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WATERSHED PLANNING FOR URBANIZATION TO AVOID UNDESIRABLE STREAM OUTCOMES

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Abstract

Watershed planning is presented as an advanced approach to development. It is imperative that the impacts of urban development on water resources be set in the context of integrating human activity into landscape form and ecological function. Preliminary results from the Urbanization Issues group of the Ecoresearch project are presented. The three areas of focus are: unintended outcomes of channel changes, the influence of off-floodplain development on non-point source surface water pollution, and innovation in the development process. Our studies were conducted in relation to proposed development in the headwaters of Laurel Creek. Virtually all Laurel Creek through the developed portion of Waterloo has had channel modifications. This led to many undesirable outcomes which were unexpected, or whose importance were not appreciated until later stages of development. Development in the watershed beyond the floodplain can also have significant adverse impacts on stream quality. These impacts may be especially large in typical suburban form with large areas of private lawn in relatively affluent neighbourhoods. We propose that in addition to maintaining channel integrity, innovative approaches to storm water management are required to protect ecological features. Attitudes to innovation in development were explored with planners and developers. It was found that controls of ecological innovations are complex. This suggested that consensus-based decision making for development has the best potential for facilitating necessary changes. Waterloo is undertaking development of the headwaters of Laurel Creek in line with recent Government of Ontario guidelines, using a round-table approach. These studies highlight some fundamental characteristics of a watershed approach to planning which should minimize unintended, undesirable stream outcomes.

Résumé

L'aménagement d'un bassin hydrographique est présenté en tant qu'approche avancée face au développement. Il est impératif que les impacts de l'expansion urbaine sur les ressources hydriques soient placés dans un contexte d'intégration de l'activité humaine dans la forme de l'aménagement paysager et la fonction écologique. Les résultats préliminaires du groupe «Problèmes d'urbanisation» du projet Éco-recherche sont ici présentés. Les trois sphères d'intérêt sont : les résultats non voulus des changements du canal, l'influence du développement hors des zones inondables sur la pollution des sources non ponctuelles des eaux de surface et l'innovation dans le processus de mise en valeur. Nos études furent menées en relation avec l'expansion proposée dans les cours supérieurs de Laurel Creek. Presque tout Laurel Creek d'un bout à l'autre de la partie aménagée de Waterloo a subi des modifications de canal. Cela a entraîné de nombreuses conséquences non souhaitées qu'on n'avait pu prévoir ou dont l'importance n'avait pu être mesurée jusqu'à des stades plus avancés du développement.

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L'aménagement dans le bassin hydrographique au-delà de la zone inondable peut également avoir des impacts négatifs considérables sur la qualité du cours d'eau. Ces impacts peuvent être particulièrement grands, dans un milieu typiquement suburbain, étant donné les vastes propriétés avec pelouse privée qu'on trouve dans les quartiers avoisinants, relativement aisés et cossus. Nous proposons non seulement que soit préservée l'intégrité du canal mais aussi que soient adoptées des approches novatrices face à la gestion des eaux pluviales pour la protection des aspects écologiques. Les attitudes face à l'innovation dans la mise en valeur furent explorées de concert avec les urbanistes et les promoteurs. Il fut constaté que les contrôles des innovations écologiques sont complexes. Il en est ressorti qu'une prise de décision par consensus pour la mise en valeur offre les meilleures chances de réussite pour favoriser les changements nécessaires. Waterloo est en train d'entreprendre l'expansion des cours supérieurs de Laurel Creek conformément aux normes adoptées récemment par le Gouvernement de l'Ontario, à l'aide de l'approche de la «table ronde». Ces études mettent en lumière certaines caractéristiques fondamentales d'une approche basée sur le bassin hydrographique pour l'aménagement, qui devrait avoir pour effet de limiter au minimum, pour les cours d'eau, les conséquences indésirables et inattendues.

Introduction

Whether the connection is made consciously or not, planning practices and policies affect the environment (Beatly, 1989). Many examples in the literature discuss the need for some kind of integrated and ecologically based planning (e.g. Slocombe, 1993; Holland, 1993; Child and Armour, 1995). The watershed has been suggested as the most appropriate boundary for implementing an ecosystem approach to planning (MOEE, MNR, 1993a). In this paper we will use the term 'watershed planning' to mean ecosystem planning at the watershed scale. There exist many definitions of ecosystem planning or management depending on the values of the definers (Jensen *et al.,* 1996). However, a unifying characteristic is that ecosystem (and therefore watershed) approaches to recognize the intrinsic connection between existing and potential land uses and the health of ecosystems over time MOEE and MNR (1993a). While there is a definite move towards planning at the watershed level, much development is still done on a property-by-property basis, and streams continue to be channelized.

The overall objective of our multidisciplinary project was to explore and attempt to resolve the apparent contradictions between the urbanization process and stream quality. Specifically we examined whether a watershed approach to planning could resolve the historical pattern of negative impacts of development on the stream environment and water quality. Investigations included: the riparian forest ecology of Laurel Creek, the influence of off-floodplain development upon non-point pollution, and the perceptions of developers and builders regarding environmental innovations in development.

With respect to the community ecology of riparian forests, our initial goal was to identify the structure of both healthy and highly-disturbed riparian forests, as well as the physical site conditions leading to their structure. We defined riparian zones as "the three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems" (Gregory *et al.,* 1991). From our work we will develop easily-measured site parameters useful for generating site-specific restoration goals.

From the initial riparian research, a complementary study developed to map historical channel changes along Laurel Creek. The results of this study are presented in this paper, and form the basis of our discussion on unintended outcomes; economic in terms of unforeseen development costs, and ecological with respect to riparian forest ecology. Based on the two other areas of study, we discuss the need for the flexibility to include environmental innovations in the actual built form of new developments. In addition to the physical attributes of developments, the potential impact on water quality of subsequent homeowner landscaping behaviour was considered.

The City of Waterloo is currently practicing the recommendations of Ontario MOEE and MNR watershed planning guidelines (MOEE and MNR, 1993a,b,c) for all green field development within its boundaries. We examined the potential and progress of this approach in the Waterloo West Side as an on-going test case to synthesize the three component projects and to evaluate the potential for watershed planning for effective water management in the context of urbanization.

Framework of Development Planning Approaches

There has been a progression of planning described by pioneering environmental planner, Dorney (Dorney, 1989). We modified his chronology replacing his final 'ecoplanning' category with 'watershed planning' to reflect advances in the social component of planning since his work. In tracing historical approaches to planning the landscape and its surface water resources, we examined how innovative environmental site planning and watershed planning concepts represent a fundamental change in the normative foundations of municipal planning.

1) Flat Earth Planning: From a water management perspective, this category could be called the 'buried stream' approach. In 'flat earth' planning, mapping of resources is limited. The underlying assumption is that humans can handle any environmental limitations encountered: there is no question as to the possibility of failing to overcome any natural features with engineered solutions. With this approach, cities such as Toronto were laid out on rigid grid patterns irrespective of drainage and topography.

2) Contour Planning: In 'contour planning,' slope and hazard land areas are significant to the planning process. Streams are invariably seen as obstacles to be overcome. The environment is either suitable for unconstrained development, or an impediment to be planned around. It is clear therefore, that this approach is associated with the rational planning tradition. The only consideration of the environment is in terms of its economic potential (for 'wise use') or limitations. The environment is valued only as an exploitable resource.

3) Feature and Constraint Planning: In 'feature and constraint planning' and design, critical features such as historical sites, archaeological sites, unique ecosystems and hazard lands are identified and incorporated into plans. While a much broader range of environmental components is identified, the biophysical environment is largely viewed as static. Many problems experienced with streams after development can be traced directly to their dynamic nature. Additionally, in this static thinking, human activity is not integrated with bio-physical landscape processes. Impacts that we would identify as problems in watershed planning, such as degradation of natural areas, would be viewed as acceptable trade-offs.

4) Watershed Planning: The most important aspect of this phase is a shift from a philosophy of conquering nature, to one which recognizes humans as a component in nature. This contemporary level is where complex interactions between people and bio-physical process are finally considered. The essential reality that, "sustaining life support systems is fundamental to the survival of human, plant and animal populations" (Perks and Tyler, 1991) is incorporated.

The broad realization that people are part of, and may be driving many 'natural' biophysical processes such as hydrological and nutrient cycling is very recent. In the context of climate change, Newby

(1990) stated that "the impacts of environmental change will, it need hardly be said, be social and economic and not merely ecological." This may seem removed from the more local effects of channelizing streams and piecemeal rather than watershed based development. However, the normative component of public support for integrated planning approaches is probably based increasingly on popular appreciation of large-scale issues such as acid rain, global warming and species extinction. We suggest that the underlying norms supporting watershed planning can be divided into two components:

1) Intrinsic value of the environment: In most cases the general public and development professionals and planners agree that the protection of natural systems is appropriate and desirable.

2) Economic: There is recognition of the value of natural 'life support systems' and non-commodity resources of which unpolluted drinking water is a prime example. Watershed planning, by being pro-active, seeks to avoid unforeseen economic consequences of uncoordinated development. 'Planning with nature' and buffering streams aims to avoid impacts and subsequent rehabilitation costs.

One way in which watershed planning extends beyond expert-based environmental planning is meaningful public participation. Expert studies alone provide no guarantee that effective planning, or stakeholder acceptance will follow. Neither innovative development proposals, nor strict environmentally-based guidelines in municipal development approval policies could be seen as successful, if development applications become entangled in lengthy Ontario Municipal Board (OMB) hearings. Elected officials need confidence that there is public support for new development guidelines.

The greatest potential strength of watershed planning is the possibility of building consensus and achieving support from traditionally-opposing contingents. It offers the prospect of protecting and enhancing the environment as well as realizing long term economic benefits. Beyond avoiding delays and expense at the development stage, watershed planning has the potential to avoid unexpected, undesirable outcomes when both economic and normative components of environmental issues are represented.

Methods

1) Mapping Channel Changes

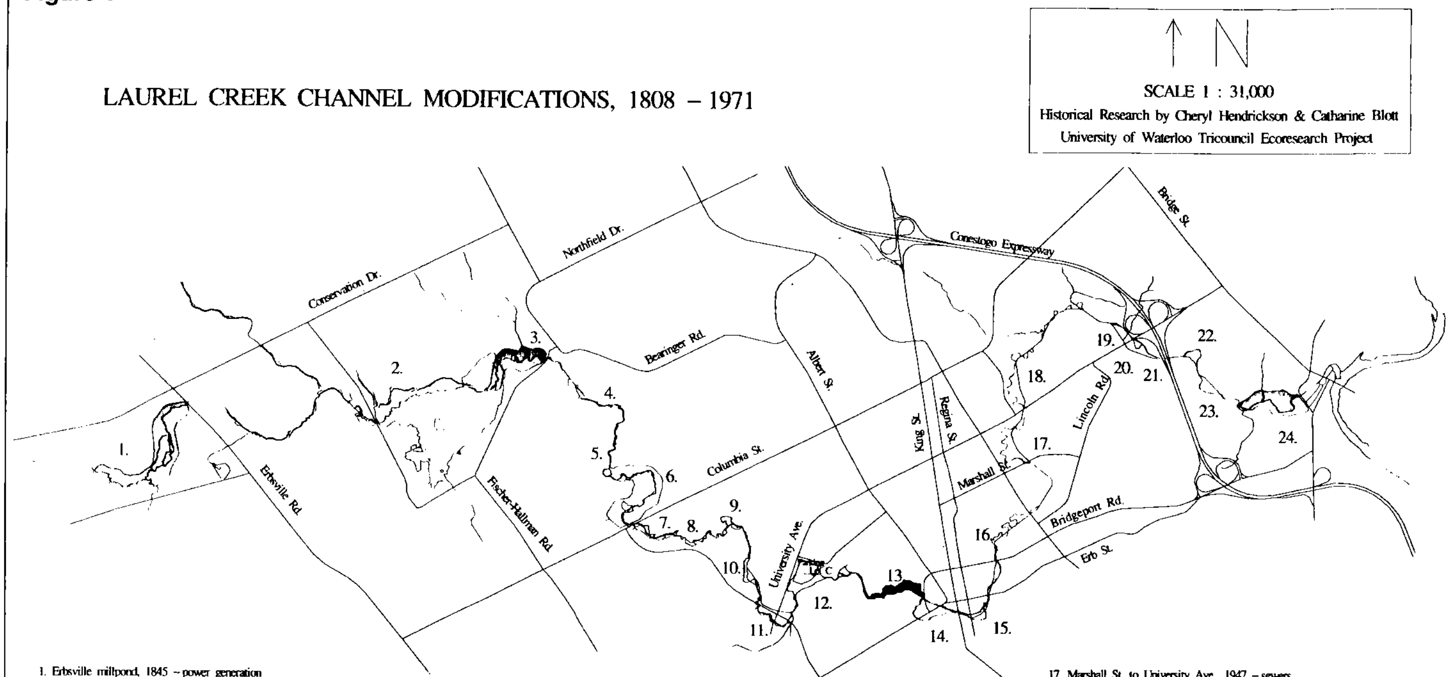
A series of aerial photographs of the creek were obtained from the University of Waterloo Map and Design Library including: 1930 (1:18 500), 1946 (1:15 500), 1955 (1:15 840), 1972(1:15 840),1978 (1:10 000) and 1990 (1:20 000). Historical series of topographic maps were also available, and were used to locate the channel position relative to surrounding, fixed features. Oblique aerial photos showing historical channel locations, and letters and notes pertaining to adjacent land use issues arising from stream straightening were obtained from the University of Waterloo archives. A GIS system set up by the *Environmental Information Systems* group of the Eco-Research project was used to produce the map (Figure 1) showing current and historical channel locations.

2) The Influence of Off-floodplain Development Upon Non-point Pollution Sources

We assessed the importance of the landscaping behaviour of urban residents with respect to potential water quality impacts. After a pretest of 50 respondents, 1013 questionnaires were mailed to householders selected randomly from the tax rolls of Kitchener and Waterloo. These were followed with up to four reminders. The 45 questions pertained to respondents' environmental attitudes, residence characteristics, maintenance practices, landscaping preferences, and demographic characteristics. 328 valid questionnaires were received, a return rate of 42.5% after correction for non-deliverables.

Figure 1

LAUREL CREEK CHANNEL MODIFICATIONS, 1808 – 1971



1. Erbsville millpond, 1845 – power generation
2. Laurel Creek reservoir, 1967 – flood control
3. Shantz's Mill, 1849 – power generation
4. North Campus Upper Dam – unknown time and use
5. North Campus Lower Dam – unknown time and use
6. Columbia Lake, UW, 1967 – flood control/aesthetics/recreation
7. Student Village, UW, 1967 – sewers/building
8. Student Village Woodlot, UW, 1967 – sewers
9. Health Services Pond, UW, 196? – aesthetics
10. Laurel Lake, UW, 1960 – aesthetics
11. Westmount/University Rds. intersection, 1961 – road construction
12. Waterloo Park Straightening/Band Shell Pond, 1966 – UW Parking Lot C/aesthetics
13. Silver Lake (Erb's Mills), 1808 – power generation/recreation
14. Silver Lake Outlet to Caroline St, '55-'66 – flood control
15. Caroline St. to Regina St., '55-'66 – flood control/parking lot
16. Bridgeport Rd. to Weber St., '30-'45 – sewers?
17. Marshall St. to University Ave., 1947 – sewers
18. Upper Hillside Park, 1947 – sewers
19. Lower Hillside Park, – sewers?
20. University Ave, pre-1967 – road construction
21. Expressway, 1967-71 – road construction/sewers
22. Upper Bechtel Park, '55-'66 – sewers
23. Lower Bechtel Park, 1971 – sewers
24. Shoemaker's Mills, Bridgeport, 1829-1967 – power generation
25. Behind Grand Hotel, 1930-45 – ?

3) Shifting Towards Ecological Sensitivity in Development

Builders and developers were identified for inclusion in a set of face-to-face, semi-structured interviews. From an initial list of 140 builders provided by the Ontario New Home Warranty Program, those constructing 25 houses or more over the preceding three years were targeted. It was thought that these active builders would have influence on the market and capacity to innovate. The list of targeted builders was checked through the Yellow Pages and through word of mouth to ensure its completeness, yielding 29 potential respondents. Three of these refused to be interviewed, three were no longer in residential construction locally, and four could not be traced, leaving 19 completed interviews. A total of 30 developers were identified through the Chamber of Commerce, Vernon's Business Sources and the Yellow Pages. One half were no longer active locally in residential development and four could not be traced, leaving 11 completed interviews. The interviews were conducted by a research assistant and were taped and transcribed.

A set of 17 planners from the Regional Municipality and the three area municipalities of Cambridge, Kitchener and Waterloo was identified. All of these agreed to a face-to-face interview discussing the constraints on innovation in residential development and their roles in the process of development.

A mail survey was sent to over 1600 area residents in the autumn of 1994. A random sample was drawn using the GIS facilities at the Regional Municipality of Waterloo, designed to include inner city and suburban respondents from each of the three local municipalities: Cambridge, Kitchener and Waterloo. The survey was administered by students in an undergraduate research methods course. Over 750 usable instruments were returned, yielding a response rate of 52%.

Unintended Outcomes Case Studies

Some social and ecological results of rationally-comprehensive based modernity have not been desirable (Goodchild, 1990). As outlined above, many negative outcomes from early approaches were predictable, and deemed to be acceptable tradeoffs at the time. We are particularly interested in another set of negative outcomes; those that were unintended and continue to go almost unnoticed. The case studies below illustrate several of these unintended outcomes of pursuing 'primitive' approaches to managing urbanizing waterways.

Laurel Creek, a tributary of the Grand River, originates in the Regional Municipality of Waterloo in relatively undisturbed swamps, forests and agricultural land. The Laurel Creek Reservoir is located about a third of the way downstream from the headwaters. Short reaches of natural channel occur downstream from the reservoir; but below that all sections have been modified in the urban areas (Figure 1).

Incremental changes to channel morphology have been made over 160 years. The first modifications were undertaken by early settlers to power mills, and for agricultural drainage. Modifications this century include channelization to lessen road and sewer construction costs, and to control flooding brought on by urbanization. Modern impoundments were designed to address flood risks and to provide aesthetic amenities for recreation areas. The long term social and economic impacts are now becoming apparent.

Economic impacts of channeling and impounding the creek include the costs of fixing the inevitable erosion and sedimentation. Social impacts occur when natural stream environments and artificial lakes are rendered unfit for recreation. Streams often become inaccessible and unattractive. Even when access to lakes is part of the development design, swimming, boating, fishing and strolling become impossible or unpleasant following the suite of environmental complications arising from the impoundments. These social impacts relate directly to ecological impacts.

The ecological impacts of stream modifications include the alteration of instream and riparian habitat (Hupp, 1992). Flood control impoundments reduce the flooding that controls the structure of some plant communities (Blom *et al.*, 1990). Impoundment decreases or eliminates the stream bank deposition of sediment, organic matter, and seeds and other propagules from upstream. We found that existing riparian vegetation communities are transformed if the historical groundwater or surface runoff patterns are changed.

Drastic changes in soils following channel alteration also cause some of the large differences between urban and undisturbed headwater plant communities. Excavating a new channel creates banks of nutrient-poor inorganic substrate from the bottom of the excavation. This is unsuitable for native riparian vegetation and can be dominated by weedy species, resulting in the community types described below. Cumulative changes in hydrology and hydric soils tend to isolate instream flow from the headwaters and from adjacent land, making urban streams function as artificial conduits through otherwise upland areas, rather than as streams interconnected with the landscape.

Specific examples of socio-economic (Case 1) and ecological impacts (Case 2) of creek alterations can be found in a short reach of Laurel Creek. They demonstrate unforeseen ramifications of moving the creek. An example of impoundment remediation, where full citizen participation was an important component of the preferred solution, is discussed in Case 3.

Case 1

The creek channel was straightened with the building of a major intersection so that the stream crossed over at one rather than three locations. The usual gabion baskets have been installed in the straightened sections to forestall bank erosion. One quadrant of the intersection formerly occupied by the creek remained undeveloped for nearly 20 years. When development of this site finally occurred, construction of the high-rise complex was complicated by a high water table and the discovery of extensive deposits of peat and other organic soils on the site. Ponding water during excavation had to be continually pumped away, while organic soils had to be excavated and replaced with more stable mineral soils. Thus, the stream channel had been moved, but typical subsurface attributes remained.

Case 2

Downstream from the intersection, the channel was moved out of a remnant riparian forest onto a turf field to provide a focal point for landscape features in a new city park. Again, the straightened channel was later stabilized with gabion baskets, and foot bridges have been replaced to accommodate the widening channel. The most dramatic effect of this change is the ecological impact on the remnant riparian forest which is severely degraded in contrast to a nearby upland forest fragment.

The most striking feature of the vegetation is the dominance of the invasive aliens European buckthorn (*Rhamnus cathartica*) and garlic mustard (*Alliaria officinalis*). The original channel is lined with peach leaf willows (*Salix amygdaloides*), although they and other mature trees are obscured by the dense growth of buckthorn. Much of the ground is too heavily shaded to support understory vegetation. In areas where some light infiltrates, garlic mustard forms monocultures. Woody debris from dying trees is caught up in the buckthorn canopy in precarious and dangerous positions presenting a hazard to users of the woodlot.

The historic pattern between the groundwater and overland flows has been altered so that former hydric soils are dry and incapable of supporting wetland or riparian vegetation. In some locations in the original channel, however, groundwater that originally fed baseflow still surfaces. Within the forest this has created small wetland pockets, and is beneficial for maintaining wetland species. Out of the forest on a turf area, the groundwater discharge creates a nuisance for users of a nearby parking lot who must avoid the ponding during spring and fall.

Case 3

While three of the four historic millponds on Laurel Creek have been drained, five more impoundments have been created between 1960 and 1967. All but one, which has already been taken off stream, are approaching the ends of their lives as they become filled with sediment. Remedial options include the conventional solution of dredging, or the creation of more self-sustaining natural channel or wetland systems which are not prone to sedimentation, and address problems of flooding and water quality.

Innovative solutions are currently underway to manage the channel erosion and widening problems in the forest site above, and the complications arising from the sedimentation of downstream Silver Lake. Silver Lake, a millpond created in 1808, will be undergoing a $1.6 million restoration which will see the creation of wetlands, naturalistic channels, and a deeper pond section over the next ten years (Silver Lake Class Environmental Assessment Study, 1995). The design is expected to address both the economic, social and ecological sustainability of the lake. Flooding, sedimentation, erosion, aesthetics and recreation have all been addressed through a stakeholder process relying on technical and community expertise.

The Influence of Off-floodplain Development Upon Non-point Pollution Sources

Recent rapid residential development in Waterloo is located largely in the middle Laurel Creek watershed, while industrial and commercial development has been focused on Forwell Creek, near its confluence with the Grand River, so Forwell Creek is not considered here. The lower portion of Laurel Creek is highly developed, the middle portion is becoming so, and the upper portion (the 'West Side') is mostly undeveloped agricultural and forest land, much of it slated for housing. In the middle watershed, development is largely of single family residences, with separate storm and sanitary sewers and adherence to conventional planning and engineering standards. Standardized building setbacks, relatively wide roads, grassed boulevards, and homogenous zoning are the norm (Fisher, 1994; Fisher *et al.*, in press). The relative affluence of the Region of Waterloo ensures that these standards are adhered to by custom, policy and law. As environmental awareness has grown, the creek tributary floodplains have tended to be dedicated to parkland in new developments. The resulting environment, which is typical of up-market suburbs throughout Eastern North America, is consciously designed to be pleasant.

Such dispersed single-family residential development is not conducive to good water quality. Runoff water quality from urban residential areas is generally low (Bryan, 1972; Dappen, 1974; Ellis, 1989; Field and Pitt, 1990; Marsalek, 1977; Myers, 1981; Oltmann and Shulters, 1989; Sansing, 1988; Singer and So, 1982; Struger *et al.*, 1994; Washington State, 1980; Woodward, 1986; Yamane and Lum, 1985). Pesticide loading is proportionately greater from urban than from agricultural watersheds (Rawson, 1974; Struger *et al.*, 1994). Much of this problem arises because single-family residence lots have a high proportion of lawns (averaging 50-65% in the Kitchener/Waterloo area), which are treated with various fertilizers, insecticides and fungicides. Such areas have been shown to contribute nutrients and pesticide residues to runoff water. For instance, Struger and Licskso (1994) found that stormwater detention pond water in a

Guelph, Ontario, residential area had 2,4-D, Diazinon and Chlorpyrifos contamination exceeding provincial water quality objectives. Carr *et al.,* (1982) found DDT, DDD and Dieldrin in sediment cores from an urban pond. Likewise, groundwater and well water pollution by nitrates has been linked to lawn fertilizer (Murphy, 1992; Exner *et al.*, 1991; Tinker, 1991; Flipse *et al.*, 1984).

In the Laurel Creek watershed, the upper, undeveloped tributaries have good water quality except for bacterial counts. In the developed middle and lower portions, residential runoff water generally enters neighbouring creeks directly through storm sewers, although in the last decade storm water detention ponds have become the norm in new Ontario subdivisions. Such ponds are highly variable in their propensity to remove nutrients (Shaw *et al.*, 1993; Hey, 1982, Toet *et al.*, 1990; Randall, 1982), but there appears to have been little work on pesticide retention in detention ponds.

The most detailed water quality measurements for Laurel Creek date from 1987 and 1991 and are summarized in GRCA (1992; 1993a). They include dry and wet weather measurement of stream nutrients, metals, pesticides and herbicides. Only potential lawn-related parameters are discussed here. Spring and summer concentrations of phosphates increased dramatically in the middle and lower portions of Laurel Creek, and the study implicated faecal contamination from waterfowl. The downstream onset of this problem also coincides with areas where lawns become a major land cover adjacent to the creek.

Measurements in 1987 at the mouth of Laurel Creek revealed trace levels of DDT and derivatives, chlordane, dicamba, aldrin/dieldrin, lindane and pentachlorophenol. The dry weather 1991 survey, in contrast, found only 2,4-D above detection limits in the urban area. In the wet weather survey, phenoxy herbicides were found more frequently with two samples exceeding irrigation water standards, both on the urbanized Clair Creek tributary.

The Eco-Research team addressed the question of how conventional residential design patterns might be modified in future development to improve runoff water quality. McKenzie (1996), working with SWMM (Storm Water Management Model) and a sub-catchment of the upper Laurel Creek, has shown that leakage of pesticides would be greater using conventional design standards and practice than using cluster development with the same net housing unit density. The main difference between the two types is the proportion of lawn area. Likewise, Suffling *et al.* are currently using a questionnaire technique to demonstrate that pesticide and fertilizer loading is higher in the up-market developments, such as those of the middle Laurel Creek, than in less expensive housing. (We define 'loading' as the mean proportion of lot area in lawn x percentage of householders who use a given product). For single family housing, the mean proportion of lawn per lot is remarkably stable with respect to residential market value and the style of housing (except in the small proportion of residences above $300,000 where it is significantly higher). Thus high loading in more expensive developments does not generally result from an increase in the relative amount of lawn, rather, the proportion of householders who undertake pesticide and fertilizer application rises with property market value and householder income. This suggests that the key to the problem lies not only with choice of housing design, but also with the individual behaviour of householders regarding their private lots. Unfortunately, the local population is deeply divided on the lawn pesticide issue (Keuper, 1994).

What does this mean for Laurel Creek and similar watersheds? Economic buoyancy of the Waterloo Region and the attractiveness of the middle and upper Laurel Creek watershed promote pleasant up-market housing development. The increased incidence of extreme high and low stream flow associated with such developments is now being ameliorated by improved stormwater management practices (especially storm water detention ponds), but the water quality problems that result from urban development have yet to be tackled effectively. Thus the pleasant environment of the subdivision is unintendedly purchased at the expense of water quality in neighbouring streams. Rehabilitation of creek floodplains and margins serves to filter out locally-generated pollutants, to provide habitat, and ameliorate water temperatures. What it cannot do is remove residues entering via storm drains (unless this is handled through special measures such as constructed reed-beds). The market-driven concentration of up-scale housing in attractive watersheds increases non-point pollutant loading, and this is likely to be reflected in increased chemical contamination of creek water, even as other improvements take effect. Thus stream rehabilitation concentrating only on the stream banks or the floodplain may effect dramatic improvements, but results will always be constrained by people's behaviour in the wider watershed.

Development of much of the upper Laurel Creek watershed is mandated in City of Waterloo plans, but this policy came under intense criticism from environmental groups. As a result, development standards have been upgraded for new developments in this area. These include the extensive protection of natural areas, measures to increase infiltration of urban runoff, and areas of clustered housing (though this is being promoted largely for socio-economic reasons). Measures are being considered to make innovative storm water management infrastructure robust enough to work after numerous changes of homeowners who may no longer understand the original goals of the development. Strategies include easements to protect swales and large scale collection of roof water to infiltration areas (Trushinski, 1996). Waterloo planners intend to emphasize to prospective home buyers that semi-natural and naturalised vegetation is to be integral to these neighbourhoods. They would also like to encourage stewardship arrangements for vegetation management (Trushinski, 1996). These changes give hope for future improvements to land management in the watershed, but they should also be accompanied by a concerted effort to modify landscaping practices on individual house lots. Such changes are unlikely to be achieved by fiat, but must arise through a collective change in community standards.

Shifting Towards Ecological Sensitivity in Development

While the first two research groups explored the need for watershed planning to consider how ecological form and function can be maintained, the third group explored the potential for market-driven innovation in development.

Commentators have noted the generally innovative nature of the development industry in Canada (Miron, 1993). However, the record of innovations diminishing the impacts of development on ecological form and function is less impressive. Innovations can be defined as "the introduction of changes to building techniques, design and planning, affecting housing and neighbourhood development" (Skelton *et al.*, 1995). A shift in development patterns towards greater ecological sensitivity can be observed, yet it is clear that the prevailing practices of urban land use planning and management fail to embrace ecological concerns as an over-riding priority. At the same time, many stakeholders in the development process are keenly interested in finding ways of helping these innovations 'get through.' Survey and interview work with Waterloo area builders and developers (Skelton *et al.*, 1995), planners (Skelton, 1995) and residents (Moore Milroy *et al.*, 1995) has shed light on the problem that it is difficult to produce ecologically-benign urban environments that many people desire. Predictably, one theme in the survey responses portrayed development as governed by market dynamics which severely constrain adoption of ecological innovations. However other responses suggested that many aspects of the development process seem not to be driven by strict market considerations. The studies were specific to residential development, but they potentially provide additional ways of conceptualizing development dynamics generally.

Of a sample of 30 builders and developers (Skelton *et al.*, 1995), over two-thirds considered themselves innovative. Their practices were usually modified in response to perceived changes in consumer demand, (for example, altering lot sizes and internal house configurations in shifting economic and demographic circumstances). We had not specifically asked about ecologically-driven innovations in order to determine whether respondents' concept of innovation embraced ecology. Though a majority felt themselves to be innovative, few ecologically-driven innovations were mentioned. The innovations directed towards ecological improvement were specifically associated with upscale development, as respondents described their view that development is primarily shaped through the activity of producers and consumers in the market. For planners in the Region (Skelton, 1995), planning was seen to be subordinate and external to the market; and thus planners generally shared with builders and developers the view that the market shapes development patterns. Analysis of the results suggests a distinction between respondents' normative view that gives priority to market relations, and a descriptive view that recognizes that development forms are adopted through complex interactions of many constituents. The builders, developers and planners described numerous ways in which government regulation, consumer groups and advocates, for example, were firmly connected to, and influential in shaping development.

Similarly, in a mail survey of over 1600 area residents (Moore Milroy *et al.*, 1995), about 80% felt that what is offered in the housing market represents what the development industry wants to provide. However, they also clearly identified the role of government and consumer organizations in promoting ecological concerns in development.

The survey and interview work support the contention that development is shaped by a broader set of considerations than the action of producers and consumers would suggest. It has recently been suggested that a useful theoretical formulation posits development as a social process, embracing economic, political and cultural forces (Gottdiener, 1985; Skelton *et al.*, 1995). This formulation legitimizes new strategies for influencing development patterns; for example, demonstration projects and consensus-building negotiation that provide opportunities for emerging ecological knowledge to guide development decisions.

Summary

These three investigations (channel changes, off-floodplain pollution, and stakeholder analysis) support the potential of the watershed planning process in avoiding unexpected outcomes of development. In our framework of planning approaches, a key aspect of watershed planning was the inclusion of human activity as a component of ecosystems. Both the channel change and non-point pollution studies highlight the reality that human development and land use become an intrinsic part of not only the form, but the ecological functions of landscape.

One of the major goals for development in the West side of Waterloo is an explicit consideration of built form/ecosystem function (Trushinski, 1996). Preliminary to development in Waterloo, the Laurel Creek watershed study was prepared with a strong emphasis on public and stakeholder input through a consensus-based process (GRCA, 1993a). The round table process involved a wide range of watershed residents including citizens, planners, resource managers and development interests. Their input occurred over 18 months through committees, public meetings and workshops, meetings with special interest groups, and informal discussions between citizens and the study's Public Participation Coordinator giving rise to, "confidence that the plan will be implemented and supported by a broad base of watershed residents" (GRCA, 1993b).

A key issue for water management professionals arising from the Waterloo experience is that this consensus-based process resulted in water quality and ground water recharge and surface runoff objectives being set at the outset of the development process. The unusually strict objectives include many constraint areas where no net change to runoff or infiltration will be allowed as the result of development. Stream bank buffer strips will be implemented along the length of the stream following the existing channel. The planners associated with the project are optimistic that developers eager to receive approvals for development will propose innovative approaches that will enable the objectives to be met.

In addition to providing incentive to developers and builders, it is clear from the watershed study that individual homeowner behaviour must also reflect ecological goals. Planners intend to work with developers to educate and inform potential homebuyers. Strategies pursued and proposed include open house presentations, newsletters and explanatory signage prominent at model home locations. It is hoped that the increase in public awareness through the round table process, combined with approaches to informing new homeowners, will enhance the effectiveness of the innovative designs for protecting stream quality.

Recognizing potential impacts by involving a variety of experts and stakeholders is a planning challenge. Its goal is to ensure that human modifications to natural processes are guided in acceptable directions. Broad consultation and consensus building provides opportunity for both economic and environmental ethical norms to be incorporated. Our development study identified the complexity of the factors influencing the extent to which environmental innovations are pursued by developers. Based on our studies and the Waterloo experience, there is evidence that watershed planning has the potential to contribute in a variety of ways to successful, innovative approaches:

- planners can explore what innovations are necessary,
- public input can help to identify the possibilities for innovative designs,
- public input can lay the framework ror modifying home-owner behaviour and developing stewardship arrangements to support ecological objectives,
- the development industry can gain assurance of market support for innovations.

Having confirmed the potential of the watershed planning process to avoid unintended outcomes in general, and for Waterloo in particular, the real test remains. It is necessary to develop evaluation approaches to examine changes in water quality and adjacent plant communities, avoid costly remediation and flood control works, and gain the acceptance by planners and homeowners of innovative development.

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