Growing with the Flow: Uniting Ecological Design and New Urbanism for Water Quality Planning

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Résumé
Les liens entre la qualité de l'eau et l'aménagement du territoire sont évidents en milieu urbain ou les surfaces imperméable, les contaminants, l'extraction de la végétation, et les formes conventionnelles de gestion et d'ingénierie conduisent à des effets négatifs en ce qui concerne la qualité de l'eau et les bassins versants. Le nouvel urbanisme est considéré comme une option pour contrôler l'étalement urbain ainsi que ses impacts sociaux et environnementaux. Toutefois, les bénéfices du nouvel urbanisme peuvent-être diminués par les effets négatifs de la qualité de l'eau. Cet article examine comment les risques de la qualité de l'eau peuvent-être adressés en combinat le nouvel urbanisme et le design écologique. Il s'agit d'une approche de d'aménagement du territoire qui incorpore les principes et processus du monde naturel pour l'aménagement des communautés et des infrastructures. L'article analyse tout particulièrement les communautés basées sur le nouvel urbanisme dans le sud de l'Ontario. L'étude présente une série de stratégies et d'objectifs qui combine ensemble le nouvel urbanisme et le design écologique concernant la qualité de l'eau.

Mots clés: qualité de l'eau, l'aménagement du territoire, design écologique, nouvel urbanisme, les bassins versants.

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Abstract
The links between land use and water quality are evident in urban settings where impervious surfaces, contaminants, vegetation removal, and conventional forms of planning and engineering lead to negative effects on water quality and watersheds. New urbanism has been lauded as an option for controlling urban sprawl and addressing the resultant social and environmental impacts. However, the benefits of new urbanism can be diminished by negative effects on water quality. This article examines how these water quality risks can be addressed by combining new urbanism with ecological design, a planning approach that incorporates processes and principles from the natural world into the design of human communities and infrastructure. In particular, the possibilities for new urbanism in southern Ontario are focused upon. A series of planning objectives and strategies is outlined through which planners can unite new urbanism and ecological design to address the water quality weaknesses of new urbanism and build on the strengths of these two planning approaches.

Key words: ecological design, new urbanism, water quality, land use planning, watershed planning

Introduction

Land use and water quality are inextricably linked. However, the urban centres in which we reside conceal this relationship. As humans congregate in cities, the combined effects of our communities result in increasingly serious threats to water quality. Substantial landscape change due to urbanization and associated sprawl has occurred during the last half century and is expected to continue through the coming decades (Alberti *et al.* 2007), necessitating a transformation in our approach to planning and development. The planning process faces challenges at a variety of scales in order to address links between land use and water quality in an urban and suburban context (Alberti 1999).

Urban and suburban regions are increasingly developing instruments to deal with sprawl-related threats to water quality. For example, in southern Ontario, policy tools such as the Greenbelt Act (2005), Places to Grow Act (2005), and Provincial Policy Statement (2005) aim to intensify the built form of residences and employment in currently occupied areas and realize the development potential of infill sites and brownfields, rather than building on previously undeveloped greenfields. Southern Ontario municipalities have also adopted different approaches to planning and designing their communities alongside these policy mechanisms. The municipality of Markham is especially renowned for its commitment to building new urbanist communities, and include communities such as Angus Glen, Markham Centre, Wismer

Commons, and famously Cornell (Gordon and Tamminga 2002; Gordon and Vipond 2005; Skaburskis 2006). However, while proponents of new urbanism's neo-traditional design praise its higher gross densities, mixed use, open spaces, decreased automobile traffic, and increased community interactions and bonds (Congress of the New Urbanism 2001; Berke et al. 2003; Gordon and Vipond 2005), new urbanist communities are also cited for high levels of impervious surfaces and difficulties integrating and linking with regional ecosystem planning and restoration (Girling and Kellett 2002; Gordon and Tamminga 2002). Building upon these strengths and addressing these weaknesses regarding urban and suburban water quality requires that new urbanism better integrate ecological processes into its communities.

This article focuses on how the drawbacks of new urbanism for water quality planning and management can be addressed by implementing ecological design, a planning and design approach in which natural processes and principles play the central role. First, I will briefly outline the links between urbanization and decreased water quality in urban and suburban areas. In the second section of this article, the planning approach and goals of new urbanism will be summarized, and associated social, environmental, and water quality strengths and limitations will be reviewed. Thirdly, I will describe ecological design and outline the eight major principles of its implementation. In the fourth section, I suggest a framework composed of planning objectives and strategies that integrate new urbanism and ecological design to address the water quality weakness of new urbanism while building upon the strengths of both these planning approaches. Challenges to the integration of ecological design in urban planning are then highlighted and areas for future study are outlined.

Links Between Urbanization, Water Quality, and Watershed Health

Urbanization exacts a severe toll on water quality and watershed health. The process of urbanization is associated with vegetation clearing, soil compaction, engineered storm water drainage systems, and increases in impermeable surfaces. This leads to increased runoff speed and volume, causing erosion and increased sediment pollution (Arnold and Gibbons 1996; Alberti 1999; Jones *et al.* 2000; Carter et al. 2007). Further to these damages, non-point source pollution from urban sources such as cars, lawns, roads, construction sites, and personal use, results in increased contaminants (Ferguson and Debo 1990, 11; Carter and Jackson 2007). In addition to overall levels of impermeable surface, the patterns in which we build our communities also affect the hydrological cycle and water quality. Such patterns can include the location or connectivity of impervious surfaces and their proximity to water bodies (Jones et al. 2000;

Alberti *et al.* 2007), which can affect the health and cohesiveness of riparian areas vital for slowing runoff and filtering contaminants (Peterjohn and Correll 1984; Ferguson and Debo 1990, 11; Booth and Jackson 1997).

Urbanization also results in habitat fragmentation, decreased connectivity, increased edge effects, and degraded water quality due to de-vegetated, unconnected land cover and greater levels of impervious surface (Conway and Lathrop 2005). The impervious surface levels of urban areas are so consistently destructive to aquatic habitat and their associated ecological services, that the effects are sometimes referred to as "urban stream syndrome" (Walsh et al. 2005). Exceeding a threshold of 10 per cent to 25 per cent impervious cover can impact aquatic ecosystems (Schueler 1994; Arnold and Gibbons 1996; Booth and Jackson 1997) and even moderately developed watersheds can reach these levels, with large lot residential areas consisting of 12 per cent to 40 per cent impervious surface and more intense commercial and industrial land, such as shopping centers, reaching over 90 per cent impervious surface (Berke *et al.* 2003; Hough 2004, 2). Thus, urbanization influences the connection between natural habitats, vegetation, water quality, and overall watershed health.

New Urbanism: Strengths and Weaknesses for Water Quality Planning

New urbanism attempts to offer an alternative to the automobile-centric subdivisions at the root of urban sprawl. It adopts a neo-traditional perspective which takes pre modern-zoning era towns as its inspiration and advocates compact, mixed-use, pedestrian-friendly styles of community planning in order to achieve social and environmental sustainability (Katz 1994, x). New urbanism seeks to create closely knit, dynamic, diverse, and interesting communities rather than the amalgamation of homogenous single-use houses that are found in conventional North American subdivisions. To this end, there is an emphasis on a human-scaled public realm in which diverse community members are encouraged to gather and the basic unit of planning is the neighbourhood (Congress for the New Urbanism 2001). Ideally, the diversity of housing suits a variety of economic and social needs, with mixed land uses breaking down conventional boundaries that normally segregate residents of varying incomes, backgrounds, and life stages, instead encouraging and strengthening community bonds and identity (Congress of the New Urbanism 2001; Berke *et al.* 2003; Grant 2006; Tomalty and Haider 2010). Wide sidewalks, cycling paths, and streetscapes that are suited for humans rather than automobiles support walking and cycling as feasible modes of transportation. Reduced automobile reliance allows narrower roads, parking lots, driveways, and other car-related impervious surfaces, although a highly connective road network is also a new urbanist feature. These communities also aim for higher density neighbourhoods through compact built form and the elimination or reduction of prominent garages, yards, and lot size. This allows for maximum open public space while increasing population densities. Prominent, quality public spaces are designed to facilitate community interactions and further encourage pedestrian-oriented mobility (Katz 1994, xxv-xxx; Berke et al. 2003; Tomalty and Haider 2010).

New urbanist design frequently results in social and resident benefits. In their comparison of new urbanist and conventional development communities in Canada, Tomalty and Haider (2010) found better pedestrian connectivity, a greater percentage of streets with sidewalks, greater perceptions of street safety and convenience for walking and cycling, and greater resident satisfaction with the physical design of streets, landscaping, and façades in new urbanist neighbourhoods. These social benefits can also result in environmental benefits, notably water quality protection. The emphasis on substantial open spaces and compact high-density built form makes large permeable surfaces and the restoration and preservation of riparian areas, wetlands, forest, and other ecologically important habitat more feasible (Gordon and Tamminga 2002). Reduced roads and driveways further decrease impervious surfaces and discourage the use of polluting cars. Minimal private yards result in less conventional lawn cover and associated irrigation, pesticide, and fertilizer use. These compact, high-density communities also counteract the expansive and consumptive nature of conventional subdivisions which lie at the heart of urban sprawl, allowing the preservation of larger open areas devoted to forests, agriculture, or ecologically sensitive habitat (Berke *et al.* 2003).

However, the theory and practice of new urbanism's social goals can differ and sometimes fall short (Grant and Bohdanow 2008). While some have found that new urbanist neighbourhoods reported a higher sense of community than traditional suburban and/or post-World War II neighbourhoods (Kim and Kaplan 2004; Youngentob and Hostetler 2005), others do not find such a direct correlation between form and social connectivity (Talen 1999). Lund (2003) does indicate that the parks, retail shops, and pedestrian-friendly neighbourhoods and streets of new urbanist communities do contribute to increased pedestrian travel and community interactions, but notes that demographics, resident attitudes, and perceptions of the local environment are significant factors which also affect levels of walking, interactions, and community dynamics. While there can be almost double the number of stores and services in the community centre versus conventional developments (Tomalty and Haider 2010), new urbanist communities sometimes have difficulty drawing in commercial interests—particularly non-franchised independent ones which are often viewed as characteristic of neo-traditional "towns"—as well as confronting resident resistance to non-traditional suburban work-live-play arrangements (Grant 2002). Furthermore, while new urbanist rhetoric speaks of diverse mixed communities, in reality, these neighbourhoods are often critiqued for exhibiting a narrow, homogenous, upper-middle class population (Al-Hindi 2001) and reinforcing associated values, amenities, and traditional suburban interests disguised as "sustainability" (Zimmerman 2001). Finally, Grant (2006) suggests that residents may be unwilling to accept smaller residences in exchange for the greater social and environmental responsibility that new urbanism implies.

Similarly, despite claims touting the neo-traditional planning style as a sustainable alternative to conventional development and a solution to the environmental impacts of urban sprawl, this assertion has not always played out either in principle or in practice. Berke (2002) notes that of the twenty-seven principles listed in the *Charter of the New Urbanism* (Congress for the New Urbanism 2001) which guide planning at the regional, neighbourhood, and block scale, none of the neighbourhood and block principles specifically address the maintenance or restoration of ecosystem health and associated ecosystem services, instead focusing on the use of open space and conservation areas as a mechanism for delineating and connecting neighbourhoods. As well, despite Youngentob and Hostetler (2005) finding a deeper sense of community in neo-traditional neighbourhoods, they also found that such communities exhibited decreased environmental behaviours, attitudes, and knowledge compared to traditional and post-World War II communities. In her study of new urbanist communities in Southern Ontario, Conway (2009) shows that the higher road densities of new urbanist communities—which are a key characteristic that facilitates increased road connectivity (Tomalty and Haider 2010)—were correlated with lower levels of vegetation on residential properties. As well, while Tomalty and Haider (2010) note that more new urbanist residents report a decline in their car use versus residents of conventional developments, new urbanist communities are often located on suburban greenfields resulting in criticisms that these communities are an excuse for placing suburban residences on smaller lots, thus resulting in high-density urban sprawl (Grant 2002; Conway 2009).

This planning approach can also disregard specific water quality issues posed by urbanized sites and watersheds, and the resultant neighbourhoods demonstrate this attitude (Berke *et al.* 2003). New urbanist neighbourhoods, which entail mixed-land use and higher housing densities, possess a substantially higher Total Impervious Area (TIA) than similarly sized conventional subdivision communities (Arnold and Gibbons 1996; Alberti 1999; Girling and Kellett 2002; Alberti *et al.* 2007). This is partially due to non-automobile forms of paving such as increased sidewalks, cyclist and pedestrian pathways, and narrower but more extensive road networks with higher connectivity

(Berke *et al*. 2003). Therefore, while single family residential lots pose an inefficient use of space and resources, they often demonstrate a lower percentage of impervious surface of approximately 40 per cent TIA or less, compared to new urbanist communities which may exhibit 50 per cent TIA or more (Girling and Kellett 2002). However, multi-family parcels can accommodate a much larger number of households and Girling and Kellett (2002) find that a new urbanist style neighbourhood can display a stormwater peak flow of 0.075 cubic feet per second per household, compared with 0.12 cubic feet per second per household in a conventional subdivision. Similarly, in a modelling exercise comparing high density and standard suburban developments, Jacob and Lopez (2009) state that while total runoff volume and per acre loadings of total phosphorus, nitrogen, and suspended solids increased with density, per capita loadings and runoff decreased with density. However, in many cases, both lower and higher density communities still result in impermeable surface levels higher than the 10 per cent to 25 per cent TIA threshold which results in degraded streams and water quality (Schueler 1994; Arnold and Gibbons 1996). Jacob and Lopez (2009) also warn that higher density communities which have lower per capita runoff and pollutant loadings, will still result in a much greater total pollutant load than lower density developments if development is extended over an entire watershed, highlighting the continued need for protection of open space.

Although greenways are often used to provide pedestrian and cycling connections within the community, the emphasis on non-motorized forms of transportation means that new urbanist communities are also more likely than conventional developments to include impervious paths and trails through greenways to accommodate pedestrians and cyclists. In addition, about three-quarter of Canada's new urbanist developments are located on greenfields in suburban or ex-urban areas rather than urban infill sites, are unconnected to other communities, and far from efficient public transportation, thus remaining dependent on automobiles (Berke *et al.* 2003; Grant and Bohdanow 2008). This greenfield development contributes to the loss of vegetated permeable space and degradation of associated habitat, ecological services, and watershed health. New urbanist communities also continue to use conventional stormwater systems which speed water away from the landscape using engineered solutions that ignore natural processes (Girling and Kellett 2002; Bohdanow 2007). However, in their study of infiltration and runoff rates between conventional curvilinear, urban cluster, coving, and new urbanist communities, Brander et al. (2004) finds that although urban cluster layouts displayed the lowest runoff rates, differences between the community types decreased as an increasing number of infiltration practices were implemented. Therefore, working with ecological processes, rather than against them, offers some promise for addressing the environmental drawbacks associated with new urbanism.

Principles of Ecological Design

In order to address water quality problems caused by urbanization, planners are increasingly integrating human and ecological systems. This union can be achieved through the application of ecological design, an approach which incorporates ecological processes and principles into the planning and design of human cities, communities, infrastructure, agriculture, and industry (Hough 2004, p 15-25; Todd 2005). The goal of ecological design is two-fold: (1) to restore ecosystems that have been disturbed or degraded by human activities, and (2) the development of new sustainable ecosystems that have both human and ecological value, are achieved by sensitively integrating human purposes with the larger patterns and flows of the natural world, and that allow the study of those patterns and flows to inform human action (Van Der Ryn and Cowan 1996, 17-18; Mitsch and Jorgensen 2004, 23; Orr 2002, 20). In an urban context, the successful incorporation of ecological design would fulfill Register's (1987) vision of the ecocity which seeks to rebuild cities "to fit gracefully, non-destructively, even regeneratively into their bioregions" in order to achieve the goals of (1) fuller creative evolution of society and the individual; and (2) healthy coevolution and mutual support with nature" (Register 1987, 7-8).

The implementation of ecological design can take numerous forms and incorporate a multitude of techniques and approaches. Various characteristics of ecological design have been set forth by scholars and practitioners including McHarg (1969), Todd and Todd (1994, 1996, 2003, 2005), Van Der Ryn and Cowan (1996), McDonough and Braungart (2002), Orr (2002), Hough (2004), Mitsch and Jorgensen (2004), and others. The preceding literature and associated case studies were reviewed for common themes that describe the processes, concepts and essence of ecological design. Upon an initial review of the themes that emerged, certain concepts which shared sufficient commonalities were merged. For example, McDonough and Braungart's (2002, 59) criticisms of societal expectations that technological advancements will solve ecological crises, was amalgamated with calls for full-cost accounting (Van Der Ryn and Cowan 1996, 82, 93) into "8) Questioning our current technological state." This review indicates that eight ecological design principles consistently emerge which can be applied to community planning for water quality.

1) Planning for Place

The qualities and context of a site or place, such as its climate, topography, soil, or culture, will determine the shape the community should take (McDonough and Braungart 2002, 29; Hough 2004, 15; Lovell and Johnston 2009). Planning and design must respect and exalt a site's characteristics, while acknowledging and fitting into larger context (See Principle 4: Taking a systems approach).

Planning for place necessitates the consideration of multiple context and scales. Pickett and Cadenasso (2008) state that good ecological design is not an end in itself, but must also fit into a geographical and social context. However, while ecological design suggests that we size our designs to achieve a more human scale (Orr 2002, 8; Van Der Ryn and Cowan 1996, 68), it also necessitates an awareness of larger regional contexts, such as a host watershed (Royal Commission 1992; Hough, 2004, 19).

2) Working with Natural Processes

Even in urban settings, our society is supported by surrounding natural processes. Planning must acknowledge this interdependence and learn to incorporate natural processes into all facets of life. For example, practitioners assert that by supporting the capacities of wetlands to provide water filtration, temperature moderation, flood control, and food production, we can help meet our own needs while still respecting the needs of non-human species (Todd and Todd 1994, 64-68; Alberti and Marzluff 2004).

Ecological design can also take more engineered, human-ecological hybrid forms, such as the Living Machine systems designed by John Todd of the University of Vermont and Ocean Arks International for use in industrial and residential wastewater treatment (Todd and Josephson, 1996; Todd et al. 2003; Todd, 2005, 170-176). Living Machines and other solar aquatic systems consist of a linked series tanks containing aerobic and anaerobic aquatic ecosystems, and which utilize the natural processes present in each of the ecosystems to treat water to high, sometimes tertiary, standards. Periodic pulses or perturbations of the newly developing ecosystems, such as changes in light regimes or water flow, provide disturbances similar to those found in nature, thus encouraging the ecological technologies to become robust enough to survive the inevitable failure of some of the system's components (Todd and Josephson, 1996; Mitsch and Jorgensen, 2004, 95). This approach to wastewater treatment makes use of the inherent natural processes found in various ecosystems and species while incorporating built form and human influence.

3) Making Natural Processes Visible

Conventional planning obscures the natural processes that surround us, leading to our failure to visualize and appreciate the effects of our actions on the environment. This is evident in the visible interruption of the hydrological cycle by curbs, storm sewers, and treatment plants. By making these processes visibly and physically apparent, ecological design seeks to help humans better understand the consequences of our and revel in the natural world that we inhabit (Van Der Ryn and Cowan 1996, 164-165; Hough 2004, 23; May, 2006).

As an extension of this principle, Brown, Harness, and Johnston (1998), and later Lovell and Johnston (2009), advocate the use of "eco-revelatory design" to focus attention on natural processes, encourage their preservation and maintenance, and underscore and communicate the cultural values of nature that are reproduced on the landscape.

Village Homes in Davis, California is renowned for encouraging both a sense of community, and energy and natural resource conservation. Most houses in the community face onto vegetated common areas and paths rather than streets, reinforcing the focus on pedestrian and bike travel, the relevance of quality vegetation and permeable surfaces, and making alternate forms of land cover apparent to residents. The community's drainage system also maximizes permeable vegetated surfaces and extends throughout community common areas, with the land being contoured to capture and direct most runoff through a network of creek beds, swales, and pond areas, and allowing rainwater to infiltrate the soil rather than be conveyed through storm drains. In addition to storing moisture and filtering contaminants from runoff, this network provides a visually attractive landscape design and makes stormwater processes visible and aesthetically interesting to residents (Jackson 1999; Francis 2002; Village Homes 2008).

4) Taking a Systems Approach

A holistic viewpoint is required to truly understand the relationships within and between ecosystems, as well as the interactions between the natural world and human cities, societies, and economies (Todd and Josephson 1996; Van Der Ryn and Cowan 1996, 137; Mitsch and Jorgensen 2004, 27-35; Todd 2005, 162-163). For instance, while Principle Two suggests that we work with the filtration capabilities of wetlands, overloading a wetland with upstream contaminants can cause severe damage to this ecosystem (Helfield and Diamond 1997). Instead, contaminant sources and loadings from the entire watershed are taken into account and addressed. For example, in their study of water quality in Chesapeake Bay, Cadenasso et al. (2008) find that the city of Baltimore's focus on maintaining and enhancing riparian areas was insufficient for reducing nitrate pollution and instead watershed-scale planning was required. A systems approach also acknowledges the links between water quality and water quantity issues.

There are also systemic links between social and ecological wellbeing. The Royal Commission on the Future of the Toronto Waterfront (1992) notes that while "Conventional development often sweeps the past aside in favour of all that is new and modern" instead "the natural topography and countryside can be used to define urban form, ensuring a sense of continuity with the past and maintaining valued elements of the landscape (Royal Commission 1992, 78-79). Thus, good planning acknowledges the relationship between environmental and cultural histories and continuously links human and non-human landscapes.

5) Diversity

A diversity of species, ecosystems, cultures, businesses, and technologies sets the stage for healthy, dynamic ecosystems and human communities (Van Der Ryn and Cowan 1996, 124; Hough 2004, 19; Mitsch and Jorgensen 2004, 95) and ecological design advocates a diversity of ecological, production, and cultural functions such as managing water quality and quantity, waste management and recycling, and food production (Lovell and Johnston 2009). When incorporated into human communities or infrastructure, more diverse ecosystems tend to maintain their health better than monocultures, thus necessitating less maintenance and financial outlay (Wells and Yeang 2010). Biodiverse designs can also effect positive impacts on humans and their wellbeing. Fuller et al. (2007) finds greater physical and psychological benefits were accrued to the users of more biodiverse urban greenspaces than those who utilized greenspaces with less species richness. As well, the more diverse and complex a food web or ecosystem is, the greater the degree of resilience in the face of outside forces or stressors (Fischer et al. 2006; Lovell and Johnston 2009; Wells and Yeang 2010).

6) Self-design

Ecological design recognizes that ecosystems are dynamic and changing, and it makes use of the capacity of ecosystems and human communities to evolve, respond, and self-design in reaction to external pressures (Hough 2004, 15; Mitsch and Jorgensen 2004, p.23; p.27-35). Working with such systems can also result in lower energy costs for system maintenance than those "managed" by humans (Mitsch and Jorgensen 2004, 95). This is exemplified by plans to allow the Don River in Toronto, Ontario to resume its delta-building tendencies to provide flood protection and wildlife habitat, rather than maintain the expensive annual dredging process (Royal Commission 1992).

The city also has an evolutionary process that changes and adapts to unforeseen economic and social conditions over time and self-design can be found among and planned for in human communities and systems. Often the planning process and its associated by-laws, codes, and regulations conflict with the organic process in which people modify and shape their own living environments (Jacobs 1961; Hough 2004, 16). Planning and design in a human context is shaped by powerful political and economic forces. Ecological design asserts that is in response to these outside forces, communities and cities often employ local knowledge and materials to create, build, and maintain their places, self-designing from within. As well, since ecological design typically unfolds over many years or even decades, it is imperative that it co-evolve with the wishes of its future stewards (Van Der Ryn and Cowan 1996, 152-153), underscoring the importance of planning for flexibility and allowing the public sufficient space and opportunity for future changes as they organize their own places over time.

7) Exploiting Opportunities Created by Nature and Society

The elimination of "waste" requires that we change our systems of production so that the unwanted products of one life cycle become the requirements for another (Todd and Todd 1994, 69-74; Van Der Ryn and Cowan 1996, 105-107; Hough 2004, 22). The common tendency is to regard environmentally sensitive design as a mitigative process which minimizes the destruction of physical and life systems, thus suggesting an acceptance of negative values and implying that some loss, wastage, or disruption to the environment is inevitable**.** However, by creatively making use of all opportunities and fully integrating all ecological and human processes to eliminate wastage, ecological design sets the stage for true sustainability and reorganizes human developmental processes so that they contribute to the environments that they depend on (McDonough and Braungart 2002, 53-55, 72; Hough 2004, 22).

8) Questioning our Current Technological State

Instead of expecting that ecological crises will be solved through technological advances, ecological design questions the normative assumptions we hold about our current societal and economic systems to better understand their consequences and alternatives (Van Der Ryn and Cowan 1996, 4-5; McDonough and Braungart 2002, 59). In order to answer these questions, ecological design compels us to better understand the full impact of the materials and processes we use. These impacts can include acres of degraded land, kilowatt-hours of energy, gallons of water, pounds of eroded soil, and the other environmental impacts inherent in design. Using life cycle analysis, the impacts of various stages of economic activity—from resource extraction through to manufacturing, distributing, retailing, consuming, and discarding —are revealed, giving planners and society the power to make more ecologically sound choices (McDonough and Braungart 2002, 38; Van Der Ryn and Cowan 1996, 82, 93).

Uniting Ecological Design and New Urbanism: Planning Guidelines

While some planning approaches and policies attempt to address the environmental pressures that arise from resource intensive lifestyles and communities, multiple barriers remain. Policy tools have emerged to protect green space and encourage infill development and intensification, but do little to improve watersheds which are already developed. As well, although some watersheds are bounded by administrative boundaries—such as some rivers in the Greater Toronto Area which are under the governance of the Toronto and Region Conservation Authority (Toronto and Region Conservation 2012)—watersheds are also crosscut by political borders with increased cooperation and coordination being required if we are to address the upstream factors that are vital for water quality. Tackling these dilemmas require that planners question long held assumptions and transform their approaches to planning cities and communities. New urbanism and related styles of planning have been lauded as tools to address urban sprawl but demonstrate a stronger focus on social benefits and such communities remain high in impervious surfaces. However, many of the water quality weaknesses inherent to new urbanism can be addressed, and its benefits maximized, when combined with ecological design.

Uniting ecological design and new urbanism can result in dynamic, enriching communities which integrate and care for the land, water, and human and non-human life alike at both the local and watershed level. These planning approaches allow for a cohesive model that builds on each framework's strengths. To this end, I suggest that the principles of ecological design be utilized to address the weakness of new urbanism—mainly a propensity for greenfield development, a homogenization of the physical and hydrological landscape, development that is not suited to the hydrological limits of the landscape, and a high degree of impermeable surfaces—as well as build on the potential strengths of new urbanism—such as its focus on large public spaces which can be utilized to integrate social and ecological health, and better connect communities with the larger watershed context. These principles are further supplemented by the fields of sustainable stormwater management and eco-revelatory design and hydrology. I offer a framework composed of four major planning objectives, with each objective implemented by specific design strategies and through which the principles of ecological design are woven **(Table 1).**

Table 1: Objectives and Design Strategies for Integrating New Urbanism and Ecological Design

Objective 1: Site Selection
Objective 2: Maintaining and enhancing the environmental features and social assets of a site
Strategy 2a: Restore hydrological patterns by designing for place
Strategy 2b: Tailor water use to respect local water and ecological resources
Strategy 2c: Design for the aesthetic, educational, and recreational use of water
Objective 3: Using ecological design to address the impermeable surface issues inherent in new urbanism
Strategy 3a: Fit land cover to its intended use
Strategy 3b: Use materials that benefit the larger environment
Objective 4: Building on the strengths of ecological design and new urbanism
Strategy 4a: Maximize the potential of open public space
Strategy 4b: Design for flexibility

Before questioning our current technological state when applied to materials and techniques, planning must challenge the perception that all sites are appropriate for development. Many unprotected sites still possess high ecological or cultural values, both in their own right and within a larger ecosystem, watershed, or community. At such locations, even "sustainable" development can be harmful and should be limited, with development instead focusing on sites that offer easy access to resources and infrastructure, such as public transportation, reducing the need for impervious roads and resultant water pollutants produced by cars (Thompson and Sorvig 2000, 54, 175-176). This issue has been advanced by legislation such as Ontario's *Green Belt Act* (2005), which serves to protect important agricultural land and green space surrounding the Greater Toronto Area. Yet urban sprawl, fuelled by demands for conventional North American forms of housing and communities, often leapfrogs these limits and continues unimpeded on the other side (Neptis Foundation 2005; Gombu 2007). The futility of limiting sprawl in this manner emphasizes the need to make good use of infill sites. In southern Ontario, policies such as the *Places to Grow Act* (2005) and the *Provincial Policy Statement* (2005), encourage brownfield or infill development, an approach which also exploits the opportunities posed by "waste" sites for important social and environmental benefits.

Similarly, new urbanist communities, no matter how compact or efficient, can present similar or heightened water quality pitfalls compared to conventional developments. These can occur if new urbanist sites are located on vegetated, previously undeveloped sites, especially when those sites are disconnected from other communities, workplaces, services, and public transportation. Such planning exemplifies the underlying flaws of planning out of context. The overarching influence of ecological design on the location of new urbanist communities questions the assumption that a "sustainable" community is independent of the larger landscape and context in which it is placed, instead viewing it as an integral part of a larger system or watershed. This concept is extended by Register (1987) who suggests a complete rebuilding of communities to remedy the severe water, landscape, and climatic impacts of car-dependent sprawl.

Once an appropriate site has been selected, the integration of new urbanism with ecological design can serve to protect and even enrich the qualities of a site that make it valuable for water quality at both ecological and social dimensions. These subsequent strategies can also be applied to existing new urbanist communities.

Objective 2: Maintaining and Enhancing the Environmental Features and Social Assets of a Site

New urbanism's emphasis on public space and strong community ties can be successfully translated into a means of acknowledging, protecting, and restoring important site features when combined with ecological design. This can be addressed through three specific strategies: restoring hydrological patterns by planning for place; tailoring water use to respect local water resources; and emphasizing the aesthetic, educational, and recreational aspects of water.

Strategy 2a: Restore hydrological patterns by designing for place

Rather than homogenize the landscape, maintenance of ecological and hydrological services requires the protection and enhancement of the inherent natural processes that are a part of a site, such as wetlands, streams, riparian zones, and other important areas of vegetation. Even where no wetlands or surface water bodies are present, existing drainage patterns should be maintained or re-established. If new patterns are created, they should be designed to correspond as closely as possible to natural patterns, allowing water to be retained and absorbed into the soil at a similar rate to natural conditions (Thompson and Sorvig 2000, 30-32; Lovell and Johnston 2009).

Strategy 2b: Tailor water use to respect local water and ecological resources

Recognizing the local and regional water resource limits of a site and maximizing its use relies heavily on the intimate landscape knowledge required by planning for place. Instead of forcing inappropriate vegetation or development where it is unsupportable by local water supplies, planning for place acknowledges both the hydrological limits of a site and the mechanisms that have already evolved there in response to native water levels. This approach advocates recognition of the natural processes through which certain species of vegetation have evolved in conjunction with their location, as well as encouraging attention to the qualities of a place that make it unique (Van Der Ryn and Cowan 1996, 42; Thompson and Sorvig 2000, 159-160; Lovell and Johnston, 2009). Promoting the cultivation of quality, native vegetation is doubly beneficial in that it increases permeable surfaces, stabilizes soil, prevents erosion from runoff, filters contaminants through the vegetation itself and through the microbial communities that inhabit its root zones, and eliminates the pesticides, fertilizers, and excessive water use required to sustain a grass lawn. A variety of vegetation provides visual interest for residents and offers a more robust, healthy lawn system that better responds to changing temperature and precipitation (Bormann et al. 1993, 62; Girling and Kellett 2002). This approach to vegetation can be complemented by harvesting rainwater using the contours of the landscape, thus utilizing precipitation as a resource and challenging the idea that water must be removed quickly from a site through conventionally engineered stormwater systems (Thompson and Sorvig 2000, 70-72).

Strategy 2c: Design for the aesthetic, educational, and recreational use of water

Water also serves aesthetic purposes. Although the playful movement and shimmering beauty of water provides sensory pleasure, designs often waste treated water and exacerbate the public perception that water supplies are secure, limitless, and unthreatened by contamination or overuse (Thompson and Sorvig 2000, 135; Hough 2004, 33). As well, aesthetic uses of water remain separate from its functional uses, skewing the perceived value of this resource. However, rather than denying citizens the delightful sensations that water can provide, ecological design emphasizes the links between water use and water supply, and exploits the presence of water for both utilitarian and pleasurable purposes (Hough 2004, 37; May 2009). Working with the landscape and allowing water to flow through communities after rainfall provides visual interest, as exemplified by the infiltration and water storage system at Village Homes (Francis 2002; Village Homes 2008), thus recharging groundwater supplies, supporting vegetation and wildlife, and making clear the links between water use and water availability

(Hough 2004, 72-76). Making these natural processes visible can be especially effective in new urbanist communities which are already designed to encourage resident contact in public spaces, consequently ensuring that the maximum number of people will witness and interact with these processes. To ensure appropriateness of context, Cadenasso et al. (2008) call for an analysis of how ecological design fits into the specific physical attributes, social structure, and values of neighbourhoods. This includes an examination of demographic composition such as density, gender, age, ethnicity, income, education, and national origin of residents, as well as resident preferences regarding design options.

Objective 3: Using Ecological Design to Address the Impermeable Surface Issues Inherent in New Urbanism

A major weakness of the new urbanist approach regarding water quality is the high level of impermeable surfaces present. However, considering new urbanism's capacity to accommodate more residents than conventional subdivisions —and associated lower per capita runoff rates—addressing these impermeability concerns could result in a dramatic increase of water quality benefits. This challenge can be achieved through two strategies: Fitting land cover to its intended use; and using materials that benefit the wider environment.

Strategy 3a: Fit land cover to its intended use

Ecological design questions whether all transportation—related surfaces—including roads, sidewalks, paths, or parking lots—must be covered with impermeable surfaces. Instead, fitting paving materials to their intended use can contribute to a more permeable land cover by working with and maximizing the natural infiltration abilities of soil and the landscape. Though a large proportion of impermeable surfaces in new urbanist communities can be attributed to paved paths and sidewalks (Girling and Kellett 2002), the removal of sidewalks could result in safety concerns and decreased pedestrian traffic. However, while residents will demand that highly trafficked sidewalks and paths are durable, safe, and easy to travel, these needs do not preclude the use of surfaces that are more permeable than asphalt or concrete. Ecological design utilizes the stability and permeability of different materials, matching the appropriate properties to their intended use and questioning the idea that all trafficked surfaces require identical levels of imperviousness. Despite the decreased durability of permeable pavement for highly travelled roadways when compared to asphalt or concrete (Berke *et al.* 2003), minor roads, sidewalks, and well-used paths and parking areas are an appropriate use of this material. Meanwhile, rarely used parking areas, less travelled paths or those intended for recreational hiking or cycling can be covered with highly permeable materials such as gravel, mulch, wood chips, or grass (Thompson and Sorvig 2000, 180-186).

Strategy 3b: Use materials that benefit the larger environment

Ecological design can take the above strategy even further by using materials or techniques that actively benefit not only water quality, but also the wider environment. Examples include replacing conventional roofing materials with green roofs covered in native plants to filter and slow runoff (McDonough and Braungart 2002, 74, 82-83). Similarly, shunning monoculture grass lawns in favour of diverse and site-appropriate lawn cover not only reduces or eliminates pesticide, fertilizer, and excessive water use, but also enhances the overall environment by providing increased visual interest and wildlife habitat (Bormann *et al.* 1993, 62; Girling and Kellett 2002). Since a large proportion of permeable surfaces in new urbanist developments consist of turf lawns, these recommendations are particularly applicable. Therefore, while artificial or human-made materials may suit certain purposes, ecological design looks to appropriate living materials and systems to exploit their flexible characteristics and regenerative, self-designing abilities.

Objective 4: Building on the Strengths of Ecological Design and New Urbanism

New urbanism already offers several water quality benefits not available in a conventionally-planned community. These include a walkable community with reduced automobile use and the preservation of higher levels of natural land cover, forests and agricultural areas than a lower density community spread over a larger area. The emphasis on large, open public spaces is a particular opportunity that can be successfully exploited to combine new urbanism with ecological design and maximize its potential for water quality protection and enhancement. Open space also offers flexibility for future planning and, when combined with new urbanism's high density housing, workplaces, services, and other amenities, presents an ideal template on which to plan and design both locally and within a watershed context. This objective can be achieved through the following strategies: Maximizing the potential of open public spaces; designing for flexibility; and designing for a watershed context.

Strategy 4a: Maximize the potential of open public spaces

At a smaller site-specific scale, the substantial public areas present in new urbanist communities provide a canvas on which natural processes can be utilized to preserve and enhance water quality. Undeveloped areas on-site provide space to preserve or re-establish living systems, such as wetlands or forests, and the ecological services they provide. It also provides space for remediative strategies, such as bioswales to slow and filter runoff from existing impermeable surfaces. In addition, open space allows the maximization of water's aesthetic, recreational, educational, and functional potential, and can include strategies such as stormwater basins, wetlands, or stormwater fountains which flow after rain. Siting public spaces around existing natural systems serve to visually and experientially highlight them for residents, ensuring that community members interact with and learn from the natural processes surrounding their home and making these phenomena a social centre of the community (Hough 2004). Quality open spaces also provide community character and ties by replacing front lawns—which lack community use or meaning—with quality public space in which neighbours can meet, children can play, and community business can be conducted (The Congress of New Urbanism 2001).

The open spaces of new urbanist communities can also provide the space and flexibility for the preservation and restoration of hydrological patterns and landscape infiltration capacities, offering an ecological alternative to traditional stormwater management methods (Girling and Kellett 2002; Berke *et al.* 2003; Åstebøl et al. 2004; May 2009). These methods can be economically attractive, since working with and enhancing the natural processes found on-site is sometimes more cost effective than conventional forms of conveyance using pipes, sewers, and other traditional materials and techniques (Girling and Kellett 2002).

Strategy 4b: Design for flexibility

New urbanism's focus on public space rather than private lawns, also has implications for the way that citizens relate to and interact with place, its natural processes, and each other. Large public spaces provide an elasticity which current and future residents can work with as they design and redesign their communities as populations and needs change and in response to their surroundings and outside influences (Van Der Ryn and Cowan 1996, 152-153; Hough 2004, 16). This flexibility allows the incorporation of new landscape features and vegetation as climate, species, or water conditions change.

Strategy 4c: Design for a watershed context

The parks, greens, and squares found in new urbanist neighbourhoods provide a larger, more comprehensive ecological sphere than private front lawns in which the public can engage with the natural processes surrounding and sustaining them. Substantial public areas provide landscape-scale flexibility and encourage links between smaller-scale, site-specific water quality planning and effects at a larger spatial scale, making new urbanism an ideal component of watershed planning (Gordon and Tamminga 2002). At both the local and watershed dimension, a large open area that provides quality vegetation and habitat is more ecologically valuable than many small permeable areas (such as turf-covered yards) spread over the same site (Conway and Lathrop 2005). New urbanism's emphasis on significant open public spaces allows the space and flexibility for integrating the community into watershed-scale improvements, such as protecting or restoring extensive wetland and riparian areas or integrating natural drainage patterns and networks into urban centers (Girling and Kellett 2002). For example, the City of Markham initiated its Natural Features Study (NFS) in 1993 to guide the building and expansion of new developments, including several new urbanist communities. This resulted in regional environmental policies such as a greenway system, watershed and sub-watershed planning strategies (Tamminga 1996; Gordon and Tamminga 2002), and a comprehensive landowner stewardship program including public education and participation in decision making (Hough 2004, 241-246). In particular, the community of Cornell is noted both for incorporating and protecting woodlots and small steams into its Secondary Plan, and also for using regional-scale natural features highlighted by the NFS to delineate its perimeter and re-link a large woodlot within the community with a restored natural regional network (Gordon and Tamminga 2002). It is also vital to heed Jacob and Lopez's (2009) warning that higher density communities spread over an entire watershed will result in significantly greater runoff and pollutant loadings than a lower density community over the same area.

Planning for a watershed context is a vital design goal, since any wetlands (whether constructed or naturally-occurring), basins, vegetation, or other manifestations of ecological design will simply be an end-of-pipe solution if the fundamental land-use problems which create pollution and high runoff volumes are not eliminated (Helfield and Diamond 1997). For example, the Royal Commission (1992) notes that "Just as the people of the Greater Toronto region are linked to their waterfront, so the health and life of the waterfront depend on the region" with the quality of the waterways that feed the city's waterfront being influenced by upstream factors affecting their watershed (Royal Commission 1992, 20). Thus, there remains a critical role for various levels of government in providing strong, clear protection of open and naturalized space.

Conclusion

Urbanization requires that we address the disjuncture between human society, economy, and the ecosystems that support us. This paper demonstrates how new urbanism can be united with ecological design for the preservation and enhancement of water quality in community planning. However, ecological design holds potential for a much wider application.

Thus far, ecological design has been implemented at small to medium scales. Many first-generation ecological design projects based on small-scale experiments and introduced technologies have been adopted in recent years, albeit in a piecemeal fashion. Therefore, a major challenge for ecological design is its translation from local scale to broader scale while retaining the principles and character that make it so promising. Meeting this challenge will require a better understanding of the mechanisms that link urban patterns to human and ecosystem functions at multiple spatial and temporal scales, and how human and ecological patterns emerge from the interactions between socio-economic and ecological/biophysical processes in urban settings (Alberti and Marzluff 2004; McDonald and Patterson 2007). By understanding the dynamic interactions between ecosystems and human society, we will be better situated to improve the environmental performance of cities, urbanized regions, and watersheds through the development of more effectives theories, concepts, and principles about the ideal urban form for broader scale human-dominated landscapes (Musacchio and Wu 2007)**.**

Planning is beginning to acknowledge the importance of incorporating natural processes into cities, and urban sustainability has become one of the primary goals of this field. Yet despite this realized importance of ecological systems and boundaries, the planning discipline remains rooted in the humanities and social sciences instead of being meaningfully informed by the biophysical sciences. This disjuncture between social science and natural science perspectives in the urban setting will perpetually impede the goal of true sustainable planning and our ability to address these issues in a holistic manner which respects ecological boundaries (McDonald and Patterson 2007). The improved integration of ecological research into urban policy, planning, design, and management strategies will be necessary for understanding the effects of long term changes in urban spatial patterns, landscapes and environmental quality (Musacchio and Wu 2004). The realization of these objectives requires that the fields of ecology and planning move beyond bridging, to achieve a more sophisticated union and transformation of these two disciplines with the goal of fully integrating the knowledge and application of natural processes into planning theory and practice.

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