in 24 hours. For many soil conditions this is not possible unless engineered infiltration devices and/or soil enhancements are incorporated.

The 1974 Amble Green project in Surrey B.C. provides a good and durable example of this strategy. The curbless streets in this project infiltrate 100% of the water that falls on them. Soil conditions are forgiving but by no means ideal. Nevertheless the project infiltrates not our target of 1” per day but 4”: the amount of rain associated with the 100-year storm event in this city. Project proponents were required to infiltrate all rainwater that fell on the site because of inadequate off site city storm drain interceptors. Broad grassy boulevards located between sidewalks and the curbless streets absorb most of the rainfall, with additional infiltration provided by hidden “French drain” infiltration chambers located below. Occasional “blue-green” infiltration depressions are the fail safe for the plan – large dished areas often in the middle of cul-de-sac bulbs that can hold large amounts of water long enough to eventually infiltrate into soils below. As this project demonstrates, curbless streets save money and do the job; but in the minds of many they have one problem. Without curbs what will prevent parking cars from migrating onto the grass? At Amble Greene this is largely not a problem, but in the few places where it is, owners have arrived at a simple control strategy. Hand placed rocks located at street edge provide sufficient discouragement.

Figure X. Blenham Street, Vancouver, B.C. This street is characteristic of most streets built in the city prior to 1950. Two 7' wide crushed stone paved parking strips astride a 14' two way travel way for a total "curb to curb" width of 28'. Note grading of tree boulevard which effectively prevents cars from migrating onto soft shoulder. Sidewalks are included on both sides, one of which is visible to the right. Total ROW width is 60'.

Example 2. Blenham Street, Vancouver, BC.
While not specifically designed as a green street, this road section is an even more economical and elegant solution to the problem than the one at Amble Greene. Hundreds of older streets in many streetcar cities, particularly in the Vancouver B.C. Region, were built to this standard. Most still exist. Thus there are hundreds of examples of this street type, with over 70 years of performance to assess. These extremely inexpensive streets are queuing streets as discussed in the interconnected streets chapter preceding. Measuring roughly 28' feet from the outside edge of parking bays to the other outside edge, they are comprised of two 6.5' parking bays and one 15' paved two way travel section. The two 6.5' parking strips are paved in crushed stone, which is a cheap and highly pervious surface. Infiltration occurs under the cars, thus the tree boulevards need not dish down to accept water, but can rise higher than the road and parking portion of the section. This subtle landform provides the proper elevational superiority for pedestrian comfort and safety, while preventing cars from migrating onto the grass. It is an extremely beautiful design which should be widely used. Sadly all of the examples of this street type are a legacy of an earlier time. The streets at Pringle Creek are very close to this typology, only differing in that they employ much narrower crushed stone strips at verges with pervious pavements doing the work of infiltration across the whole section rather than in crushed stone beds under parked cars.

Figure X. East Clayton project first phase yard infiltration systems. Disconnected down spots discharge into highly permeable crushed stone layer. Drainage from driveway is shed into grassy areas and thence into infiltration basin below the drain inlet shown.

Example 3. East Clayton, East Clayton, Surrey B.C.
The East Clayton Sustainable community plan was a product of a University of British Columbia/City of Surrey design charrette held in the spring of 1998. Green Street sections agreed to at the charrettes lacked curbs and resembled in function and form the streets of Amble Greene, also located in Surrey. Concerns raised after the Charrette led to a change in the plans. Curbs were added to all streets. To allow for natural infiltration, slots were introduced into curbs to allow channeled water to escape from gutters into lowered tree boulevards. Tree boulevards allowed for infiltration and cleansing before directing excess water to drain inlets above buried infiltration chambers. These

Figure X. East Clayton project first phase street drain systems. Conventional storm drain inlets on streets have been eliminated. Instead rainwater is directed through slotted curb to grassy boulevard, where it can infiltrate and enter infiltration basin under drain inlet. Amounts in excess of infiltration capacity of basin are directed to conventional storm drain pipes to storm drain ponds and then to stream.

Figure X. Foreground streets are rear lanes for the future Pringle Creek development. Thirteen foot wide fire access lane is paved with pervious asphalt bordered by crushed stone infiltration verges. Filter fabric visible at edges contains the crushed stone base preventing migration of soil fines into the reservoir.

infiltration chambers were in turn tied into a subsurface system of pipes, pipes sized in this case for the 100 year storm. The hybrid system that resulted is a fairly literal combination of a green street strategy with a conventional grey street strategy. The one inch per day infiltration target is achieved through ubiquitous infiltration in tree boulevards. Otherwise, with the curbs and substantial subsurface system of pipes it operates conventionally. This approach, in the minds of its proponents, had the advantage of limited risk. Conventional systems provided as part of the plan were robust enough and their function well enough understood that approving agents were comfortable they would not fail in extreme circumstances. The down side was that this "belt and suspenders" system was substantially more costly than either a curbless green street like those at Amble Greene or a conventional street. Contractors estimated that the system cost $5,000 dollars per lot more than conventional street systems, or an additional $120 per foot of frontage.

Lanes

Lanes or rear alleys are a common and important feature of walkable streetcar cities. As discussed in previous chapters, it is almost impossible to have10 to 20 livable and attractive detached housing units per acre without them. Unfortunately they add yet another usually paved surface to contend with, and increase the percentage of land given over to ROWs appreciably. Fortunately the same strategies used to mitigate the impacts of streets can apply to lanes. If lanes are paved they can be either paved with pervious pavements as at Pringle Creek or paved down the center with a narrow band of impervious pavement crowned to shed into pervious verges as in many older parts of Vancouver. Streetcar cities usually devote 20' to laneway ROWs. Of this 12' can be paved leaving 4' on each side for infiltration verges and necessary large storm conveyance. The same strategies for determining the reservoir depth discussed above come into play here. In highly sandy soils the one inch per day can be absorbed under soft verges with relative ease. If parent soils are less forgiving then soft verges need to be underlain with a reservoir that integrates with the structural support for the paved lane. Laneways at Pringle Creek are designed to do this, albeit with the added benefit of pervious pavement for the travel way. Laneways, given that they are where cars are stored off the lane in garages or drives, include many places where verges must be paved. The denser the project and the more garages, the more soft verge will be lost. As the soft verge disappears increasingly heroic strategies for infiltration are required. For this reason, a switch to pervious pavements for lanes may be even more compelling than it is for roads in some projects.

Figure X. Traditonal Vancovuer, BC lane paved with crushed stone. Areas outside of tire tracks have grown over creating healthy root zones for plant growth and associated infiltration.

Finally there is the option to not pave at all. In Vancouver and other North American streetcar cities, lanes were never paved. They were simply resurfaced with a structurally sound granular material, usually crushed basalt or granite. Depending on the minimum size of fines and maintenance protocols, paving lanes with crushed granite or basalt is a low cost highly effective infiltration strategy for laneways. Implementation barriers in the way of this low cost solution include fears about what children might do with the stones, and the need for city maintenance protocols for refreshing and re-grading crushed stone lanes.

Conclusion

At some point our tendency to spend more and more per family on roads must surely end. Overextended infrastructure is already bankrupting some communities and others will follow. Even at the national scale there are problems, with estimates of the unfunded demands for upgrading US highway infrastructure in the 100s of billions; it boggles the mind to consider what that number would be if local infrastructure were included. Certainly a landscape pattern which is overcommitted to the car and under-committed to transit, biking and walking is the root of the problem. But the tendency to build infrastructure in defiance of natural system behaviors is a linked pathology. Street systems seem to have been intentionally designed to be ignorant of natural processes. Unsurprisingly this has caused the destruction of these same systems.

Fortunately this can be corrected. Lighter, greener, cheaper, and smarter infrastructure is certainly conceivable, and in fact already exists. While variations exist across North America, the four rules for green infrastructure are quite simple: infiltrate rather than drain, infiltrate everywhere, infiltrate one inch per day, and heavy soils are good soils. The solutions are not complex - changing behaviors, however, will be. Fundamental shifts will be required in the way the problem is approached, and the people who are at the table trying to solve it. Decision makers must think laterally about the many issues that touch on infrastructure, not just traffic and stream protection. Challenges are even more daunting when we accept the challenge to retrofitting the millions of square miles of existing street infrastructure. Fortunately we have as much time, and energy, and resources at hand, to fix the problem as we had to create it.