LANDSCAPE ALTERNATIVES FOR COST SAVINGS AND RESOURCE CONSERVATION IN MEDIUM-DENSITY CANADIAN HOUSING

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ABSTRACT

The grounds of Canadian homes typically consist of trimmed lawns sparsely planted with ornamental trees and shrubs. Despite their low initial cost and immediate impact, conventional landscapes require significant annual capital and physical resources, such as fuel, water, herbicides and fertilizer However, low-maintenance alternatives exhibit lower consumption rates and annual cost savings This paper investigates the saving potential of four low-maintenance alternatives when compared to a conventional option through an evaluation of life cycle cost and annual maintenance resource consumption

The five options were simulated using the proposed site and building of a low-rise, multi-residential housing project in Ottawa, where only the planting design varied for each simulation The four alternatives involved: 1) replacing 70% of lawn areas with woody plants grouped in mulched beds, 2) eliminating turf and including 85% woody plants and a hard surface area of 15%, 3) replacing 70% of the turf area with naturalized woodland plantings and 4) replacing all turf areas with 85% naturalized woodland and tall grass prairie plantings and including a hard surface area of 15% Only species that are well-adapted to the site conditions were selected for the alternatives.

The author surveyed contractors for initial costs and consulted a National Capital Commission database for maintenance requirements. Published sources also provided data on cost and material expenditures. With this data, payback periods were calculated The following payback periods for the most likely maintenance scenario resulted from the analysis of alternatives one to four: 1) 19 years, 2) 42 years, 3) 9 years and 4) 20 years Assuming ten years or less as a desirable payback period, only one of the alternatives could be paid back in a desirable time frame. However, variables including an irrigation system and hired maintenance produced three other scenarios for each alternative Most of these exhibited desirable payback periods when compared to the conventional option. In addition to annual costs, resource consumption was significantly reduced. The analysis showed the following ranges in annual savings: fuel use was reduced by 63% to 100%, fertilizer by 62% to 98%, water by 66% to 98% and herbicides by 64% to 100%

While Alternative 3, the naturalized alternative with 30% turf area, exhibited the greatest cost saving potential, dramatic reductions in resource consumption resulted for all of the alternatives This study demonstrates that shifting the emphasis away from manicured landscapes is an important step toward resource conservation and, in many situations, long-term affordability

RÉSUMÉ

Sur le terrain des maisons au Canada, on trouve généralement du gazon taillé avec ici et là des arbres et des arbustes d'ornement Le terrain paysagé traditionnel exige chaque année des ressources financières et matérielles, comme du combustible, de l'eau, des herbicides et des engrais Il existe toutefois d'autres solutions de faible entretien pour lesquels le taux de consommation est moindre et les économies annuelles supérieures. Il est question dans ce document des économies possibles offertes par quatre solutions de faible entretien comparativement à une option traditionnelle

Les cinq options ont été simulées sur le terrain de l'immeuble propose pour un ensemble multi-résidentiel d'habitations basses à Ottawa, où seul le plan de plantation variait pour chaque cas. Les quatre solutions étaient les suivantes . 1) remplacer 70 % du terrain gazonné par des plantes ligneuses groupées; 2) éliminer le gazon pour aménager 85 % du terrain avec des plantes ligneuses et paver l'autre 15 %, 3) remplacer 70 % de la surface gazonnée par des plantes boisées naturalisées, 4) remplacer toute la surface gazonnée par 85 % de plantes boisées naturalisées et des plantes hautes de prairie, et paver l'autre 15 % Seulement des espèces bien adaptées aux conditions du terrain ont été retenues dans chaque cas

L'auteur a demandé à des entrepreneurs d'indiquer les coûts initiaux et a consulté une base de données de la Commission de la capitale nationale, de même que des sources publiées, pour les besoins d'entretien. Voici les périodes de récupération pour le scénario d'entretien le plus probable d'après l'analyse des quatre solutions 1) 19 ans, 2) 42 ans, 3) 9 ans; 4) 20 ans. En supposant que 10 ans ou moins soit une période de récupération souhaitable, seulement l'une des quatre solutions donnerait lieu à une récupération dans le délai souhaité. Toutefois, des variables telles l'aménagement d'un réseau d'irrigation et l'embauche de préposés à l'entretien ont donné lieu à trois autres scénarios pour chaque solution. Dans la plupart des cas, les périodes de récupération étaient souhaitables, comparativement à l'option traditionnelle D'après l'analyse, les économies annuelles se situent dans les fourchettes suivantes · la consommation de combustible a été réduite de 63 % à 100 %, d'engrais, de 62 % à 98 %, d'eau, de 66 % à 98 %, et d'herbicides, de 64 % à 100 %.

Si la troisième solution présentait les meilleures possibilités d'économies, des réductions très importantes de consommation de ressources ont eu lieu dans tous les cas Cette étude montre que des solutions de faible entretien peuvent donner lieu à des économies de ressources et, dans de nombreuses situations, être plus abordables à long terme

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

The yards of North American urban neighbourhoods typically follow a pattern a landscape dominated by *introduced*[1] trees and shrubs rising out of neatly trimmed, green lawns and decorative annual flowers. However, these conventional landscapes require significant physical and capital resources to maintain. Massive doses of water, energy, synthetic fertilizer, herbicides and pesticides are necessary to keep turf green These inputs result in higher annual household costs for the consumer. Moreover, the quality of water, soil and air is degraded as these resources are consumed.

In addition to its virtues of immediate impact and low initial cost, the tradition of well-maintained lawns has been an expectation for North American households (Wilson, 1991; Hough, 1990). However, that perception is changing Over the past decade, municipalities and homeowners across Canada have been replacing high input landscapes with lower maintenance alternatives. This has been a result of the desire to reduce operating costs as affordability and *life cycle costing*[2] become increasingly important issues An equally important factor is the growing concern for the environmental impacts of lawn mowers, chemicals and excessive water use in the landscape.

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[1] Dirr (1983) defines *introduced* plants as those which are "brought intentionally from another region for the purpose of cultivation".

[2] Brown and Yanuck (1985) define *life cycle costing* as "a method of expenditure evaluation which recognizes the sum total of all costs associated with the expenditure during the time it is in use".

This paper investigates the potential for savings in annual costs and resource consumption of alternatives to the conventional pattern of residential landscapes in two ways. 1) Two alternatives demonstrate the saving potential by replacing lawn areas with grouped beds of *well-adapted woody plants*[3]. one with lawns reduced to 30% of the planted area, the other with lawns eliminated; 2) Two other alternatives replace lawn areas with *naturalized*[4] plantings: one with lawns reduced to 30% of the planted area, the other with lawns eliminated. It was assumed that as resource consumption decreased, annual cost savings would also decrease. Since the alternatives' initial costs were assumed to exceed those of the conventional option, one of the goals of the analysis was to determine the alternatives' *payback periods*[5]. Moreover, the analysis was to indicate the potential savings in expenditures of fuel, water, fertilizers and other materials.

These alternatives require fewer maintenance inputs largely because they are composed of interdependent plant communities which take advantage of natural processes. For

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[3] *Well-adapted woody plants* refers to tree, shrub and groundcover species which are well-adapted to local environmental conditions.

[4] Hough *et al* (1982) define *naturalization* as "the introduction of natural landscape elements into the urban environment, such as woodlands, meadows and wetlands that are self-perpetuating and productive communities achieved through ecologically sensitive management rather than through total maintenance control". The process is also referred to as *reforestation*, which Hough et al (1982) define as "the establishment of woodland communities on land which has not supported trees for a long period of time".

[5] Brown and Yanuck (1985) define the term *payback period* as "the length of time necessary to recover the initial investment of a project". This investment can be recovered through savings in annual operational costs.

example, a canopy of trees provides a moist, protected environment for shade-loving groundcover. Since grassed areas do not naturally occur as trimmed green "weedless" swards, inputs are required to maintain this condition. Moreover, only plant species which are well-adapted to local conditions, thus requiring considerably fewer inputs, were selected. While the first two alternatives use conventional nursery stock, the second two present a different method of planting. These alternatives share an important feature increasing reliance on natural processes rather than horticultural technology

1.2 Rationale for Study

With the growing awareness of the impact of landscape maintenance on the quality of water, soil and air, low-maintenance initiatives are gaining momentum (Goode, 1990)[6] This concern also addresses consumer demands for affordability While many low-maintenance projects have been implemented in Canada, comprehensive analyses comparing cost and resource consumption for several different alternatives are rare The results of this study will provide the data necessary for making informed decisions about adapting low-maintenance landscapes It will provide both an economic and ecological rationale for those decisions.

According to Friedman *et al* (1993), resource conservation has become one of the key issues debated in the field of housing Changing attitudes and lifestyles toward resource conservation have created a greater demand among homeowners However, willingness

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[6] The City Green movement exemplifies the basic shift in the way our culture treats cultivated areas (Hightshoe, 1988).

to adapt conservation technologies is largely contingent upon cost effectiveness. In the *CMHC*[7] study Consumer Housing Choices and the Environment (1990), one of the key criterion used to judge the desirability of an environmental option was its economic benefits. Participants justified decisions on the basis of payback period. As stated in the Our Common Future, economic and environmental issues are inextricably linked (Reic, 1991) Affordability is a critical housing issue due to the increased cost of land, infrastructure and construction as well as the decline in median income relative to median housing prices (Friedman *et al*, 1993)

While payback period studies on building and mechanical conservation technologies are well-researched, payback studies on resource conserving landscapes are rare. Although this paper discusses studies which indicate annual cost savings for low-maintenance alternatives, payback analyses are not included in these studies. Moreover, most of the studies which denote the economic benefits of low-maintenance alternatives by comparing initial costs with annual costs savings are applied to the institutional sector. Thus, this study helps to fill a literature void in payback analyses for low-maintenance alternatives in the housing sector

Standards for predicting maintenance requirements are beginning to be developed by municipalities and other government agencies. However, very little published material exists for maintenance standards (O'Brien *et al*, 1992). This is partially because

[7] *Canada Mortgage and Housing Corporation*

maintenance operations, such as tree care, have been difficult to predict Annual inputs are dependant on a multitude of factors including climate, soil type and exposure Traditionally, requirements are estimated by a trial and error method (Abbott and Miller, 1987). According to Ferguson (1987), hard research is lacking on maintenance requirements, such as water, for most landscape plants Those performance standards that exist are used to estimate worker efficiency, plan budgets and forecast future work loads (O'Brien *et al*, 1992). These standards generally pertain only to conventional plantings. Records of maintenance requirements for low-maintenance landscape, particularly the naturalized alternatives, are rare This study incorporates the unpublished data on maintenance requirements and applies them in a payback period calculation.

1.3 Background Information

1.3.1 Impact of Landscape Maintenance

Canada contributes disproportionately to environmental stresses because of higher per capita energy and water consumption and higher generation of pollutants (Robinson, 1991). The following discussion indicates the contribution of landscape maintenance to environmental stress as well as the economic considerations of this consumption pattern.

1.3.1.1 Annual Costs

Statistics Canada's most recent report on household expenditure indicates that landscape maintenance occupies a significant portion of household operational expenditures They report that the average annual, per family expenditure on horticultural goods and services in Ottawa was $163.00 in 1986. This represents 7% of household operation expenses (Statistics Canada, 1991). Homeowners in single detached dwellings spent $253.00 on horticultural goods and services, at 11% of operation expenses Given a 4% inflation rate, this would be $333 00 in 1993 dollars[8]. Over a 30-year period of ownership, the annual operation costs of a house will be 9 times the purchase price, given a 9% annual interest rate (Brown and Yanuck, 1985).

Canadians are likely to be spending even more on landscape maintenance as the true cost of resources is factored into materials consumed. An Environment Canada study reveals that current rate practices do not recover the costs of providing the water (Reic, 1991)[9] Only about 10% of actual costs are recovered in irrigation water charges (EC[10], 1990). Often rates provide a negative incentive to conserve, due to declining block rates[11]. As a result, Canadian municipalities will be forced to restructure water rates, as U.S. municipalities have done (Reic, 1991). The Green Plan for a Healthy Environment (1990), stated that "the key to conserving water is paying a fair price for the water we use." CANMET (1991) predicts that water rates will increase by as much as 50% over the next five years in many parts of Canada.

[8] A 4% rate of inflation is the value used in current economic analyses of engineering projects in Canada (Friedman *et al*, 1993).

[9] In 1992, the average cost of water in Canada was $0.65 cents per 1000 litres (Lee and Lirange, 1993) which is among the lowest water rates in developed countries (EC, 1990).

[10] Environment Canada

[11] In this case, consumers pay less per unit, the more they consume.

As previously discussed, reducing annual operation costs is a critical factor in encouraging Canadians to conserve resources The conservation efforts which arose after the energy crisis in the mid-1970s provide a classic example of the power of economic incentives in resource conservation. Lower consumption would not only economically benefit the individual consumer but the society as a whole[12].

1.3.1.2 Water Consumption

As a result of increased demand, Canada's lakes and rivers are under significant pressure to supply clean water to Canadian homes. Although Canada is a water-rich nation, Canadians should be concerned with water quality and quantity issues A serious imbalance exists between the location of supplies and centres of demand (CANMET, 1991). From 1981 to 1986, gross water use in Canada increased by 5% (Reic, 1991) Canada has the second highest average daily household water use per capita in the world at 350 litres (EC, 1990). In many regions, the demand for water has exceeded the groundwater aquifers' natural discharge rates (Reic, 1991). Concurrent with the increase in demand, is an increase in the amount of wastewater to be treated The increased use and expansion of facilities causes increased costs.

During the summer, about half to three-quarters of all municipally-treated water is sprayed onto lawns (EC, 1990). Given that the municipal sector is the third highest water user at

[12] In 1989-90, all levels of government spent 6.5 billion dollars on water purification, water pollution control and sewage collection (Statistics Canada, 1991).

4711 billion litres (EC, 1990), reducing water use in the landscape has serious implications According to CMHC, a typical suburban lawn can require up to 200 000 litres of water during a single growing season. According to CANMET (1991), an average residential lawn will soak up about 100 000 litres of water, most of which is lost to run-off and evaporation A Canadian study states that 15.6% of average monthly household water demand is consumed in lawn watering for the full year (A.C.E., 1991). In the U.S., lawn watering accounts for 29% of annual household water consumption at 140 000 litres annually (Robinette, 1984) In south-western states, the largest residential water use is landscape irrigation, accounting for 40% of household consumption (Ferguson, 1987; McPherson, 1989). This heavy consumption rate explains why lawn watering is one of the first areas to be restricted in any water shortage situation (Robinette, 1984).

1.3.1.3 Energy Consumption

With over 40 million lawnmowers consuming 200 million gallons of gasoline annually in the U S., the impact of lawns on energy consumption is significant (Diekelmann and Schuster, 1982) Savage (1987) states that in 1986, Canadians used about 25 million gallons of gasoline to mow lawns The impact of energy consumption on environmental quality is manifested in phenomena such as the greenhouse effect, acid rain and ozone depletion (CMHC, 1992). According to Statistics Canada (1991), Canada has the highest per capita rate of greenhouse gas emissions in the world.

1.3.1.4 Chemical-use

Lawns also require fertilization to ensure vigorous and healthy growth In the US, more fertilizer is consumed on lawns in one year than is used in India each year for food production. As much as one-sixth of all commercial fertilizers are used to produce green lawns instead of food (Diekelmann and Schuster, 1982) Forty percent of all pesticides are used on lawns and gardens (Norris, 1983) Acre for acre, approximately 15 times more pesticides are applied on urban lawns and gardens than rural areas (Rubin, 1989)

This consumption rate has serious implications for groundwater quality (Reic, 1991) The use of synthetic fertilizers, pesticides and herbicides kills organisms which act as food for wildlife (WEPD, 1993). Statistics Canada (1991) states that the contamination of ground water by industrial, agricultural and domestic activities is already a serious problem Thirty-three percent of Canadians rely on groundwater as their source of drinking water (Decker, 1992). Fertilizers also seep into storm sewers as run-off and eventually into lakes and streams where they lower dissolved oxygen levels and release ammonia which is toxic to fish (WEPD[13], 1993). Groundwater contamination is extremely difficult and costly to clean up, since it can remain in the supply from two weeks to 10 000 years (EC, 1990). While not all chemical applications reach water supplies through leaching or run-off, reducing or eliminating fertilizer and pesticide application is the best way to avoid contamination (WEPD, 1993).

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[13] Water Environment Protection Division of the Regional Municipality of Ottawa-Carleton (RMOC)

1.3.2 Alternatives

The rationale for selecting the following alternatives as solutions to the environmental and economic issues are discussed further in Chapters Two and Three.

1.3 2 1 Well-adapted Woody Plant Beds

Figure 1 1 The conventional landscape

Without extensive human intervention, lawn areas would be invaded by alien species and within a short time cease to exist (Gilbert, 1989, Diekelmann and Schuster, 1982)[14] Moreover, a landscape of specimen trees isolated in manicured lawns, as shown in figure 1.1, is dependant on horticultural support (Hough, 1984) The proposed alternatives require considerably less human intervention For example, with careful species selection and design, a landscape which requires no water inputs beyond those provided by precipitation, is an attainable expectation (Reic, 1991) Adapted woody plants are increasingly being used as a lower maintenance substitute for mown swards (Cobham, 1990) According to Gilbert (1989), although woody plant beds are initially costly, in the long term they are cheaper than mown grass to manage.

Low maintenance landscapes were pioneered in the south-west U.S. American programs

[14] Advances in horticultural technology have produced low maintenance turfgrass cultivars. Also, organic lawn care practices are gaining popularity. However, this study will examine maintenance requirements for traditional lawns and lawn care.

for implementing water conserving landscapes recommend that the most significant savings come from reductions in turf area and replacing introduced species with native ones (Reic, 1991) Generally, turf areas should be limited to what is useful for social and play activities[15]. As *xenscapes*[16] emerged out of the arid climatic conditions of the American south-west, *mesiscapes*[17] emerged out of the more rainy New England states (Licht, 1990) Despite the abundance of water, consumers in Massachusetts have seen their water bills triple in recent years (Licht, 1990)

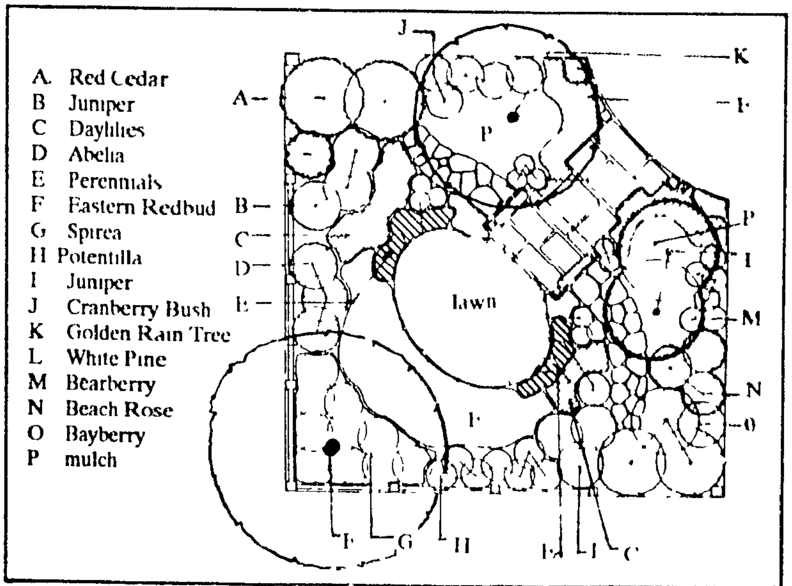

Figure 1 2 Mesiscape plan for the Northeast garden display at "Conserve 90" (from Licht, 1990)

Growing awareness of the benefits of low maintenance landscapes has resulted in the occurrence of many Canadian initiatives. Canadian consumer guides, such as <u>Water No</u>

[15] For example, the City of San Diego sets limits on turf through a landscape zoning ordinance (Reic, 1991). In Phoenix, turf limitation ordinances require home-owners to obtain a permit prior to lawn installation (McPherson, 1989).

[16] *Xeriscapes* are landscapes which minimize irrigation water requirements. The term is derived from the Greek work "xeros" meaning dry (Cox, 1991).

[17] Licht (1990) defines *mesiscapes* as "a regionally sensitive approach to water conserving landscape techniques", suitable for medium rainfall.

Time to Waste (EC, 1990), recommend converting lawns into xeriscapes or native, low-maintenance groundcovers As maintenance costs continue to increase, municipalities have started to consider alternative management techniques, particularly the reduction of lawn areas Canadian projects, such as the Ontario Government's Queen's Park Xeriscape Demonstration Garden, indicate the efforts being made to educate and provide examples of low maintenance landscapes (MNR[18], 1992). Annual maintenance costs of Toronto's IBM headquarters were reduced by $43.00 per 100m^2 when lawn areas were replaced with native woody plants (Hough *et al*, 1992).

A study by the North Marin County Water Board (Nelson, 1987), compares the resource consumption of lawns and woody plant alternatives. When 55% of lawn areas were replaced with tree, shrub and herbaceous groundcover beds, the following annual savings occurred 49% of water use, 25% of labour, 52% of fertilizer, 44% of fuel and 22% of herbicides (Nelson, 1987). This resulted in a $75 annual saving over an approximately $200 expenditure on annual maintenance per unit with water conserving alternatives.

Native plants generally require less maintenance because they have evolved to adapt to local conditions (MNR, 1990) As a result, they are more resistant to disease, pests and drought than introduced species. Native plant communities can not only survive the rigors of climate and disease but can also reproduce themselves without much special attention from year to year (Dorney, 1985). However, Moll (1986) indicates that not all non-native

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[18] Ontario Ministry of Natural Resources

species require more water, energy and chemicals to stay healthy. It is preferable to use native species and substitute suitable exotics where necessary (MNR, 1990)

1.3.2.2 Naturalization

Naturalization[19] involves human plant establishment initially and a limited management program to assist natural processes in plant growth The term *managed succession*[20] suggests the supporting role of humans in plant communities that rely primarily on non-human inputs (Hough *et al*, 1982). However, without this initial human intervention, several decades would be required for a desirable growth state to be achieved (Diekelmann and Schuster, 1982; Thorn and Huang, 1990)

With naturalized plantings, virtually no external sources of energy, nutrient or water should be needed since all inputs come from on-site sources or can easily be performed by hand (Diekelmann and Schuster, 1982; Lamb, 1993) In addition to reduced maintenance inputs, naturalization offers an alternative to conventional plant installation techniques which rely on imported topsoil, fertilizer and well-established plant material (Hough *et al*, 1982). This practice is expensive, consumptive and ultimately conducive to plant community instability (Baines, 1986). Furthermore, evaluations of residential

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[19] The City of Ottawa Department of Recreation and Culture (City of Ottawa, 1993) define naturalization as "the management of land to allow the process of plant growth, regeneration and/or succession to occur."

[20] Managed succession will be defined and discussed in Chapter Three.

naturalization experiments indicate considerable decreases in cost and increases in user preference[21]. While the cost of maintaining horticultural plantings rises, naturalized areas continue to drop while stability continues to increase over time (Hough *et al*, 1982; McCormick, 1991)

In the late 1970s, a new type of park, dubbed "Ecology Parks", emerged in Britain's cities (Johnston, 1990). In these small, inner city parks, woodland and wildflower communities were planted on vacant lots as an ecologically sound alternative to the conventional approach to public open space (Gordon, 1990). Today, these parks provide shelter for wildlife, cost little to maintain and have fostered a new sense of community pride. Compared to laying turf, installation costs and labour for Toronto's Ecology Park[22] were initially higher. However, after three years, the site showed a dramatic drop in annual maintenance costs (Pollution Probe, 1988).

One of the first naturalized woodland areas in Canadian cities is the NCC's[23] South-west Transitway Corridor Naturalization Project, shown in Figure 1.3. The project was initiated to determine the feasibility of establishing self-sustaining woodland areas in Ottawa. It

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[21] The first experiment in naturalization of dense urban housing was completed in 1979 for an apartment complex in Delft, Holland (Bos and Mol, 1980; Spirn, 1984) and followed by projects like Warrington New Town in Britain (Scott, 1986).

[22] Located in a downtown Toronto neighbourhood, Ecology Park was planted from 1985 to 1987 on a vacant lot owned by the Metropolitan Toronto government (Gordon, 1990). It was recently removed for the Spadina subway station expansion.

[23] National Capital Commission

reflected an image change away from manicured parks and neatly trimmed lawns to low-maintenance landscapes as a result of declining budgets, escalating costs and public environmental awareness (Hough *et al*, 1982). According to Hough *et al* (1982), with the widespread public concern in Canada for the environment, municipal parks personnel have been under increasing pressure to modify the traditional view of parks as high-maintenance grass and tree open spaces More emphasis has been placed on creating a diversity of naturalized urban spaces Similarly, the City of Ottawa (1993) promotes naturalization to infuse variety and a sense of natural processes into urban parklands

Figure 1 3. Test plot in the South-west Transitway Corridor Naturalization Project

The NCC has found that since planting phase two of the South-west Transitway Corridor in 1988, maintenance activities have been limited to mowing one to two metre wide strips of grass along pathway edges (Gauthier, 1993) A cost comparison of maintaining a formal, manicured landscape and a reforested plot, both one acre in size, by the City of North York, indicates that over a three year period, the formal treatment cost $8 529 00 while the naturalized alternative cost $2792.00 to maintain (Granger, 1984) Similarly the

City of Kitchener has adopted naturalization for several of its parks[24].

1.3 2 3 Aesthetics

One of the NCC's reasons for establishing naturalized areas was to enhance the variety of landscapes in the national capital (Holubowich, 1990). Open spaces that support wildlife and provide contact with nature in the city offer different social and aesthetic experiences to more manicured gardens[25] Planting naturalized communities also provides wildlife with their preferred food, protective cover and habitat[26]. According to Hightshoe (1988), aesthetic preference has already

Figure 1 4 Comparison of conventional use of lawn and trees (top) with a naturalized alternative (bottom) for the same site (Diekelmann and Schuster, 1982)

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[24] School yards including Kew Beach, Ossington and Ridgeview Public Schools in the Toronto area are also converting lawn and asphalt areas into naturalized woodlands and meadows (Savage, 1987). Naturalization projects are planned or completed in the following public schools in the Ottawa area: Briargreen, Riverview, Woodroofe, Grant, Churchill (Pink *et al*, 1993).

[25] The following description of Toronto's Ecology Park (Pollution Probe, 1988) illustrates the aesthetic possibilities of naturalization:

"When walking through our woodland in spring, delicate wild strawberries grace the rich humus earth. Brightly-coloured hummingbirds hover beside trumpet creeper vines which scale the adjacent brick wall. Above, a multi-layered canopy of native choke cherry, red maple saplings and striking red osier dogwoods are alive with warblers."

[26] For example, an NCC study showed that songbird populations increased simply by eliminating mowing under tree canopies (Hough *et al*, 1982).

begun to change as a new landscape ethic emerges[27]. This new ethic supports the public's growing interest in environmental issues.

1.4 Research Question

What are the potential savings in annual cost and resource consumption when conventional landscapes are compared with low-maintenance alternatives? Do these savings result in a *desirable payback period*[28] for the homeowner?

1.5 Goals and Objectives

The goal of this study is to provide a measure of the potential savings in annual costs and resource consumption of low maintenance alternatives to conventional residential landscapes. Guidelines which apply to any Canadian housing situation will also be provided. The objectives are to:

1. provide background information for the five landscape options;
2. simulate five landscape options;
3. analyse the simulations by calculating: a) capital costs, b) annual costs and resources

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[27] In an attempt to test the acceptability of water conserving landscape, Thayer (1982) conducted a study of public response to eight alternatives. Respondents stated that the alternatives with a 50% reduction in irrigation water were as acceptable as the typical irrigation control landscape with turf. A survey in San Francisco, tested residents' responses to landscapes that used only 40% as much irrigation water as those of nearby communities. The residents reported that they were pleased with their lush, green surroundings (Ferguson, 1987).

[28] The criteria for selecting ten years as a *desirable payback period* will be discussed in Chapter Six.

consumed in annual maintenance and c) payback periods;

4. formulate conclusions and guidelines

1.6 Intended Audience

This study is directed toward landscape architects, architects and urban planners. However, any group or individual making decisions about managing landscapes can use the conclusions about potential savings. For example, single and multi-family residents can also benefit from the results of this study.

1.7 Methodology

Although the case study methodology was considered in this investigation, variables involving building and site configuration would affect the evaluation of landscape elements Ideally, all parameters, except for landscape elements, should be held constant for each alternative. Therefore, the alternatives were simulated[29]. The site and building parameters remained constant for each of the five alternatives. These fixed parameters were derived from a proposed housing co-operative in a downtown Ottawa community. While variables occurred in the planting design, most of the landscape design elements, for example, path lay-outs, sense of canopy, colour and amenity space, were as consistent as possible. The variables included species selection, size of lawn area and method of planting The site analysis and simulations are illustrated in Chapter Four.

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[29] AutoCAD, an architectural design program, will be used for the simulations.

The simulation of landscape options includes·

1. The conventional landscape: trimmed lawns sparsely planted with trees, shrubs, groundcovers and annuals;

2. Alternative 1: lawn area limited to 30% of planted area, and replaced with beds of grouped, well-adapted groundcover and shrubs with a canopy of hardy, native trees also grouped in mulched beds

3. Alternative 2: lawn area eliminated and replaced with beds of grouped, well-adapted groundcover and shrubs with a canopy of hardy, native trees also grouped in beds,

4. Alternative 3: lawn area limited to 30% of planted area and replaced with naturalized woodland plantings with shrub and groundcover edges and

5. Alternative 4: lawn area eliminated and replaced with woodland and tall grass prairie plantings with shrub and groundcover edge.

Initial costs were determined by two methods. 1) Yardsticks for Costing provided comprehensive listings of costs for landscape elements While this source provided both current and local, published cost data, only standard landscape items are covered 2) In order to obtain current, local prices for non-standard items, primarily for the naturalized alternatives, a survey of contractors was conducted. Contractors provided prices for installing the alternatives based on a specification describing materials and tasks. The naturalized alternatives incorporated specifications for local projects, for example, the South-west Transitway Corridor, by local practitioners. Capital costs of maintenance equipment was included in the total initial cost. Prices were derived from the Canadian

Tire catalogue (1993) since this type of retail outlet is where residents are most likely to buy such items. The specification for the conventional landscape and woody plant alternatives was based on the National Master Specification (1992). The methodology for calculating payback periods is from Brown and Yanuck (1985).

Since annual requirements, like pest and weed control, are difficult to predict in advance, records kept from previous years provide the best method of calculating maintenance requirements While some standards from maintenance records have been published, these are not specific to the local conditions of this study. An NCC database, called Operation Management System, provided the local source needed for this study. The NCC uses this system to predict annual requirements in terms of labour, equipment and materials. Published sources, like those of OMAF[30], helped to fill some gaps and inconsistencies in the database.

1.8 LIMITATIONS

Beyond achieving savings through annual maintenance reductions, planting design has a significant impact on resource consumption in other household operations. For example, the shading effect of trees in the summer and their wind-blocking effect in the winter can significantly reduce energy consumption in household heating and cooling[31].

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[30] Ontario Ministry of Agriculture and Food

[31] For example, a study by Akbari and Taha (1991), indicates that significant savings for a residential neighbourhood can be achieved by increasing vegetative cover by 30%. In five Canadian cities, heating energy was reduced by 10% to 35% and cooling by 40

Furthermore, vegetation can greatly effect the quantity of stormwater run-off[32]. While these areas were reviewed for this paper, the analysis will focus on the costs and materials consumed in annual landscape maintenance. Moreover, the environmental impacts of consuming these resources will not be evaluated.

User-preference was also reviewed for this paper. Evaluating the social aspects of low-maintenance alternatives would have completed the sustainable development triad, which includes economy, ecology and community and ensured a more equitable comparison of the five options. While user preference was beyond the scope of this investigation, it is included in the general discussion.

The most accurate portrayal of annual requirements would have been obtained by implementing the five options and keeping maintenance records over several years. Since this was beyond the scope of this study, data on maintenance requirements was derived from published sources and the NCC database. Since only commercial and institutional sources were available and the simulations apply to housing, time requirements cited in the analysis are slightly lower than they would be in a real situation, due to the lower efficiency of a homeowner compared to a professional worker. Moreover, resource and

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to 100%.

[32] Based on calculations from "Surface Water Drainage" estimating run-off for similar soil types and climate conditions, forests with a well-developed understorey accumulate 40% less run-off than lawn areas and 20% less than dense meadows (Sykes, 1985).

time requirements assume that the maintenance intensity will be sufficient to sustain the intended appearance of the given landscape application. Thus, differences in aesthetic standards among various user groups are not accounted for.

The alternatives were applied to an 84-unit housing co-operative located in a downtown community in Ottawa Only the common space, located in the courtyard of the U-shaped building was designed and evaluated for this paper[33]. The small private patios were left out of the design and the analysis. The low-rise, medium-density building, is discussed in the Chapter Four. A single housing format was chosen to simplify the analysis and the comparison. Generally, the principles would apply to most residential landscapes, regardless of house typology. However, results will differ according to geographic location, since the emphasis in this study was placed on utilizing local data.

1.9 Conclusion

Before presenting the simulations, the conventional option and alternatives need further definition. The next two chapters will provide the reader with background information necessary to understand the components of each simulation. Moreover, the background will provide a rationale for choosing these elements for low-maintenance alternatives.

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[33] The design elements examined here include only planting and paving. The design was deliberately simplified for the purpose of clarity and sustaining a focus on low-maintenance alternatives. A more realistic design would include structures such as screening, play structures, seating and walls. Also grading and drainage is not included in the analysis.

CHAPTER TWO: LITERATURE REVIEW: CONVENTIONAL OPTION AND WELL-ADAPTED WOODY PLANT BEDS

2.1: INTRODUCTION

In the previous chapter, low-maintenance alternatives to conventional residential landscapes were introduced. In order to establish a rationale for selecting the four alternatives as solutions to reducing costs and consumption, background information is provided. In addition to presenting the maintenance requirements of the planting options, discussing the physiological and ecological relationships between plants and their environments will explain the differences in maintenance needs The survival strategies of certain species and plant communities render them less dependent on horticultural inputs than others. Both the annual maintenance requirements of *establishment*[34] and post-establishment will be discussed Although current dollar figures and local environmental factors will be applied to the simulations in Chapter Four, time requirements will be given here as a relative indication of maintenance inputs[35]

In this chapter, background will be provided for the elements included in the conventional option and first two alternatives. The discussion will be arranged around low-maintenance

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[34] Cobham (1990) defines *establishment* as "the prolonged period of 'childhood' during which woody plants need careful nurturing". Once they are established, usually within two to five years, biological requirement for the original maintenance regime decreases.

[35] The many variables including site conditions and equipment make estimates difficult. However, records of previous operations offer an indication of annual requirements. Time requirements offers a relative indication of total costs because labour accounts for approximately 66 to 75% of total cost (Cobham, 1990).

landscape principles including the following: 1) limit use of lawn areas; 2) use woody plants including trees, shrubs and groundcover; 3) select species adapted to local conditions; 4) group plants in mulched beds and 5) use hard-surface areas.

2.2 Limit Use of Lawn Areas

Turf is usually chosen as the primary vegetative cover because of its virtues of immediate impact and low initial cost[36] Although the capital cost of installing lawns is relatively low, annual requirements of maintaining lawns are higher than alternative strategies. Moreover, requirements remain constant each year, unlike the other strategies which exhibit decreasing inputs over time

2.2.1 Annual Requirements

Annual labour requirements for maintaining a $100m^2$ turf area, calculated from the various sources, are summarized in Table 2 1 and detailed in Appendix One.

Table 2.1: Annual time requirements for 100m2 lawn area

source	time (hours)[1]
Cobham (1990)	18.5
Wright (1980)	14 to 17
Institute of Maintenance Research (1983)	18.0

1. Refer to Appendix 1 for details.

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[36] According to Wilson (1991), the lawns and scattered exotic trees that are so important to the postwar suburban landscape derive from the English country estates of the eighteenth century. Lawns and ordered tree groupings offered a controlled, pristine and yet natural, green appearance; all of which represented the stylistic preference of the time (Spirn, 1984). This pastoral style has persisted in contemporary urban society because of a passive image of nature for the dual purposes of escape and exploitation (Wilson, 1991).

According to OMAF (1990), resources required for average annual maintenance are 1 5 to 2 kilograms per $100m^2$ of nitrogen split into two to four applications and an irrigation depth of three cm at weekly intervals[37] The OMAF estimation would result in a water requirement of 60 000 litres per year for a $100m^2$ area According to a CMHC publication, a typical suburban lawn, at $350m^2$ can require up to 200 000 litres (Reic, 1991) Fuel consumed in mowing every seven to ten days, and herbicide, pesticide and fungicide applications on an as needed basis are also part of the material requirements of traditional lawn care (Cobham, 1990; OMAF, 1990; Ortho, 1990, Turgeon, 1990)

2.2.2 Physiological and Ecological Relationships

While the figures shown in Table 2 1 indicate the requirements for traditional lawn maintenance, organic maintenance practices require significantly fewer material inputs (Rubin, 1989). Moveover, low-maintenance, water-conserving turfgrass species can be selected For example, Table 2.2 shows the range

Table 2.2: Summer ET rates for turfgrass
(from Beard, 1985)

Common Name	ET rate (cm/week)
Tall Fescue	5 1-8 9
Perennial Ryegrass	4 6-7.9
Kentucky Bluegrass	2 8-4 6

[37] According to Beard (1982), turfgrasses in northern temperate regions with moderate humidity have an evapotranspiration rate of 2.3 to 2.5cm per week. Records from the Toro Company (1966) indicate weekly rates of 0.4cm in the summer months. Thus, two additional cm of water are required each week to account for this discrepancy between water needs and availability through rainfall. However, environmental factors other than rainfall, such as sunlight, temperature and soil type, influence the water requirement.

in *evapotranspiration*[38] (ET) rates of three turfgrass species. Although organic lawn care reduces dependence on chemical herbicides, pesticides and fertilizer, time demands are still relatively high[39].

Continuous cutting leads to a weakened condition which promotes pests, diseases and weeds, since mowing creates wounds which pathogens can enter (Dernoeden, 1991).[40] Mowing also promotes weed invasions by thinning the vegetative cover. Like mowing, pedestrian circulation promotes wounds that pathogens easily invade. In addition, circulation causes compaction which impedes air and water movement in the soil (Anderson and Eggins, 1987). This causes a decline in plant vigour.

According to Muggas *et al* (1992) few soils have enough natural nitrogen to maintain desired turfgrass quality and recuperative ability through the growing season. They recommend three to four pounds of nitrogen fertilizer application per $100m^2$ for high-maintenance areas and one or two pounds for low-maintenance lawns. This is the rate

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[38] Hausenbuiller (1985) defines *evapotranspiration* as "the combined loss of water from a given area and during a specified period of time, by evaporation from the soil surface and by transpiration from plants".

[39] Annual fertilizing, albeit with less soluble and harmful sources, is necessary even when practising organic lawn care(Rubin, 1989). Aerating to alleviate compaction and weed problems should occur at least twice per year. Watering and mowing rates are similar to regular lawn care (Rubin, 1989).

[40] For example, studies at the University of Maryland show that when mowing heights were increased from 3.8 to 7.6 cm, disease resistance was improved (Dernoeden, 1991).

for a quick release, soluble nitrogen source. The nitrogen application rates recommended result in excessive nitrogen loss due to *leaching*[41] particularly on sandy *loam soils*[42] Chemical nitrogen is highly water-soluble and quickly leaches away into the water table

Organic fertilizers have very low leach potential as indicated in Table 2.3. When little organic matter is in the soil, the leaching process is hastened (Rubin, 1989). Over-use of chemical fertilizers can also kill beneficial organisms in the soil (Rubin, 1989).

Table 2.3 Characteristics of common turfgrass nitrogen sources (from Muggas et al 1992)

Fertilizer source	N content %	Leaching potential	Burn potential	Low temp response	Residual effect
Inorganic					
Ammonium nitrate	33 34	High	High	Rapid	Short
Calcium nitrate	16	High	High	Rapid	Short
Ammonium sulfate	21	High	High	Rapid	Short
Organic - natural					
Activated sewage sludge	6	Very low	Very low	Very low	Long
Manures	3 10	Very low	Very low	Very low	Long
Other natural products	3 10	Very low	Very low	Very low	Long
Organic - natural					
Urea	45 46	Moderate	High	Rapid	Short
Urea solutions	12 14	Moderate	High	Rapid	Short
Sulfur coated urea	14 38	Low	Low	Moderate	Moderate
Resin coated urea	24 35	Low	Low	Moderate	Long
Isobutylidene diurea (IBDU)	30 31	Mod low	Low	Moderate	Moderate
Methylene ureas and ureaformaldehyde*	38	Low	Low	Low	Med long to long

Thus, continued chemical use can lead to a weakened state and prolonged dependency.[43] This not only affects plant health but soil and water quality as well For example, two of

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[41] Hausenbuiller (1985) defines *leaching* as "the removal of materials in solution by water percolating through the soil".

[42] Hausenbuiller (1985) defines *loam soil* as having intermediate textural properties, that is, as close a balance of sand, silt and clay as any soil class.

[43] Chemical use can poison beneficial predators, such as birds. When this natural control is reduced,pests are allowed to multiply more rapidly (WEPD, 1993). This may further the need for chemicals and set a cycle in motion.

the most commonly used herbicides, 2,4-D and dicamba, are identified on a U.S. *EPA*[44] list of herbicides that have the greatest potential for leaching into the groundwater (Petrovic, 1989)

Although lawns generally contain more than one cultivar to widen the genetic base of the sward, species diversity is still limited (Dernoeden, 1991). Therefore, if herbicides and pesticides are used, they are applied to the entire turf area even where selective products are used. When these are applied repeatedly, resistant individuals will increase in number until most of the population is resistant and the chemical control fails (Sanders, 1989).

2.3 Use Woody Plants

Woody plants are increasingly replacing turf as a low-maintenance alternative. Despite establishment and senility periods which require more care, the adult woody plant will likely be maintenance-free, with proper species selection and early management (Cobham, 1990). Unlike this extended low-maintenance period for woody plants, turf areas do not experience post-establishment reductions of maintenance inputs. According to Baines (1982), if woody plant beds survive the critical two or three years of establishment[45], they will "provide many more years of relatively maintenance-free, low-

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[44] *Environmental Protection Agency*

[45] Correct establishment practice is critical to the long-term growth of woody plants. If they suffer unchecked drought or disease in the early years they may never recover (Cobham, 1990). For example, a study of Seattle street trees indicates that 100% of trees irrigated for the first two years of transplanting survive while only 20% survive without supplemental watering (Lindsey and Bassuk, 1991). After establishment, biological requirements for

cost pleasure. They certainly present a far more economical option than the convenient but costly grass."

One of the objectives of this study is to determine whether the annual maintenance savings are sufficient to offset the additional capital cost. For example, while trees are typically the least expensive plants to maintain over the life of the landscape, they are the most costly ones to install (Hensley, 1991). Cost analyses and payback calculations will be investigated for the simulations in Chapters Four to Six.

2.3.1 Annual Requirements

Through calculations from Cobham (1990), the following annual time requirements shown in Table 2.4 and Appendix One, can be expected:

Table 2.4: Annual requirements for woody plant options

item	time[1]
Tree (during establishment)	36 min./tree
Tree (after-establishment)	19 min./tree
Shrubs (after establishment)	2.6 hours/100m^2
Groundcover (during establishment)	2.6 hours /100m^2
Groundcover (after establishment)	2.3 hours/100m^2
Vines (after establishment)	28 min. /10m^2

1. Refer to Appendix 1 for details and sources.

Table 2.5: Annual requirements of 100 m^2 high-maintenance plantings (from Cobham, 1990)

item	labour (hours)
herbaceous borders	24.5
rockeries	18.0
herbaceous beds	25.2
annuals	80.0
herbacious groundcover	17.0

In comparison to woody plants, Cobham (1990) notes the following annual maintenance requirements of 100m^2 beds of other plantings,

environmental control decrease. Other objectives, such as appearance, may dictate maintenance inputs.

as shown in Table 2.5[46]. When compared with herbaceous plantings and lawns, woody plants offer significant saving potential.

2.3.2 Physiological and Ecological Relationships

While the majority of turfgrass species have been quantifiably assessed for maintenance requirements, assessments for trees and shrubs are more difficult to predict (Beard, 1992) According to O'Brien *et al* (1992) very little published material exists on performance standards for tree care.

As shown in Figure 2.1, the only tree care activities that most municipalities engage in are pruning, removal and replacement (O'Brien *et al*, 1992). The average annual cost per tree for street tree care in the U.S. was $10.62 in 1990

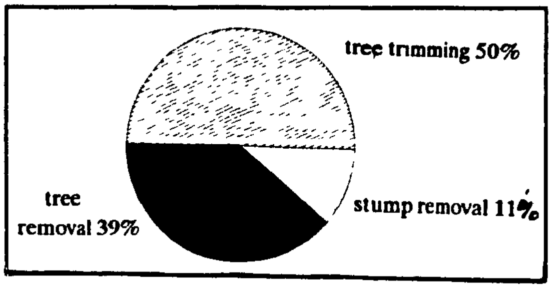

Figure 2.1 Maintenance distribution of Toledo's work database (from O'Brien et al, 1992)

(Zeming *et al*, 1991). After establishment, pruning is needed infrequently[47]. Pruning is usually the result of interference with other elements, such as overhead wires, buildings or views (Harris, 1983). Most conifers require little or no pruning even in confined spaces (Harris, 1983; Ortho, 1990). Most shrubs need very little pruning with the exception of

[46] A general rule of thumb, if low-maintenance is an objective, is to avoid any plant that needs to be lifted, separated, covered, planted annually, limed or otherwise requires predictable annual care (Smithers, 1988).

[47] However, pruning requires more time, as trees age. For example, to medium prune a 40cm diameter oak requires 2.1 hours and a 75cm maple requires 5.2 hours (Abbott and Miller, 1987).

removing diseased or damaged wood (Cobham, 1990)[48]. In contrast, if cutting is neglected, lawns will quickly begin to look unkempt (Knopf, 1991). Tree and shrub pruning times are generally both less frequent and more flexible than lawn mowing (Knopf, 1991).

Unlike turfgrass species, water-use assessments for trees and shrubs are lacking (Beard, 1992; Ferguson, 1987; Lindsey and Bassuk, 1991)[49]. Rough estimates can be obtained by calculating the available moisture potential[50] for a given soil texture. Figure 2.2 indicates that 20 to 25% of rainfall will be available for plants in a loam soil[51]. By calculating average annual rainfall for the region during periods of evapotranspiration, the soil's available water content can be determined For example, an average annual rainfall accumulation for Ottawa during months with ET

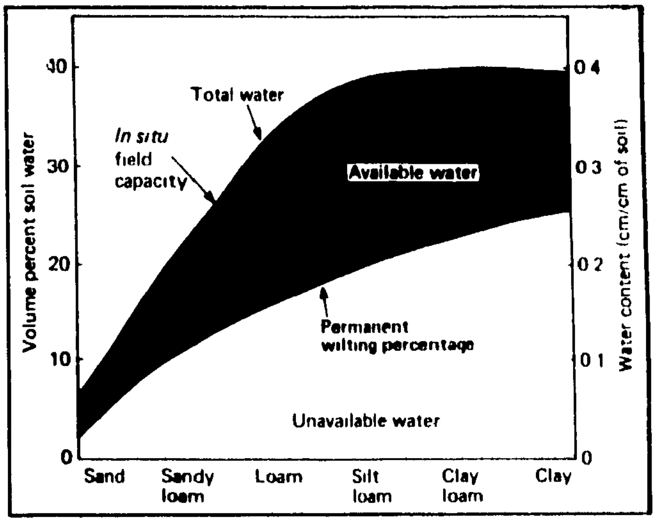

Figure 2 2 Relative available water in soils of different textures (from Kozlowski, 1987, after Cassell, 1983)

[48] According to Cobham (1990), annual pruning is not only unnecessary buc it destroys the formation of a closed weed-suppressing canopy.

[49] According to horticulturalists Chong (1993) and Perumel (1993), computer programs for calculating water requirements do not yet exist.

[50] Hightshoe (1988) defines available moisture potential as "the capacity of soil to hold water available for use by plants".

[51] Hausenbuiller (1985) and Harris (1983) indicate the same available water content for loam soils.

rates is 52.8 cm (The Toro Company, 1966). Approximately 25% will be lost through evaporation and 50% through percolation and run-off (Robinette, 1984). A mulch will decrease evaporation loss by 43% (Smith and Rakow, 1992). Therefore, available water for this example is 18.8 cm. According to Hightshoe (1988), many tree and shrub species require less than 15 cm of available water[52].

Since the available water estimate is calculated from rainfall averages, it does not account for occasional drought periods which would require additional water. A further limitation of this approach is that it does not account for specific wind, radiation and temperature data (Chong, 1993). ET rates are affected by sunlight, air temperature, wind speed and humidity (Lindsey and Bassuk, 1991). For example, for every 6 °C temperature increase, water loss doubles (Coder, 1990). Although water availability may fall below the plants ET rate during a drought period, most species can tolerate water deficits of 50% of their ET rate without critical long-term effects (Harris, 1983).

Woody plants have extensive root systems, so they can draw water from a larger soil area than relatively shallow-rooted turf. Therefore, turf needs to have regular irrigation (Welsh, 1991; Thayer and Richman, 1984) unlike trees for which Starbuck (1992) and

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[52] Species which would require no additional water beyond rainfall in this example include; *Abies, Betula, Carya, Catalpa, Celtis, Crataegus, Cornus, Fraxinus, Gleditsia, Ostrya, Pinus, Populus, Prunus, Quercus, Rhus, Ulnus* and *Viburnum*.

Cobham (1990) recommend watering only on an as needed basis during drought[53] According to Starbuck (1992), established trees need little attention most years, because they draw water from deep in the soil profile [54].

While most turfgrasses require regular fertilization, recent research shows that most varieties of shrubs and trees do not benefit from fertilizers, peat moss or other soil boosters (Rubin, 1989). Healthy trees and shrubs do not need annual fertilization. Fertilizers should only be applied when growth is poor and the problem can not be traced to anything else (OMAF, 1990; WEPD, 1992).

Despite the negative impact of herbicides on the water table, commercial maintenance companies use them because they reduce labour costs, since hand-weeding takes five times longer than spraying (Cobham, 1990). However, most established plants with closed canopies exercise their own weed control, since weeds generally invade exposed soil (Cobham, 1990). Therefore, groundcovers and shrubs should be planted densely to reduce the area of exposed ground during establishment (Thoday, 1982, Smithers, 1988) While dense plantings alleviate weed problems, thus causing reduced annual costs, they also result in higher initial costs. Thus, a trade-off should be made between time, cost and material consumption.

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[53] Irrigation of established shrubs is seldom necessary (Cobham, 1990).

[54] A list of water-conserving shrubs from Toronto's Queen's Park Demonstration Garden is shown in Appendix Two.

A cheaper solution to eliminating exposed soil patches during establishment may be mulching the plant bed. Mulch acts as a physical barrier to weeds in addition to all its other benefits, which include the reduction of soil temperature, evaporation, run-off and soil compaction By eliminating bare soil though dense plantings or mulch, weeds will not be a problem (Ortho Books, 1990). Weed control will be minimal after canopy closure. Given the conservation objectives of this study, weed prevention is preferable to herbicide use.

2.4 Select Species Adapted to Local Conditions

According to Hensley (1991), plant selection is the most important criteria for determining the amount of maintenance a tree will require. If plants have been appropriately selected and arranged, maintenance is likely to be needed for aesthetic rather than biological reasons after establishment (Cobham, 1990). For example, if trees are selected that only grow as large as the site or design allows, pruning will be minimal (Hensley, 1991). As illustrated by the calculation of water requirements earlier in this chapter, matching trees with local climate conditions can eliminate the need for irrigation. The environmental requirements of various tree and shrub species from Hightshoe (1988) are shown in Appendix Three.

Although disease and pest attacks cannot be predicted in advance for woody plants, epidemics are much rarer with a greater species diversity. Avoiding certain species that are susceptible to pests and disease is the best approach. Although a few diseases and pests affect healthy plants, most attack only plants that are weakened or low in vigour (Harris, 1983). Moreover, the mixed nature of the planting usually means that disease attacks are rarely severe or even noticeable (Cobham, 1990)

Raupp *et al* (1985) found a 94% reduction in pesticide use when an Integrated Pest Management (IPM) approach was substituted for spraying. By identifying "key" plants for local conditions, the implementation of an IPM program can be greatly facilitated. This can be accomplished by avoiding certain plant genera. For example, Figure 2 3 indicates that *Malus* had the highest frequency of problems, while *Viburnum* had the lowest Most of the more tolerant species are native, while the majority of susceptible species are introduced species According to Raupp *et al* (1985), "By substituting problem free genera for problem prone ones, landscape planners will greatly reduce the long-term problems and costs associated with maintaining the landscape" Although regional differences will affect the plant's susceptibility, certain species are more problem-prone than others (Raupp *et al*, 1985)

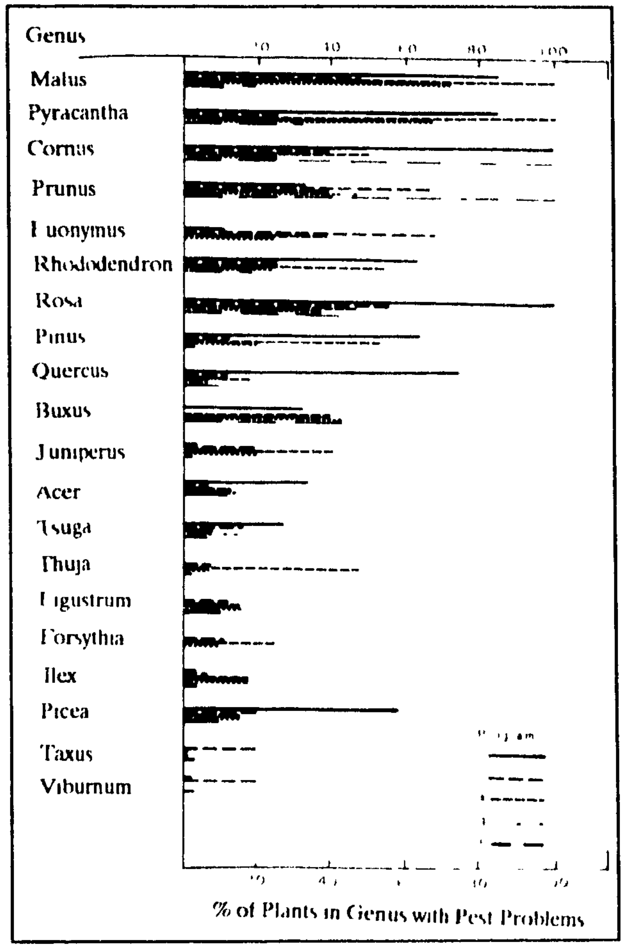

Figure 2 3 Frequency of pest, disease or improper culture problems by five IPM programs (from Raupp et al, 1985)

Deep-rooted species with high root to shoot ratios are best able to cope with water stress (Kramer, 1987) Evergreen plants are usually more drought tolerant than deciduous plants (Clark & Kjelgren, 1990) Many conifers are tolerant of low soil fertility because of an efficient internal system for cycling what few nutrients are available (Cobham, 1990; Thorne and Huang, 1990).

When properly sited, native species are generally better adapted to local climate and soil conditions and more resistant to local pest and disease than exotics (MNR, 1990). Native plants have adapted to the insect, disease and climatic environment through thousands of years of mutual living (Dorney, 1985). For example, native species attract more pest predators, such as birds, than non-natives (Dorney, 1985). However, the use of only natives is not always preferable. Native plants will not always be best suited to the given site, particularly with urban sites, where environmental conditions have been altered. Not all non-natives require more water, energy and chemicals to stay healthy. According to MNR (1990), it is generally preferable to use native species and substitute suitable exotics where necessary.

2.5 Group Plants in Lawn-free Mulched Beds

Specimen trees rising from an open grassed sward evokes an image of traditional urban plantings (Hough, 1984) as shown in Figure 2.4.[55] Although grasses may not seem to be

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[55] This approach is common because it permits maximum use of the ground plane (Hough, 1984), in addition to evoking immediate visual impact and the clean, green image discussed earlier.

a serious competitor for trees, their root systems enable them to out-compete trees for soil moisture and nutrients (Bradshaw, 1986). Turfgrasses dominate the root zone and lead to drought-stress even under established trees (Baines, 1986, McGuirk, 1992). The nature of

Figure 2 4 The conventional option specimen trees rising out of a lawn (adapted from Padolsky, 1988)

soil structure usually causes roots to grow best near the soil surface (Watson, 1989) For undisturbed soils, root growth is optimized in the top 30 cm, while in poor soils, the best growth is in the top 15cm (Watson, 1989).[56] A light, weekly application of 2 5cm of water will be mainly taken up by turf and never reach the tree's roots (Starbuck, 1992).

Figure 2 5 Comparison of tree root density in top soil layers under grass and mulch (from Watson, 1989)

Watson (1989) conducted a study of the extent of competition between tree and grass roots Figure 2 5 shows greater root density in trees grown in organic mulch and even bare soil compared to those grown in turf (Watson, 1989) Turfgrasses suppress tree root growth by up to 90% in the top few inches of soil which facilitate optimum amounts of water and oxygen

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[56] This is less problematic for deep-rooted trees, such as Oaks.

Planting in turf also increases compaction around the roots due to pedestrian circulation (Kramer, 1987) This stress renders the tree prone to insect and disease problems. In addition, isolating plants increases the ET potential since the relative humidity surrounding the tree is lower than in the closed canopy of a tree grouping (Clark and Kjelgren, 1990). Moreover, individual shrubs and trees provide less valuable cover for wildlife than grouped plantings (MNR, 1990).

In addition to turf-free zones around trees, hard-surfaces should be avoided within the tree root zone In urban environments root zones are restricted due to containerisation or proximity to pavement For example, a 10.6m high tree would require a planting area 7.6m in diameter and one metre deep in a sandy loam soil to supply enough water to the roots (Kramer, 1987). This is considerably less space than street trees and other urban plantings typically occupy.

Moisture, nutrient and exposure problems can be alleviated by grouping trees in mulched beds or in non-competitive groundcover beds. Mulching will reduce the need for weed suppression, water and nutrition in addition to giving the bed a finished appearance prior to achieving groundcover closure. Although shrubs, groundcovers or perennials also compete with trees when planted in tree root zones, their roots are similar to tree roots. Thus, each plant is at less of a disadvantage than when planted with more vigorous turfgrass species (Watson, 1989). Maintaining a weed-free area of at least a one metre diameter around the base of establishing trees and shrubs is also recommended to alleviate competition (Cobham, 1990).

The role of mulch in reducing weeds is demonstrated in Figure 2.6 which compares a weed count of various mulch types against a 1.5m^2 control plot without mulch (Billeaud and Zajicek, 1989) While the weed count for the control plot was 29, that of the pinebark nugget mulch test plot was one.[57] After groundcover and shrub plantings are established, the closed-canopy will control weed invasions (Thoday, 1982). Therefore, mulching requirements will be minimal

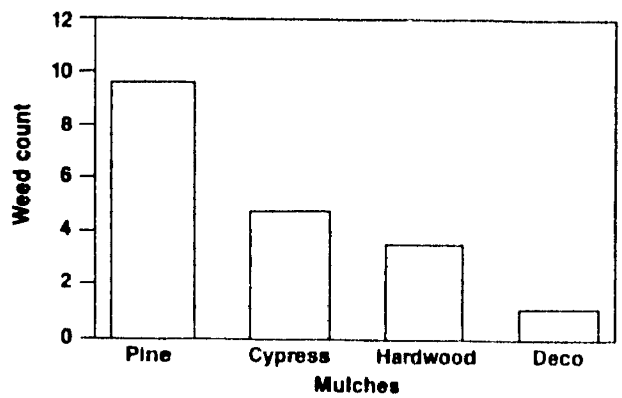

Figure 2.6 Effect of mulch type on weed count Weed count in contol plot, with no mulch was 29 (from Billeaud abd Zajicek, 1989)

In addition to controlling weeds, mulches improve soil moisture, regulate soil temperature, promote aeration, reduce erosion and boost soil nutrient levels According to Billeud and Zajicek (1989), mulching costs can be recouped after one year, through reduced maintenance requirements. A study comparing the use of different mulch materials with bare soil plots indicates the following benefits. moisture in mulched plots was approximately twice as high as the bare soil plots, the summer temperature was reduced

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[57] A study by Smith and Rakow (1992) indicates that increasing mulch depth beyond the optimal 3.8 cm increases water-loss saving only marginally. The detrimental effects caused by oxygen reduction will out-weigh the benefits of increasing this depth.

by 8 to 13° F and the average time required to remove weeds was reduced by two-thirds (Smith and Rakow, 1992). According to a study by Smith and Rakow (1992), applying a 3 5 cm mulch layer resulted in reduced evaporational water loss ranging from 27% to 50% relative to a bare soil control plot.

Water-use efficiency can be achieved by grouping plants according to *hydrozones*[58]. Zoning should respond to the following factors: intensity of human activity and visual impact as well as site constraints such as slope, drainage, shade and wind (Ferguson, 1987). For example, water-loss through ET can be reduced by almost 50% when turfgrass is located in full shade (Beard, 1992). Figure 2.7 illustrates four levels of irrigation intensity associated with site requirements and human activity. The principle hydrozone accommodates the greatest level of human impact and the largest subsequent water and energy use[59]. Secondary zones accommodate less intense activity and visual impact. Minimal and elemental zones require the fewest inputs.

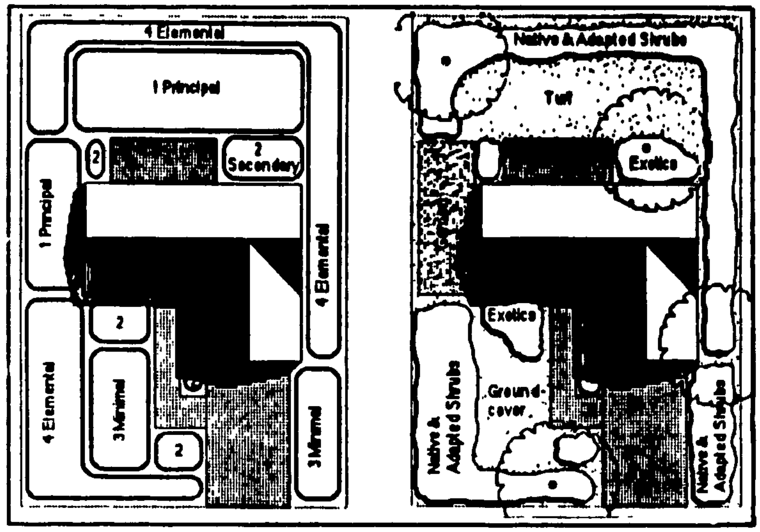

Figure 2 7 Hydrozones (from Ferguson, after Thayer and Richman, 1984)

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58 According to Thayer and Richman (1984), *hydrozones* are areas of a given site with similar water requirement intensities.

59 This generally should occur in the rear yard, not the front yard where turf is often used as a visual groundcover (Reic, 1991).

2.6 Use Hard-surfaced Areas

In addition to well-adapted woody plants, hard surfaces can be a low-maintenance alternative to turf. Concrete surfaces normally require little more than annual cleaning and brushing (CMHC, 1982). Unit pavers may need to be replaced if cracking occurs Since mortar is not used in most unit paver applications, damaged blocks are simply replaced and sand is brushed back between the space Gravel and stone dust require frequent maintenance including weeding, raking and annual topping Paved areas require sweeping, washing and weeding (CMHC, 1982)

While significant annual savings can be achieved by replacing lawns with hard surfaced areas, the additional capital costs associated with various surfaces cause long payback periods. A study from shown in Table 2.6 compares the number of years taken to recoup the additional capital cost of lawn alternatives, through reduced maintenance. The five hard-surface treatments exhibit the longest payback times

Payback periods of lawn alternatives (Cobham, 1990 adapted from Parker, 1982)

Surface	Relative index of capital cost	Relative index of annual maintenance cost	'Break-even' point (years)
Small lawn	1.0	0.25	not applicable
Groundcover	2.0	0.05	5-7
Shrubs	2.8	0.06	8-11 25
Hoggin	4.0	0.03	12-14
Concrete	5.0	-	14-16
Tarpaving	7.0	-	
Various pavings	12-20	-	>20
Cobbled concrete	30.00	-	
Gang mown grass	0.25	-	not applicable

2.7 EXAMPLES

Xeriscapes have become a popular low-maintenance alternative particularly in the arid American south-west. In addition to reducing water consumption, following xeriscape principles reduces the need for other materials such as fuel, fertilizer, herbicides and pesticides. The following summary of xeriscape principles from Reic (1991) and MNR (1992) resembles that of the low-maintenance alternatives discussed earlier:

- limit use of turf areas only for specific social and recreational functions;
- select water-efficient plants suited to the local site conditions including climate, soil type and site drainage,
- group trees, shrubs and groundcover in beds rather than in isolation;
- group plants with similar water requirements into hydrozones;
- use mulches to reduce evaporation and prevent weed growth;
- use an efficient irrigation system that prevents water loss through evaporation and surface run-off and
- improve the soil's water holding capacity.

Table 2.7: Water-use comparison (from Ferguson1987)

Plant type	Water-use reduction compared to lawns
- xeric native plants	73%
- average tree and shrub	30%
- groundcover	23%
- vines	39%

If xeriscape principles are implemented, it is reasonable to expect 60% to 70% water savings (Ferguson, 1987). However, in many climatic regions, the water requirements of mesiscapes can be supplied entirely by rainfall (Licht, 1990). Ferguson (1987) compared the water requirements of four plant options shown in Table 2.7 with those of lawns. This shows that xeric native plants show impressive savings when compared to lawns

A comparison of annual water-use by McPherson *et al* (1990) showed that for equivalent areas, the following irrigation requirements could be assumed 76cm for mesiscapes, 15.2 cm for xeriscapes and 114.3cm for lawns McPherson *et al* (1989) compared the irrigation cost of three landscape alternatives: a *zeroscape*[60], a shrub bed and a lawn Water consumption for the shrub beds was 7% that of the lawn and only slightly higher than the zeroscape alternative. While this study was conducted in the American south-west, the figures compare relative requirements which are relevant in other locations The initiators of the Xeriscape Demonstration Garden at Toronto's Queen's Park, predict that water use will drop by 74% as compared to the water used previously (Erskine, 1992)

A study by the North Marin California Water District compares the resource consumption of conventional landscapes with low-maintenance alternatives.The study compares the use of water, labour, fertilizer, fuel and herbicide for traditional landscapes and water-conserving projects. The water-conserving design criteria were as follows 1) limit use of turf in narrow pockets, 2) limit turf to less than 40% of the total landscape area, 3) locate turf only in one area with turf perimeter not more than 30 linear feet and 4) replace turf with beds of grouped water-conserving tree and shrub varieties Water-loving plants were

[60] *Zeroscapes* are inert landscape designs which require no water.

located in drainage zones and shaded areas. Appendix Four indicates the following savings: water was reduced by 54%, labour by 25%, fertilizer by 61%, fuel by 44% and herbicides by 22% (Nelson, 1987). Overall savings were $75.00 per unit per year over a total cost of $213.00 for the traditional option. This represents a 35% reduction in cost Figure 2 8 indicates the tremendous saving potential of the alternative designs in water-use alone.

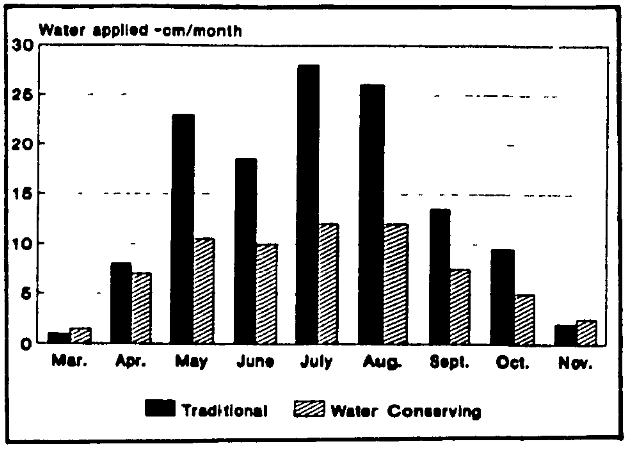

Figure 2 8 Comparison of water-use for traditional and water-conserving landscapes in Marin County California (Nelson, 1987)

2.8 Conclusion

This discussion offers a rationale for selecting well-adapted woody plants grouped in mulched beds as a low-maintenance alternative. It also defines the conventional option and the ecological relationships which cause its higher consumption rate. One of the main criteria for reducing maintenance inputs is limiting lawn areas. The impact of replacing lawn areas partially and completely on both initial and annual costs, as well as the need to mitigate for the loss of socializing space, will be investigated in the simulations.

The principles discussed in this chapter will be incorporated into the simulations. Each alternative will be assessed for both cost and resource consumption in current values pertaining to local site conditions. In the next chapter, principles which explain the saving potential of naturalized landscapes will be discussed.

CHAPTER THREE: LITERATURE REVIEW: NATURALIZATION

3.1 INTRODUCTION

In the previous chapter, principles for implementing low-maintenance landscapes were discussed. In this chapter, principles for naturalized landscapes including *woodland*[61] and *tall grass prairie*[62] will be discussed. These principles will determine the criteria for the simulation of Alternatives 1 to 4 and the Conventional Option. Rationale for selecting these alternatives will be provided by showing their saving potential based on results of implemented examples. The physiological and ecological relationships between plants and their environments will explain the reduced need for maintenance The time and materials consumed in annual maintenance, as well as the results of other examples, will indicate the saving potential of the naturalized alternatives. Detailed, site specific cost and resource comparisons for the simulations will occur in Chapter Four

3.2 BACKGROUND: ECOLOGICAL SUCCESSION

Bradshaw (1984) summarizes the basics of naturalization in his statement

> "What ultimately survives in nature is that which is best fitted to its environment So if we attempt to model landscape design on natural systems and use natural processes to achieve desired end-points, we are more likely to produce resilient

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[61] According to Dorney (1980), a *woodland* garden emulates the dynamics, textures, scents and colours of local, indigenous hardwood forests.

[62] Kline and Howell (1987), define *tall grass prairies* as "biological communities dominated by grasses.... Among the grasses are an array of herbaceous, non-grass-like flowering plants, collectively called forbs".

and self-sustaining solutions."

Following the clearance of vegetation by human or natural causes[63], plants recolonize the site in a relatively predictable manner. Ecological succession is a model used to describe this process[64], which is illustrated in Figure 3.1.

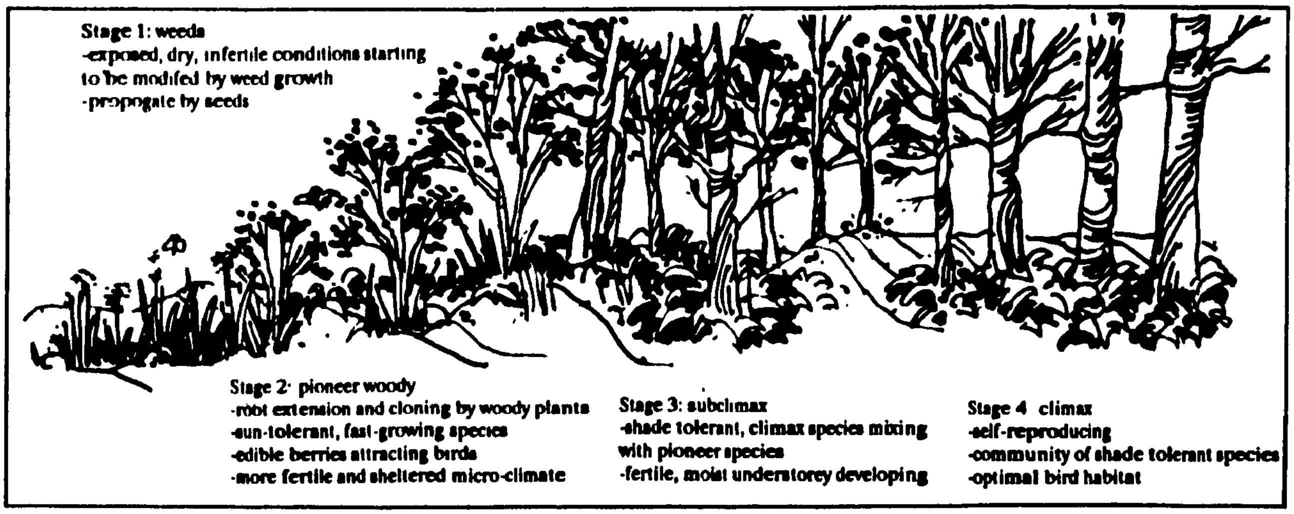

Figure 3 1 Stages of woodland development through ecological succession (adapted from Dorney, 1980)

The usual sequence of recolonization after clearance begins with species which tolerate exposed, windy, dry and infertile conditions. These annuals regenerate by numerous widely dispersed seeds. As soil quality and micro-climatic conditions are altered[65],

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[63] Vegetation clearance can be initiated through many factors. For example, mowing is a form of clearance. It reverts the plant community to an early successional stage on a cyclical basis. It brings ruderal and competitive species into prominence (Rorison and Hunt, 1980).

[64] According to Grey (1992), this model unrealistically simplifies the complexity of variables involved in community growth, however, it can be used to explain the basics of naturalization.

[65] Weeds improve soil quality by: retaining moisture, protecting it from evaporation, fertilizing it annually with dead weeds, thus, encouraging microorganisms (Spirn, 1984).

perennial species out-compete the early invaders as they become more adapted to the new site conditions. As these species create a canopy for shade-tolerant plants, they squeeze out less shade-tolerant species and prevent their re-entry. Pioneer species, including poplar and birch, continue to modify conditions by contributing to the build-up of nutrients, moisture, protection and shade. Finally, the climax species, which are generally hardwoods, such as maple and beech, establish themselves. At this point, environmental conditions will remain relatively stable Long-term maintenance of naturalized areas is aimed at preventing the development of competing vegetation and ensuring desirable form (Cobham, 1990).

In climatic conditions which favour woodland communities, this process would normally require 100 to 235 years without human input (Dorney, 1980). However, with planting, weed control and limited maintenance at the beginning of the process, a woodland can be achieved within 10 to 20 years (Dorney, 1980). Tall grass and wildflowers communities would naturally require 20 years to establish into a self-reproducing state. However, with initial intervention and limited long-term maintenance, a tall grass prairie community can be established in three to five years (Kline and Howell, 1987). According to the City of Ottawa (1993), planted and managed woodlands and prairies require 10 to 25 years and two to three years, respectively.

Managed Succession

Naturalization differs from standard horticultural procedures, which create artificial growing conditions for individual plants rather than for the overall health and longevity of plant communities (Hough *et al*, 1982). Conventionally, trees are planted in environments that are different from the moist, shaded, protected forest in which they evolved[66]. In nature, trees grow in communities or groups in which mutually dependant plants adapt to similar environmental factors (Diekelmann and Schuster, 1982). The conditions of natural plant communities can be used as a model for landscape design. Managed succession aims to give natural succession a helping hand by speeding up the early stages and sketching out the more attractive ones (Baines and Smart, 1984)[67]. After an initial planting, ground preparation and early management, the plant community is virtually self-perpetuating (Hough et al, 1982).

Specimen trees set apart on mown lawns are a key element in the conventional landscape. However, when these trees die, nothing is left in their place. Since they cannot regenerate themselves in this environment they must be removed and replaced at great expense (Spirn, 1984). An advantage of naturalization over the conventional use of vegetation is that the costly replacement of plant material is eliminated. Since conditions are favourable for plants which propagate by seed[68], *runners*[69], root extensions

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[66] Trees should be planted with moisture loving groundcover, which emulates the forest floor, rather than grasses (Watson, 1989).

[67] Naturalization involves varying degrees of human intervention. For example, the City of Ottawa (1993) defines four naturalization categories, ranging from abandonment to managed succession, referred to as *Open Area Reforestation*.

[68] Most trees seed every one to four years (Dorney, 1985).

or cloning, human intervention is limited. These communities are virtually self-perpetuating (Dorney, 1985). According to Dorney (1985), a tall grass prairie will produce enough seed by the fourth year to double its size and be self-sustaining. Thus, after establishment, replacement is unnecessary, unlike conventional plantings which require replacement

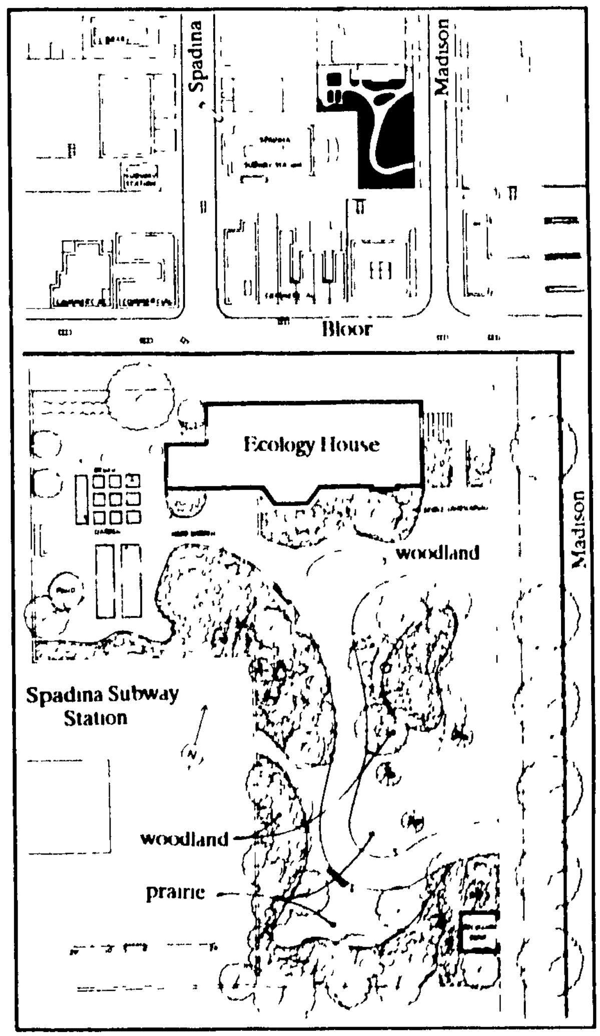

Figure 3 2 Ecology House, Toronto top, context map bottom, landscape plan (from Gordon, 1990)

While the previous description may evoke images of many acres of land, the owner of a standard suburban residence can create a woodland or prairie garden because the principles of establishment and maintenance are similar. According to Dorney (1980), woodland gardens can be established on areas as small as 20m^2 and the minimum practical size for prairie gardens is four square metres. Even on small plots, species diversity is impressive. For example, Larry Lamb has noted the persistence of 270 species on his 27.6m^2 residential prairie garden in Waterloo (Hoepfner, 1992). Figure 3.2 shows Ecology Park, with its woodland and tall grass prairie, on a dense downtown Toronto site

[69] According to DeWolf (1987) a *runner* is a prostrate shoot, rooting at its nodes.

Naturalized plantings can be established through the following principles:

WOODLANDS
1. plant small stock at close spacings
2. mix pioneer and climax species
3. select species from a regional native landscape
4. control weeds before planting
5 avoid soil amendments
6. maintain by thinning

TALL GRASS PRAIRIE
1. establish tall grass by seed and wildflowers by transplants
2. control weeds during planting and avoid soil amendments
4. maintain by burning or mowing and weeding

3.4 WOODLAND

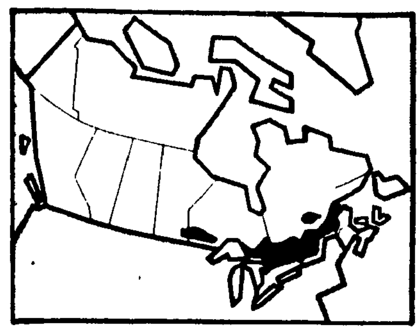

Figure 3 3 Map of Great Lakes-St Lawrence Forest Region (from Hosie, 1979)

Ottawa, the location of the study site, is located in the Great Lakes-St. Lawrence Forest Region (Hosie, 1979)[70]. These mixed deciduous and coniferous forests includes pine, birch, maple and oak. This community is characterized by trees, shrubs and groundcover interdependent for shade, wind and erosion protection, moisture and nutrients[71]. The following principles should be followed for the successful implementation of a naturalized woodland

[70] Since the simulation site is Ottawa, only plant communities appropriate for this region will be discussed.

[71] The forest floor consists of rich, humus-laden soil created by generations of fallen leaves and decaying trees and shrubs (Dorney, 1980)

3.4.1 Plant Small Stock

Conventional planting calls for nursery grown, ball and burlap trees In addition to the high initial expense associated with staked standards, using relatively mature stock results in high mortality rates and replacement (Insley and Buckley, 1986) For example, a study of replacement rates of roadside plantings over five years indicates that 26% to 40% of plants needed replacing. According to Baines and Smart (1984), inappropriate planting techniques and maintenance have lead to perhaps a 70% to 80% death rate within the first ten years of a tree planting.

According to Watson (1987), as much as 98% of the root system is typically lost during transplanting. Since nursery production techniques encourage low root to shoot ratios, the root systems' ability to supply enough water and nutrients to the above ground parts of the tree to sustain vigorous growth is impeded The greater the imbalance between root and crown, plant growth and long-term health is impeded According to Scott (1986), studies show that two-year seedlings catch up to older standards within three years with healthier growth and more natural form, as shown in Figure 3 4

A more cost-effective alternative to mature nursery stock which results in lower mortality rates and less maintenance is the use of bare-rooted seedlings[72]. Among the seedlings,

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[72] Seedlings are grown in a nursery or protected environment and transplanted on site. They are younger and smaller than standard nursery trees. Baines and Smart (1984) recommend transplanting two-year seedlings approximately 50cm in height. Seedlings planted in the NCC's South-west Transitway reforestation project were 1250cm tall (Corush *et al*, 1987). Although least

some larger standard stock can be planted to create more immediate visual structure and variety during establishment (Cobham, 1990). Moreover, this size variety more closely emulates the growth of a natural forest canopy. The experience in many Dutch city park naturalization projects has been that initial costs were kept down by planting massive quantities of young seedlings and relatively few of the more expensive large trees (Spirn, 1984)

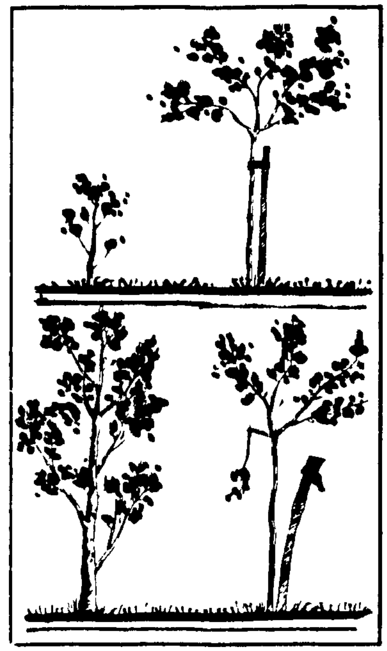

Figure 3.4 Top two-year old seedling (left) and standard tree (right) at planting time, Bottom same two or three years later (from Baines and Smart, 1984)

3.4.2 Mix Pioneer and Climax Species at Close Spacings

While many approaches for establishing woodlands can be taken, planting is generally initiated with pioneer species for the following reasons: they can tolerate exposed light and wind conditions, they are fast growing and they quickly establish a protected, fertile microclimate for climax species. Once pioneer species are established, the sensitive climax stock can be planted. Hough *et al* (1989) concluded that greater survival rates in the NCC Transitway Corridor test plots were achieved when an initial pioneer planting

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expensive initially, direct seeding on-site is often problematic because of hostile, exposed environments and competition by other species if not planted into an existing canopy (Insley and Buckley, 1986).

was allowed to establish an environment conducive to future hardwood plantings[73]

Alternatively, pioneer and climax species can be planted simultaneously, as shown in Figure 3 5 While this mix resulted in lower survival rates in the test plots, planting can occur in one operation, rather than over several years Also less thinning and removal of pioneer species is needed after canopy closure Appendix Five shows an initial lay-out and plant list mixing pioneer and climax species. In addition to this dense matrix of pioneer species, initial plantings should include an edge of shrubs. This provides not only an aesthetic finish in an urban context but prevents harsh winds from penetrating the interior This also assists the control of weedy invasions (Dorney, 1985, Hough *et al*, 1982).

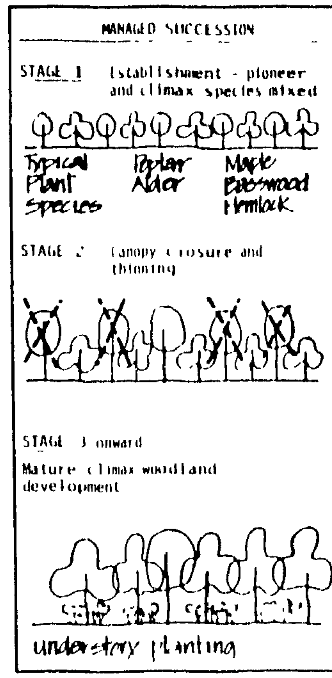

Figure 3 5 Planting and maintenance strategy when climax and pioneer species planted at the same time (from Hough et al, 1982)

If initial plantings are closely spaced, weed control during establishment will be reduced However, the need for long-term *thinning*[74] increases (Cobham, 1990) For example, results for the NCC's South-west Transitway Corridor, showed that dense spacings of 1 5

[73] According to Baines (1986), when attempts to establish these species are made without the benefit of this closure, mortality rates are high.

[74] According to Cobham (1990), *thinning* is the selective removal of young trees or branches to promote more open form and encourage desirable tree species.

m centres exhibited the highest growth rate (Hough *et al*, 1989)[75]. This density results in a greater initial investment and a greater need for thinning and removal after establishment However, dense plantings rapidly suppress weeds and generally result in a higher growth rate in both pioneer and hardwood species

Figure 3 6. Dense woodland planting at Eco-Plans Ltd, Waterloo (from Dunster, 1990)

Observations made through the South-west Transitway Corridor test plots planted in 1983, determined the most successful strategies for establishing woodlands in the region. These strategies were incorporated into the 1988 planting of the transitway. In addition to determining optimum size and spacings, an optimum species mix was incorporated into the 1988 plantings Deciduous and coniferous species were mixed, as shown in Appendix Six Pioneer and climax species were planted simultaneously (Corush *et al*, 1987). After the faster growing pioneer species are thinned out, the mature woodland will consist mostly of climax species

3.4.3 Select Species From a Regional Native Landscape

One of the keys to naturalizing is the selection of plants which are able to grow and reproduce without compromising the vitality of others. This will create a habitat within which the need for routine care is minimized (Diekelmann and Schuster, 1982). Usually

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[75] Seedling spacing in the 1988 planting was also at 1.5m centres (Corush *et al*, 1987).

this will involve modelling plant selection after species found in local communities which are native to the region. However, each site begins with unique environmental conditions which may not be appropriate for species native to regional forests. Species that are appropriate for a forest in this region are shown in Appendix Six.

3.4.4 Control Weeds Before Planting

Controlling weed competition is fundamental to the successful establishment of woodland plantings. Unlike turf, which requires continuous weed control, the woodland garden requires more intensive control during initial establishment but generally no control afterwards. Until canopy closure, weed control will be necessary. However, by the third year, a low canopy will close, thus eliminating the area of exposed, infertile soil This creates conditions which favour more desirable species and reduces competition from invading weeds (Dorney, 1980).

Two approaches to weed control can be taken: mechanical and chemical Mechanical control involves hand or machine pulling of weeds. Chemical treatment involves initial application of a residual herbicide prior to planting with one application annually for the first three years until canopy closure (Hough *et al*, 1982). While hand weeding is time consuming[76], regular chemical control runs contrary to the conservation objectives of this study[77].

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[76] Hand weeding takes approximately 23 minutes for a 100m2 plot before establishment (Cobham, 1990)

A study of the cost benefits of cultivation treatments shows that the greatest net growth per dollar spent occurred when the herbicide Simazine was applied at a rate of three pounds per acre (Van Althen, 1971 cited by Hough *et al*, 1982). Manual weeding and black polyethylene weed barriers were the most expensive weed control options. The savings caused by chemical controls is due to lower labour expenditures compared to manual weeding and lower material costs compared to weed barrier and mulching. If cost reduction is the main objective and the maintenance is performed by a hired team, herbicides are recommended over mechanical methods because of time-efficiency (Haggar, 1980).

Weed prevention is less time consuming and environmentally damaging than the weed control measures described above. Plastic sheeting around plant bases provides a highly effective weed barrier (Hough *et al*, 1982). The use of biodegradable material, such as leaf mulch or newspapers, will also help control weeds and improve the soil's organic content. In the NCC study, black, perforated polyethylene sheeting was one of several ground preparation techniques[78]. Shredded bark mulch covering the plastic improves the appearance. This proved to be the most successful weed control method (Hosler, 1993). Despite higher initial costs, these are easily offset by its effectiveness in reducing weeds

[77] Approximately 1.9 litres of herbicide will be consumed in this spot spraying (Cobham, 1990).

[78] The plot covered with a woven fabric weed barrier suffered weed problems and substantially less growth than plots covered with perforated black polyethylene (Hosler, 1993).

(Hough *et al*, 1989). [79] This technique was implemented in the 1988 transitway plantings (Corush *et al*, 1987).

According to Baines and Smart (1984), it is much better to eradicate competition from weeds before planting than afterwards. Months before planting, the area should be sprayed with a non-selective systemic contact herbicide. Since an enormous reservoir of weed seeds lie dormant in the soil, the disturbance caused by planting will trigger mass germination. Months later the site should be ploughed, disced and cultivated Immediately before planting, another application of residual herbicide or a course mulch layer will prevent weed germination. This technique was the most successful site preparation method on the transitway test plots (Hough *et al*, 1988). It was also implemented on the 1988 transitway planting (Corush *et al*, 1987).

According to Scott (1986), the ground should be kept weed free for the first three years to reduce competition for pioneer and climax species By the second year, little to no weeding is required, depending on how well-weeded the site was prior to planting (Haggar, 1980). While public perception of naturalized gardens often involves fear of *noxious weeds*[80], these are associated with cultivated land, poorly kept lawns and vacant

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[79] A disadvantage of this approach is that the weed barrier does not biodegrade. Although it photodegrades, the mulch covering prevents light exposure. Thus, if it is not removed manually, it will remain in-place (Hosler, 1993).

[80] *Noxious weeds*, such as ragweed and poison ivy, are classified as such because they may have adverse affects on human health (Hough et al, 1987).

lands. A biologically complex landscape with later successional species out-competes noxious weeds and therefore would not appear in established woodland or prairie gardens (Hough *et al*, 1987)

3.4.5 Avoid Soil Amendments

On construction sites or other disturbed lands, nitrogen will be in short supply and soils will be compacted (Bradshaw, 1986). The conventional approach to improving soil calls for the application of topsoil. According to Baines (1986), this process is both expensive and often counter-productive. Topsoil will boost growth of herbaceous weeds which dominate the root zone and out-compete trees and shrubs for moisture. Trees planted in topsoil often die as a result of this competition (Baines and Smart, 1984). Standard procedure also calls for chemical nitrogen which leads to leaching and erosion, particularly in the absence of plant roots and surface vegetation (Bradshaw, 1986).

According to Hough *et al* (1982) the alteration of existing soil by adding fertilizer, peat moss and topsoil is to be avoided. The experience in Dutch naturalization schemes shows that greater plant diversity was achieve at considerably lower cost by avoiding imported topsoil (Spirn, 1984) According to Baines and Smart (1984) it is far easier to establish

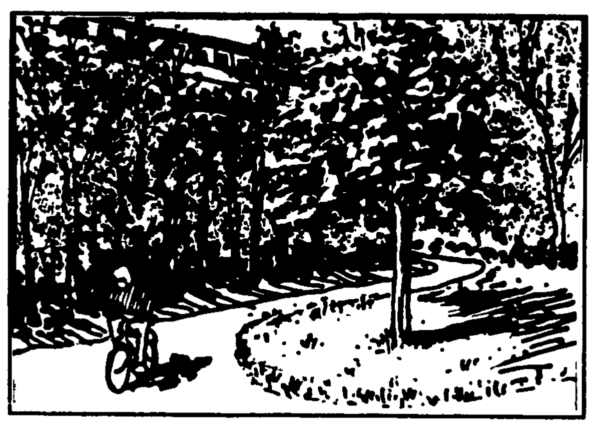

Figure 3 7: Naturalized open-space in Dutch housing, Delft (adapted from Hough, 1984) woodlands on sub-soil or even crushed brick rubble than topsoil[81].

An alternative to importing topsoil on nutrient-poor soils is the planting of a nurse crop of nitrogen fixing plants, such as clover or winter rye, prior to planting seedlings Nurse crops also aerate the soil, (Hough *et al*, 1982) and do not contribute to leaching[82] The natural accumulation of organics through leaf litter should mean that organics do not need to be added (Diekelmann and Schuster, 1982). After establishment, additional fertilizer, organic matter and moisture content will be unnecessary because of the continuous decomposing, protective layer on the forest floor (Chernets, 1988).

After a thorough watering at initial planting, watering should occur after one week and every few weeks for the first year (Baines and Smart, 1984; Hough *et al*, 1982). Watering during drought periods, is all that is necessary after the first year (Hough *et al*, 1982). This policy proved effective in the 1988 transitway planting. According to Dorney (1980), once the root system of woodland plants are settled in, after the second or third year, no watering is needed. As the woodland matures, it mulches itself, providing moisture retention and run-off reduction. Some signs of pest and disease may appear from time to time, but native woodland stock that is vigorous can generally withstand these attacks

[81] A five metre high canopy can be expected on nutrient-poor site within five years (Baines and Smart, 1984).

[82] While the NCC test plots indicate that annual grasses outcompete clover and lead to weed problems the following year, Hough *et al* (1989) stated that external circumstances may have led to this problem. Thus, no conclusions can be drawn about the effectiveness of the nurse crop.

with minimal damage This environment is more likely to attract birds and predatory insects that control pests than conventional landscape (Dorney, 1980).

3.4.6 Maintenance by Thinning

The pioneer species that created the canopy for shade tolerant trees should be gradually and selectively removed. Following canopy closure, thinning is required to prevent leggy growth and the suppression of slower growing species and create a multi-aged dynamic structure (Scott, 1986) On small sites with strong visual contact, an important design consideration is the three-tiered layering of growth into canopy, middle-storey and forest floor (Diekelmann and Schuster, 1982). Damaged and rubbing or overcrowded branches on both trees and shrubs must be removed. Figure 3 8 shows the aesthetic affects of different thinning regimes.

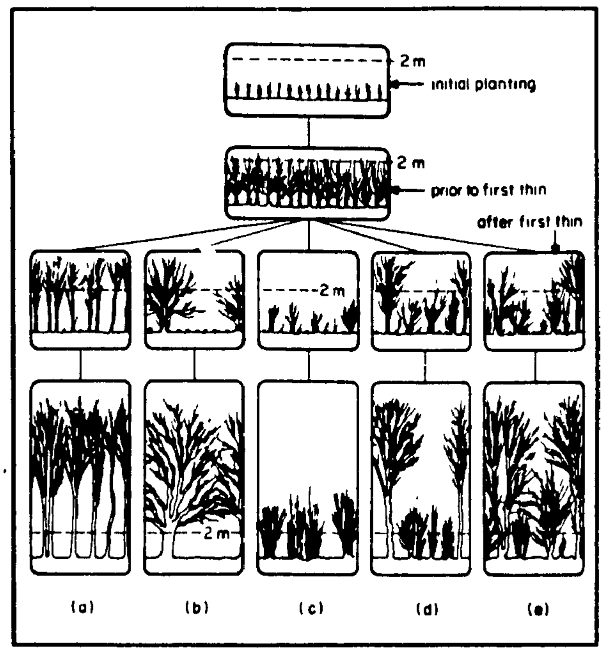

Figure 3 8 Five thinning programs for various visual effects (from Tregay, 1986)

3.4.7 Cost Comparison Examples

According to the NCC's database of annual maintenance requirements (NCC ELM 1993), the annual maintenance costs for the South-west Transit Corridor plantings totalled $19 428.00. In comparison, the database shows that annual maintenance costs for plantings along the Aviation Parkway totalled $74 791.00. These examples are both transportation corridors with similar functions However, the latter consists of conventional plantings, while the former is primarily naturalized. Therefore, the per hectare[83] cost of maintaining them illustrates the saving potential of naturalized alternatives in comparison to the conventional option. The per hectare costs were $386.00 for the transitway and $2078.00 for the parkway.

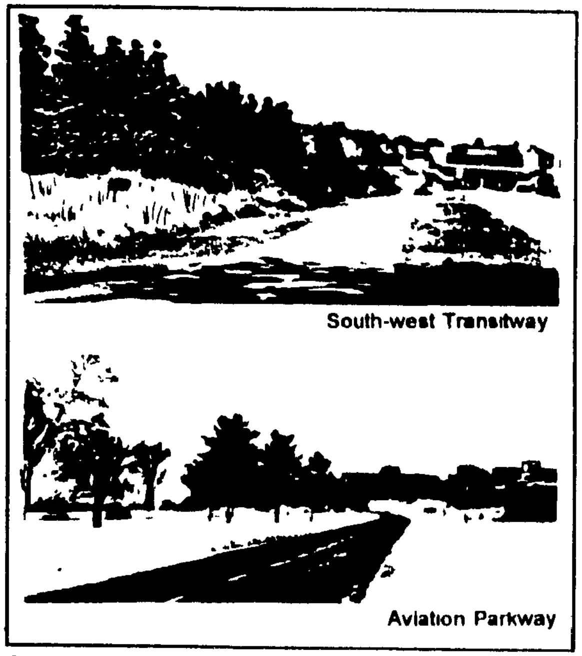

Figure 3 9 Comparison of naturalized and conventional plantings on two transportation corridors in Ottawa

The City of North York collected cost and maintenance data from the planting and three year maintenance of 2 one-acre landscape plantings: one was a woodland and the other was a formal lawn and specimen tree planting. The cost of installation and maintenance for first three years[84], was $15 243 for the formal landscape, as detailed in Appendix Seven. The naturalized landscape involved the planting of 1 000 bare-rooted hardwood species at one metre centres into existing turf. Mowing of turf was terminated except at

[83] The area in hectares was calculated from Facs Inventory Site Summary (NCC ELM, 1993). Only planted areas are included in the calculation of area and cost.

[84] Maintenance included weeding and frequent watering plus weekly mowing of grass, annual application of herbicides, pruning of shrubs and removal and replacement of dead plant material.

path edges. The cost of planting and three year maintenance[85] of the naturalized alternative was $4 429.00. In addition to these cost savings, energy savings in terms of equipment and fuel as well as chemical and water use are desirable attributes of the woodland project. This data provides conclusive evidence of the cost and resource saving potential of woodlands.

Appendix Seven shows costing details for three naturalization projects. An estimate, by Hough *et al* (1989), of a 1985 woodland planting shows a $7.50 square metre cost for combined installation and first year maintenance. In comparison, the 1985 price for installed sod was $6.45 per square metre (Hanscomb, 1985). Thus, in the 1985 example, the woodland installation cost slightly more than the turf.

According to calculations from Hough *et al* (1990), the initial cost of installing 100m^2 woodland planting, would have been $3 540.00 in 1990. (Refer to Appendix Seven for costing details). Calculations shown in Appendix Eight, indicate that the maintenance requirements of a 100m^2 woodland garden, average approximately 48 minutes annually for the first 15 years and 30 minutes for the next ten years. According to Parker (1986), the payback period of woodland plantings over turf is 20 years. A detailed payback analysis of the simulations which include woodlands will be discussed in Chapters Four to Six.

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[85] Maintenance consisted of a↑ annual hand-weeding of plant pits and application of liquid, rodent repellant. No watering was carried out. No other maintenance costs were foreseen in the initial ten years of the woodland establishment.

3.5 PRAIRIE

Like woodlands, tall grass prairie gardens promote reduced annual maintenance compared to the conventional option. However, an advantage of prairie gardens over woodlands is that establishment is faster[86]. Like woodland gardens, established prairie plants out-compete early season grasses and invasive annuals, such as dandelions, because of deeper roots and greater height (Dorney, 1980).

Existing site conditions may favour prairie gardens over woodlands. For example, most species require six or more hours of full sunlight per day (Elmhirst and Caine, 1990) Without this, they will be replaced by more shade-loving species. Grassland species tend to favour soils that woody species do not, i.e. those which are dry, exposed and infertile. Figure 3.10 illustrates the visual impact of prairie gardens in a residential context.

Figure 3.10: Prairie garden at Lamb residence, Waterloo (from Hoepfner, 1992)

3.5.1 Establish Grass by Seed and Wildflowers by Transplant

While many sources recommend planting with a seed mixture of perennial grasses and wildflowers, commercial seed mixes from outside the bio-region that are not adapted to

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[86] While woodland establishment takes about 20 years, a prairie community can be established in two years (Dorney, 1980).

local conditions, should be avoided (Diekelmann and Schuster, 1982; Mulligan, 1988)[87]. Unfortunately, little Ontario-produced seed is available commercially (Elmhirst and Caine, 1990. Dorney, 1985) Most mixes come from the U.S. mid-west. Morover, many of the seed mixes contain annual, biennial and perennial plants which require high annual maintenance (Burley and Burley, 1991). A further disadvantage to seeding is the fact that, since prairie seeds do not germinate at once, some will lie dormant for up to the fourth year (Mulligan, 1993). This will result in bare patches which will attract weed invasions. Thus, the appropriateness of seed mixes is in question.

A solution to the problems associated with seeding is the use of wildflower *plugs*[88]. The advantages include: 1) more control over which plants are expressed (Mulligan, 1993), 2) annual weeds are not introduced and 3) weedy invasions are prevented because of reduced exposed ground (Hoepfner, 1992) While plugs are more expensive than seeds, experiments, such as Metro Toronto's Humber River study and the NCC wildflower gardens,

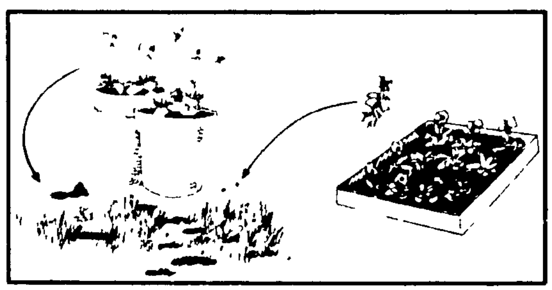

Figure 3 11: Wildflower seedlings (plugs) grown in pots and planted directly into existing grassland (from Baines and Smart, 1986)

[87] Even the seeds of native species will have low germination rates if they were produced outside the bio-region (Mulligan, 1988). Research at Cornell University indicates that plots sown with non-native/non-naturalized plants reverted to weed in one to two years (Stroud, 1989). Research at the National Wildflower Research Centre showed that native plants outlived non-natives by a three to one ratio (Stroud, 1989).

[88] *Plugs* are small, pot-grown seedlings (Baines and Smart, 1984)

show that plugs establish more successfully than seeds (Elmhirst and Caine, 1990).[89] Moreover, despite the capital cost of plugs is higher than seeds, the cost of turning the soil, applying herbicides or hand weeding can offset the initial cost of using plugs (Mulligan, 1993)[90]. Plugs should be introduced into established prairie grasses (Baines and Smart, 1984)[91]. Species lists for grasses and wildflowers are shown in Appendix Nine. According to Dorney (1985), by the fourth year, the tall grass prairie plants will be four to seven feet tall.

3.5.2. Control Weeds Before Planting and Avoid Soil Amendments

Similar ground preparation techniques to those of the woodland plantings is recommended: disc and cultivate to an even tilth and spray with a contact herbicide (Baines and Smart, 1984). Generally, the results of experiments, such as the NCC wildflower projects, indicate that eliminating existing weeds prior to planting was essential for desirable species survival (Elmhirst and Caine, 1990) Table 3 1 shows that a general increase in wildflower populations occurred in plots treated with the post-emergent herbicide, Fusilade. Also, tilling permitted higher seedling establishment rates of meadow

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89 Nuzzo also found that the use of plugs resulted in long-term cost saving over direct seeding (Elmhirst and Caine, 1990).

90 To give shape to the garden and provide winter interest, shrubs can be planted on the garden edge or as specimens (Hoepfner, 1992)

91 According to Mulligan (1993) and Baines and Smart (1984) spacing should be at 300 to 500mm centres. Grass seed should be sown at a rate of one to 1.5 grams per square metre.

plants than the un-tilled plots. If tilled before planting, the garden's weed time can be halved (Dorney, 1985)[92]. While many sources discourage the use of mulch, the Ridgeview Public School prairie and woodland naturalization project in Georgetown, Ontario found that adding mulch resulted in successful establishment (Scallen, 1991) [93].

In a study of roadside meadow establishment in Massachusetts, Ahern *et al* (1992) compared the plant survival rate of test plots with and without fertilizer. There was no significant difference between meadow populations in untreated quadrants and those in treated areas with fertilizer, as indicated in Table 3.1. Soil amendments such as topsoil and fertilizer are discouraged (Baines and Smart, 1984) Since these plant communities thrive on dry, nutrient poor soils, fertilizing and watering are neither necessary or desirable (Mulligan, 1988).

Table 3.1: Wildflower population densities per square meter avg. June to Aug. 1990 (from Ahern et al, 1992)

	No fert.	10-10-10	Urea	Avg.
No Fusilade				
-till	90	66	59	72
-till/herbicied	98	111	66	92
-no till	56	87	109	84
-average	81	88	78	82
Fusilade				
-till	95	87	80	87
-till/herb	99	76	73	83
-no till	94	99	147	113
average	96	87	100	94

92 While some studies recommend tilling, others show that this causes disturbance of weed seeds and causes them to germinate (Elmhirst and Caine, 1990). Test results at the Atlanta Botanical Garden show that avoiding tilling saves time and eliminates the need to spray (Stroud, 1989).

93 Mulch served to conserve moisture and shield the future seedlings from the full intensity of the sun (Scallen, 1991). Herbicide use was required only to selectively spray out unsightly or invasive weeds.

These low fertility, drought tolerant species would be squeezed out by other species by watering and fertilizing. (Hough, 1987; Mulligan, 1988). According to Ahern *et al* (1992), pesticides are not necessary.

3.5.3 Maintain by Burning or Mowing and Weeding

In areas where tall-grass prairie communities do not naturally occur, such as the national capital region, prairies would eventually develop into woodlands (Mulligan, 1988, Hightshoe, 1988). If left unmaintained, these areas would be colonized by herbaceous weeds and eventually by woody plants (Burley and Burley, 1991) In order to keep the woody portion from quickly spreading and eventually replacing the shade intolerant prairie grasses, it is necessary to burn or mow the vegetation once a year (Ahern *et al*, 1992, Mulligan, 1988, Hoepfner, 1991, Elmhirst and Caine, 1990) Burning both controls woody plant growth which shades and weakens sun-loving prairie plants and eliminates thatch build-up (Hightshoe, 1988; Lamb, 1985) However, burning may be prohibited in an urban context [94].

Unlike woodland gardens in which weeds are eliminated after canopy closure, weeds are a perennial maintenance issue for the prairie (Hightshoe, 1988) Dorney (1985) estimated that annual weeding requirements in hours for a 74m^2 model are ten hours the first year, eight hours the second year, one to two hours in the third and fourth year and one hour

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[94] Prairie burns are still controversial but prairie restorationists agree that they are essential for weakening aliens while prairie species are still safe beneath the soil (Lamb, 1985).

thereafter. Others, such as Diekelmann and Schuster (1982), claim that some weeding is necessary in the first year, but that by the second or third year, little weeding is required depending on the thoroughness of weed cleaning prior to planting. By the end of the third season, plantings have unusually filled in, eliminating ground exposure and thus eliminating weeds

3.5.4 Costs and Annual Requirements

The Massachusetts Department of Public Works manages roughly 3300 acres of roadside turf at a 1987 cost of approximately $337 per acre. According to Ahern *et al* (1992), a cost saving of 83% or $280 per acre per year can be realized with meadow naturalization compared to maintained lawns. Similarly, Diekelmann and Bruner (1988) calculated capital costs and annual maintenance costs for two 730m^2 plots planted with 1) sod and 2) tall grass prairie While the tall grass prairie's initial cost was $3 670.00 higher, its annual savings were $113 00 when compared to the sodded plot, as shown in Appendix Ten Calculations from Dorney (1985) and Cobham (1990), shown in Appendix Eight, indicate that the maintenance needs of a 100m^2 prairie garden are 7.1 hours annually for the first three years and two hours annually thereafter.

3.6 Conclusion

The previous discussion indicates that the savings in initial cost and maintenance of both woodland and tall grass prairie gardens, compared to the conventional use of vegetation, are impressive. Even when compared to Alternatives 1 and 2, naturalized gardens result in reduced initial costs. In addition to cost savings, the labour requirement for annual maintenance is reduced in the naturalization alternatives compared to the other options

Since naturalized gardens take full advantage of the site's environmental conditions, the need for material and labour maintenance inputs is reduced from the other landscape options. Through a process of managed succession, whereby human intervention initiates and assists natural processes, naturalized gardens can be established in a fraction of the time nature would require. By planting young seedlings and controlling weeds during the first few years, dynamic and richly varied plant communities can be established. The principles discussed in this chapter provide criteria for the simulation of Alternatives 3 and 4. Detailed, site specific cost and resource comparisons will occur in Chapters Five and Six.

CHAPTER FOUR: METHODOLOGY; SIMULATIONS

4.1 Introduction

To evaluate the alternatives for their savings potential, the case study methodology was considered. However, the inevitable number of building and site variables would have affected the evaluation of landscape elements Ideally, all parameters, except for the plantings, should be held constant for each alternative. Therefore, the alternatives were simulated[95]. The simulations were performed on a proposed low-rise, multi-unit, co-operative housing project in Ottawa, as shown in Figure 4.1.

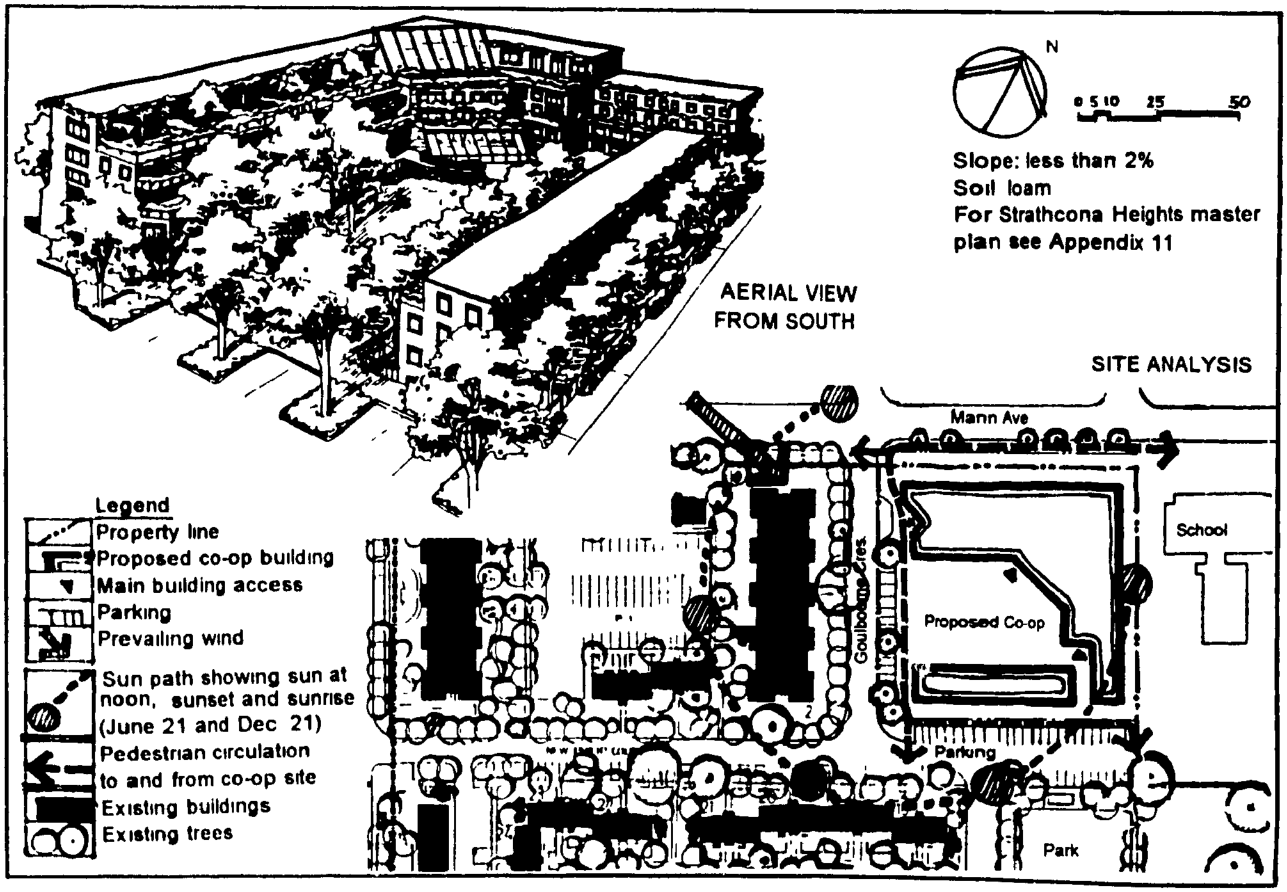

Figure 4 1 Conservation Co-op proposed site analysis and aerial view

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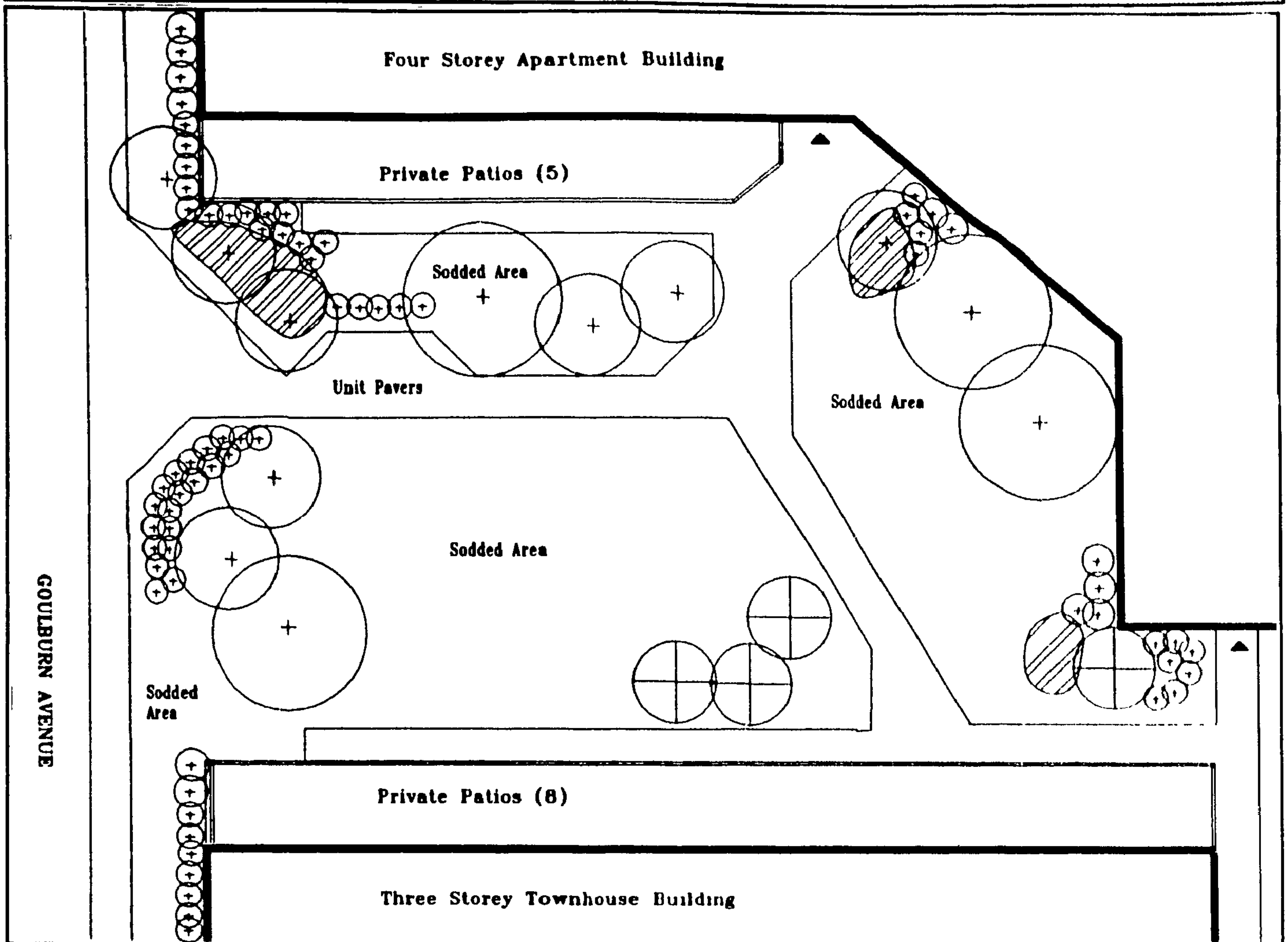
95 Utilizing AutoCAD for the simulations made quantity take-offs and changes simpler and estimates more accurate.

Figure 4.2: Conventional Option
90% Lawn/ 10% Ornamental Shrubs, Annuals and Perennials with 40% Tree Cover



Legend

LARGE DECIDUOUS TREES (80mm cal)
Gleditsia triacanthos var. inermis
Tilia cordata

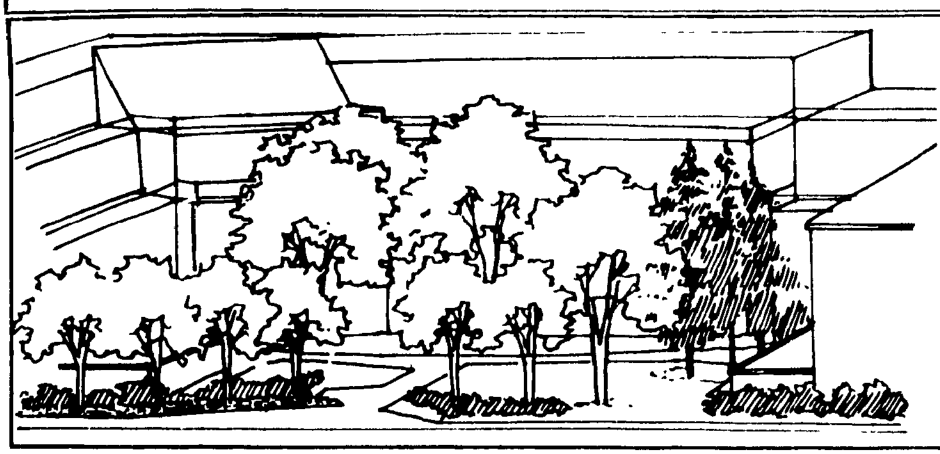
SMALL DECIDUOUS TREES (50mm cal)
Cornus mas
Malus profusion

EVERGREEN TREES (2400mm Ht.)
Pinus nigra

SHRUB ACCENT (60-120 cm Ht 1750mm O.C.)
Euonymus alatus 'Compacta'
Taxus cuspidata 'Nana'

SHRUB ACCENT (50cm Ht @ 1000mm O.C.)
Spiraea bumalda 'Anthony Waterer'
Symphoricarpos alba

Annuals/ Perennials (300 mm O.C.)



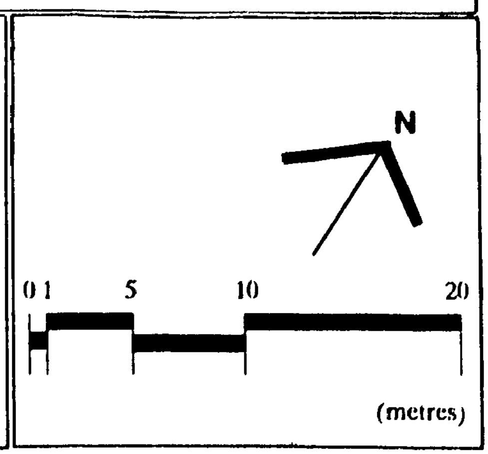


Figure 4.3: Alternative 1
30% Lawn/ 70% Woody Plants (40% Tree Cover)

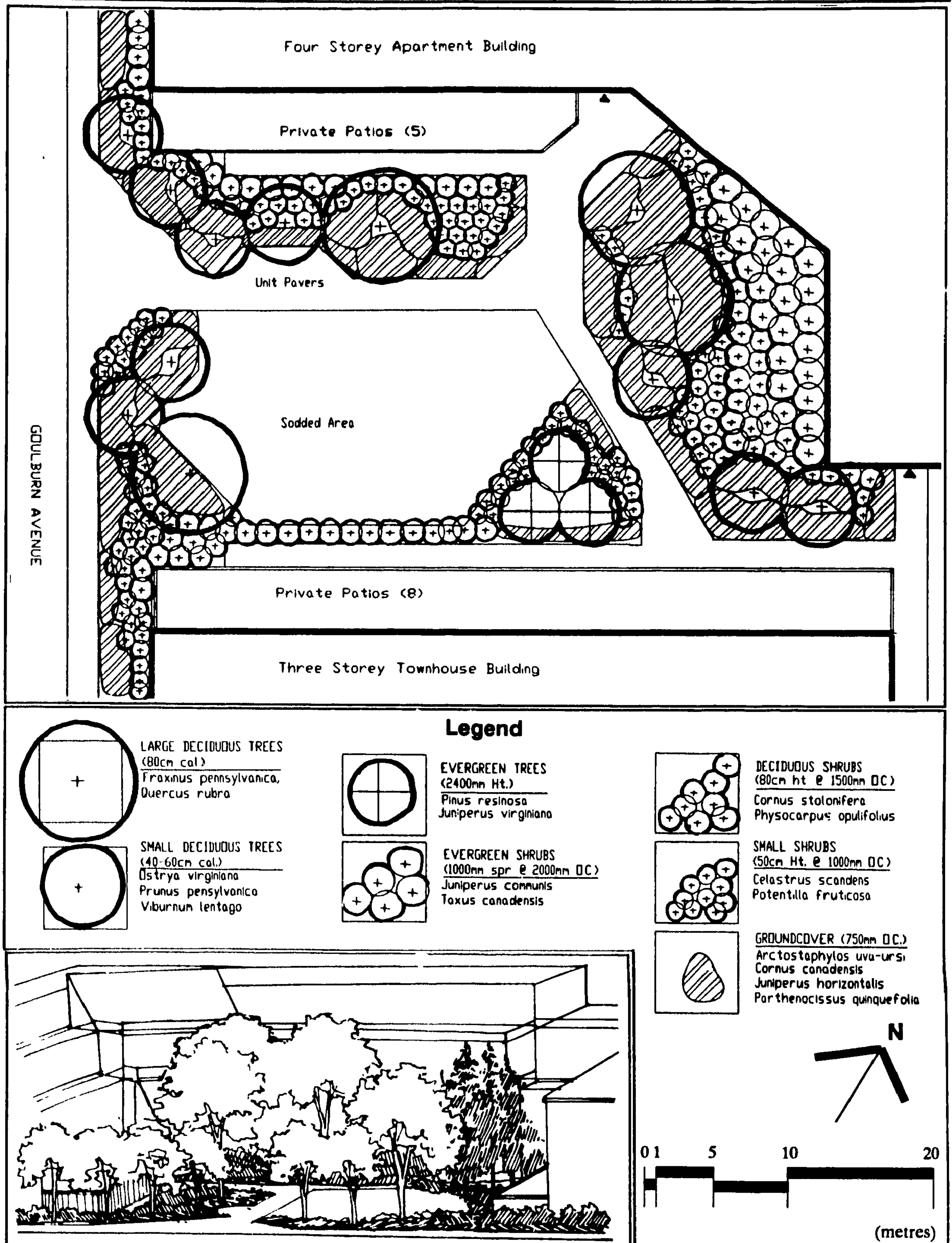


Figure 4.4: Alternative 2
No Lawn/ 85% Woody Plant Beds, 15% Pavers (40% Tree Cover)

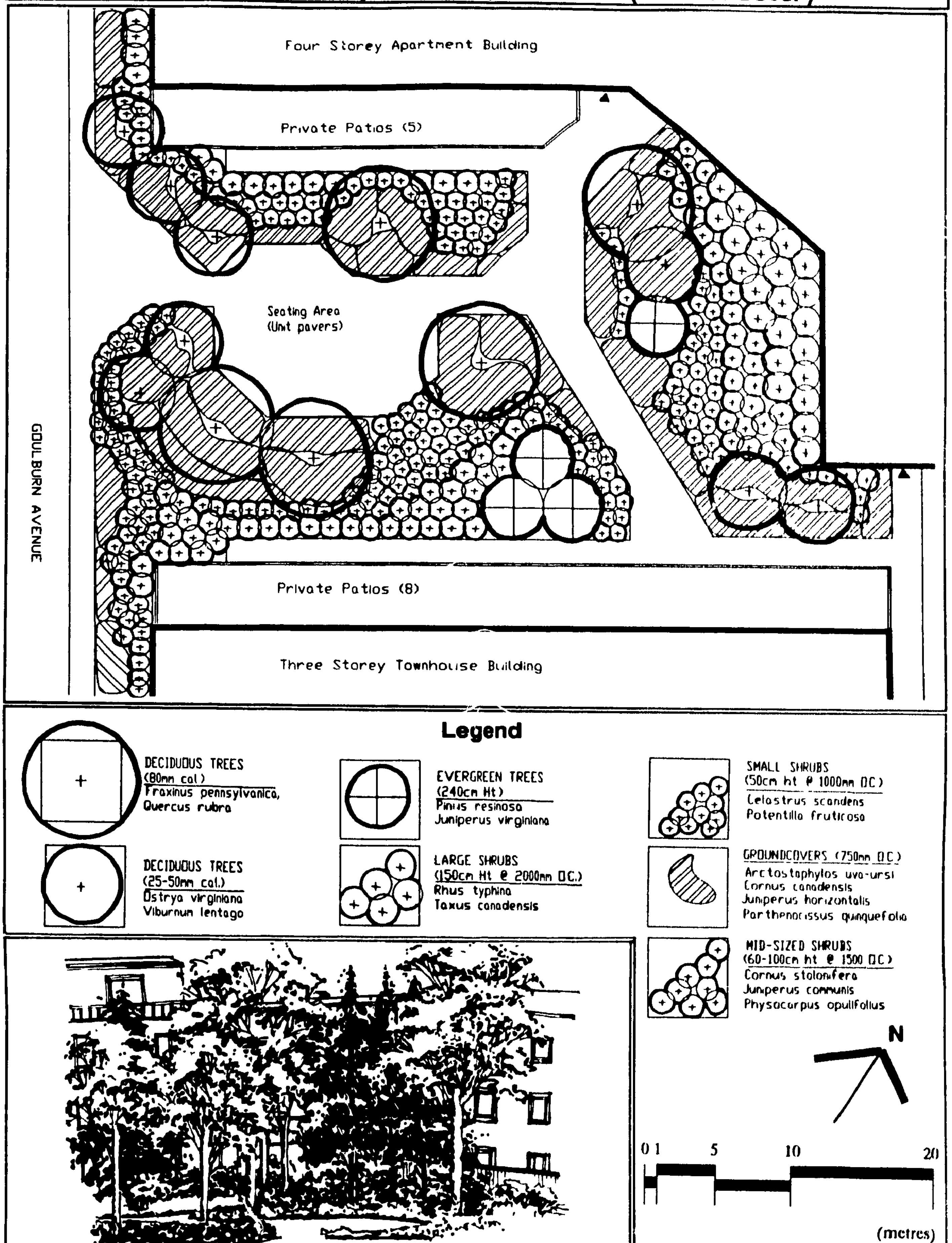
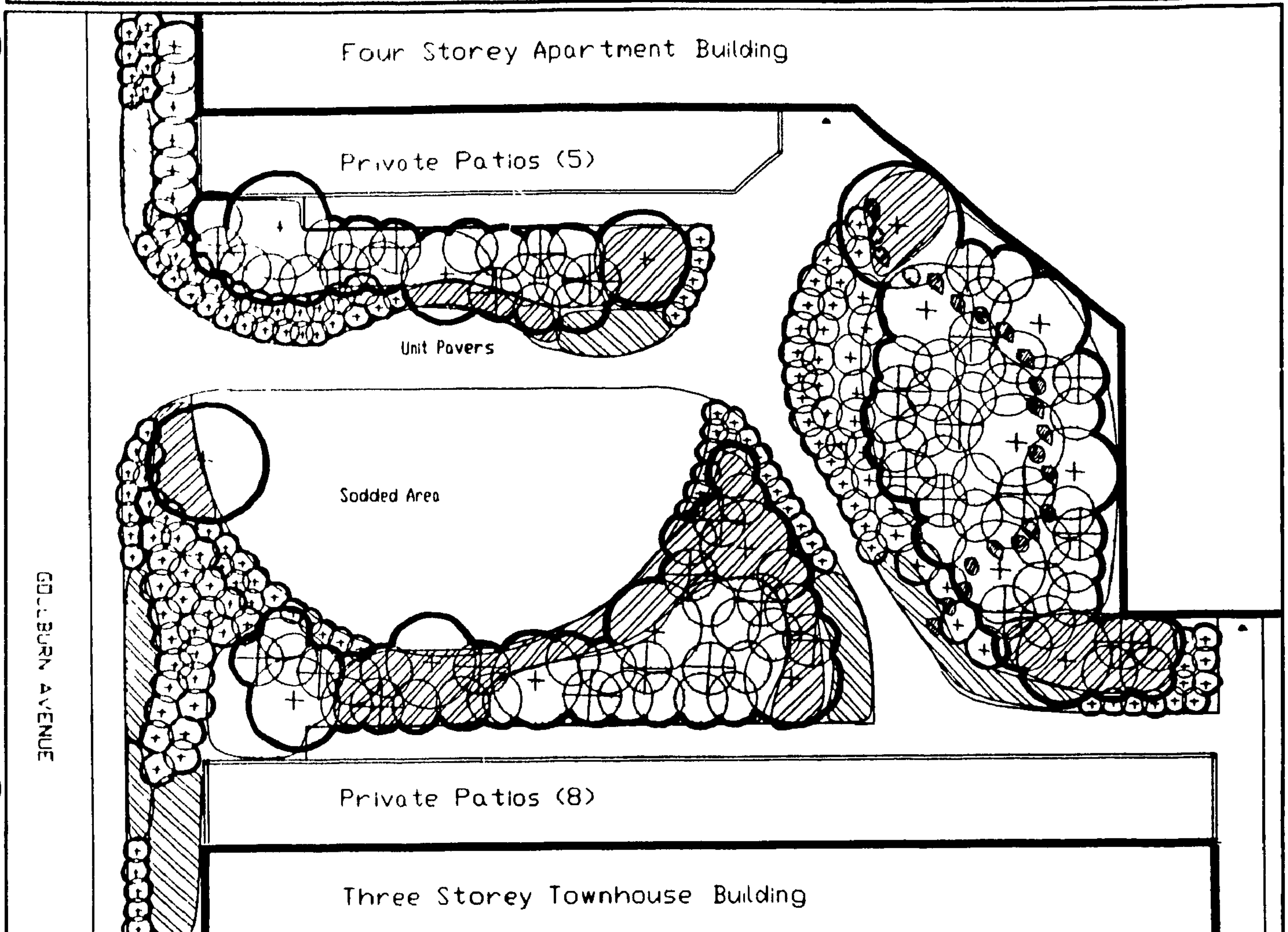


Figure 4.5: Alternative 3
30% Lawn/ 70% Woodland Plantings



Legend

BARE ROOT SEEDLINS (1500mm and 1250mm Ht @ 1500mm OC)
Fraxinus pennsylvanica,
Ostrya virginiana
Prunus pennsylvanica
Betula papyrifera
Populus tremuloides
Populus deltoides

B&B EVERGREENS (1250mm Ht @ 1500mm OC)
Picea glauca
Pinus strobus

B&B STANDARDS (25mm and 50mm cal)
Acer rubrum
Prunus pennsylvanica
Ostrya virginiana
Pinus strobus

SHRUB EDGE (2000mm spr @ 1750mm OC)
Juniperus communis
Physocarpus opulifolius

SHRUB EDGE (50cm ht. @ 1000mm OC)
Celastrus scandens
Potentilla fruticosa

WOODLAND GROUNDCOVER (750mm OC)
Anemone canadensis
Fragaria virginiana
Parthenocissus quinquefolia
Viola sororia

GROUNDCOVER (750mm OC)
Cornus canadensis
Gaultheria procumbens
Juniperus horizontalis

black embossed film weed barrier with mulch covering

Woodland Stepping Stones

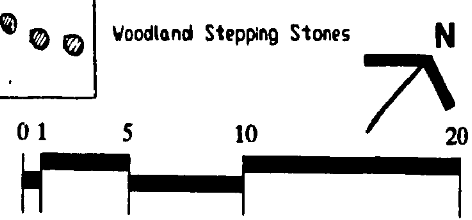


Figure 4.6: Alternative 4
No Lawn/ 85% Woodland Plantings and Tall Grass Prairie, 15% Pavers

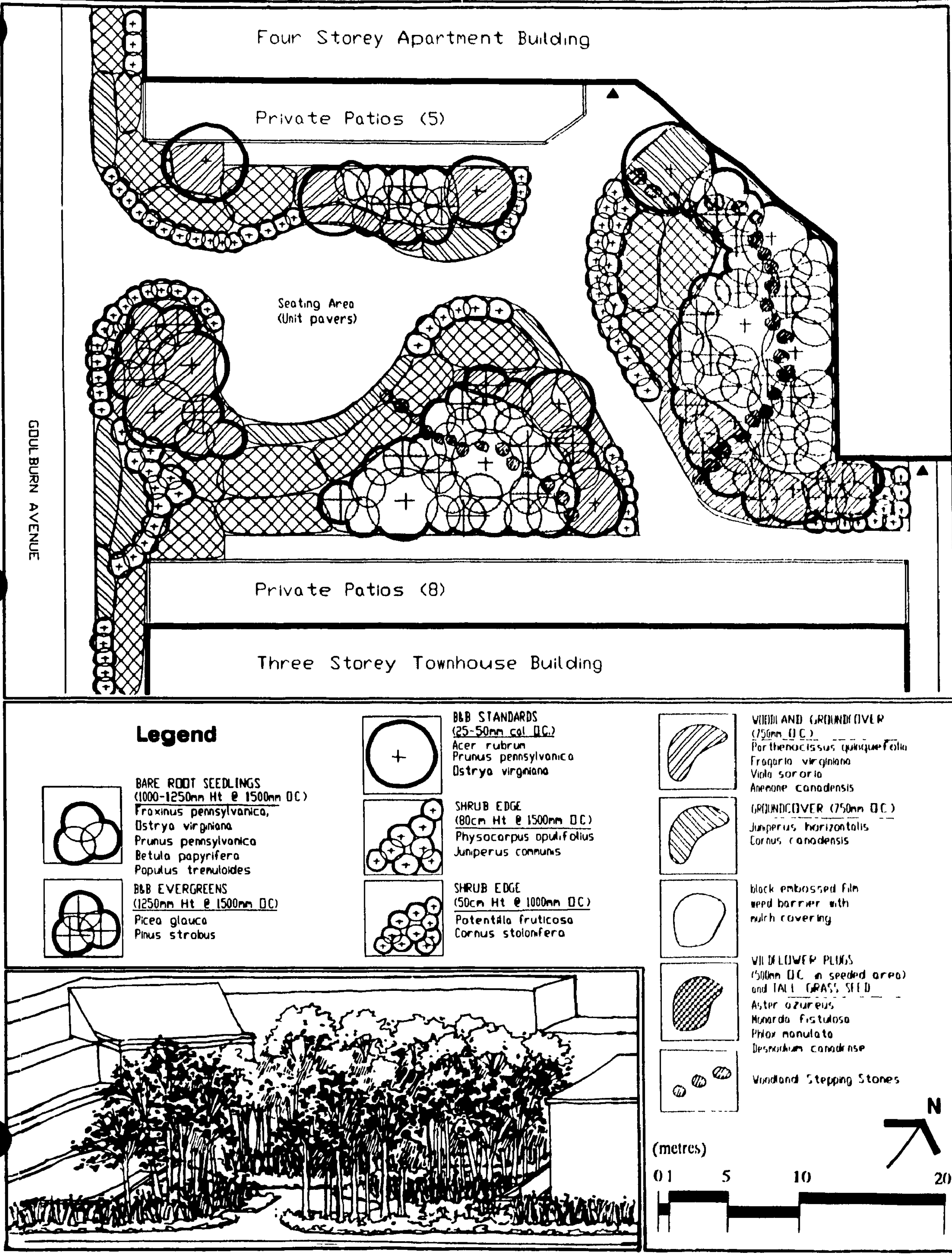
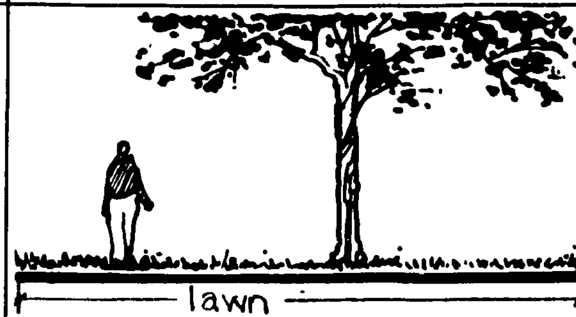
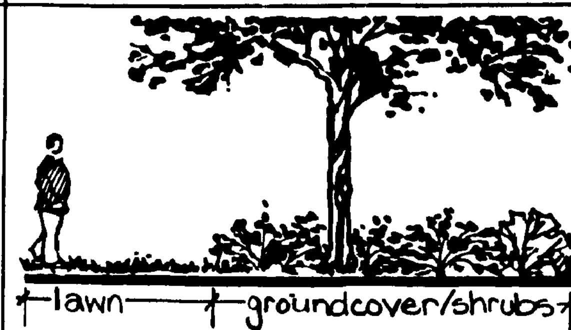
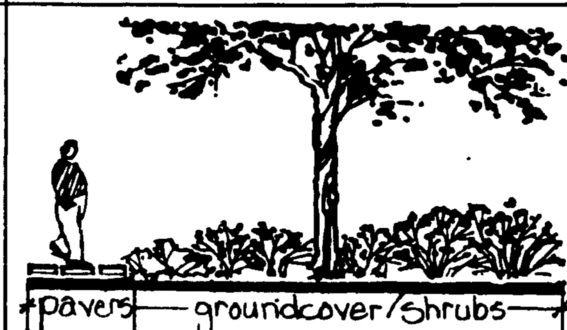
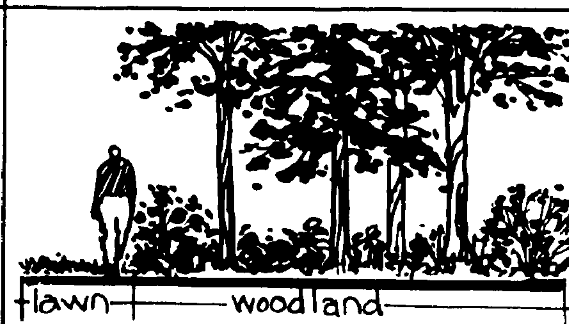
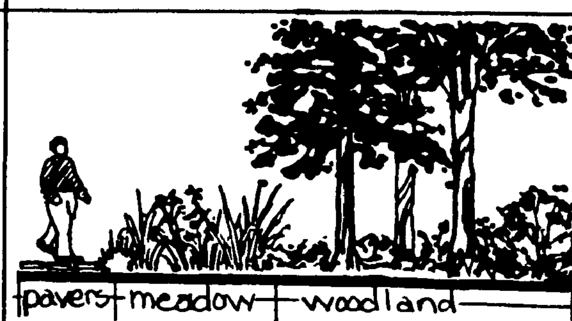


Figure 4.7
Summary of Planting Options

Alternative	Plant Groups	Planting Technique	Sketch
Conventional Option	-95% lawn -non-native tree (eg. Crab apple, Honeylocust) and shrub species (eg. Honeysuckle, Hydrangea) -flowering annuals, bulbs, perrenials	-lawn area sodded -standard tree and shrub planting from NMS -trees planted individually in lawn area -standard nursery stock (ball & burlap trees 3-5 year old)	
Alternative 1	-30% lawn -native or well-adapted tree (eg. Red Ash, Red Pine) shrub (eg. Canada Yew, Common Juniper) and groundcover (eg. Bunchberry, Bearberry)	-trees, shrubs and groundcover grouped in mulched beds -standard tree and shrub planting from NMS -standard nursery stock (ball & burlap trees, 3-5 year old) -lawn area sodded	
Alternative 2	-native or well-adapted tree (eg Red Ash, Red Pine) shrub (eg. Canada Yew, Common Juniper) and groundcover (eg. Bunchberry, Bearberry) -no lawn area: unit pavers to provide socializing surface in lieu of lawn	-trees, shrubs and groundcover grouped in mulched beds -standard tree and shrub planting from NMS -trees are ball & burlap3-5 year old nursery stock	
Alternative 3	-30% lawn area -native woodland tree (eg. Paper Birch, Red Maple) and woodland groundcover species (eg. Canada Anemone) -native or well-adapted shrub and groundcover species listed above	-bare-root seedlings and whips planted at 1250mm height (1-2 year stock) -plant 1500mm on centre -beds prepared with black film weed barrier with mulch covering or woodland grouncover -anchor planting trees and shrubs from NMS with standard nursery	
Alternative 4	-native woodland species listed above -shrub and groundcover species listed above -native wildflower (eg Azure Aster, Showy Trefoil) and grasses (eg Canda Wild Rye) -no lawn: unit pavers in lieu of lawn areas	-woodland planting same as above -anchor planting trees and shrubs from NMS with standard stock -meadow: native grasses grown from seed -nursery grown plugs planted later in tall grass area -no soil ammendment	

4.2 Site Lay-out

Multi-unit, low-rise housing projects usually require a large, common open space in addition to small private patios or balconies This typology was chosen for the simulations because the numerical results of the analysis can be articulated more readily with an open space of this scale than with a small private yard However, the alternatives are equally appropriate for small, private yards in single-family housing typologies[96]

A brief glance at the five simulations, shown in Figures 4 2 to 4.6 indicates that the general lay-out for each plan is consistent With the exception of the planted areas and the central seating area, all other parameters were held constant[97]. While the naturalized alternatives exhibit a more organic path lay-out, the ratio of paved to planted areas is the same. The central seating area was enlarged in Alternatives 2 and 4 to mitigate for the elimination of lawn area. Since lawns accommodate social gathering and play, the hard-surface area provided a design solution which would accommodate these activities. The aesthetic affect of each option will be different due to the texture, size,

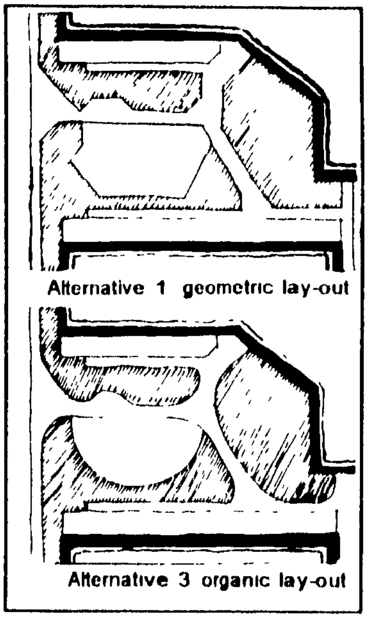


Figure 4 8 Lay-out comparison

[96] Dorney (1980) states that the smallest area in which a thriving woodland community can be established is 20m². Even the small lot standards recommended by the RMOC (1992) call for larger rear yards than this. Therefore, a woodland garden would be appropriate for most single-family housing.

[97] Elements other than planting and circulation, such as benches, planters and play equipment, were not included in the designs or cost estimates.

density and form inherent in each planting group. Despite these differences, consistency was retained in certain elements of the planting design For example, the tree canopy remained between 40% for the first three options and 70% for the naturalized alternatives.

The existing site features and building foot-print, as shown in Figure 4.1, were simplified to minimize unique features specific to this site Since analyzing resource consumption and payback periods was this study's goal, simplifying the existing features and design focussed the analysis on low-maintenance alternatives which could apply to any site

4.3 Criteria for Species Selection and Planting Techniques

Table 4.1: Criteria for Plant Selection

Simulation	Criteria for Plant Selection[1]	Source
Conventional Option	-species used in typical urban planting designs -mix of introduced and native species chosen for their aesthetic qualities rather than for their ecological properties, such as pest resistance or low-water requirements	-Dirr (1983)
Alternatives 1 & 2	-pest-resistant, water-conserving, -native and/ or well-adapted to environmental conditions	-Hightshoe (1988)[2] -cross referencing with Native Trees of Canada (1979) and Dorney (1980) ensured species native to this region . -Dirr (1983) -shrub species from Queen's Park Xeriscape Demonstration Garden (1992)
	Plant Sizes and Techniques: -standard nursery stock and planting technique	-National Master Specifications (1992)[3]
Alternatives 3 & 4	-climax and pioneer species -native, well-adapted to environmental conditions	-South-west Transitway Planting Plan (1987)[4] -Dorney (1980) -Elmhirst and Cain (1990)
	Plant Sizes and Techniques: -seedlings with some standard nursery stock -1 5m spacing, mix pioneer and climax species -perforated weed barrier with mulch	-South-west Transitway Planting Plan (1987)[5] -Dorney (1980); Mulligan (1993); -Baines and Smart (1984)

1. Refer to the simulation sheet for species and plant sizes
2. This source profiles plants native to the North America including categories such as water requirements and frequency of pests and disease
3. Refer to Appendix 12 for details of planting techniques
4. Planting plans and specifications were prepared by (Corush et al, 1987)
5. After five growing seasons, all parameters including species selection, size and planting techniques, have resulted in successful growth in site conditions similar to those of the study site. Refer to Chapter 3 for more details on Transitway test plots.

Table 4.1 summarizes the criteria and sources for the species and planting techniques selected for the simulations The plant list was also based on a mixing of deciduous and coniferous species The naturalized options also included a mix of pioneer and climax species. This mix promotes variety in both the visual effect and the rate of growth A framework of larger nursery stock planted among the seedlings imparts both variety and a natural appearance since a forest canopy in nature grows at an uneven rate [98] Most of the area was planted with bare-root seedlings, 1 250mm in height The spacing, at 1500mm, was determined by the plots with the best growth in the earlier South-west Transitway Corridor test plots, as were the species and ground preparation techniques.

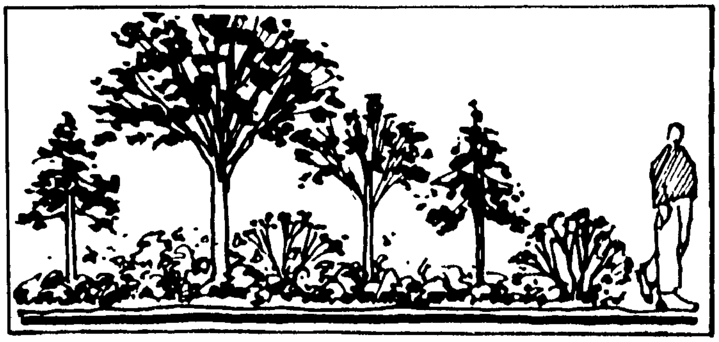


Figure 4 9 Size and species variety for woodland

Since the black embossed, perforated film, covered with wood chip mulch most successfully eliminated competition from weeds in the 1984 and 1988 transitway planting, this ground preparation technique was chosen for the simulations[99] According to the specifications, rodent repellant, root stimulant, fertilizer and weekly waterings also formed part of the contract. Other ground preparation techniques included clearing existing

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[98] Hough *et al* (1982) recommend planting colourful shrubs around the woodland perimeter impart a sense of definition or edge. Refer to the character sketches shown in the simulations, Figures 4.2 to 4.6, and the summary sketches in Table 4.7.

[99] The advantages of this technique are described in Chapter three.

vegetation, mechanically discing the soil to a depth of 150 to 200mm to an even tilth and removing stones and debris over 50mm in diameter [100].

The planting techniques for the tall grass prairie, as outlined in Chapter Three, were also derived from a local source[101] Nursery grown plugs were planted into previously established tall grass areas. The importance of weed suppression before planting is stressed in Baines and Smart (1984). Therefore, in the simulations, the residual herbicide, Simazine, was applied prior to planting Ground preparation techniques for discing and cultivating soil were the same as those of the woodland specification

4.4 Capital Costs Calculation

Table 4.2 summarizes the sources and the rationale for choosing them in calculating capital costs for the simulations The limitations of Hanscomb (1993) led to formulating a brief specification for a contractor survey, shown in Appendix 13. The survey procedure and participants are outlined in Table 4.2[102].

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[100] Refer to Appendix 12 for tree planting details for the naturalized and standard options.

[101] The techniques used were recommended by Julie Mulligan of Project Planning in Ottawa. These establishment techniques are confirmed by Baines and Smart (1984).

[102] Refer to Appendix 14 for an item by item cost listing. Initial costs include: installed plant material with first year maintenance, maintenance equipment and installed unit-paving in the seating areas of the alternatives with no lawn. All other hard-surfaced areas were omitted from the initial cost calculation. Refer to Appendix 12 for details of naturalized planting installation.

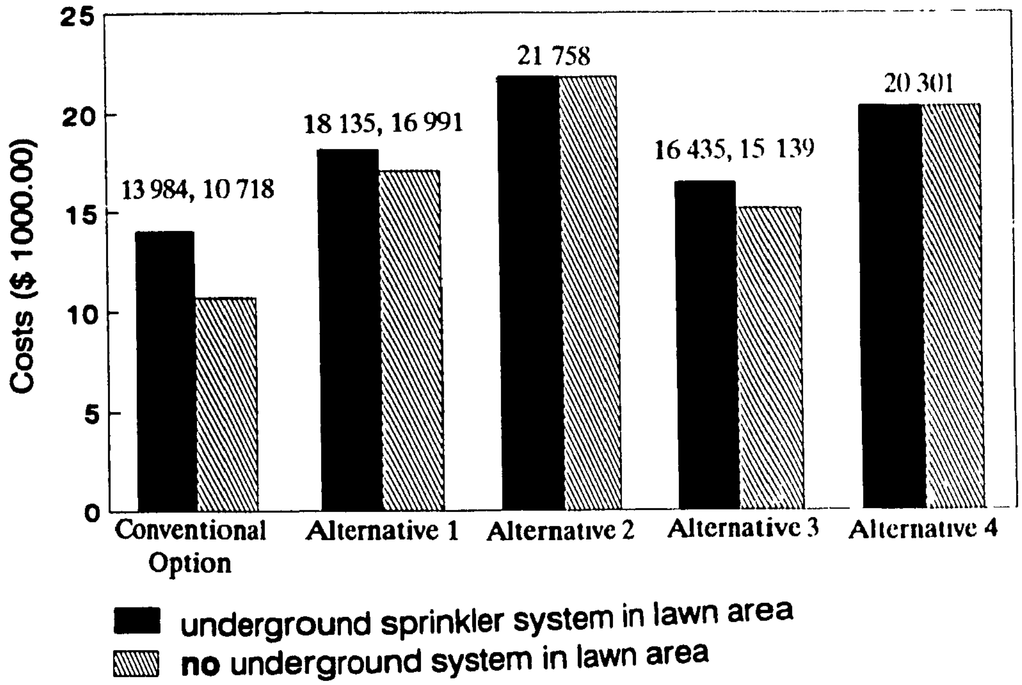
Table 4.2: Method for Capital Cost Calculations

Souce	Advantages	Disadvantages
Yardsticks for Costing[1] (Hanscomb 1993) for standard items	-costs are current, -data is derived from local sources -material and installation are included -reliable, published source	-did not include non-standard items such as seedling installation for Alternatives 3 and 4 -options are limited and inflexible
Contractor Survey[2] for non-standard items	-costs are currenct -from local sources -flexiblity for non-standard items	-unpublished -pricing methods differ
Canadian Tire Catalogue (1993)[3] for maintenance equipment	-costs are current -published, reliable source -retail outlet at which homeowners are likely to buy items	

1. This annual source compiles cost data from across the country for a range of construction items, including landscape elements. Costs are presented for each major urban centre, including Ottawa
2. A specification, as shown in Appendix 13 was sent to 10 local, mid-sized contractors. Each contractor was asked to estimate the price of performing the tasks listed in the specifications. The estimates were averaged and used in calculating capital cost Ten contractors agreed to participate, based on names that were recommended by Dave Lashley, Landscape Architect Three contractors replied; James Landscaping, Meikneicht Leisher Contractors and Excel Contracting. The average costs are shown in Appendix 14. Appendix 14 applies the contractors' prices to non-standard items for the woodland and tall grass prairie plantings.
3. Unlike the installation, residents will likely maintain the landscape themselves. Therefore, equipment costs were sourced from a retail outlet.
4. Prices do not include PST or GST.

As discussed in Chapter Two, drip irrigation systems are preferable to sprinkler systems because water is applied directly to root areas under the soil surface (RMW, 1990) However drip systems were avoided for two reasons 1) The quantity of water required for shrub and tree beds for the alternatives is so low that the additional cost of an installed irrigation system could not be justified 2) According to Holmes Irrigation (1993), drip systems are not recommended for turf areas Thus, an underground sprinkler system was used for turf areas and an off-the-shelf, portable system for planting beds Since users may find the cost of an underground system prohibitive, a cheaper, off-the-shelf, portable system was chosen as a second option for watering turf areas Figure 4 10 compares the initial costs of the five options A second cost figure is provided for options which include turf areas to account for the cheaper turf irrigation system[103]

Figure 4.10: Inital costs



4.5 Maintenance Requirement Calculations

4.5.1 Labour

Maintenance operations, particularly tree and shrub care, are difficult to predict because of the influence of complex environmental variables, such as rainfall, exposure to wind, soil type and cover type. Each plant has its own unique situation Traditionally, maintenance people have learned to estimate jobs by the trial and error method (Abbott

[103] Refer to Appendix 14 for sources and an item by item cost listing.

et al, 1987) [104] Of the municipalities and institutions that maintain urban lands in Ottawa, the NCC offers by far the most comprehensive records of maintenance requirements.

While using national standards could have provided a much simpler method of predicting annual requirements, they had limited value for this study Since maintenance requirements are dependent on several environmental variables, particularly climate, it was essential to obtain records from local sources For example, the frequency of lawn mowing and watering from the southern U.S would differ from that of Ottawa. While this makes the study less relevant for Canadians beyond the national capital region, accuracy was the prime objective in selecting evaluation criteria

Over the past ten or more years, the NCCs Environmental Land Management Branch (ELM) has been keeping daily records of time, material and equipment expenditures for specific maintenance operations (Kaleta, 1993) These records have been compiled into the Activity Performance Report (APR) (NCC ELM, 1992). This data was also incorporated into a computer program called Operation Management System (OMS) (NCC ELM, 1993) The database is a tool for forecasting annual costs. [105]

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[104] O'Brien *et al* (1992) state that only seven percent of American municipalities have effective tree maintenance programs and rarely collect daily records of maintenance operations.

[105] Files are organized by location: sites include parks, corridors, parkways and building grounds. The database on each site is broken down into maintenance operations. For example, in the tree care category, a field for each of the following operations is included for each location: weeding/ edging, fertilizing, watering, pest control, pruning, removing and replanting. For each operation the following annual requirements are provided: time requirements,

A further advantage of the OMS is the fact that files are organized by location[106] This facilitated comparisons between standard tree and shrub plantings and hardy, native plantings grouped in beds[107]. Consulting files for sites which embody both approaches, provided a more accurate picture of the advantages of the alternatives For example, tree and shrub care data for the conventional option was averaged over four NCC sites with similar planting characteristics[108].

One of the disadvantages of the system is that the data was only recently entered into the system. Inconsistencies or errors will take years to be corrected Moreover, differences in maintenance intensity levels and recording techniques will affect the accuracy of the results. However, consideration of these pros and cons led to the conclusion that the advantages of this system outweigh the disadvantages

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monthly distribution, frequency, percentage of area requiring input and material and equipment quantities and costs. Refer to Appendix 15 for a sample sheet from the database.

[106] The other maintenance standards did not differentiate between exotic, high-maintenance applications and hardier, low-maintenance plantings.

[107] While the estimates reflect maintenance requirements for plant groups, such as beds of hardy, native trees and shrubs, they do not reflect specific species.

[108] Maintenance requirements from the OMS database include a range of plant ages. Thus, the difference in requirements for post and pre-established plants is accounted for. However, some of the requirements were derived from sources other than the NCC. Thus the additional requirements in the first three years may not be accounted for. Refer to Chapter Two for more details on pre-establishment requirements.

With regard to labour requirements, other sources were used in combination with the OMS for four reasons. 1) With the exception of lawn mowers, do-it-yourself maintenance operations would be performed by hand-operated equipment[109]. However, most of the operations in the OMS database were performed with mechanized equipment rather than by hand As a result, time requirements were derived from other sources which list standards for hand-operated tasks Despite this, the local nature of the analysis data was maintained since frequency data was obtained from the NCC, a local source. Therefore, the standards from the Institute of Maintenance Research (IMR, 1982) and from Amenity Landscape Management (Cobham, 1990), were used in calculating time requirements for a single operation, independent of frequency or percentage of area[110].

2) Annual requirements for groundcover were unavailable from the OMS. Thus, another source, Cobham (1990), was used. 3) Considerable variation occurred between frequency and percentage of treated area for turf maintenance in the OMS sites surveyed. Therefore, the NCC's APR was used because it presents yearly averages for all NCC sites over the past ten years. 4) Maintenance requirements for the woodland and tall grass prairie were not included in the OMS database. Therefore, published sources, such as Hough *et al* (1990) and Dorney (1985) were consulted.

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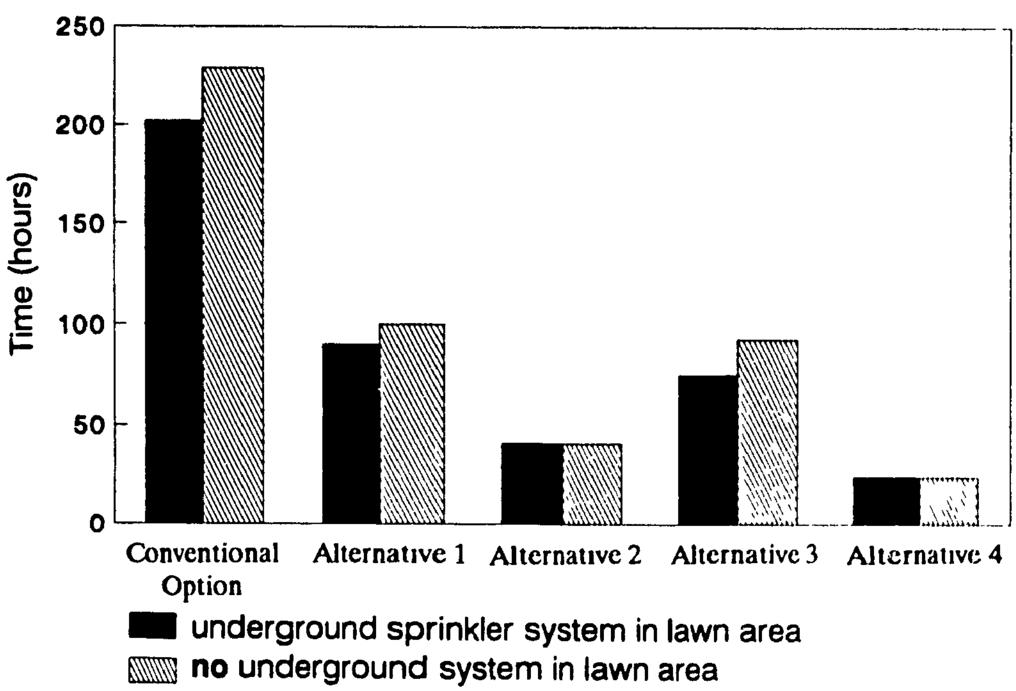
[109] Snow removal is not included in the annual maintenance operation.

[110] For example, a single mowing of $100m^2$ turf area requires roughly the same amount of time anywhere. It is the annual frequency and the percentage of the $100m^2$ area on which the task is performed that will provide a more local perspective on annual labour requirements.

5) Tree pruning time requirements were derived from a database of 6 272 municipal work records collected in the City of Toledo, Ohio Over a 31 month period, records were collected and analyzed to establish performance standards for tree maintenance This study of tree care operations discussed by O'Brien *et al* (1992), provides a more detailed indication of the time requirements for tree pruning than the OMS database A related study by Abbott and Miller (1987) provides factors for environmental variables such as the presence of overhead wires and proximity to buildings In the case of our study site, no over-head wires are present, but most of the trees are within 7 5m of a building, therefore, the time rates from O'Brien *et al* (1992) were increased by 20%

Figure 4.11 compares annual maintenance time requirements for the four alternatives Details and sources are shown in Appendix 16.

Figure 4.11: Annual maintenance time requirements



4.5.2 Materials

Once again, it should be emphasized that progress in turfgrass technology has resulted in low-maintenance cultivars In combination with organic turf maintenance, the resources consumed in lawn care can be significantly reduced. However, this analysis will include conventional turfgrass species and maintenance operations.

In the case of turf maintenance materials, OMS data was only shown for comparison purposes The range in annual material and cost expenditures was so great between the files consulted that their reliability was questionable Where published sources on material expenditures per task were available, this data was combined with frequencies per task from the OMS to maintain a local perspective Generally, the OMAF publications filled this gap[111]. Both material and labour requirements for groundcover plantings were not included in the OMS database As a result, this information was obtained from another source: Amenity Landscape Management (Cobham, 1990).

4.5 2 1 Water-use Calculation Methodology

The most difficult resource expenditure to predict was water. In the OMS database, only the costs for equipment and labour are included. Since the water itself was not considered to be an expense, water quantities for turf were derived from other sources. An estimation of average Ontario irrigation requirements from OMAF (1990), suggests

[111] For maintaining a local perspective, OMAF publications provided an appropriate alternative to Ottawa sources, since OMAF figures pertain to Ontario conditions.

a weekly application of three cm. According to the OMS database, turf watering occurs ten times annually in the locations surveyed for this study At this rate, 30 000 litres would be consumed annually The variables which affect water use rates could only be specifically accounted for by assuming a range of site conditions in the NCC data and an averaging of environmental conditions from other sources

Water requirements for trees were calculated with the NCC data on frequency and percentage of area watered. For example, on average, tree watering in the standard tree planting examples occurred once annually. However, only 26% of the total area was treated For hardy, grouped trees, only 2% of the total trees were treated[112] According to Harris (1984) average trees should be watered to a depth of 120cm per watering According to Lofgren (1982) approximately 15cm of water is necessary to reach this depth in a loam soil If 26% of an area of ten trees, each five metres in diameter, is watered once per year, then annual water consumption is 7 780 litres For small shrubs, which should be watered to a 60cm depth (Harris, 1984), 7 6cm will be necessary per watering (Lofgren, 1982). Total water requirements were predicted by multiplying this rate by the watering frequency indicated for each plant option in the OMS Since the OMS database had no category for groundcover, the frequency data from Cobham (1990) was used

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[112] According to the water requirement calculation from Chapter Two, careful species selection could eliminate the need for additional water beyond rainfall.

4 5.2.2 Material Costs

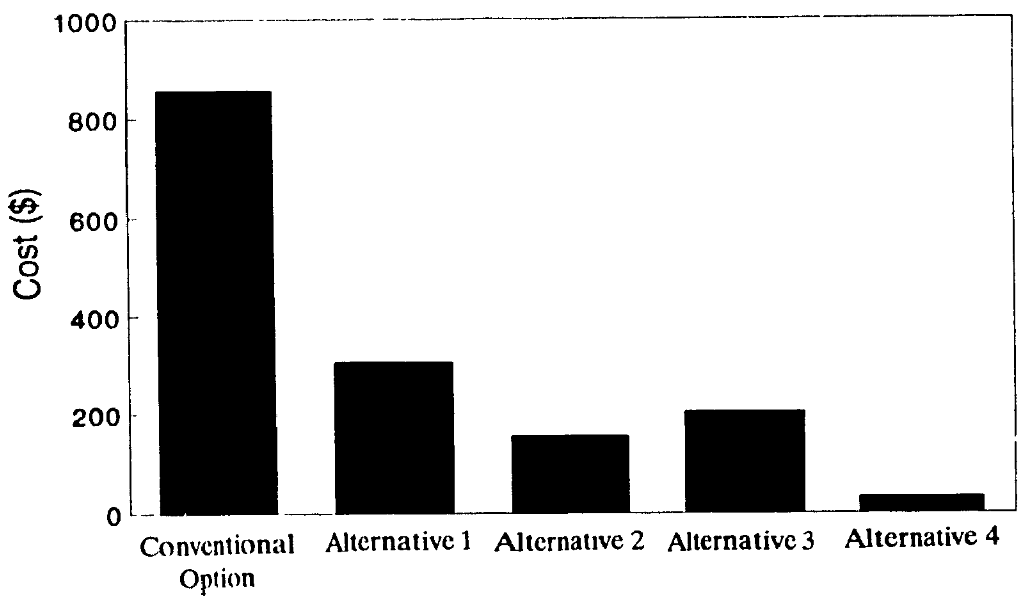
Table 4 3 shows the sources used in calculating annual maintenance material costs Figure 4.12 compares the material costs of the four alternatives

Table 4.3: Annual Maintenance Material Costs

item[1]	source
- tree removal and mulch	Contrator survey
- tree and shrub replacement	Hanscomb (1993)
- water rates[2]	RMOC (1993)
- fuel, fertilizer, pesticide and herbidice	Canadian Tire (1993)
- topsoil and mulch	NCC OMS (1993)

1. Prices do not include PST or GST.
2. Refer to Appendix 17 for calculation of water rates.

Figure 4.12: Annual maintenance material costs



4 5.2 3 Annual Maintenance Summary

Table 4 4 indicates the results of applying the annual maintenance requirements, including labour and costs, to the simulations. (Refer to Appendix 16 for sources and a detailed listing of maintenance requirements).

Table4.4: Annual Maintenance Summary Time and Costs

Option	Materials Costs ($)	Time 1[1] (hours)	Time 2[2] (hours)	Labour 1[3] ($)	Labour 2[4] ($)
Conventional Option	865.00	202	229	5055.00	5730.00
Alternative 1	305.00	90	100	2250 00	2500.00
Alternative 2	154.00	41	41	1030 00	1030 00
Alternative 3	202.00	75	93	1875 00	2325.00
Alternative 4	31.00	24	24	605 00	605 00

1. Time 1 refers to the time, requirement, in hours, for do-it-yourself maintenance, assuming an underground irrigation system in the lawn area.
2. Time 2 refers to the time requirement, in hours, for do-it-yourself maintenance, assuming no underground irrigation system.
3. Labour 1 refers to the cost, in dollars, of hiring a professional maintenance team, assuming an underground irrigation system in the lawn area. The cost assumes a $25.00 per hour rate
4. Labour 1 refers to the cost, in dollars, of hiring a professional maintenance team, assuming no underground irrigation system in the lawn area. The cost assumes a $25 00 per hour rate
5. Refer to Appendix 16 for details and sources of annual maintenance requriemens including labour, materials and costs.

4.6 Conclusion

Now that the initial costs and annual maintenance labour and cost requirements have been determined for each option, the payback periods can be calculated These payback periods reflect the number of years required to payback the additional cost of implementing alternatives when compared to the conventional option, based on annual savings. The results are discussed in Chapter Five

CHAPTER FIVE: ANALYSIS AND RESULTS

5.1 PAYBACK ANALYSIS

As indicated in the cost estimates shown in Figure 4 10 and detailed in Appendix 14, the alternatives initially cost more than the conventional option However, the annual maintenance costs are significantly lower for the alternatives, as shown in Table 4.4 One of the objectives of this paper is to determine the length of time needed to recover this additional investment based on annual cost savings All operational costs are considered, including maintenance and replacement.

Payback analyses should account for the time value of money, since the initial amount of money would earn interest if it was invested elsewhere. In addition to the interest, or discount rate, the true time value of money must account for inflation, or escalation rate Discounted payback expanded to allow for escalation is defined as True Payback This can be calculated by the method shown in Figure 5.1.

$$n = \frac{\log\,[1 + C/S\,(1 - 1/k)]}{\log k}$$

where

"C" is the initial cost difference between the conventional option and the alternative,
"S" is the annual savings in dollars per year,
"n" is the number of years it will take for the initial cost to be recovered and

$$\text{"k"} = \frac{(1+e\,)}{(1+i)}$$

where:
"e" is the escalation or inflation rate and
"i" is the discount or interest rate.

Figure 5 1 Logarithm method of calculating true payback (from Brown and Yanuck, 1985)

A conservative estimate for interest rates in the coming years is 10%, while the rate of inflation is 4% These values are used in current economic analyses of engineering projects in Canada (Friedman *et al*, 1993) According to Brown and Yanuck (1985), the operating expenses should include item removal and replacement This expense has been accounted for in the annual maintenance materials and costs [113].

5.2 Results of the Payback Study

Table 5.1 indicates the payback periods for the alternatives, assuming that the residents do the maintenance themselves Two figures for initial turf cost are provided One includes the cost of an irrigation system with an underground pop-up sprinkler system This item caused an increase of $3 300 00 (Hanscomb, 1993) over $13 394 00 in the conventional option Since this item so dramatically affected the results, a second option was provided This

Table 5.1: Payback Periods

Option	Payback Period (years)	
	Do-it-yourself Capital Cost 1[1]	Do-it-youself Capital Cost2[2]
Alternative 1	10.0	19.0
Alternative 2	18.0	42.0
Alternative 3	4 5	9 0
Alternative 4	10 5	20 0

1. Cost 1 accounts for the cost of an underground sprinkler system
2. Cost 2 accounts for a cheaper, off-the-shelf system
3. Refer to Appendix 14 Initial Cost Calculation for details and sources
4. Refer to Appendix 16 Annual Maintenance Requirements for details and sources

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[113] Any land costs, such as taxes or insurance which would be payed annually, regardless of which landscape option was implemented, are not included in this study. Maintenance equipment has been factored into the initial cost. Although equipment may be purchased on an as needed basis, and thus factored into annual costs, this gradual purchasing is impossible to predict. Equipment repairs are also not included.

included a Canadian Tire (1993) purchased, off-the-shelf, portable sprinkler system for $65 00 The obvious disadvantage of this system is the additional time required to set up and move the equipment during each watering and the additional water consumed [114] As shown in Table 5 1 and Figure 5 1, the second option caused an increase in payback time

Figure 5.1: Payback period ("do-it yourself" maintenance)

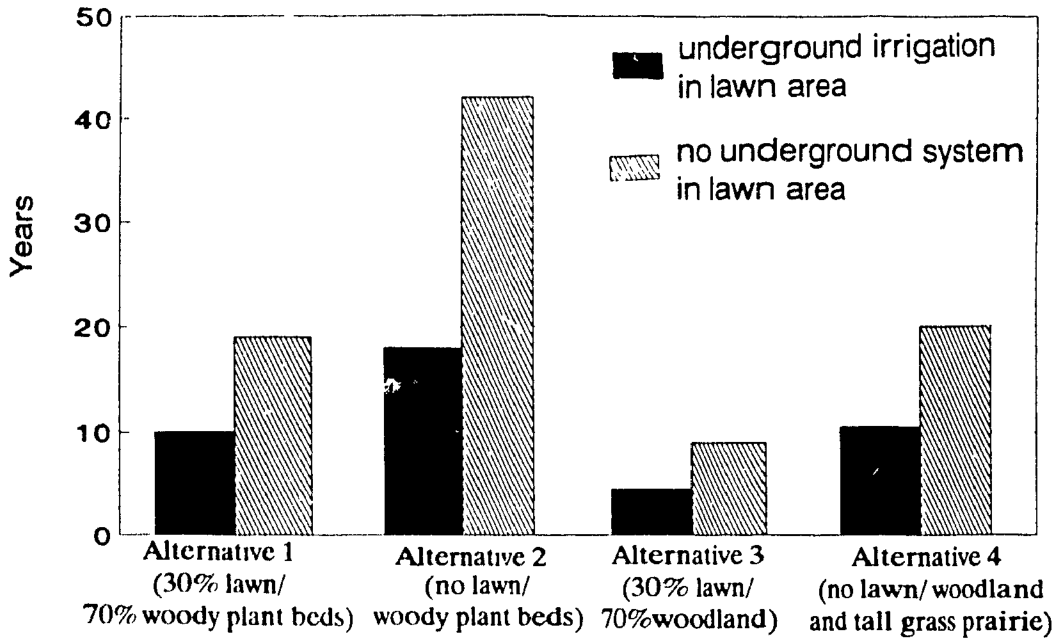

Table 5 2 indicates the payback periods for the alternatives, assuming that the residents hire a professional maintenance team. Since only the influence of material costs was factored into annual savings, this second set of payback calculations considers the time

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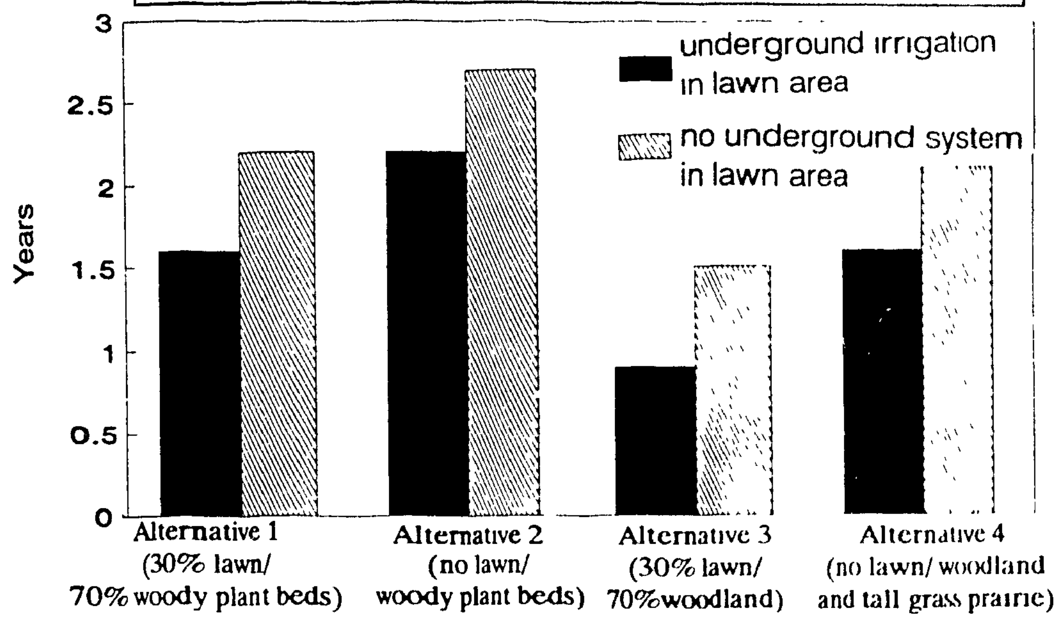
[114] The standard minute value for setting up and moving the sprinkler twice per run for a portable sprinkler stated by Cobham (1990) is 20 minutes. In addition to labour increases, water losses are greater with the cheaper system because water is often applied to non-turf areas such as paving and evaporation and run-off are increased (Robinette, 1984). However, the figures used in this study for water requirements did not specify an irrigation system. While the difference in water consumption was not accounted for in the analysis, the time requirement increase was included.

savings as well [115]. An average labour rate of $25.00 per hour was determined. This price includes equipment and material as well as labour[116] The effect of including time savings is demonstrated by the dramatic decrease in payback period for each alternative, as shown in Figure 5 2

Table 5.2: Payback Periods with Hired Labour		
Option	Payback Period (years)	
	Hired Labour Capital Cost 1	Hired Labour Capital Cost 2
Alternative 1	1 6	2 2
Alternative 2	2.2	2 7
Alternative 3	0 9	1 5
Alternative 4	1.6	2 1

1. Cost 1 accounts for the cost of an underground sprinkler system
2. Cost 2 accounts for a cheaper, off-the-shelf system
3. Refer to Appendix 14 Initial Cost Calculation for details and sources
4. Refer to Appendix 16 Annual Maintenance Requirements for details and sources.

Figure 5.2: Payback period (hired maintenance)



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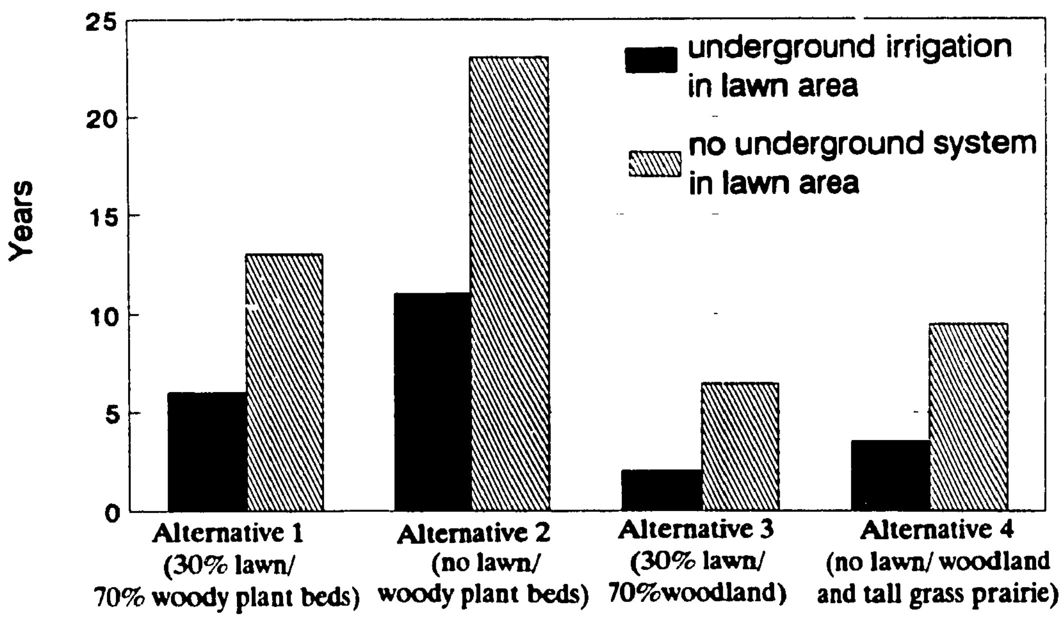
[115] Refer to Figure 4.11 and Table 4.4 for time requirements for each option.

[116] The $25.00 hourly rate was based on a phone survey of Ottawa area maintenance contractors. Six contractors responded including: Clean Cut Lawn and Lot Maintenance, Edwin Budding Lawn Care, J. Madore Beatty, Landtech Landscaping and Maintenance, Meyknecht Lischer Contractors and Sears Canada Inc.

Since annual savings were impressive, the high payback times for the do-it-yourself options can largely be accounted for by the differences in initial cost The low cost for the conventional option, compared to the alternatives, is partially the result of the 1993 cost for sod Hanscomb (1993) shows a $5 68 price per 100m^2 sodded area However, according to the same source, the 1992 cost was $8.15, while all other 1992 prices for items used in this study were similar or identical to the 1993 price. This $2 47 price drop caused the initial cost difference between the conventional option and the alternatives to increase As a result, the payback times, as shown in Figure 5 3, are more attractive than those with the 1993 sod price However, a caveat should be added Obviously, including a 1992 price influences the consistency of this investigation. Therefore, the inclusion of Figure 5 3 only serves to demonstrate the effect of price fluctuations on life cycle costing.

Figure 5.3: Payback period (1992 sod price)



5.3 Resources

The payback analysis could be presented in its own right. However, the purpose of this study was to demonstrate the relationship between cost reduction and resource conservation. Therefore the materials consumed in annual maintenance were calculated, as shown in Table 5.3, in addition to time and dollar figures

Table 5.3: Annual Maintenance Summary Materials Consumed

Option	fuel (litres)	fertilizer (kg)	water (litres)	herbicide (ml)	topsoil (m3)	seed (kg)	mulch (m3)	pesticide (kg)
Conventional Option	28.1	18.1	339 580	826	3.8	1.5	1.0	2 8
Alternative 1	10.3	6.8	114 725	299	1.4	0.58	3.9	1.2
Alternative 2	-	1.6	25 347	-	-	-	4.7	1 3
Alternative 3	9.2	5.5	98 930	272	12.6	0.5	2.5	0.16
Alternative 4	1.5	0.24	5 963	-	-	-	1.1	0.09

1. Refer to Appendix 16 for details and sources of annual maintenance requirements including labour, materials and costs.

Table 5.3 indicates that resource consumption was significantly reduced for all of the alternatives when compared to the conventional option Ranges in annual savings for four materials were as follows: fuel consumption was reduced by 63% to 100%, fertilizer by 62% to 98%, water by 66% to 98% and herbicides by 64% to 100% While the option with the lowest payback period was Alternative 3, the naturalized option with 30% lawn area, other alternatives exhibited lower material consumption rates For example, Figures 5 4 to 5 7 show that Alternatives 2 and 4, the options without lawns, consistently exhibit lower consumption rates. This point exemplifies the correlation between reducing lawn areas and conserving resources The options with lawn areas exhibited the highest consumption rates, while those without lawns, i e Alternatives 2 and 4, exhibited the lowest rates.

With the exception of fuel consumption, Alternative 4, the naturalized option with no lawn, exhibited the lowest consumption rate This option exhibited a higher fuel use rate than Alternative 2 because of the tall grass prairie which must be mowed once annually. While Alternative 4 did not exhibit the lowest payback period, it was a close second to Alternative 3 in each evaluation. However, the option with the second lowest consumption rate, resulted in the highest payback periods, because the initial cost was the highest of all the options In this example, there is a negative correlation between cost reduction and resource conservation

Figure 5.4: Water consumption

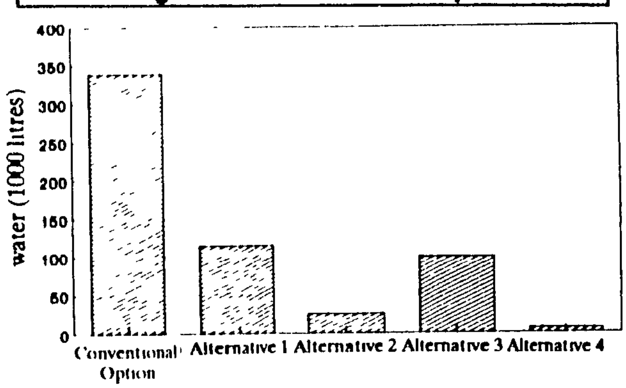


Figure 5.6: Fertilizer Consumption

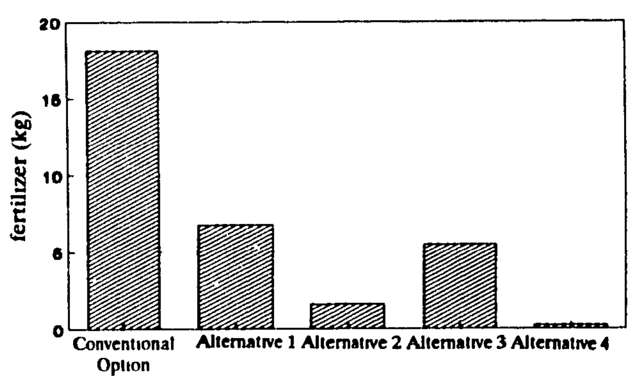


Figure 5.5: Fuel consumption

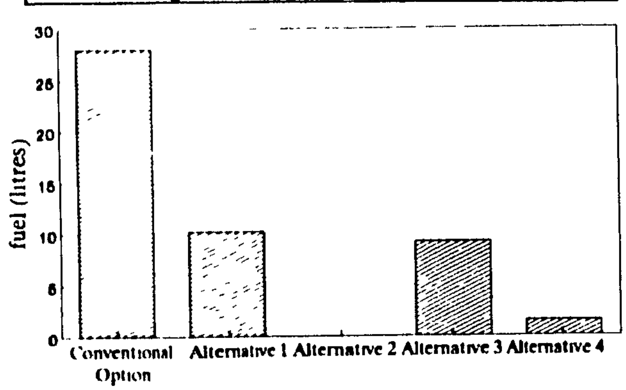
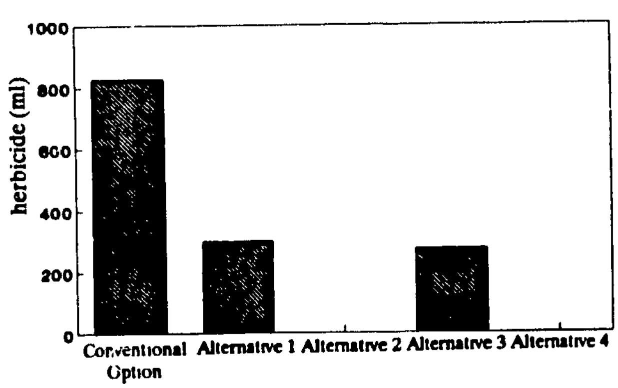


Figure 5.7: Herbicide Consumption



Since, in this study, topsoil and seed were consumed in annual turf maintenance exclusively, only the options with lawn areas include these materials Similarly, herbicide was only consumed in options with lawn areas While weed control did occur for other planting types, the sources consulted for maintenance requirements of non-turf areas included hand weeding This difference would have been accounted for in the additional labour requirement.

While less mulch was consumed in the conventional option than most of the other options, this is not alarming from an environmental point of view As discussed in Chapter Two, mulch has positive environmental effects, such as enhancing moisture retention, improving soil fertility, decreasing run-off and regulating soil temperature More mulch was consumed in the alternatives with the most shrub and groundcover plantings

Pesticide consumption shown in Table 5.3 was surprising The OMS database combines weed and pest control. Given that pesticide use is not included for turf areas, the consumption rate is surprisingly high. This may have been the result of an inconsistency in the OMS database, since there was a great range between database files surveyed No other sources with which to compare this rate were available However, the frequency and percentage of area treated, as shown in Appendix 16, was consistent in the OMS database files surveyed.

5.4 Conclusions

The return on investment for implementing resource conserving landscapes indicated in the payback analysis was less than anticipated. Alternative 3, the naturalized option with 30% lawn area, offered the lowest payback period. Similarly, the results show less of a correlation between return on investment and reduced material consumption than was anticipated. However, the decline in annual material consumption rates exhibited by each of the alternatives reflects the anticipated results. In this case, as lawn areas are reduced and plantings reflect naturalized concepts, resource consumption is reduced. The results of the payback analysis and resource consumption rate will be discussed further in the concluding chapter.

CHAPTER SIX: DISCUSSION AND CONCLUSIONS

6.1 Payback Analysis

Interpreting the results of the payback analysis shown in Figures 5 1 and 5 2 of the previous chapter yields some disappointing, and other promising conclusions There is no cut and dry answer to what consumers consider to be a desirable payback period Some may say it is the point at which investing in mutual funds pays back more quickly than investing in a conservation technology (Friedman *et al*, 1993) However, housing, unlike other sectors, offers a benchmark opportunity for measuring the acceptability of a given payback period. Since the users do not directly reap the rewards of annual savings after they move, a payback period which exceeds the duration of stay may be considered unacceptable (Camalleri, 1993). According to the General Social Survey of Statistics Canada (Che-Alford, 1992), one half of Canadian adults moved during the last five years and two-thirds in the last ten years[117]. For the purposes of this analysis, the benchmark for the minimum acceptability of a given payback period will be ten years, based on the assumption that most Canadians will move during this time frame

Given a ten year benchmark, two of the four alternatives resulted in a desirable payback period, when an underground irrigation system was installed in the turf areas.[118] Without

[117] This rate is affected by tenure status. For example, three times as many renters (33%) as owners (12%) moved in 1989. Despite this high turnover rate, the co-op's concern about investing in conservation would be greater than non-co-op communities since the Board of Directors would determine policy for the whole co-op. Thus, acceptable payback duration may be longer in this case.

[118] Refer to Appendix 14 for initial cost differences between the different irrigation options.

this expensive option, assuming an off-the-shelf, portable sprinkler system, only one alternative produced acceptable results This is because the cheaper system reduced the conventional option's initial cost significantly, since its lawn area is 85% of the total area, while it reduced the alternatives' initial costs only marginally, since they contain a maximum of 30% lawn area Despite decreases in initial costs with the expensive irrigation system, the annual savings stayed the same[119]. Given the tendency to reduce initial costs, it is likely that residents will chose the option with the cheaper sprinkler system In either case, Alternative 3, the naturalized option with 30% lawn, clearly offered the most desirable return on investment.

When the annual time savings were factored into the analysis, assuming a maintenance company is hired, each alternative's payback period was reduced[120]. The time savings were multiplied by a labour rate of $25.00 per hour and material and equipment costs were eliminated. This resulted in very attractive investment returns, since each alternative could be payed back in under ten years. However, given the co-operative nature of this housing sector, residents would likely maintain the landscape themselves (Tasci, 1993). Thus, given the most likely maintenance scenario for this co-op, only one of the four alternatives offers an acceptable return on investment. Why then have the low-maintenance alternative examples discussed in the literature review exhibited both long-

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[119] Unfortunately, the reduced water requirement for an underground system could not be accounted for. This option would have produced more impressive annual savings.

[120] Figure 5.2 of the previous chapter shows how the payback period could be reduced if a maintenance company was hired.

term cost and resource savings? These examples, such as the South-west Transitway Corridor, were implemented to reduce operating costs and conserve resources However, most of these examples are institutional projects, involving professional maintenance teams, resulting in impressive cost reductions due to time savings, as opposed to just material savings. Other housing examples discussed, such as the study by Nelson (1987), also demonstrate impressive savings due to reductions in the need for hired labour

Although great efforts are being made to promote life cycle costing, the term is not familiar to the average citizen (Brown and Yanuck, 1985). Traditions do not yield easily Vast amounts of private and public purchasing are still based on the lowest initial cost This point is exemplified in the development of the co-operative housing project used in this study. Financing for Conservation Co-op was based on the maximum unit price, which accounts only for initial costs If life cycle costing was factored into the financing, the conservation potential could be more easily achieved Thus, even a study which demonstrates a desirable payback time for a conservation alternative, is no guarantee that everyone will be sufficiently convinced.

6.2 Resource Consumption

Observations from the literature review suggested that one of the keys to conserving resources in annual maintenance is reducing the lawn area This observation is supported by the results of this analysis Consumption of most materials was lowest in the alternatives with no lawn and highest in the conventional option, with 90% lawn

Therefore, a positive correlation does exist between reducing lawn areas and promoting resource conservation

Similarly, the literature review suggested that grouping woody plants in beds would conserve resources compared to individually arranging trees and shrubs. In addition, the use of hardy native plants would reduce consumption rates. This observation is also supported by the results of this study, since the conventional option exhibited considerably higher consumption rates than the alternatives. Similarly, the literature indicated significant annual savings with naturalization. Again, this conclusion was supported by this investigation. The naturalized alternative with lawn, Alternative 3, exhibited lower consumption rates than the other options with lawn. The naturalized alternative with no lawn exhibited lower consumption rates than its non-naturalized counterpart, Alternative 2.

6.3 Balancing Economic, Environmental and Social Issues

While the potential for reducing the consumption of materials in annual maintenance was demonstrated in the analysis, the positive correlation between cost and resource savings was less than anticipated. Despite the more impressive annual savings of the alternatives with no lawn, the payback times were higher than that of Alternative 3, which included 30% lawn. Even Alternative 1, woody plant beds with 30% lawn, which had the highest consumption rate of the alternatives, could be payed back in half the time that Alternative 2, with no lawn, which had the second lowest consumption rate of all the options.

This point exemplifies the need for residents to make trade-offs in decision making If cost reduction is the main objective, Alternative 3 is the most appropriate of the solutions In this example, initial cost was kept low by including a certain percentage of lawn area Reducing lawn areas to only 30% seemed to balance initial cost increases with annual savings more effectively than eliminating lawns completely In other examples, the low-maintenance lawn alternatives such as shrubs, groundcover and unit pavers caused such initial cost increases that, despite impressive annual savings, the payback times were unacceptable. Where resource conservation is the main objective, the alternatives without lawn areas exhibit the most impressive results. Of these, the naturalized alternative consumed the fewest materials in annual maintenance.

If the objective of cost savings is tempered by a desire to retain a conventional appearance, Alternative 1 is the best solution The inclusion of a lawn area in this example may be considered essential because of the important social and recreational opportunities which lawns offer. Even the provision of an enlarged hard surfaced seating area may be considered insufficient to mitigate for the loss of a lawn area Also, the less naturalized concept is more similar aesthetically to the conventional option than the other alternatives. However, while the other alternatives offer an unconventional aesthetic quality, many users will regard the alternatives' social opportunities as more positive than those of the conventional option. The environmental quality of songbird sounds in a woodland retreat can provide a welcome contrast to the more manicured approach, particularly in a dense urban context For example, the City of Ottawa (1993) identified the aesthetic and educational opportunities of putting city dwellers back in touch with natural processes as key merits in their naturalization program.

6.4 Impact and Feasibility of Implementing Low-maintenance Alternatives

By applying the results of this single project to the community level, the conservation potential of the alternatives can be broadened in scope. The landscaped open space area of Strathcona Heights[121], the community in which the co-op is located, is six hectares (Padolsky, 1988) By applying the findings of the co-op simulation analyses to the community level, the following annual savings could be achieved if any of the alternatives were applied fuel savings ranging from 712 litres to 1124 litres, fertilizer from 452 kg to 714 kg, water from 8 994 000 litres to 13 344 000 litre and herbicide from 21 litres to 33 litres In addition to conserving these and other resources. cost savings ranged from $22 400 to $33 360 annually, assuming the residents maintain the landscape themselves. Assuming they hire a maintenance company, cost savings could range from $112 200 to $178 000 for the community

While these savings reflect the conservation potential of a single community, the results of applying these principles to more and more projects municipally or even nationally would have a significant impact on addressing the global environmental issues discussed in the introduction However, variety is essential in the urban landscape. While these principals will not address the unique features of every site and every user group, the

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[121] Refer to Appendix Ten for Strathcona Heights Master Plan.

environmental impacts will only improve if more low-maintenance alternatives are implemented.

The prominence of implemented projects and studies indicates the feasibility and level of support for low-maintenance landscapes Implementing these alternatives in Ottawa is particularly feasible because of the City's policy of promoting naturalization as outlined in Strategies Towards Managed Naturalization in Existing Parkland (City of Ottawa, 1993) The Official Plan (City of Ottawa, 1991) indicates that funds saved from eliminating the need for regular maintenance could be applied toward naturalization projects

6.5 GUIDELINES

While the initial costs, annual savings and payback times are indicated for a specific project in a specific location, the principles can be applied to other projects The results could be applied more readily to a similar housing typology and geographic location For example, the payback times will likely be different for a single-detached house in Winnipeg. As a result, one of the secondary goals of this project was to provide guidelines which could be applied to other projects in other regions The following guidelines resulted from this investigation:

1. **Limit turf area** to that which is useful for specific social and recreational functions Minimize the use of turf as a purely visual groundcover

2 **Select water-efficient plants suited to local site conditions**, such as climate, soil type and site drainage Try to use native material unless a well-adapted, lower-maintenance introduced species is available

3 **Group trees, shrubs and groundcover plantings in beds**, rather than locating them in isolation, surrounded by turf or paved areas.

4 **Use mulch** to reduce evaporation and to prevent weed growth in planting beds.

5 **Naturalize your landscape** so that plantings rely more on natural process for healthy sustained growth than horticultural technology For woodlands, install young seedlings in beds prepared to reduce weed growth and retain moisture and nutrients Select tree and woodland groundcover species which would be found in local woodlands For tall grass prairie, install wildflower plugs in tall grass areas Mow once annually.

6 For aesthetic enhancement of naturalized plantings, **define the edges** with colourful shrubs or groundcover Also, **variety in the size and character of plant material** will provide visual interest and a more natural appearance Establish an informal path network in the woodland area.

7 Where life cycle costing is the prime objective, establish **naturalized plantings around a small lawn area** of about 30% of the total planted area.

8. Where resource conservation is the prime objective, replace lawn areas with naturalized plantings or woody plants grouped in mulched beds Mitigate for the loss of lawn as a social space by expanding the hard-surfaced area, but only if a porous paving is used.

9. If cost and resource savings are tempered by a desire to retain a conventional appearance, establish hardy woody plant beds around a small lawn area, of about 30% of the total planted area.

10. **Keep records of annual expenditures** of labour, materials and costs, bearing in mind that inputs will be higher in the first few years during plant establishment for all items except turf Over several years, perform your own payback analysis as a feedback mechanism for the cost and resource efficiency of your landscape

6.6 Further Study

Calculating the true implications of resource consumption is beyond the scope of this paper. Accounting for *embodied energy*[122] and tracing the precise environmental impact of consuming resources in landscape maintenance[123] would augment the findings of this

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[122] *Embodied energy* accounts for the inputs required to produce and transport an item before it arrives on site. Before a nursery-grown tree arrives on-site, water, fertilizer and other resources are consumed in the nursery.

[123] For example, how much of a given pesticide application actually seeps into the water-table?

study. Without analyzing the specific impacts, this paper assumes that reducing consumption of chemical products, water and fuel in landscape maintenance will help to alleviate some of the environment problems we now face. However, the environmental impact of landscape design on resource consumption does not stop at accounting for materials consumed in annual maintenance Energy consumption in home-heating and cooling is affected by landscape design Similarly, planting design influences on-site stormwater management, which also has environmental impacts. These influences should be combined with the environmental impact of landscape maintenance for a full analysis of the impact of vegetation on the environment.

While social and aesthetic issues were discussed in this study, they were not analyzed in the evaluation of landscape alternatives. To alleviate this gap in the analysis, design features remained as consistent as possible given the changes in plant material and lay-out needed for the analysis However, a user preference analysis would have ensured a more equitable comparison of alternatives, as well as adding an important dimension to an analysis of landscape alternatives

The use of simulations as a methodology for this evaluation was the result of the time constraints of a master's thesis A more accurate portrayal of the saving potential of the alternatives would have been feasible through direct observation. For example, if five test plots were planted, data on initial cost and annual requirements could be recorded, as these tasks were performed. Unfortunately, many years would be required for sufficient growth and data collection. Given the time frame of this study, cost and material consumption estimates were based on predictive models like surveying contractors, consulting published sources and the OMS database.

6.6 Conclusions

The findings of this investigation help to fill part of the literature void on the cost and resource saving potential of landscape alternatives. Firstly, while other analyses show the economic, environmental and social benefits of low-maintenance alternatives in an institutional context, this study points out the implications of applying these considerations to housing. Secondly, it considers payback periods rather than just annual savings Thirdly, it compares more than one alternative with a conventional option

While it is unlikely that this analysis will lead to homeowners ripping out their existing landscapes and replacing them with low-maintenance alternatives, hopefully it will form part of a compelling body of literature which will gradually redefine conventional practices As public understanding of life cycle costing and environmental issues becomes more prevalent, studies like this will increasingly be consulted Design alternatives which address current economic, social and environmental concerns are bound to be practical and long-lasting.

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APPENDIX ONE
PRELIMINARY REVIEW OF MAINTENANCE REQUIREMENTS FOR LAWN, TREES, SHRUBS, WOODY GROUNDCOVER AND VINES

Table 1: Annual maintenance requirements $100m^2$ turf area		
task	time[1]: source Cobham (1990)	Material notes
hand fertilizer application:	3 min.	- 1.5-2 kg, OMAF (1990)
irrigation	6.6 hours	- 60 000 L OMAF (1990)
mowing (24" push mower)	7.2 hours	- fuel (not found in lit review
raking	11 min.	-
overall herbicide with knapsprayer	20 min.	- annually Cobham (1990)
edging	4 hours	-
topdress	11 min.	topsoil (not found in lit review)
Total	**18.5 hours** [2]	

1. Not all of these tasks will be performed in every situation nor are all tasks included here For example, if aerating occurs annually, certain other requirements could be reduced or eliminated. A list of organic maintenance tasks would be different to this one The items shown represent a conventional approach to lawn maintenance which will vary from job to job
2. Results will vary with species, soil and climate conditions as well as aesthetic objectives These figures represent averages.

Parker and Wright (1980) show annual hourly inputs for small lawns to be 14 to 17 hours per $100m^2$. According to the Institute of Maintenance Research (IMR, 1982) the following time values can be expected for lawn maintenance:

Table 2: Annual time requirement for 100m2 turf area	
task	time
mowing (16" push mower)	2.5 hours
hand edge trim and clean-up	12.5 hours
hand fertilizing	15 min
weed control (3 gal hand pump)	30 min
hand rake	60 min
hand sweep	75 min.
TOTAL	**18.0 hours**

Table 3: Annual requirements one tree (pre-establishment)[1]		
Task	Time (minutes) /tree/6years	Material Notes
hand pruning	70	-
watering[2]	120	- water up to 10 times in the first season (10L/ watering) and during drought
weed control	20	- if trees are properly mulched during planting, weeding should be minimal
fertilization	7	-controversial, eg. Insley (1982) recommends against use of fertilizer for trees
TOTAL	**217 minutes / 6 years or 36 minutes /year**	

1. All data sourced from Cobham (1990).
2. Cobham (1990) compares the cost of watering newly planted trees six times in the first year after planting and not watering newly planted trees. The comparison shows that watering was cheaper than replacing the 30% of the trees that died due to the lack of watering.

Table 4: Annual requirements one tree (post-establishment) [1]		
Task	Time (minutes)	Material Notes
hand pruning	15	-
weed contol	4	- mulch and hand weeding
water	-	- as needed in drought
removal[2]	-	-
Total	**19 minutes**[3]	

1. All data sourced from Cobham (1990).
2 Tree removal is not included due to the difficulty of to predicting its frequency. Cobham (1990) estimates that to trim off and dispose of branches, cut trunk and remove stump for a 9.1m tree (15cm diam) will require 1.6 hours .
3. There will usually be no need to fertilize mature trees to promote growth (Cobham, 1990). Fertilizing should only occur if the growth problem cannot be traced to anything else (OMAF, 1990).

Table 5: Annual requirements 100m² shrub area[1]			
task	% area treated/year	total time (minutes)	material notes
prune[2]	7	35.0	-
remove dead plants	1	2.0	-
replant	1	15.0	-
spot treat with herbicide	15	6.8	- after canopy closure, weed control will be minimal[3]
handweed	15	12.0	-
fertilize (1/10 y)	10	0.7	- 1.5-2 kg/application/100m2
mulch	7	7.0	- after canopy closure, mulching will be minimal
clean-up	600	30.0	-
rejuvenate (15-20 y)[4]	5	50.0	-
watering	-	-	- as needed during drought [5]
pest control [6]	-	-	-
Total		**2.6 hours**	

1. All data from Cobham (1990).
2. Most shrubs need very little pruning with the exception of removal of diseased or damaged wood. Evergreens need little or no pruning even in confined spaces (Harris, 1984).
3. Mulching and close spacing during establishment will virtually eliminate weed problems.
4. Vigorous mature shrubs require at least 25 to 30% of the older branches removed annually. Vigorous species are better coppiced to just above ground level every 15 to 20 years (Cobham, 1990; Harris, 1984).
5. Irrigation of established shrubs is seldom necessary (Cobham, 1990).
6. Most shrubs are relatively pest and disease-free (Cobham, 1990).

Table 6: Annual requirements 100m² groundcover area (during establishment -1 to 3years)			
item	frequency (Cobham)	total time (Cobham)	material notes
fertilization	1	5 min.	-1kg nitrogen (Thoday, 1982)
hand weeding[1]	15	4.6 hours	-
mulching	1	9.2 min.	- restore 50mm depth until canopy closure (Thoday, 1982)
watering	10	3.3 hours	- 1 000 litres every two weeks and in drought periods (Cobham, 1990)
TOTAL		**7.8 hours**	

1. Thoday (1982) recommends a contact herbicide every eight weeks during the growing season in the first three years. However, hand weeding , a more time consuming equivalent to herbicide use is shown here because it is more consistant with the objectives of this study.

Table 7: Annual requirements
100m² groundcover area (after establishment)

item	frequency	time	source	total time	material notes
hand weeding	1	18.4 min.	IMR[1]	18.4min.	-
rejuvination[2]	10-15y	16.6 h	Cob	1.3hours	
mulching	10-15y	27.6 min.	IMR	2.2min.	-100mm mulch after rejuvination (Thoday, 1982)
watering	10xeach 10-15y	20min.x10	Cob	16min.	-1 000 litres every two weeks the first year after rejuvination and in drought periods (Cobham, 1990)
fertilization	10-15y	5 min.	IMR	-	-0.5 to1kg nitrogen after rejuvination (Thoday, 1982)
hand weeding[3]	15x each 10-15y	18.4min.	IMR	22min.	
TOTAL				**2.3 hours**	

1. Institute of Maintenance Research (1982)
2. After rejuvination, watering, fertilizing and mulching will be necessary in the first year (Thoday 1982).
3. Thoday (1982) recommends a residual herbicide of 10 grams after rejuvination, but hand weeding is shown here.

Table 8: Annual requirements
10m² climbing vine area (after establishment)[1]

task	frequency	minutes/task	total minutes
wiring of wall	1x/25 years	120.0	4.8
re-planting	1x/50 years	14.6	3.0
removal	1x/50 years	90.0	1.8
mulching	1x/ year	3.0	3.0
pruning	1x/ year	7.5	7.5
tying-in	1x/ year	7.5	7.5
Total			**27.6 minutes[2]**

1. All data from Cobham (1990).
2. Irrigation will occur eight times per year and fertilizing will occur once per year in the first five years prior to establishment.

APPENDIX TWO
PLANT LIST OF SHRUBS AND PERENNIALS FOR THE XERISCAPE DEMONSTRATION GARDEN, QUEEN'S PARK, TORONTO
(from MNR, 1992)

DECIDUOUS SHRUBS

Acanthopanax sieboldianus	Fiveleaf Aralia
Acer ginnala	Amur Maple
Amelanchiar alnifolia	Saskatoon Serviceberry
Amelanchiar canadensis	Downy Serviceberry
Aralia elata	Japanese Angelica Tree
Aronia arbutifolia	Red Chokeberry
Aronia melanocarpa	Black Chokeberry
Buddleia davidii	Butterfly Bush
Caragana arborescens	Siberian Peashrub
Caragana arborescens `Pendula'	Cutleaf Peashrub
Caragana aurantiaca	Pygmy Peashrub
Caragana frutex `Globusa'	Globe Peashrub
Cercis canadensis	Eastern Redbud
Chaenomeles japonica	Japanese Quince
Chaenomeles speciosa	Flowering Quince
Chaenomeles speciosa `Texas Scarlet'	Texas Scarlet Flowering Quince
Chaenomeles speciosa `Toyo-Nishiki'	Toyo-Nishiki Flowering Quince
Cornus mas	Cornelian Cherry
Cotinus coggygria	Smoketree
Cotinus coggygria `Purpureus'	Purple Smoketree
Cotinus coggygria `Royal Purple'	Royal Purple Smoketree
Cotoneaster divaricatus	Spreading Cotoneaster
Cotoneaster horizontalis	Rockspray Cotoneaster
Eleagnus umbellata `Cardinal'	Cardinal Autumn Olive
Euonymus europea	Spindletree
Forsythia x intermedia `Spectabilis'	Showy Forsythia
Hippophae rhamnoides	Seabuckthorn
Hypercium	St Johnswort family
Hypercium kalmianum	Kalm St Johnswort
Hypercium kouytchense	Sungold Hypercium
Kolkwitzia amabilis	Beautybush
Ligustrum amurense	Amur Privet
Ligustrum ibolium	Ibolium Privet
Ligustrum obtusifolium regelianum	Regel's Privet
Lonicera tatarica	Tatarian Honeysuckle
Myrica pensylvanica	Northern Bayberry
Rhus aromatica	Fragrant Sumac
Rhus aromatica `Gro-Low'	Gro-Low Fragrant Sumac
Rhus typhina	Staghorn Sumac
Rhus typhina `Lacianata'	Cutleaf Staghorn Sumac
Rosa hugonis	Father Hugo Rose
Rosa multiflora	Japanese Rose
Rosa rubrifolia	Redleaf Rose
Rosa wichuriana	Memorial Rose
Spiraea bumalda `Anthony Waterer'	Anthony Waterer Spirea
Spiraea bumalda `Goldflame'	Goldflame Spirea
Spiraea nipponica `Halward's Silver'	Halward's Silver Spirea
Spiraea vanhouttii	Bridlewreath Spirea
Viburnum lantana `Mohican'	Wayfaring Tree
Weigela florida `Bristol Ruby'	Bristol Ruby Weigela
Weigela florida `Variegata'	Variegated Weigela

EVERGREEN AND BROADLEAF EVERGREEN SHRUBS

Arctostaphylos uva-ursi 'Vancouver Jade'	Vancouver Jade Bearberry
Euonymus fortunei	Wintercreeper Euonymus
Euonymus fortunei 'Coloratus'	Colorata Euonymus
Euonymus fortunei 'Sarcoxie'	Sarcoxie Euonymus
Juniperus chinensis 'Hetzii'	Hetz Juniper
Juniperus chinensis 'Mountbatten'	Mountbatten Juniper
Juniperus chinensis 'Pfitzeriana Aurea'	Golden Pfitzer Juniper
Juniperus scopulorum 'Blue Heaven'	Blue Heaven Juniper
Juniperus scopulorum 'Winter Blue'	Winter Blue Juniper
Mahonia aquifolium	Oregon Grape
Pinus mugo mugo	Mugho Pine
Yucca filamentosa	Adam's needle
Yucca glauca	Spanish Bayonet

PERENNIALS

Achillea tomentosa	Dwarf Wooly Yarrow
Anthemis tinctoria 'Golden Orange'	Marguerite Daisy
Campanula poscharskyana	Serbian Bellflower
Cerastium tomentosa	Snow in Summer
Coreopsis verticillata	Threadleaf coreopsis
Dianthus deltoides 'Brilliant Cascade'	Garden Pink
Dianthus gremadin	Carnation
Echinops banaticus 'Blue Globe'	Blue Globe Thistle
Euphorbia polychroma	Cushion Spurge
Echinacea purpurea	Purple coneflower
Gaillardia grandiflora 'Dazzler'	Blanket Flower
Hemerocalis 'Bengaleer'	Daylily
Kniphofia uvaria	Red Hot Poker
Lavandula officinalis	Lavender
Liatris pycnostaschya	Gay-Feather
Liatris pycnostaschya 'Alba'	White Gay-Feather
Liatris punctata	Dotted Gay-Feather
Limonium latifolium	Sea Lavender
Linum perenne	Blue Flax
Malva moshata 'Rosea'	Rose Mallow
Monarda fistula	Wild Bergamot
Nepeta	Catmint
Origanum vulgare 'Aureum'	Golden Oregano
Penstemon 'Prairie Fire'	Beardtongue
Penstemon 'Pinifolius'	Pine Leaved Penstemon
Phlox subulata 'Rubrum'	Moss Phlox
Rudbeckia fulgida 'Goldstrum'	Black Eyed Susan
Rudbeckia hirta 'Rustic Mix'	Gloriosa Daisy
Salvia officinalis	Garden Sage
Stachy's lanata	Lamb's Ear
Thymus pseudolanuginosus	Wooly Thyme
Thymus serphyllum	Mother of Thyme
Thymus vulgaris	Common Thyme

SEDUMS

Sedum cauticola	Shortleaf Stonecrop
Sedum kamtschaticum	Orange Stonecrop
Sedum spectabile 'Variegatum'	Showy Stonecrop
Sedum spurium 'Dragon's Blood'	Two Row Stonecrop

APPENDIX THREE
ENVIRONMENTAL CHARACTERISTICS OF NATIVE TREES
(from Hightshoe, 1988)

Soil Correlations: Table IV

	Texture					Drainage						Moisture					Reaction-pH				
	coarse	mod coarse	medium	mod fine	fine	very poor	poor	mod. poor	mod. well	well	excessive	wet	moist	average	dry	droughty	4.0-5.0	5.1-6.0	6.1-6.5	6.6-7.5	7.6-8.5
Abies balsamea	X	X	X	X		X	X	X	X	X		X	X				X	X	X		
Abies concolor		X	X	X				X	X	X			X	X	X		X	X	X		
Abies lasiocarpa		X	X					X	X	X			X	X	X		X	X	X		
Acer negundo		X	X	X	X		X	X	X	X		X	X	X	X	X		X	X	X	
Acer nigrum	X	X	X						X	X			X	X					X	X	
Acer pensylvanicum	X	X	X						X	X			X	X			X				
Acer rubrum	X	X	X	X	X	X	X	X	X	X		X	X	X			X	X	X		
Acer saccharinum		X	X	X	X		X	X	X	X		X	X	X	X			X	X		
Acer saccharum	X	X	X						X	X			X	X					X	X	
Acer spicatum	X	X	X						X	X			X	X			X				
Aesculus glabra	X	X	X					X	X	X		X	X	X	X				X		
Aesculus octandra	X	X	X					X	X	X		X	X	X	X				X		
Alnus rugosa	X	X	X	X	X	X	X	X	X	X		X	X							X	
Amelanchier canadensis	X	X	X						X	X			X	X					X		
Amelanchier laevis	X	X	X						X	X			X	X					X		
Aralia spinosa	X	X	X	X	X	X	X	X	X				X	X	X				X		
Asimina triloba		X	X	X					X	X			X	X					X	X	X
Betula lenta	X	X	X	X					X	X			X	X	X		X				
Betula lutea	X	X	X	X			X	X	X	X			X	X			X	X	X	X	X
Betula nigra	X	X	X	X	X		X	X	X			X	X	X	X		X	X	X		
Betula papyrifera	X	X	X	X			X	X	X	X			X	X	X			X	X	X	X
Betula populifolia	X	X	X	X			X	X	X	X	X		X	X	X			X	X	X	
Carpinus caroliniana			X	X	X		X	X	X	X	X		X	X					X	X	
Carya cordiformis	X	X	X	X				X	X	X		X	X	X	X			X	X	X	X
Carya glabra			X	X	X				X	X				X	X	X			X	X	
Carya illinoensis		X	X	X			X	X	X				X							X	

Soil Correlations: Table IV

	Texture					Drainage						Moisture					Reaction pH				
	coarse	mod coarse	medium	mod fine	fine	very poor	poor	mod. poor	mod. well	well	excessive	wet	moist	average	dry	droughty	4.0-5.0	5.1-6.0	6.1-6.5	6.6-7.5	7.6-8.5
Carya ovata			X	X	X			X	X	X		X	X	X	X	X			X		
Carya tomentosa	X	X	X	X	X				X	X	X			X	X	X			X		
Castanea dentata	X	X	X	X	X			X	X	X			X	X	X		X	X			
Catalpa speciosa			X	X			X	X	X	X		X	X	X	X	X			X	X	X
Celtis occidentalis		X	X	X				X	X	X		X	X	X	X					X	X
Cercis canadensis		X	X	X					X	X			X	X	X				X	X	X
Chionanthus virginicus		X	X	X	X		X	X	X	X	X		X	X			X	X	X		
Cladrastis lutea	X	X	X	X					X	X		X	X	X						X	X
Cornus alternifolia		X	X	X				X	X	X			X	X						X	
Cornus florida		X	X	X	X		X	X	X	X			X	X	X			X	X		
Cotinus americanus	X	X	X	X					X	X	X		X	X	X	X				X	X
Crataegus crusgalli		X	X	X	X			X	X	X	X		X	X	X	X			X	X	X
Crataegus mollis		X	X	X	X			X	X	X	X		X	X	X	X			X	X	X
Crataegus nitida		X	X	X	X			X	X	X	X		X	X	X	X			X	X	X
Crataegus phaenopyrum		X	X	X	X			X	X	X	X		X	X	X	X			X	X	X
Crataegus pruinosa		X	X	X	X			X	X	X	X		X	X	X	X			X	X	X
Crataegus punctata		X	X	X	X			X	X	X	X		X	X	X	X			X	X	X
Diospyros virginiana			X	X					X	X				X	X	X			X		
Euonymus atropurpureus		X	X	X				X	X				X	X						X	
Fagus grandifolia		X	X	X					X	X			X	X					X		
Franklinia alatamaha		X	X	X	X				X	X			X	X			X	X			
Fraxinus americana		X	X	X				X	X	X			X	X					X	X	
Fraxinus nigra		X	X	X	X	X	X	X				X	X				X	X	X		
Fraxinus pennsylvanica	X	X	X					X	X	X		X	X	X	X	X			X	X	
Fraxinus quadrangulata	X	X	X	X				X	X	X	X	X	X	X	X	X				X	X
Gleditsia triacanthos		X	X	X	X			X	X	X		X	X	X	X	X			X	X	

Soil Correlations: Table IV

	Texture: coarse	Texture: mod. coarse	Texture: medium	Texture: mod. fine	Texture: fine	Drainage: very poor	Drainage: poor	Drainage: mod. poor	Drainage: mod. well	Drainage: well	Drainage: excessive	Moisture: wet	Moisture: moist	Moisture: average	Moisture: dry	Moisture: droughty	Reaction-pH: 4.0-5.0	Reaction-pH: 5.1-6.0	Reaction-pH: 6.1-6.5	Reaction-pH: 6.6-7.3	Reaction-pH: 7.4-8.5
Gymnocladus dioicus																					
Halesia carolina																					
Hamamelis virginiana																					
Juglans cinerea																					
Juglans nigra																					
Juniperus virginiana																					
Larix laricina																					
Liquidambar styraciflua																					
Liriodendron tulipifera																					
Maclura pomifera																					
Magnolia acuminata																					
Malus ioensis																					
Morus rubra																					
Nyssa sylvatica																					
Ostrya virginiana																					
Oxydendrum arboreum																					
Picea engelmanni																					
Picea glauca																					
Picea glauca densata																					
Picea mariana																					
Picea pungens																					
Pinus banksiana																					
Pinus flexilis																					
Pinus ponderosa																					
Pinus resinosa																					
Pinus rigida																					

Soil Correlations: Table IV

	Texture: coarse	Texture: mod. coarse	Texture: medium	Texture: mod. fine	Texture: fine	Drainage: very poor	Drainage: poor	Drainage: mod. poor	Drainage: mod. well	Drainage: well	Drainage: excessive	Moisture: wet	Moisture: moist	Moisture: average	Moisture: dry	Moisture: droughty	Reaction-pH: 4.0-5.0	Reaction-pH: 5.1-6.0	Reaction-pH: 6.1-6.5	Reaction-pH: 6.6-7.3	Reaction-pH: 7.4-8.5
Pinus strobus																					
Platanus occidentalis																					
Populus deltoides																					
Populus grandidentata																					
Populus tremuloides																					
Prunus americana																					
Prunus pensylvanica																					
Prunus serotina																					
Prunus virginiana																					
Pseudotsuga taxifolia																					
Ptelea trifoliata																					
Quercus alba																					
Quercus bicolor																					
Quercus borealis																					
Quercus coccinea																					
Quercus ellipsoidalis																					
Quercus imbricaria																					
Quercus macrocarpa																					
Quercus marilandica																					
Quercus montana																					
Quercus muhlenbergi																					
Quercus palustris																					
Quercus stellata																					
Quercus velutina																					
Rhododendron maximum																					
Rhus copallina																					

Soil Correlations: Table IV

	Texture: coarse	med. coarse	medium	med. fine	fine	Drainage: very poor	poor	mod. poor	mod. well	well	excessive	Moisture: wet	moist	average	dry	droughty	Reaction-pH: 4.0-5.0	5.1-6.0	6.1-6.5	6.6-7.5	7.6-8.5
Rhus glabra	■	■	■	■	■				■	■	■			■	■	■			■	■	
Rhus typhina	■	■	■	■	■				■	■	■			■	■	■			■	■	
Robinia pseudoacacia	■	■	■	■					■	■	■			■	■	■		■	■	■	■
Salix amygdaloides	■	■	■	■	■	■	■	■				■	■							■	
Salix bebbiana	■	■	■	■	■	■	■	■				■	■							■	
Salix discolor	■	■	■	■	■	■	■	■				■	■							■	
Salix nigra	■	■	■	■	■	■	■	■				■	■							■	
Sassafras albidum		■	■	■	■					■	■		■	■	■	■			■		
Sorbus decora	■	■	■	■	■	■	■	■	■	■		■	■	■				■	■	■	
Taxodium distichum			■	■	■	■	■	■	■			■	■						■		
Thuja occidentalis		■	■	■	■		■	■	■	■		■	■	■	■				■	■	■
Tilia americana		■	■						■	■			■	■						■	
Tsuga canadensis		■	■	■			■	■	■	■		■	■	■			■	■	■	■	
Ulmus americana		■	■	■				■	■	■			■	■	■					■	■
Viburnum lentago		■	■	■				■	■	■			■	■	■				■	■	■
Viburnum prunifolium		■	■	■					■	■				■	■	■				■	■
Viburnum rufidulum		■	■	■					■	■				■	■	■				■	■
Zanthoxylum americanum		■	■	■					■	■				■	■	■			■	■	■

Silvical Characteristics: Table V

	Growth: slow	medium	fast	Longevity: short	medium	long	Physiol: infrequent	frequent	Disease: infrequent	frequent	Insect: infrequent	frequent	Wind Ice: infrequent	frequent
Abies balsamea	■				■		■		■		■			■
Abies concolor	■					■	■		■		■			■
Abies lasiocarpa	■	■				■	■		■		■			■
Acer negundo			■	■			■			■		■		■
Acer nigrum	■	■			■		■			■		■	■	
Acer pensylvanicum	■				■		■			■		■		■
Acer rubrum		■	■		■			■		■		■		■
Acer saccharinum			■	■				■		■		■		■
Acer saccharum	■				■		■			■		■	■	
Acer spicatum	■			■				■	■		■			■
Aesculus glabra	■				■			■		■	■		■	
Aesculus octandra	■				■			■		■		■	■	
Alnus rugosa			■	■			■		■			■		■
Amelanchier canadensis		■			■		■		■		■		■	
Amelanchier laevis		■			■		■		■		■		■	
Aralia spinosa			■	■			■		■		■		■	
Asimina triloba	■				■		■		■		■			■
Betula lenta	■				■		■			■		■	■	
Betula lutea		■			■		■			■		■	■	
Betula nigra			■	■			■		■		■			■
Betula papyrifera		■		■			■			■		■	■	
Betula populifolia			■	■			■			■	■			■
Carpinus caroliniana	■				■		■		■		■		■	
Carya cordiformis	■					■	■		■		■		■	
Carya glabra	■					■		■		■		■	■	
Carya illinoensis	■					■	■		■		■		■	

Silvical Characteristics: Table V

	Growth			Longevity			Physiol		Disease		Insect		Wind Ice	
	slow	medium	fast	short	medium	long	infrequent	frequent	infrequent	frequent	infrequent	frequent	infrequent	frequent
Carya ovata	■	□	□	□	□	■	■	□	■	□	■	□	■	□
Carya tomentosa	■	□	□	□	□	■	■	□	■	□	■	□	■	□
Castanea dentata	□	■	■	□	□	■	■	□	□	■	■	□	□	■
Catalpa speciosa	□	□	■	■	□	□	■	□	■	□	■	□	□	■
Celtis occidentalis	□	■	□	□	□	■	■	□	□	■	□	■	■	□
Cercis canadensis	■	□	□	■	□	□	■	□	■	□	■	□	□	■
Chionanthus virginicus	■	□	□	□	■	□	■	□	■	□	■	□	■	□
Cladrastis lutea	□	■	□	□	■	□	■	□	■	□	■	□	□	■
Cornus alternifolia	■	□	□	□	■	□	■	□	■	□	■	□	□	■
Cornus florida	□	■	□	□	■	□	□	■	■	□	■	□	■	□
Colinus americanus	■	□	□	■	□	□	■	□	■	□	■	□	■	□
Crataegus crusgalli	■	□	□	■	□	□	■	□	□	■	□	■	■	□
Crataegus mollis	■	□	□	■	□	□	■	□	□	■	□	■	■	□
Crataegus nitida	■	□	□	■	□	□	■	□	□	■	□	■	■	□
Crataegus phaenopyrum	■	□	□	■	□	□	■	□	□	■	□	■	■	□
Crataegus pruinosa	■	□	□	■	□	□	■	□	□	■	□	■	■	□
Crataegus punctata	■	□	□	■	□	□	■	□	□	■	□	■	■	□
Diospyros virginiana	■	□	□	■	□	□	■	□	□	■	□	■	■	□
Euonymus atropurpureus	□	■	□	□	■	□	■	□	□	■	■	□	■	□
Fagus grandifolia	■	□	□	□	□	■	□	■	■	□	■	□	■	□
Franklinia alatamaha	■	□	□	□	■	□	■	□	□	■	■	□	■	□
Fraxinus americana	□	■	□	□	■	□	■	□	□	■	□	■	■	□
Fraxinus nigra	□	□	■	■	□	□	■	□	□	■	□	■	□	■
Fraxinus pennsylvanica	□	□	■	□	■	□	■	□	□	■	□	■	□	■
Fraxinus quadrangulata	□	□	■	□	■	□	■	□	■	□	□	■	■	□
Gleditsia triacanthos	□	□	■	□	■	□	■	□	■	□	□	■	■	□

Silvical Characteristics: Table V

	Growth			Longevity			Physiol		Disease		Insect		Wind Ice	
	slow	medium	fast	short	medium	long	infrequent	frequent	infrequent	frequent	infrequent	frequent	infrequent	frequent
Gymnocladus dioicus	■	■	□	□	■	□	■	□	■	□	■	□	■	□
Halesia carolina	□	■	□	□	■	□	■	□	■	□	■	□	■	□
Hamamelis virginiana	□	■	□	□	■	□	■	□	■	□	■	□	■	□
Juglans cinerea	□	□	■	■	□	□	■	□	■	□	■	□	□	■
Juglans nigra	□	□	■	□	□	■	■	□	■	□	■	□	■	□
Juniperus virginiana	■	□	□	□	□	■	■	□	□	■	■	□	■	□
Larix laricina	□	□	■	□	■	□	■	□	■	□	□	■	□	■
Liquidambar styraciflua	■	■	□	□	□	■	□	■	■	□	■	□	■	□
Liriodendron tulipifera	□	■	■	□	■	□	□	■	■	□	■	□	□	■
Maclura pomifera	□	□	■	□	□	■	■	□	■	□	■	□	■	□
Magnolia acuminata	□	■	□	□	■	□	■	□	■	□	■	□	■	□
Malus ioensis	□	■	□	■	□	□	■	□	□	■	□	■	■	□
Morus rubra	□	□	■	■	□	□	■	□	□	■	□	■	□	■
Nyssa sylvatica	■	□	□	□	■	□	■	□	■	□	■	□	■	□
Ostrya virginiana	■	□	□	□	■	□	■	□	■	□	■	□	■	□
Oxydendrum arboreum	■	□	□	□	■	□	■	□	■	□	■	□	■	□
Picea engelmanni	■	□	□	□	□	■	■	□	□	■	□	■	□	■
Picea glauca	■	■	□	□	□	■	■	□	□	■	□	■	□	■
Picea glauca densata	■	□	□	□	□	■	■	□	□	■	□	■	■	□
Picea mariana	■	□	□	□	■	□	■	□	□	■	□	■	□	■
Picea pungens	■	□	□	□	□	■	□	■	□	■	□	■	■	□
Pinus banksiana	□	□	■	■	□	□	■	□	□	■	□	■	□	■
Pinus flexilis	■	□	□	□	□	■	■	□	□	■	□	■	■	□
Pinus ponderosa	□	■	□	□	□	■	■	□	□	■	□	■	■	□
Pinus resinosa	□	■	□	□	□	■	□	■	□	■	□	■	■	□
Pinus rigida	□	□	■	■	□	□	■	□	□	■	□	■	□	■

Silvical Characteristics: **Table V**

	Growth			Longevity			Physiol		Disease		Insect		Wind Ice	
	slow	medium	fast	short	medium	long	infrequent	frequent	infrequent	frequent	infrequent	frequent	infrequent	frequent
Pinus strobus		■				■		■		■		■	■	
Platanus occidentalis			■			■	■			■	■		■	
Populus deltoides			■	■			■			■		■		■
Populus grandidentata			■	■			■			■		■		■
Populus tremuloides			■	■			■			■		■		■
Prunus americana			■	■			■		■		■		■	
Prunus pensylvanica			■	■			■		■		■			■
Prunus serotina			■		■		■		■		■		■	
Prunus virginiana			■		■		■			■	■			■
Pseudotsuga taxifolia		■				■	■		■		■			■
Ptelea trifoliata	■	■			■		■		■		■		■	
Quercus alba	■					■	■			■		■	■	
Quercus bicolor		■	■		■			■	■		■		■	
Quercus borealis		■				■	■			■		■	■	
Quercus coccinea		■	■			■	■			■		■	■	
Quercus ellipsoidalis	■					■	■		■		■		■	
Quercus imbricaria	■					■	■		■		■		■	
Quercus macrocarpa	■					■	■			■	■		■	
Quercus marilandica	■					■	■			■	■		■	
Quercus montana	■					■	■			■		■	■	
Quercus muhlenbergii	■					■	■		■			■	■	
Quercus palustris		■	■		■			■	■		■		■	
Quercus stellata	■					■	■			■		■	■	
Quercus velutina		■			■		■			■		■	■	
Rhododendron maximum		■			■			■		■		■	■	
Rhus copallina			■	■			■		■		■			■

Silvical Characteristics: **Table V**

	Growth			Longevity			Physiol		Disease		Insect		Wind Ice	
	slow	medium	fast	short	medium	long	infrequent	frequent	infrequent	frequent	infrequent	frequent	infrequent	frequent
Rhus glabra			■	■			■		■		■			■
Rhus typhina			■	■			■		■		■			■
Robinia pseudoacacia			■	■			■		■			■		■
Salix amygdaloides			■	■			■			■		■		■
Salix bebbiana			■	■			■			■		■		■
Salix discolor			■	■			■			■		■		■
Salix nigra			■	■			■			■	■			■
Sassafras albidum		■		■				■	■		■			■
Sorbus decora		■		■			■			■		■		■
Taxodium distichum		■				■		■	■		■		■	
Thuja occidentalis		■	■			■	■		■		■			■
Tilia americana		■			■		■			■		■	■	
Tsuga canadensis	■	■				■		■	■			■	■	
Ulmus americana		■			■		■			■		■	■	
Viburnum lentago			■	■			■		■		■		■	
Viburnum prunifolium	■	■		■			■		■		■		■	
Viburnum rufidulum		■		■			■		■		■		■	
Zanthoxylum americanum			■	■			■		■			■	■	

Soil texture (cont.)

Texture can be estimated in the field by rubbing a small amount of moist soil between the thumb and forefinger. Sand particles can be seen easily and feel gritty. Silt particles can be seen with a magnifying lens, and when dry they feel like flour. When wet they have a smooth, floury feel with little evidence of stickiness. Clay particles are very fine. Clay is sticky and plastic when wet and can be molded; it will dry into a hard mass.

Textural class for the surface layer is always a part of the soil type name, e.g. Muscatine silty clay loam. Textural class for subsoil and parent material is given in profile descriptions which are a part of all survey reports.

Texture is a permanent soil property that greatly influences root growth and plant health and vigor. Soils with a high proportion of either coarse particles (sandy soils) or fine particles (high clay soils) are often low in productivity. Sandy soils do not hold enough water for good plant growth and they are poor storehouses for plant nutrients. They must receive frequent additions of water and nutrients to be productive. The main problem with high clay soils is their slow permeability and poor internal drainage, which are the result of their large number of very small pores. Soils high in clay will often be so wet that root development is hindered.

The most productive soils are usually medium to moderately fine in texture. Examples are loams, silt loams and silty clay loams. Such soils are good storehouses for plant nutrients and are capable of storing a high proportion of water available to plants. Conditions are generally very favorable for root growth.

COARSE
Soils containing 35% or more of sand, gravel, or stone particles above 1.0 millimeters in diameter.

MEDIUM COARSE
Soils containing 35% or more of sand particles of .50 to 1.0 millimeters in diameter.

MEDIUM
Soils that have evenly divided amounts of sand, silt, and clay particles between .05 and .50 millimeters in diameter.

MEDIUM FINE
Soils with 30% or more of silt size particles between .002 to .05 millimeters in diameter.

FINE
Soils with 30% or more of clay particles below .002 millimeters in diameter.

SOIL DRAINAGE

Drainage refers to the frequency and duration of periods of saturation or partial saturation of the soil. Six classes of natural soil drainage (Table IV) are recognized.

EXCESSIVELY DRAINED
Water is removed from the soil very rapidly. Excessively drained soils are commonly very coarse textured, rocky, or shallow. Some are on slopes so steep that much of the water they receive is lost as runoff. All are free of mottling due to wetness.

MODERATELY WELL DRAINED
Water is removed from the soil somewhat slowly during some periods. Moderately well drained soils are wet for only a short time during the growing season. They commonly have a slowly pervious layer within or directly below the solum, or periodically receive high rainfall, or both. Most plants attain their best development on moderately to well drained sites.

WELL DRAINED
Water is removed from the soil readily but not rapidly. It is available to plants throughout most of the growing season, and wetness does not inhibit growth of roots for significant periods during most growing seasons. Well drained soils are commonly medium textured. They are mainly free of mottling.

SOMEWHAT POORLY DRAINED
Water is removed slowly enough that [illegible]
[illegible] slowly [illegible]
[illegible]

POORLY DRAINED
Water is removed so slowly that the soil is saturated periodically [illegible] season [illegible]
wet [illegible]
season [illegible]
water table, slowly [illegible] layer [illegible]
combination of these.

VERY POORLY DRAINED
Water is removed from the soil so slowly that free water remains at or on the surface for most of the growing season. Very poorly drained soils are commonly level or depressed and are frequently ponded. Yet, where rainfall is high and nearly continuous, they can have moderate or high slope gradients, as for example in "hillpeats" and "climatic moors." Wet sites have cold soils which results in much shorter growing season.

AVAILABLE SOIL MOISTURE CAPACITY

Available moisture capacity refers to the capacity of soils to hold water available for use by most plants (Table IV). It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. Field moisture capacity is the moisture content of a soil held between the soil particles by surface tension after the gravitational or free water has drained away 2 or 3 days after a soaking rain. It is also called normal field capacity, normal moisture capacity, or capillary capacity. It is commonly expressed as inches of water per given depth of soil. The capacity in inches in a 150 centimeter (60-inch) profile or to a limiting layer is expressed as:

VERY HIGH (wet)
More than 30 cm (12 inches)

HIGH (moist)
22.5 to 30 cm (9 to 12 inches)

MODERATE (average)
15 to 22.5 cm (6 to 9 inches)

LOW (dry)
7.5 to 15 cm (3 to 6 inches)

VERY LOW (droughty)
0 to 7.5 cm (0 to 3 inches)

SOIL REACTION

Soils can be divided into seven classes based on measurable differences in chemical reaction (Table IV). The degree of acidity or alkalinity of a soil is expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degree of acidity or alkalinity is expressed as:

Soil reaction (cont)

as precisely neutral in reaction because it is neither acid nor alkaline. The degree of acidity or alkalinity is expressed as

SLIGHTLY ACID 6.1 to 6.5	NEUTRAL 6.6 to 7.5
MODERATELY ACID 5.1 to 6.0	ALKALINE 7.6 to 8.5
STRONGLY ACID 4.1 to 5.0	STRONGLY ALKALINE* 8.6 and higher
EXTREMELY ACID* Below 4.0	

* Plant growth is severely restricted due to hostile soil chemistry. These classes are not included in Table IV and must be modified if plant growth and survival is to be possible. Soil pH can be modified toward neutrality by the introduction of lime to acidic soils. Sulphur, aluminum sulfate or calcium sulfate lowers pH. The most appropriate planting is that which is best suited to local existing conditions. Trees already growing on the site and in surrounding areas should be utilized as a guide in plant selection.

HARDINESS

Although the combined effects of many environmental factors determine true plant adaptability, winter hardiness is the most important single governing factor according to many contemporary authors. The United States Department of Agriculture publishes a hardiness map which shows the average annual minimum temperatures for most of North America. Each zone delineated on the USDA map includes 10 degree increments and is split into an *a* and *b* area with the lower temperature occurring in the *a* zone. Temperatures of adjacent zones become increasingly similar near their boundaries. A plant species that flourishes in one part of a given zone is likely to be adaptable in other parts of the same zone or in a warmer zone. Other factors of the physical environment must also be relatively comparable.

USDA Hardiness Zones mapped in figure 2

Zone 2	-50 to -40F
Zone 3a	-40 to -35F
Zone 3b	-35 to -30F
Zone 4a	-30 to -25F
Zone 4b	-25 to -20F
Zone 5a	-20 to -15F
Zone 5b	-15 to -10F
Zone 6	-10 to 0F

ZONE 2

[illegible]
[illegible]
Acer negundo (Box Elder)
Acer spicatum (Mountain Maple)
Alnus rugosa (Hazel Alder)
Betula papyrifera (Paper Birch)
Carpinus caroliniana (American Hornbeam)
Fraxinus nigra (Black Ash)
Fraxinus pennsylvanica lanceolata (Green Ash)
Larix laricina (Eastern Larch)
Malus ioensis (Prairie Crabapple)
Picea engelmannii (Engelmann Spruce)
Picea glauca (White Spruce)
Picea glauca densata (Black Hills White Spruce)
Picea mariana (Black Spruce)
Picea pungens (Colorado Spruce)
Pinus banksiana (Jack Pine)
Pinus flexilis (Limber Pine)
Pinus resinosa (Red Pine)
Populus tremuloides (Quaking Aspen)
Prunus pensylvanica (Pin Cherry)
Prunus virginiana (Common Chokecherry)
Quercus macrocarpa (Bur Oak)
Rhus glabra (Smooth Sumac)
Salix bebbiana (Bebb Willow)
Salix discolor (Pussy Willow)
Sorbus decora (Showy Mountain-ash)
Thuja occidentalis (Eastern Arborvitae)
Ulmus americana (American Elm)
Viburnum lentago (Nannyberry Viburnum)

Hardiness (cont)

ZONE 5b

Asimina triloba (Common Pawpaw)
Carya tomentosa (Mockernut Hickory)
Chionanthus virginicus (White Fringetree)
Cornus florida (Flowering Dogwood)
Halesia carolina (Carolina Silverbell)
Quercus marilandica (Blackjack Oak)
Quercus stellata (Post Oak)
Sassafras albidum (Common Sassafras)

ZONE 6

Carya illinoensis (Pecan)
Cotinus americanus (American Smoketree)
Franklinia alatamaha (Franklinia)
Liquidambar styraciflua (American Sweetgum)
Oxydendrum arboreum (Sourwood)

GROWTH RATE

The measured vertical increase in height during one growing season determines the rate of plant growth. Different species have correspondingly varying rates of growth. Rate is also influenced by numerous variables such as age and factors of the plant's physical environment. Generally young trees grow rapidly, adding a great deal of height before slowing with maturity. Three classes are designated (Table V).

SLOW
having an annual leader increment of 30 centimeters (12 inches) or less
indicator—*Quercus alba* (White Oak)

MEDIUM
between 30 and 60 centimeters (12 to 24 inches) per year
indicator—*Acer saccharum* (Sugar Maple)

FAST
possessed of the potential to produce 60 centimeters (24 inches) or more of leader growth annually
indicator—*Larix laricina* (Eastern Larch)

LONGEVITY

Longevity refers to length of time a selected plant can be expected to live where environmental conditions are favorable (Table V).

[illegible]

[illegible]

[illegible]

APPENDIX FOUR
COMPARISON OF TRADITIONAL AND WATER-CONSERVING LANDSCAPES
(from Nelson, 1987)

Comparison of traditional and water conserving landscapes—Mar 1-Nov 15, 1985

Parameter	Traditional Landscapes				
	Crossroads	Deerfield	Meadows	The Woods	Weighted Average
Water applied to landscape					
Per du*—*100 cu ft (100 m³)*	105 (2 97)	101 (2 86)	83 (2 36)	62 (1 77)	77 (2 18)
Per du per day—*gal (L)*	216 (818)	206 (780)	171 (647)	126 (477)	157 (594)
Over entire landscape—*in (cm)*	79 (200)	63 (160)	66 (168)	38 (96)	53 (135)
Labor expended					
Turf per du—*hours*	6 0	5 6	7.4	7 3	7 1
Nonturf per du—*hours*	4 8	5 1	6 1	6 5	6 1
Total—*hours*	10 8	10 7	13 5	13 8	13 2
Turf per 1000 sq ft (90 m²)—*hours*	8 0	6 3	11 2	10.1	10 0
Nonturf per 1000 sq ft (90 m²)—*hours*	5 7	5 0	7 2	5 3	5 9
Fertilizer applied†					
Turf per du—*lb (kg)*	25 1 (11 4)	43 5 (19 7)	27.7 (12 6)	38 5 (17 5)	33 2 (15 0)
Nonturf per du—*lb (kg)*	4 7 (2 1)	0	3 4 (1 5)	6 0 (2 7)	4 6 (2 1)
Total per du—*lb (kg)*	29 8 (13 5)	43 5 (19 7)	31 1 (14 1)	44 5 (20 2)	37 8 (17.1)
Turf per sq ft (0 1 m²)—*oz (g)*	0 53 (15)	0 78 (22)	0 68 (19)	0 85 (24)	0 75 (21)
Nonturf per sq ft (0 1 m²)—*oz (g)*	0 09 (2 5)	0	0 06 (1 7)	0 08 (2.3)	0 07 (2 0)
Fuel (gasoline) used					
Mowing and hauling turf‡—*gal (L)*	2 42 (9 16)	1 84 (6 96)	1.15 (4 35)	2.07 (7 83)	1 76 (6 66)
Hauling nonturf clippings‡—*gal (L)*	1 15 (4 35)	0 19 (0 71)	0.28 (1 0)	0 36 (1 3)	0 42 (1 5)
Total—*gal (L)*	3 57 (13 5)	2 03 (7 68)	1 44 (5 45)	2 42 (9 16)	2 18 (8 25)
Herbicide applied§					
Turf area per du—*oz (g)*	0 79 (22)	1 71 (48 5)	0 48 (13)	0 63 (17)	0 64 (18)
Nonturf area per du—*oz (g)*	0 66 (18)	1 71 (48 5)	0 69 (19)	0 24 (6 8)	0 52 (14)
Total area per du—*oz (g)*	1 45 (41 1)	3 42 (96 9)	1 17 (33 2)	0 87 (24)	1 16 (32 9)
Total savings per du—$					

*du—dwelling unit
†Typically a fast acting mix similar to 16N-6K 8P
‡Average round trip haul distance to dump was 13 7 mi (22 0 km)
§Almost exclusively, Roundup, Monsanto Co , Agricultural Products, St Louis, Mo

Comparison of traditional and water conserving landscapes—Mar 1-Nov 15, 1985 (continued)

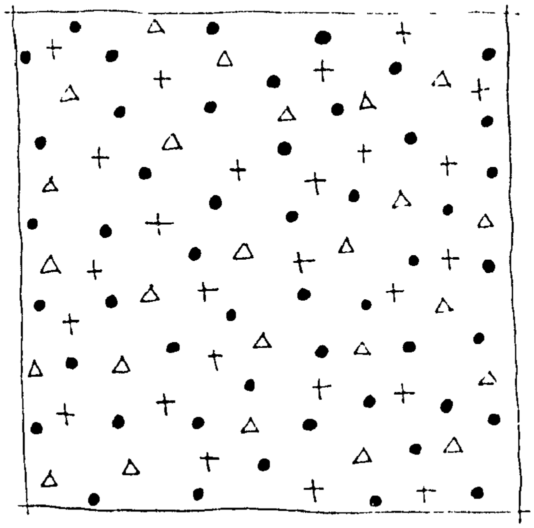
Water Conserving Landscapes				Decrease		Unit Cost	Savings	
Ignacio Creek	Scottadale	Oakmont	Weighted Average	*amount*	*percent*		*$/du*	*percent*
39 (1 1)	39 (1 1)	20 (0 56)	36 (1 0)	41 (1 1)	54	$0 69/100 cu ft (2 83 m³)	28 37	37 8
80 (303)	79 (299)	41 (155)	72 (272)	85 (322)	54			
43 (109)	49 (124)	6 (15)	27 (68)	26 (66)	49			
5 7	2 7	4 9	4.2	2 9	41	$11 30/hour	33 39	
6 5	3 0	11 9	5 8	0 3	5	$11 30/hour	3 30	
12 2	5 7	16 8	10 0	3 2	25	$11 30/hour	36 69	48 9
13 4	11 4	15 1	13 0	3 0†	30†			
9 6	4 2	3 2	4 6	1.2	21			
14 5 (6 58)	9 8 (4 4)	9 3 (4.2)	11 3 (5 12)	21 9 (9 93)	66	$0 38/lb (0 45/kg)	8.31	
4 7 (2 1)	0	9 3 (4.2)	3.3 (1 5)	1 3 (0 59)	28	$0 38/lb (0 45/kg)	0 49	
19 2 (8 71)	9 8 (4 4)	18.6 (8 44)	14 6 (6 62)	23 2 (10 5)	61	$0 38/lb (0 45/kg)	8.80	11 7
0 55 (16)	0 65 (18)	0 46 (13)	0 57 (16)	0 18 (5.1)	24			
0 11 (3 1)	0	0 04 (1 1)	0.04 (1 1)	0 03 (0.85)	43			
1 17 (4 43)	0 64 (2 4)	1 12 (4 24)	0 91 (3 4)	0 85 (3 2)	48	$0 98/gal (3 8/L)	0.84	
0 31 (1 17)	0 06 (0.23)	0 88 (3 3)	0.30 (1 1)	0 12 (0 45)	29	$0 98/gal (3 8/L)	0.12	
1 48 (5 60)	0 70 (2 6)	2 00 (7.57)	1.21 (4 58)	0 97 (3 6)	44	$0 98/gal (3 8/L)	0 96	1 3
0 00 (0 0)	0 06 (1 7)	0 00 (0 0)	0 03 (0 8)	0 61 (17)	95	$0.70/oz (28/g)	0 42	
0 35 (9 9)	0 41 (11)	3 00 (85.0)	0 87 (24)	0 35 (9 9)†	67†	$0 70/oz (28/g)	0.24†	
0 55 (15 6)	0 47 (13)	3 00 (85 0)	0.90 (25)	0.26 (7 4)	22	$0.70/oz (28/g)	0 18	0 3
							75 00	

APPENDIX FIVE
SAMPLE PLANT LIST AND PLANTING PLAN FROM CITY OF KITCHENER NATURALIZATION/REFORESTATION PROJECT

(from Hough et al, 1990)

Idlewood Creek
City of Kitchener
July 1990

RANDOM LAYOUT



SCALE 1:100
TOTAL NO OF PLANTS IN 100M²
100

SPACING 1.0m O.C.

● POPLAR, ALDER 50%
+ MAPLE, WHITE ASH 25%
Δ WHITE PINE, LARCH, SERVICEBERRY, WITCH-HAZEL 25%

PLANT LIST - IDLEWOOD CREEK
City of Kitchener
Project #1014
Date October 5, 1990

Quantity	Botanical Name	Common Name	Size	Root	Remarks
	Evergreen Trees				
40	Larix laricina	Larch	80 cm	pot	)
43	Pinus strobus	Eastern white pine	80 cm	pot	) dense vigorous uniform specimen
108	Thuja occidentalis	White cedar	100 cm	B R	)
	Deciduous Trees				
[illegible] 2	Acer rubrum	Red maple	50 cm	B R	)
[illegible]	Acer saccharinum	Silver maple	150 cm	B R	)
360	Alnus incana	Alder	100 cm	B R	)
50	Fraxinus americana	White ash	50 cm	B R	) straight strong trunk
44	Fraxinus nigra	Black ash	150 cm	B R	) vigorous healthy specimen
[illegible]	Populus balsamifera	Balsam poplar	60 cm	B R	)
[illegible]	Populus canadensis	Carolina poplar	200 cm	B R	)
63	Populus deltoides	Cottonwood	60 cm	B R	)
30	Populus tremuloides	Trembling aspen	60 cm	B R	)
	Deciduous Shrubs				
105	Amelanchier alnifolia	Saskatoon berry	40 cm	B R	)
33	Amelanchier canadensis	Serviceberry	60 cm	B R	)
305	Cornus sericea	Red osier dogwood	30 cm	B R	) vigorous dense specimen
42	Hamamelis virginiana	Witch-hazel	60 cm	B&B	) minimum of 5 main stems
[illegible]	Salix discolor	Pussy willow	40 cm	B R	)
55	Viburnum lentago	Nannyberry	60 cm	B R	)
42	Viburnum trilobum	High bush-cranberry	40 cm	B R	)

Note Spring planting only of bare root stock

APPENDIX SIX
PLANT LIST FROM SOUTH-WEST TRANSITWAY CORRIDOR NATURALIZATION/REFORESTATION PROJECT
(from Corush et al, 1988)

Plant List/Liste des plantes

		A1	A2	A3	A4	A5	A6	B1	a1	TOTAL	HEIGHT/HAUTEUR	COMMENTS
REFORESTATION WHIPS/SEEDLINGS REBOISEMENT DE JEUNES PLANTS	ACER RUBRUM	475	225					30		730	1250 MM HT	BARE ROOT/RACINES À NU
	FRAXINUS PENNSYLVANICA LANCEOLATA				80	110	155			345	1250 MM HT	BARE ROOT/RACINES À NU
	CRATAEGUS SP				100		155			255	1250 MM HT	BARE ROOT/RACINES À NU
	BETULA PAPYRIFERA / NIGRA			720	80	170				970	1250 MM HT	BARE ROOT/RACINES À NU
	POPULUS ALBA	475	225	360		110		30		1200	1250 MM HT	BARE ROOT/RACINES À NU
	POPULUS DELTOIDES			360						360	1250 MM HT	BARE ROOT/RACINES À NU
	POPULUS TREMULOIDES	315								315	1250 MM HT	BARE ROOT/RACINES À NU
	PICEA GLAUCA	315	110	360		170	385	40		1380	1250 MM HT	B&B / EN TONTINE
	PINUS STROBUS						75			75	1250 MM HT	B&B / EN TONTINE
SHRUBS/WHIPS ARBUSTES/FOUETS	SHEPHERDIA ARGENTEA								230	230	300 MM HT	BARE ROOT/RACINES À NU
	CORNUS STOLONIFERA								115	115	300 MM HT	BARE ROOT/RACINES À NU
	AMELANCHIER CANADENSIS								115	115	300 MM HT	BARE ROOT/RACINES À NU
	CELASTRUS SCANDENS								55	55	300 MM HT	BARE ROOT/RACINES À NU
	VIBURNUM TRILOBUM								55	55	300 MM HT	BARE ROOT/RACINES À NU
ANCHOR PLANTING/ ARBRES D'ORNEMENT	ACER RUBRUM	40	15							55	1750 MM HT	BARE ROOT/RACINES À NU
	FRAXINUS PENNSYLVANICA LANCEOLATA	30	15	25	40		40			150	1750 MM HT	BARE ROOT/RACINES À NU
	POPULUS DELTOIDES	40	30	25	10					105	1750 MM HT	BARE ROOT/RACINES À NU
	PICEA GLAUCA	40	25	35			60			160	1500 MM HT	B&B / EN TONTINE
	PINUS STROBUS						30			30	1500 MM HT	B&B / EN TONTINE
GROUNDCOVER/ COUVRE-SOL	POLY / MULCH / POLYVINYLE/PAILLIS	●	●		●		●	●				
	DIRECT PLANTING / TRANSPLANTATION			●		●						
	"MINI-MOW"								●			
	STRAW MAT / MATELAS DE PAILLE											

APPENDIX SEVEN
COST COMPARISONS OF NATURALIZATION/REFORESTATION PROJECTS

COST COMPARISON OF MATERIAL, LABOUR AND EQUIPMENT FOR FORMAL AND NATURALIZED LANDSCAPES FROM NORTH YORK NATURALIZATION PROJECT
(from Granger, 1984)

Formal Treatment with Turf

Plant material and avg.size	no	total price ($)
60 mm cal trees	23	2 061
50 cm height shrubs	155	900
ground cover	100	390
Total material cost		3 353
Equipment and Labour for planting		1 663
Three years of maintenance (equipment and labour)		8 529
Replacement		1 697
Total		**15 243**

Naturalized/Reforested Landscape

Plant material and avg size	no	total price ($)
15-39 cm seedlings	1000	420
wood chip mulch	45 cubic yards	300
total material cost		720
equipment and labour for planting		918
Three years of maintenance (equipment and labour)		2 791
Total		**4 429**

Cost per m2 @ approx. 4050m2 =$1.10 for 1981 naturalized planting and $3 76 for formal landscape

Cost Estimate for City of Kitchener Naturalization/Reforestaion Project Woodland and Meadow Planting (from Hough et al, 1990)

Idlewood Creek (Phase One)

Item	Size	Quan	$/unit	Total $
Evergreen trees				
specimen trees	80-100mm	193	50 00	9 650.00
Deciduous trees				
whips	100-200cm	918	30.00	27 540 00
seedlings	30-60cm	450	10.00	4 500.00
Deciduous shrubs				
shrubs	60-80cm	202	20.00	4 040.00
seedlings`	25-40cm	517	10.00	5 170.00
Bed preparation				
clearing and discing				
black plastic	2005m^2	2005m^2	2.50	5 012 50
mulch	2005m^2	2005m^2	2.50	5 012.50
Meadow		2 850m^2	2.50	7 125.00
Total				**78 075.00**

Cost /m^2 @ 2005m^2 for woodland = $35.38 in 1990 prices
Cost /m^2 @ 2850m^2 for meadow = $2.50 in 1990 prices

COSTS OF MATERIAL, LABOUR AND FIRST-YEAR MAINTENANCE FROM NCC'S SOUTH-WEST TRANSITWAY CORRIDOR NATURALIZATION PROJECT TEST PLOTS (from Hough *et al*, 1989)

Item	Quan	Price ($)
Labour		8 767 61
Equipment		3 651 92
Material: Seedlings		
Populus tremuloides	332	2 155.00
Hybrid poplar sp.	190	570 00
Alnus crispa "mollis"	537	295 00
Betula papyrifera	83	445 00
Fraxinus americana	300	270 00
Acer saccharum	186	320 00
Picea glauca	25	262 00
Quercus rubra	27	305 00
Tilia americana	36	229.00
Cornus stolonifera	100	200 00
Salix nigra	65	243.75
Acer negundo	82	205.00
Juglans nigra	42	46 20
Total		5 275 15
Maintenance		
Labour		4 435 56
Material		187.00
Equipment		619 00
Total		5 241 56
Total		**23 307.53**

Cost per m^2 @ 8 800m^2 = $2.65 for the 1983 planting

APPENDIX EIGHT
ANNUAL MAINTENANCE REQUIREMENTS FOR WOODLAND AND TALL GRASS PRAIRIE GARDEN

Table 1: 100m2 Woodland Area
Annual Labour Requirments

Item (source: Hough et al, 1990)	total time (hours) (source: Cobham, 1990)
Years 1 to 5 (before canopy closure)	
- addition of mulch and removal of perforated polyethelene	9.0
- hand cultivate for critical weed growth	1.3
-water in drought periods	as needed
Years 5 to 15 (after canopy closure)	
- remove 30% of pioneer species	1.6
Years 15 to 25	
- gradually remove rest of pioneer species	3.2
-thin climax species	2.4
Years 25+	
- continued thinning of climax species	as needed
TOTAL (until year 15)	**0.8 hours**
TOTAL (until year 25)	**0.5 hours**

1. Maintenance of shrub and groundcover edge in addition to this time requirements.

Table 2: 100m2 Tall Grass Prairie Area
Annual Labour Requirements

item	source	total time (hours)
Years 1 to 3 (pre-establishment)		
-hand weeding	Dorney (1985)	6
Years 3+ (post-establishment)		
- one mowing	Cobham (1990)	1.0
- hand weeding	Dorney (1985)	1.0
TOTAL(until year 3)		**7.1 hours**
TOTAL (after year 3)		**2.0 hours**

1. Maintenance of shrub and groundcover edge in addition to this time requirements.

APPENDIX NINE

PLANT LISTS: PERENNIAL WILDFLOWERS NATIVE TO ONTARIO
(from Elmhist and Caine, 1990)

AND PLANTS FOR THE PRAIRIE GARDEN (from Dorney, 1980)

Table 1: Perennial wildflowers that are native to Ontario[1], that have been recorded or planted on roadsides, or recorded in Ontario tallgrass prairie communities

Scientific Name	Common Name	Height[2] (cm)	Soil Moisture[2] Regime	Source[3]
Anaphalis margaritacea	pearly everlasting	30 - 60	mesic	8
Anenome cylindrica	long-headed thimbleweed	30 - 70	mesic - dry	4
Antennaria neglecta	pussey toes	5 - 30		5
Apocynum androsaemifolium	spreading dogbane	30 - 120	dry	8
Aster azureus	azure aster	10 - 100	mesic - dry	4
A. erociodes	heath aster	20 - 200	mesic - dry	2,4,5
A. laevis	smooth aster	30 - 100	mesic - dry	2,4,5
A. nova-angliae	New England aster	to 250	moist - mesic	3,6
A. ptarmicoides	upland white aster	10 - 60	dry	4
Baptisa leucantha	white false indigo	to 15	mesic	7
Campanula rotundifolia	harebell	15 - 40	mesic - dry	4
Cichorium intybus	common chicory	30 - 150[5]	---	3,8
Coreopsis lanceolata	sand coreopsis	30 - 60	dry	3
Desmodium canadense	showy tick trefoil	60 - 120	mesic	2,7
Epilobium angustifolium	fireweed	10 - 200	mesic - moist	8
Euphorbia corollata	flowering spurge	50 - 100	moist - dry	4
Fragaria virginiana[4]	wild strawberry	12 - 20	moist - dry	5
Geum aleppicum	yellow avens	30 - 150[1]	---	1,4
Helianthus laetiflorus	showy sunflower	15 - 250	moist - dry	2
H. l. var. rigidis	stiff sunflower	15 - 250	dry	7
Heliopsis helianthoides	false sunflower, ox-eye	30 - 150	mesic	4,7
Krigia biflora	two-flowered eynthia, false dandelion	20 - 70	mesic	5
Lespedeza capitata	round-headed bush clover	60 - 120	mesic - dry	2,5,6,7
Liatris spicata	gayfeather, spike blazing star	30 - 180	wet - mesic	3,5
Lithospernum canescens	hoary pucoon	10 - 45	moist- dry	5
Lobelia spicata	spiked lobelia	20 - 110	mesic - dry	5
Lysimachia quadrifolia	narrow-leaved loosestrife	20 - 90	wet - moist	5
Monarda fistulosa	showy wild bergamot	60 - 90	wet - dry	4
Penstemon gracilis	slender beard-tongue	20 - 40	dry	4
Phlox divaricata	sweet william phlox, blue phlox	15 - 40	moist	6

Table 1: Perennial wildflowers that are native to Ontario[1], that have been recorded or planted on roadsides, or recorded in Ontario tallgrass prairie communities (cont'd)

Scientific Name	Common Name	Height[2] (cm)	Soil Moisture[2] Regime	Source[3]
P. maculata	wild sweet william	30 - 90[1]	mesic-moist[1]	1
P. pilosa	prairie phlox	10 - 75	mesic	6
Potentilla arguta	tall cinquefoil	30 - 100	mesic - dry	4
Prunella vulgaris	healall	5 - 60	---	5,8
Pycnanthemum virginianum	mountain mint	30 - 100	moist - dry	7
Ratibida pinnata	greyhead prairie coneflower, yellow coneflower	50 - 150	dry	2,4,6,7
Silphium terebinthinaceum	prairie dock	100 - 300	mesic - dry	7
Solidago altissima	tall goldenrod	70 - 200	moist - dry	2
S. canedensis	Canada goldenrod	30 - 150	moist - dry	3,8
S. juncea	early goldenrod	60 - 130	dry	5
S. nemoralis	gray goldenrod, field goldenrod	15 - 100	dry	4
S. ohioensis	Ohio goldenrod	30 - 90	wet - moist	5
S. rigida	stiff goldenrod	30 - 150	mesic - dry	2,7
S. speciosa	showy goldenrod	60 - 200	moist - dry	4
Verbena stricta	hoary vervain	30 - 120	mesic - dry	4
Veronicastrum virginicum	culver's root	100 - 200	wet - mesic	5,7
Zizea aurea	golden alexanders	30 - 100	moist	5

1 Reference: Fernald, 1970
2 Reference: Sullivan and Daley, 1981
3 Sources: 1 - Eaton and Schrot, 1987
2 - Landers, 1972
3 - Mass. Dept. of Public workds, 1989
4 - Ray, 1987
5 - Roberts et al., 1977
6 - Salac et al., 1978
7 - Schramm, 1968
8 - Strickland and LeVray, 1980
4 Fernald (1970) indicated that G. a. var. strictum is native but G. a. is not
5 Alex and Switzer

Table 2: Perennial wildflowers that are naturalized in Ontario[1] that have been recorded or planted on roadsides, or recorded in Ontario tallgrass prairie communities

Scientific Name	Common Name	Height (cm)[1]	Source[2]
Achillea millefolium	yarrow	30 - 100	2,4
Chrysanthemum leucanthemum	ox-eye daisy	30 - 100	2,4
Echium vulgare	blueweed	30 - 90	4
Hemerocallis fulva	day lily	50 - 200[3]	1
Hiercium aurantiacum	orange hawkweed	20 - 70[3]	4
H. florentinum	king-devil hawkweed	15 - 100[3]	3
Hypericum perforatum	common St. John's-wort	30 - 90	4
Hypochaeris radicata	cat's-ear	20 - 40[3]	1
Linaria vulgaris	toadflax	to 130	4
Lotus corniculatus	bird's-foot trefoil	low, spreading[4]	1,4
Potentilla argentae	silvery cinquefoil	10 - 50	4
Ranunculus acris	common buttercup	10 - 150	4
Sedum purpureum	live-forever	20 - 80	1
Vicia cracca	purple vetch	spreading or climbing[4]	4

[1] - Reference: Fernald, 1970
[2] - Sources: 1 - Eaton and Schrot, 1987
2 - Mass. Dept. of Public Works, 1989
3 - Roberts et al., 1977
4 - Strickland and LeVray, 1980
[3] - Height of flower stem (scape)
[4] - Reference: Alex and Switzer

PLANTS FOR THE PRAIRIE GARDEN*

Grasses

- Big Bluestem[3]
- Canada Wild Rye[3]
- Indian Grass[3]
- Little Bluestem[3]

Herbaceous Plants

- Azure Aster[3]
- Black-Eyed Susan[2]
- Butterfly Weed[2]
- Canada Goldenrod[2]
- Common Evening Primrose[2]
- Indian Paintbrush[2]
- Jerusalem Artichoke[3]
- Long-Headed Thimbleweed[2]
- Poke Milkweed[2]
- Prairie Smoke[1]
- Round-Headed Bush Clover[3]
- Showy Tick Trefoil[2]
- Sunflower - common[2] and prairie[2]
- Wild Bergamot[2]

Shrubs

- Carolina Rose[2]
- New Jersey Tea[1]
- Winged Sumac[4]

1 Spring flowering (May-June)

2 Summer flowering (July-August)

3 Fall flowering (September-October)

4 Produces berries attracting birds

* We suggest local weed by-laws be checked as some may prohibit planting certain herbaceous species. By-laws vary considerably between jurisdictions.

APPENDIX TEN
COST COMPARISON OF LAWN AND PRAIRIE GARDEN INCLUDING INITIAL AND ANNUAL COSTS

(from Diekelmann and Bruner, 1988)

COSTS FOR 8,000 SQ. FT. (80' x 100') (1987 PRICES)

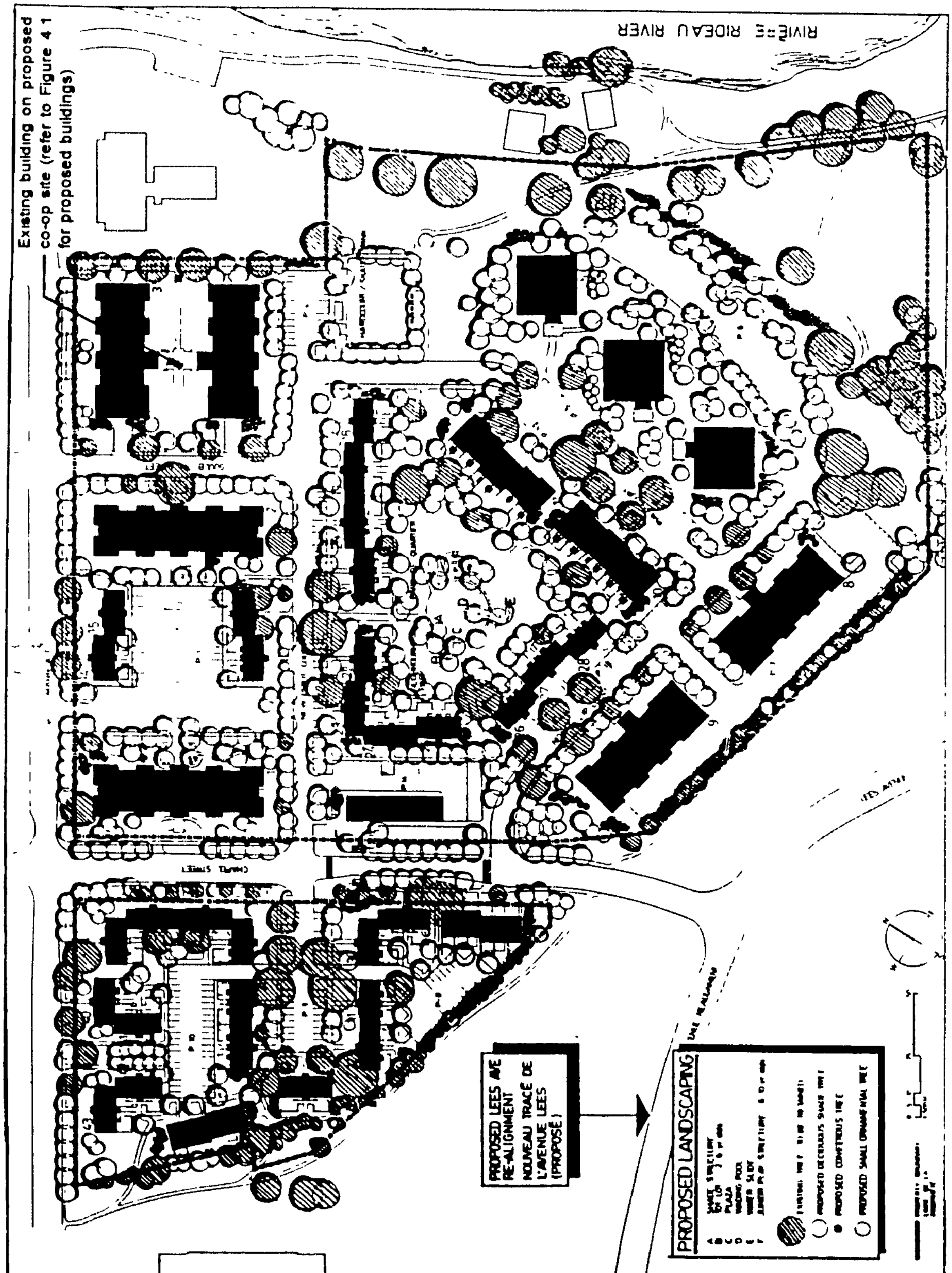
	LAWN	PRAIRIE
SEEDS	$ 108.80 ($3.40/lb.)	$ 440.00 (5.5 oz. @ $10.00/oz.)
TOP SOIL	937.50 ($12.50/cu.yd.)	Not Needed
		8.00 (mowing-first and second growing season)
TOTAL	$1,046.30	$ 448.00
SOD & PLANTS	$1,392.00 ($1.50/yd.)	$6,000.00 ($0.50/plant)
TOP SOIL	937.50 ($12.50/cu.yd.)	Not Needed
TOTAL	$2,329.50	$6,000.00

NOTES: Site preparation and installation are not included. Site preparation costs vary according to specific needs of the site (prairies usually need less site preparation than lawns). Water requirements for installation may be equal in dry years. Labor and water costs are assumed to be equal in either planting. Multiply materials by two to three to obtain their installed cost.

MAINTENANCE COSTS FOR 8,000 SQ.FT. (80' x 100') (1987 PRICES)

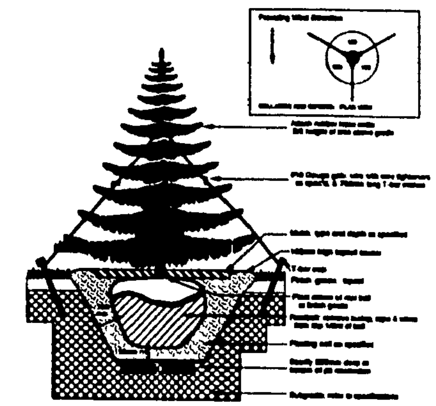
	LAWN	PRAIRIE
FERTILIZER (2 applications of 28-7-8)	$17.00	Not Needed
WATER (700 gal./week for 20 weeks)	85.50	Not Needed
WEED KILLER (1 quart)	7.50	Not Needed
MOWING (4 gallons of fuel/season)	4.00	Not Needed
MOWER REPAIRS/REPLACEMENT	30.00	30.00
TOTAL	$144.00	$30.00

APPENDIX 11
STRATHCONA HEIGHTS MASTER PLAN
(from Padolsky, 1988)



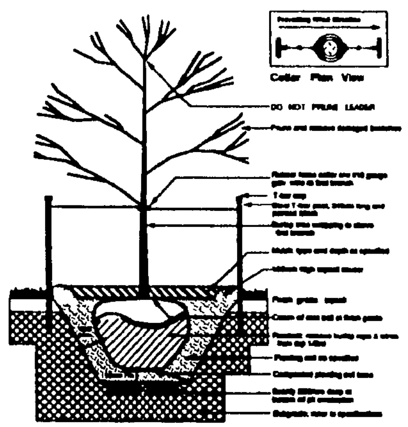
APPENDIX 12
PLANTING DETAILS FOR STANDARD AND NATURALIZED PLANTINGS

Standard deciduous/ coniferous tree, shrub and groundcover plantings from Lashley et al (1990)



15 L3 CONIFEROUS TREE PLANTING

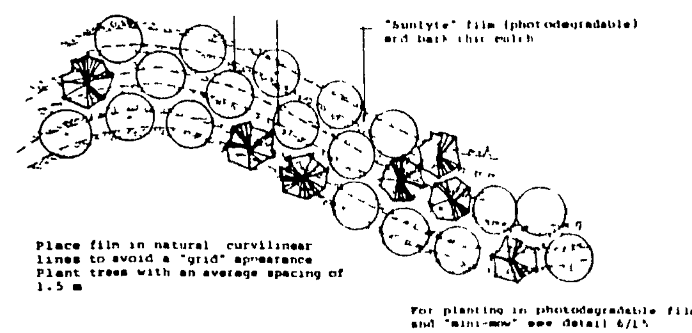
NTS



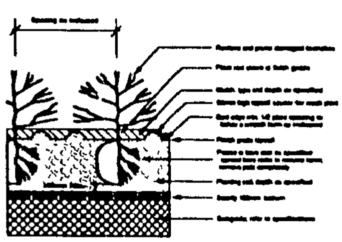
14 L3 DECIDUOUS TREE PLANTING

NTS

Naturalized Tree Planting (from Corush et al, 1987)

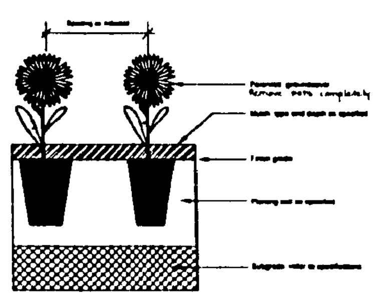


9 L5 PLANTING LAYOUT



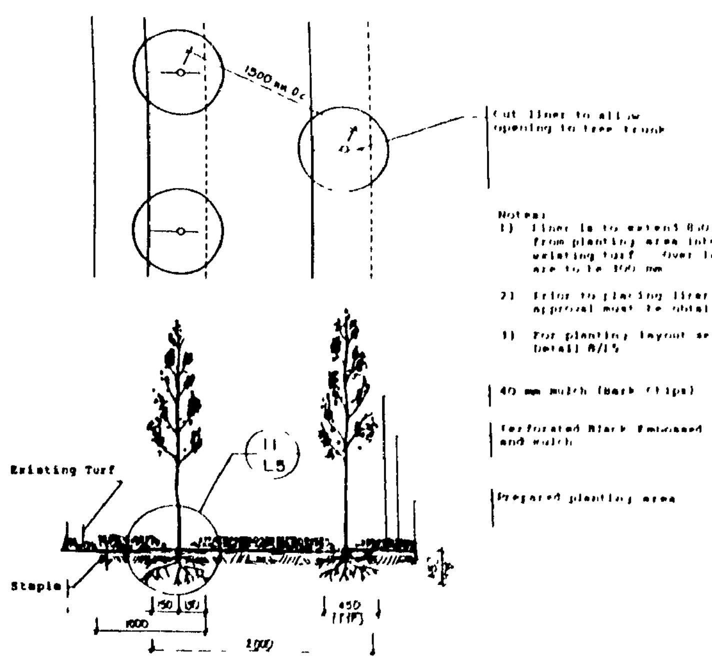
16 L3 SHRUB PLANTING IN BEDS

NTS



17 L3 PERENNIAL / GROUNDCOVER PLANTING

NTS



2 L5 "BLACK EMBOSSED POLY" & MULCH

APPENDIX 13
CONTRACTOR SURVEY FOR CALCULATION OF INITIAL COSTS OF WOODLAND AND TALL GRASS PRAIRIE PLANTINGS

Research for Installation Costs of Landscape Operations for Woodland and Wildflower Development

operation	area or unit	material cost	total cost
mechanically disc soil to depth of 150-200mm to an even tilth (no existing vegetation) -remove stones/ debris over 50mm in diam	1000m2		
spray contact herbicide simazine	500m2 @ 4.7kg/ha		
sow non-turf grass seed -bury seeds lightly and firm with roller -water to approx. 1500L	500m2 @ 1-1.5g/m2	$2.44/kg	
install nursery-grown wildflower plugs -water plugs once -no soil ammendments	500m2 @ 300-500mm O.C. 500m2	$1.50/ 4" pot	
stake-out and plant 2-yr bare-root seedling (4-5'ht) -remove dead and injured branches	500m2 @ 1.5m O.C.	$5.00/seedling	
after planting seedlings install black plastic perforated weed barrier film with staples @ 300mm centres -overlap to 300mm -cut film around trunk	200m2	$213.90 5'x 4000' roll	

operation	area or unit	material cost	total cost to implement
install pinebark mulch on weed barrier	200m @ 40mm depth		
apply rodent repellent to seedling trunks to 450mm from ground	300 seedlings @ ?L/sdl	$14.49/1L	
apply root stimulant to bare-root seedlings	300 seedlings @ ?L/sdl	$38.95/1L	
apply fertilizer in planting hole of bare-root seedlings	300 seedlings @ 42g/sdl	$20.00/kg	
water once per week for 1st 4 weeks	300 seedlings 4 times min. 5L/ tree		
install ground cover in previously prepared beds -remove pot -no soil ammendments	300m2 3.5" pot @ 600mm O.C. 1 gal. pot @ 1.5m O.C.	 $2.30/pot $10.95/pot	
mulch (pine bark)	300m2 @ 50mm depth		
water ground cover as per seedling watering			
install brick shaped unit pavers with 3mm sand swept space and pavetech edging -Base: 25mm stonedust, 150mm Granular A, 300 Granular B	100m2	for unit paver installation only, please include cost of all materials	

APPENDIX 14
INITIAL COST CALCULATION FOR SIMULATIONS: DETAILS AND SOURCES

Table 1: Conventional Option

Item	quantity	cost/unit	source	total $
Deciduous Trees (60mm cal)	4	280.00ea	H[1]	1120.00
Deciduous Trees (40mm cal)	8	165.00ea	H	1320.00
Evergreen Trees (1800mm Ht.)	4	290.00ea	H	1160.00
Shrub Accent (80-120cm Ht.)	12	23.50ea	H	282.00
Shrub Acccent (50cm Ht)	53	12.25ea	H	649.00
Annual Flowers/ Perennials	50m2	15.60/m2	C[2]	780.00
Sod (topsoil, fine grading)	852m2	5.68/m2	H	4839.00
Equipment (underground irrigation)			CT[3]	3834.00
TOTAL				**13984.00**
Equipment (portable sprinkler)			CT	568.00
TOTAL				**10718.00**

1. Hanscomb (1993) All prices from Yardsticks for Costing include staking and guying, excavation, reinstatement and quarentee. All trees are balled and burlapped nursery grown stock.
2. Prices calculated from contractor survey (Appendix 13)
3. Prices calculated from Canadian Tire 1993 catalogue. Price includes gas powered push mower, hand operated trimming, lopping, pruners, edgers, spreaders, sprayers, rakes, shovels, hose, sprinkers.
4. Prices do not include PST or GST.

Table 2: Alterative 1

Item	quantity	cost/unit	source	total $
Deciduous Trees (60mm cal)	4	280.00ea	H	1120.00
Deciduous Trees (40mm cal)	9	165.00ea	H	1485.00
Evergreen Trees (1800mm Ht.)	3	290.00ea	H	870.00
Shrub Accent (80-120cm Ht.)	91	23.50ea	H	2139.00
Shrub Acccent (50cm Ht.)	159	12.25ea	H	1948.00
Groundcover (10cm pot)	330m2	21.50/m2		7095.00
Sod	310m2	5.68/m2	H	1766.00
Equipment (underground irrigation)			CT	1712.00
TOTAL				**18 135.00**
Equipment (portable sprinkler)			CT	568.00
TOTAL				**16 991.00**

Table 3: Alterative 2

Item	quantity	cost/unit	source	total $
Deciduous Trees (60mm cal)	4	280.00ea	H	1120 00
Deciduous Trees (40mm cal)	7	165.00ea	H	1155.00
Evergreen Trees (1800mm Ht.)	4	290.00ea	H	1160.00
Shrub Accent (80-120cm Ht.)	101	23.50ea	H	2374.00
Shrub Acccent (50cm Ht.)	235	12.25ea	H	2879.00
Groundcover (10cm pot)	387m2	21.50/m2	C	8321.00
Equipment			CT	237.00
Unit Pavers	96m2	47.00/m2	C & H	4512.00
TOTAL				**21758.00**

Table 4: Alterative 3

Item	quantity	cost/unit	source	total $
Deciduous Trees (25-50mm cal)	17	165.00ea	M	2805.00
Deciduous Seedlings (1000-1250mm Ht.)	63	19.93ea	C	1255.00
Evergreen Seedlings (1000mm Ht.)	28	19.93ea	C	558.00
Shrub Accent (80-120cm Ht.)	61	23.50ea	M	1433.00
Shrub Acccent (50cm Ht.)	83	12 25ea	M	1017.00
Groundcover (10cm pot)	95m2	21.50/m2	C	2043 00
Black embossed film with mulch covering	347m2	6.43/m2	C	2231.00
Woodland Groundcover	149m2	11.00/m2	C	1639.00
Sod	280m2	5.68/m2	M	1590.00
Equipment (underground irrigation)				1864.00
TOTAL				**16 435.00**
Equipment (portable sprinkler)				568.00
TOTAL				**15 139.00**

1. Refer to Breakdown of Unit Costs from Contractor Survey for details of Woodland and Tall grass prairie costs.

Table 5: Alternative 4

Item	quantity	cost/unit	source	total $
Deciduous Trees (25-50mm cal)	15	165.00ea	M	2475.00
Deciduous Seedlings (1000-1250mm ht.)	61	19.93ea	C	1215.00
Evergreen Seedlings (1000mm Ht.)	27	19.93ea	C	538.00
Shrub Accent (80-120cm Ht.)	38	23.50ea	M	893.00
Shrub Acccent (50cm Ht.)	41	12.25ea	M	502.00
Groundcover (10cm pot)	69m2	21.50/m2	C	1484.00
Black embossed film with mulch covering	278m2	6.43/m2	C	1787.00
Tall grass prairie	231m2	17.13 /m2	C	3957.00
Woodland Groundcover	224m2	11.00/m2	C	2464.00
Equipment				568.00
Unit Pavers	94m2	47.00/m2	C	4418.00
TOTAL				**20 301.00**

1. Refer to Breakdown of Unit Costs from Contractor Survey for details of Woodland and Tall grass prairie costs.

Breakdown of Unit Costs from Contractor Survey

Cost of installed seedlings ($ ea)

seedlings	11.18
rodent repellent	0.97
root stimulant	1.16
fertilizer	1.16
watering 4x	2.56
cultivate soil	1.60
herbicide	1.77
Total cost	**19.93**[1]

Cost of installed black embossed film ($/ m2)

film	3.79
mulch	2.64
Total cost	**6.43**

Cost of installed tall grass prairie ($/m2)

disc soil	0.90
spray herbicide	1.00
sow seeds	0.93
plugs	14.30
Total cost	**17.13**

1. All prices include material and installation.
2. Refer to Tables 4 and 5 for total initial costs for Alternatives 3 and 4.
3. Refer to Appendix 13 for Contractors' survey.

APPENDIX 15
SAMPLE SHEET FROM NCC OMS DATABASE

A C T I V I T Y   P L A N N I N G

Mgmt Unit: C62B Hogs Back Park
Prog: 470 Shrubs/Hedge/Groundcover Op Activity: 471 Fertilize Shrub/Hedge

Lump Sum Total Cost: $0.00
Non-General Fund: $0.00

Inventory: 5083.50 M2
x Effort Level: 1.00

Work Quantity: 5083.50 M2
Avg Daily Prod: 5083.50 M2

RESOURCES

	Class		Quantity	Rate
L	ELE03	Elemental 03	2.00	12.14
E	22	Pick 3/4 Ton	1.00	2.15
M	230B	Gas, No-Lead	20.00	0.48
M	293A	Safe,Glov/Mit	1.00	5.12
M	NC0053	Fert 8-12-12	10.00	9.60

Crew Size: 2.00 Crew Days: 1 Unit Cost: $0.06 Budget: $322

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Percent	0	0	30	30	30	10	0	0	0	0	0	0	100
Labor Days	0	0	1	1	1	0	0	0	0	0	0	0	2
MGMT UNIT TOTALS													
Labor Days	26	82	89	92	101	78	72	31	7	7	8	7	601
Employees	1	4	4	4	5	4	4	1	0	0	0	0	

Projection Factors: OFF Budget: $83,717

[F1]: help [F2]: Distribution [F3]: RESOURCES [Esc]: quit

A C T I V I T Y   P L A N N I N G

Mgmt Unit: C32L Nepean Point
Prog: 510 Turf Maintenance Activity: 519 Turf Watering

Lump Sum Total Cost: $0.00
Non-General Fund: $0.00

Inventory: 11959.00 M2
x Effort Level: 10.00

Work Quantity: 119590.00 M2
Avg Daily Prod: 20000.00 M2

RESOURCES

	Class		Quantity	Rate
L	ELE03	Elemental 03	0.50	12.14

Crew Size: 0.50 Crew Days: 6 Unit Cost: $0.00 Budget: $290

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Percent	0	20	20	20	20	20	0	0	0	0	0	0	100
Labor Days	0	1	1	1	1	1	0	0	0	0	0	0	3
MGMT UNIT TOTALS													
Labor Days	7	10	10	12	12	10	8	4	2	2	2	2	80
Employees	0	1	0	1	1	0	0	0	0	0	0	0	

Projection Factors: OFF Budget: $10,380

[F1]: help [F2]: Distribution [F3]: RESOURCES [Esc]: quit

APPENDIX 16
MAINTENANCE REQUIREMENTS FOR SIMULATIONS: DETAILS AND SOURCES

Table 1: 100m² Turf Area
Annual Maintenance Labour Requirements

Task	Frequency	Total Time/100m2	Source
-mowing (push mower <21")	31	5.1 hours	NCC APR[1]
-hand edging, trim & clean-up	12	13.1 hours	NCC APR
-hand fertilization	2	9.5 min.	NCC APR
-watering (underground pop-up sprinkler system)	10	-	NCC[2]
-weed control (hand pump)	1	30.0 min.	IMR[3]
-hand overseeding of 10% area		7.0 min.	NCC APR
-leaf raking (hauling by municipality)	1	60.0 min.	IMR
-topdressing of 5% area		5.0 min.	NCC APR
-hand sweeping/ aerating	1	13.2 min.	NCC APR
TOTAL		**20.3 hours**	
-portable sprinkler @ 20min for set-up and visit twice during run (Cob)[4]	10	3.3 hours	NCC
TOTAL		**23.6 hours**	

1. NCC APR refer to the Activity Performance Report, NCC (1992)
2. NCC refers to OMS database, NCC (1993)
3. IMR refers to Institute for Maintenance Research (1982)
4. Cob refers to Cobham (1990)

Table 2: 100m2 Turf Area
Annual Maintenance Material and Costs

Item	Source	amount	$/unit	source	total$
-fuel @ 643ml/ hour	T[1]	3.3 L	0 56/L		1.85
-fertilizer 1.5kg/100m2	OMAF[2]	1.5 kg	4.50/500g	CT[3]	14 40
-irrigation @ 3cm/watering[4]	OMAF	30000L	0.88/1000L	RMOC[5]	26.40
-weed/ pest control	NCC	97ml	12.00/L	CT	1.16
-topsoil @ 50cm depth	OMAF	0.45m3	20.23/m3	NCC	9.10
-lawn seed @ 2kg/100m2	OMAF	180g	7.00/kg	CT	1.26
TOTAL					$54.27

1.T refers to Tecumseh Products Co. (1993), engine manufacturers of residential lawn mowers. This fuel consumption rate is specified for a 20 inch blade, 4 stroke, 3.5 horsepower push mower. Refer to table 1 of this appendix for number of hours
2. CT refers to Canadian Tire 1993 catalogue.
3. OMAF refers to Ontario Ministry of Agriculture and Food
4. Watering frequency from NCC database.Refer to table 1 of this appendix.
5. RMOC refers to the Regional Municipality of Ottawa-Carleton

Table 3: 100m2 Turf Area NCC Annual Maintenance Materials and Costs			
item	quantity/ 100m2	$/unit	total $
-fuel -herbicide (round-up) -turf fertilizer -topsoil -lawn seed	9.4L 97L 2.22kg 0.64m3 1.2kg	0.48/L 14.50/L 1.13/kg 20.23/m3 172/25kg	4.51 1.40 2.50 12.95 8.28
TOTAL			$29.64

NCC costs provided for comparison purposes. NCC database does not include price of water or amount consumed.

Table 4: Trees for Conventional Option Labour Requirments per Tree					
Task/tree	frequency source:NCC	%of area treated source: NCC	Time	source	total
-pruning >160mm cal.	1	6.5	1.7 hours	O'B[1]	7 min.
-fertilizing	1	12.5	30.0 min.	NCC	4 min.
-watering	1	26	12.0 min.	Cob	3 min.
-hand edging/weeding[2]	1	13	1.3 hours	NCC	10 min.
-disease/ pest control	1	20	1.6 hours	NCC	19 min.
TOTAL					43 min.
pruning <160mm cal.	1	6.5	1.2 hours	O'B	5 min.
TOTAL					41 min.

1. O'B refers to O'Brien et al (1992).
2. Herbicide not used for tree care by this source.

Table 5: Trees For Conventional Option Annual Maintenance Material and Costs per Tree				
item	Quantity source: NCC	$/ unit	source	total $
-garden fertilizer 8-12-12	102 g	$9.60/kg	CT & NCC	0.98
-water (150mm/ watering) [1]	1030 L	$.88/1000l	RMOC	0.89
-pesticide	183 g	$7.00/200g	CT	6.40
-removal [2]	1% of area	$300	C[3]	3.00
-replant [4]	1% of area	$280.00	H[5]	2.80
TOTAL				$14.19
Smaller tree removal	1% of area	$165.00	H	1.65
and replacement	1% of area	$200.00	C	2.00
TOTAL (small trees)				$12.04

1. Watering rates from Lofgren (1982) and Harris (1985). Frequency from NCC database
2. Tree removal would likely be performed by a contractor. As a result, this has been factored into the operational costs rather than into the time requirements.
3.C refers to Contractors survey
4. Refer to simulation for planting plan and species lists.
5. H refers to Hanscombs (1993)

Table 6: Trees for Alternative 2 and 3 Annual Maintenance Labour Requirments per Tree					
Task	frequency source NCC	% of area treated source NCC	time	source	total time
-pruning over 160mm cal	1	3%	1.7 hours	O'B	3.0 min.
-watering	1	2%	20 min.	Cob	-
-fertilizer	1	6%	42 min.	NCC	2.5 min.
-hand weeding/edging	1	13%	1.3 hours	NCC	10.0 min.
pest/disease	1	6%	1.6 hours	NCC	6.0 min
TOTAL					21.5 min.

Table 7: Trees for Alternatives 2 and 3 Annual Maintenance Material and Costs per Tree					
item	quantity	source	$/unit	source	total$
-garden fertilizer 8-12-12[1]	30g	NCC	9.60/kg	NCC & CT	0.28
-water (150mm/ watering)[2]	87 L	NCC	0.88/1000L	RMOC	-
-tree and stump removal and clean-up[3]	0.5%	NCC	300.00/tr	C	1.50
-replacement	0.5%	NCC	280.00/tr	H	1.40
-pesticide	55 g	NCC	7.00/200g	CT	1.92
TOTAL					$5.10

1. Fertilization rate from OMAF (1990).
2. Watering rate from Harris (1984) and Lofgren (1982).
3. Tree removal would likely be performed by a contractor. As a result, this has been factored into the operational costs rather than into the time requirements.

Table 8: 100m2 Groundcover Area Annual Labour Requirment				
task	frequency source: Cob	time/task	source	total time
hand weeding	1	18.4min.	IMR	18.4min.
rejuvination[1]	10-15years	16.6 hours	Cob	1.3 hours
mulching	10-15years	27.6 min.	IMR	2.2 min.
watering (set up sprinkler and visit 2x/ run)[2]	10x each 10-15years	20.0 min.	Cob	16.0 min.
fertilization	10-15years	5.0 min.	IMR	-
hand weeding	15x each 10-15years	18.4min.	IMR	22.0 min.
hadpicking litter	6	5.0 min.	Cob	30.0 min
TOTAL				2.3 hours

1. According to Thoday (1982), woody groundcover should be rejuvinated every 10-15 years. This requires severe pruning and reapplicaiton of mulch, water, fertilzer and additional hand weeding.
2. Watering rates do not account for drought periods.

Table 9: 100m2 Groundcover Area Annual Maintenance Material and Costs					
item	quantity	source	$/unit	source	total$
-fertilization	100 g	Thoday (1982)[1]	4.80/500g	NCC & CT	1.34
-mulching	0.8 m3	Thoday (1982)	10.00/m3	NCC & C	6.48
-watering	2000 L	Thoday (1982)	0.88/1000L	RMOC	1.76
TOTAL					9.56

1. According to Thoday (1982), after rejuvination, which occurs every 10-15 years, fertilizing mulching and watering should occur.

Table 10: 100m2 Shrub Area for Alternative 2 and 3 Annual Labour Requirment					
task	% of area treated/year	source	time /task	source	total time
-fertilizing	9%	NCC	5 min.	Cob	-
-watering	2%	NCC	20 min.	Cob	-
-pest/disease control	33%	NCC	30 min.	IMR	10 min.
-removal	0%	NCC			
-pruning	45%	NCC	8.3 hours	Cob	3.7 hours
-mulching	8%	NCC	30 min.	IMR	2.4 min
-hand weeding/edging[1]	50%	NCC	1 hour	IMR	30 min.
TOTAL					4.4 hours

1. Herbicides not used for shrub care by this source.

Table 11: 100m2 Shrub Area for Alternatives 2 and 3 Annual Maintenance Materials and Costs				
item	quantity[1]	$/unit	source	total$
garden fertilizer 8-12-12	140 g	4.80/500g	NCC & CT	1.34
water (750mm/ watering)[2]	168 L	.88/1000L	RMOC	-
pesticide/ disease control	94 g	7.00/200g	CT	3.29
mulch	0.4m3	8.00/m3	NCC & C	3.20
TOTAL				$7.84

1. All quantities from NCC database.
2. Watering rate from Lofgren (1982) and Harris (1984).

Table 12: 100m2 Shrub Area for Conventional Option Annual Labour Requirements					
item	frequency source: NCC	% of area treated source: NCC	Time	source	total time
-hand pruning	1	6%	8.3 h	Cob	30 min.
-hand fertilization	1	80%	5 min.	IMR	4 min.
-sprinkler watering	5	100%	20 min	Cob	1.6 hours
-hand weeding/ edging	3.5	100%	1 h	IMR	3.5 hours
-removal	1	0.3%	9.2h	NCC	2 min.
-disease/ pest control	1	60%	30 min	IMR	18 min.
mulch	1	25%	30 min.	IMR	8 min.
TOTAL					6.1 hours

Table 13: 100m2 Shrub Area for Conventional Option Annual Maintenance Material and Costs				
item	quantity[1]	$/ unit	source	total $
-garden fertilizer 8-12-12	300 g	9.60/kg	NCC & CT	2.88
-water (75mm/ watering)[2]	37 500 L	0.88/1000	RMOC	33.00
-pesticide	129 g	7.00/200g	CT	4.50
-replant	0.3% area	23.00/sh	H	3.90
-mulch	1m3	8.10/m3	NCC & C	8.10
TOTAL				52.38

1. All quanties sourced from NCC database.
2. Watering rates from Lefgren (1982) and Harris (1984).

Table 14: 100m2 Annual Flower (75%) / Herbacious Perennial (25%) Area Annual Labour Requirment				
task	time/ task	frequency	% of area	total time (hours)
-planting	17.0 h	1	75%	12.8
-bed preparation	6.5h	1.4	75%	6.8
-cultivating and weeding	1.1 h	5	100%	5.7
-watering	0 .4 h	20	100%	7.2
-pinching/ pruning	3.7 h	1	100%	3.7
-removal	7.0 h	1	75%	5.3
-bed edging (40LM)	1.4 h	1.5	100%	2.1
-pest control	2.0 min	12	100%	0.4
TOTAL				44.0 hours

1. All data from NCC database.

Table 15:100m2 Annual Flower / Herbacious Perennial Area
Annual Maintenance Materials and Costs

item	quantity	$/unit	source	total cost
-soil ammendments	3kg	9.60/kg	NCC&CT	28.80
-annual plants @ 9/m2	38flats of 12 plants	3.60/flat	C	202.00
-water	60 000 L	.88/1000L	RMOC	52.20
-pesticides	256g	7.00/200g	CT	8.96
TOTAL				291.96

1. All quantity sources from NCC.

Table 16: 100m2 Unit Paver Area
Annual Labour Requirement

task	frequency	source	time/task	source	total time
hand sweeping	18	NCC	27 min.	IMR	8.1 h

1. No materials or costs.

Table 17: 100m2 Woodland Area Annual Labour Requirments	
Item (source: Hough et al, 1990)	total time (hours) (source: Cobham, 1990)
Years 1 to 5 (before canopy closure)	
- addition of mulch and removal of perforated polyethelene	9.0
- hand cultivate for critical weed growth	1.3
-water in drought periods	as needed
Years 5 to 15 (after canopy closure)	
- remove 30% of pioneer species	1.6
Years 15 to 25	
- gradually remove rest of pioneer species	3.2
-thin climax species	2.4
Years 25+	
- continued thinning of climax species	as needed
TOTAL/ year (until year 15)	**0.8 hours**
TOTAL/ year (until year 25)	**0.5 hours**

1. Edge maintenance included in shrub and groundcover maintenance.
2. The only material expense is mulch at 4m3/ 100m2 @ $10.00/m3 =$40 for 15 years = $2.66/ year.

Table 18: 100m2 Tall Grass Prairie Area Annual Labour Requirements		
item	source	total time (hours)
- one mowing	Cobham (1990)	1.0
- hand weeding	Dorney (1985)	1.0
TOTAL		**2.0 hours**

1. Edge maintenance included in shrub and groundcover maintenance.
2. The only material expense is gasoline @ 2.25 litres/ hour x 1.0 hours = 2.25 litres @ $0.56/ litre = $1.26/ year

APPENDIX 17
WATER RATES
(from RMOC, 1993)

Water Rates	
Item	Cost ($)
Water rate per cubic metre (1 000 litres)	0 515
Regional sewer surcharge (6% of water rate)	0.031
Municipal sewer surcharge (65% of water rate)	0.335
Total cost per 1000 litres	0.88