Shirley's Brook and Watts Creek Subwatershed
Stormwater Professional's Workshop
Study Overview

Introduction

The City of Kanata and the Regional Municipality of Ottawa-Carleton retained Dillon Consulting Limited to prepare a subwatershed plan for the Shirley's Brook and Watts Watersheds to ensure that planning future development proceeds in an environmentally sound manner. The purpose of the plan is to recommend how water resources and related subwatershed features, and ecological functions should be protected and enhanced to coincide with existing and changing land use.

It is noted that although the focus of this workshop is on stormwater management, the Shirley's Brook and Watts Creek Subwatershed Study is being conducted through an ecosystem based approach. The intent is to recognize existing environmental constraint areas as well as protection/ enhancement opportunities in developing management strategies. The plan is being developed recognizing the relationships between hydrology, hydrogeology, stream morphology, aquatic habitat and terrestrial habitat.

The output of this study, the Subwatershed Plan, provides guidance to local and regional authorities in planning future land use development while ensuring the protection, restoration and enhancement of the natural features in the subwatersheds. The Plan will be useful for the review and regulation of individual development proposals at both the Secondary Plan and Draft Plan of Subdivision levels.

The Shirley's Brook watershed (28 sq. km) and the Watts Creek/Kizell Drain watersheds (25 sq. km) are the two main drainage areas within the urban portions of the City. Adjacent watersheds include the Carp River (draining into the Ottawa River) and the Jock River (draining into the Rideau River).

To date, the following activities have been completed:

- Description of existing conditions including aquatic habitat (MNR Stream Protocol Assessment, 1998) and terrestrial resources;
- Identification of Key Issues;
- Development of a vision, goal and objectives statements;
- Assessment of impacts on hydrologic process/functions; fish habitat; and water quality;
- Development of water quality and quantity targets; and
- Initial development of management strategies.

In preparation of the January 11, 1999 Stormwater Professionals Workshop, the following is a highlight of important findings to date and key issues to be addressed.

Existing Conditions/Key Issues

Geology

- The headwater areas of the subwatersheds are in the March Highlands; an area characterized by numerous bedrock outcrops, relatively thin overburden cover, and poorly drained wetlands areas. (50% of Shirley's Brook and 35% of Watts Creek is contained in this area).

- The middle and lower reaches of the subwatershed areas consists of erosional terraces characterized by marine deposits of silt and clay with much bedrock exposure.

- Soils conditions suitable for ground infiltration are limited to area of alluvial sands measuring approximately 7km by 800m (approximately 10-15% of the study area).

Groundwater

- generally considered potable within the subwatershed.

- appears to be topographically driven flowing from the recharge areas in the March Highlands in a north-east direction. Much of recharge potential in Watts Creek has been lost by development.

- discharge contributions to streamflow are anticipated to be relatively minor in terms of quantity although the contribution to overall streamflow is significant owing to the relatively low flows.

Streamflow

The following is representative streamflow data for each of the subwatersheds:

Average Streamflows (m^3/s)				
	Daily		Hourly	
	Total	Baseflow	Maximum	Minimum
Shirley's Brook	0.007 to 0.180	0.01	0.5	0.003
Watts Creek	0.029 to 0.368	0.02	3.0	0.016

Kizell Drain	0.018 to 0.463	0.02	1.4	0.015

- The streamflow response in Shirley's Brook is moderately slow. This is consistent with the forested and agricultural area drained.

- The streamflow response of Watts Creek to rainfall events is quite rapid. From the beginning of runoff, peak flows generally occurs within one hour, indicative of the urban character of the drainage area (45% of the area). It is estimated that 55% is attributed to baseflow sources and 45% from direct surface run-off.

- The streamflow response of Kizell to rainfall events is moderately rapid; from the beginning of runoff, peak flows typically occurs within 2 to 3 hours. Approximately 33% of this drainage area is urbanized.

- A number of flood susceptible areas have been identified throughout the subwatersheds

Surface Water Quality

The following table summarizes water quality within the subwatersheds:

pH	levels vary between 7.3 and 8.7 indicative of slightly alkaline waters
alkalinity	well within the drinking water criteria of 30-500 mg/L set by the ODWO
TSS	levels are generally high and exceeded MNR guideline of 80 mg/L for warm water fisheries in addition to CWQO of 10 mg/L (levels were lower in urbanized areas)
Major Ions	all parameters were for the most part below MOE criteria levels
Ammonia	levels do not exceed PWOQ criteria
Phosphorous	levels generally exceed the PWOQ of 30 ug/L (attributed to agricultural activity)
E. coli	levels exceed MOE criteria
Faecal Coliforms	levels exceed MOE criteria, particularly in agricultural areas
Trace Constituents	levels exceed PWOQ standards for aluminium, zinc and iron and at some locations, copper.
Average Daily Temperature: Summer	Shirley' Brook 19C Watts Creek 22C Kizell Drain 17C

Morphology

- The majority of the channel reaches in each subwatershed are moderately stable.

- The stream beds are considered to be erosion resistant with the result that increased flows may lead to greater bank undercutting and failures. There are also high sensitivities, depending on channel form, to changes in the existing flow and sediment regimes. The sensitivity to change is greatly increased when the channel is functionally removed from the floodplain.

- A number of erosion sites have been identified and occur in areas with low entrenchment values. Bank erosion was observed downstream of any interruptions in sediment transport, such as on line ponds and beaver dams.

- Considering the geology and low channel gradients, the dominant form of sediment transport is the suspended load. This in part indicates that the channel may be more susceptible to change from smaller, more frequent rainfall events and corresponding flows.

Aquatic Resources

- Benthic sampling indicates that substantive organic pollution is likely present.

- The watercourses can be considered as warm water tolerant streams. No rare, threatened or endangered species were collected. Much of the fish habitat has been classified as Type 2. (Some Type 1 habitat exists in the headwaters of Shirley's Brook and at its mouth.)

- Several stream reaches through both agricultural and developed areas have been channelized. This has resulted in absence of in-stream structure for fish cover and absence of pool-riffle complex that has resulted in a decrease in habitat diversity and, therefore, lower quality.

- Lack of overhead cover in agricultural and developed removes shading and results in lack of temperature moderation through these reaches.

Land Use

Land use is presented in the following table.

COMPARISON OF EXISTING AND FUTURE LAND USE SCENARIOS						
Land Use	**Existing Land Use**		**Future Land Use**		**Change**	
	Areal Coverage (ha)	**Percentage (%)**	**Areal Coverage (ha)**	**Percentage (%)**	**Areal Coverage (ha)**	**Percentage (%)**
WATTS CREEK SUBWATERSHED						
Agriculture	162	11	152	10	-10	-6
Woodland/ Forest	237	16	189	13	-48	-20
Open Space/Grassland	666	45	546	37	-120	-18
Urban/Developed	404	28	582	40	178	44
Subwatershed Total	**1469**	**100**	**1469**	**100**		
SHIRLEY'S BROOK SUBWATERSHED						
Woodland/ Forest	917	34	702	26	-215	-23
Open Space Grassland	825	31	127	5	-698	-85
Urban Developed	300	11	1687	62	13.87	462
Subwatershed Total	**2700**	**100**	**2700**	**100**	-	-
KIZELL DRAIN SUBWATERSHED						
Agriculture	79	8	79	8	0	0
Woodland/ Forest	186	19	83	8	-103	-55
Open Space/Grassland	362	36	215	22	-147	-41
Urban Developed	374	37	624	62	250	67
Subwatershed Total	1001	100	1001	100	-	-

Impact Assessment of Future Development

Change in urban areas is presented below (based on the RMOC Official Plan):

Subwatershed	Existing Developed Urban Area	Future Developed Urban Area	Increase in Urban Area	Increase in Impervious Area
Shirley's Brook	300 ha	1686 ha	462%	4% to 22%
Watts Creek	405 ha	582 ha	44%	12% to 19%
Kizell Drain	375 ha	624 ha	71%	16% to 29%

QUALHYMO modeling results, based on the above change in urban area is presented below:

COMPARISON OF QUALHYMO MODELLING WATER BALANCE CALCULATIONS FOR EXISTING AND FUTURE LAND USE CONDITIONS			
	Existing Depth	Future Depth (mm)	[3]Percentage Change (%)
SHIRLEY'S BROOK SUBWATERSHED			
Precipitation	923	923	0
[4]Evapotranspiration	611	611	0
Water Surplus	312	312	0
Runoff	55	193	245
Baseflow	38	35	-3
Groundwater Recharge	257	119	-54
WATTS CREEK SUBWATERSHED			
Precipitation	923	923	0
[4]Evapotranspiration	611	611	0
Runoff	149	208	40
Baseflow	178	175	-2
Groundwater Recharge	163	104	-36

- Regarding water quality, increased development is expected to result in increased TSS; moderate increases in E.coli and Fecal coliforms and increased pollutant loading from vehicle traffic. Decreases in agricultural activity in some basins could lead to decreases in nutrient levels and pesticides/herbicides.

- Impacts to groundwater supplies are not expected to be significant as the amount of development in the recharge areas will be minimal.

Urban Stormwater Management Practices and Key Issues

- The attached table provides a summary of potentially suitable SWMPs in the study area

- The effectiveness of up-stream control measures within the subwatersheds in reducing run-off volumes are to be presented at the workshop

- Soils conditions within the study area greatly limit the potential for infiltration based upstream control measures, yet future development is to result in a significant increase in flows.

Considering the above information, the goal of the workshop is to discuss the role of stormwater management technologies in achieving the goals for the subwatershed. Questions to be asked include:

1) What is the relative importance of the following:
   - Fish Habitat:
     - ¤ Structure
     - ¤ Water Quality
   - Recreational uses and public health concerns
     - ¤ 'playing'
     - ¤ 'swimming'

2) Source and Conveyance Controls
   2.1) How important are they to achieving the goals of the sub-watershed?
   2.2) Are they/ can they be cost effective?
   2.3) Should there be a minimum level of control they are required to achieve?
   2.4) What are the long term concerns?
   2.5) How can stakeholder support for them be increased?
   2.6) Are there incentives that could encourage the use of up-stream control measures?

3. End-of-Pipe Facilities
.31) Should end-of-pie facilities be designed with recognition of benefit upstream control measures?
3.2) How far up-stream are end-of-pipe treatment facilities required (i.e how long should we let water flow untreated)?
3.3) Should there be a limited number (ubiquitous vs centralized)?
3.4) Should artificial wetlands as end-of-pipe control measures be pursued? If so, under what conditions?
3.5) Attenuation of peak flows can lead to increased erosion and damage to channel form with implications on aquatic and terrestrial habitat, and land use.

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Urban Stormwater Management Alternatives for Shirley's Brook/Watts Creek

Stormwater Management	Benefit	Disadvantage	Applicability to Shirley's Brook/ Watts Creek	Life	Cost
Source Control Measures					
Disconnection of Roof Leaders with or without • splash pads • cisterns • ponding • soakaway	-decreased runoff quantity to receiving system; increased infiltration -runoff detainment -potential for some water quality benefit	-potential for home owner inconvenience (i.e., ponding water, clogging of pond outlet/soakaway pit if implemented) -difficult to implement in existing development	-roof runoff is relatively clean, the disconnection will reduce the runoff into the watercourses and therefore reduce in-stream erosion potential . **-recommended for new and re-development residential areas on a lot by lot basis, *where suitable soils exist.*** **- expected that there will be few areas where measure can be applied**	Long	Low
Disconnection of Foundation Drains	-decreased runoff quantity to receiving system; increased infiltration	-requires sump pump -difficult to implement in existing developments	-foundation drain runoff is relatively clean, the disconnection will reduce the runoff into the watercourses and therefore reduce in-stream erosion potential. **.-recommended for new and re-development residential areas on a lot by lot basis, where suitable soils exist.** **- expected that there will be few areas where measure can be applied**	Long	Low
Catch Basin Restrictors/ Control Orifices	-runoff detainment -potential for limited sediment removal	-potential for clogging -inconvenience due to ponding water	-new development major-minor system should be designed without the need for catch basin restrictors. **-recommended for retrofit areas**	Short	Low
Reduced Lot Grading	-decreased runoff quantity to receiving system; increased infiltration and evapo-transpiration -runoff detainment -some water quality benefit	-potential for home owner inconvenience (i.e., longer lot drainage time) -vulnerable to alterations by home owner, difficult to regulate -used mainly for new developments where topography permits	-reduced lot grading will increase infiltration and reduce the runoff into the watercourses and therefore reduce in-stream erosion potential. **-recommended for new and re-development residential areas on a lot by lot basis, where suitable soils exist.** **- expected that there will be few areas where measure can be applied**	Long	Low
Rooftop Storage	-runoff detainment	-difficult to retrofit -only suitable for flat industrial or commercial roofs	-only feasible for commercial/industrial development. It could reduce the peak runoff into the watercourses and therefore reduce in-stream erosion potential. **-recommended for new commercial and industrial developments.**	Med	Med
Parking Lot Storage	-decreased peak flow to receiving system	-more suitable for commercial and industrial areas -represents potential hazard to motorists and pedestrians	-it could reduce the peak runoff into the watercourses and therefore reduce in-stream erosion potential, also some improvement to water quality. **-recommended for new commercial and industrial developments.**	Med	Med
Porous Pavement	-decreased runoff quantity to receiving system; increased infiltration	-potential for ground water contamination -potential for clogging -not tried in Ontario	-not well tested for Ontario conditions. Suggest that a pilot study should be carried out (not part of this project) to tests its efficiency and feasibility within the study area.	Med	High
Slope Stabilization and Erosion Control Measures	-reduced maintenance of SWMPs -improved water quality		-will reduce erosion and thereby the amount of sediment entering the watercourses. **-recommended for new and retrofit developments.**	Med	Low

Stormwater Management	Benefit	Disadvantage	Applicability to Shirley's Brook/ Watts Creek	Life	Cost
			- expected to have wide application in study area		
Conveyance Control Measures					
Road Drainage • **Grassed Swales**	-potential for decreased runoff quantity to receiving system; increased infiltration -runoff detainment -improved water quality -generally preferred over ditches by the public	-mosquito breeding ground -require more land than conventional ditches	-preferred road drainage alternative, it has some water quality improvement component. **- recommended for new and retrofit developments where feasible.** **- expected to have wide application in study area**	Med	Low
Channel/Outlet Protection	-decreased erosion -improved water quality (i.e., decreased sediment loading)	-disruption of natural habitat	**-recommended for new and retrofit developments, but must not disrupt the local habitat** **- expected to have wide application in study area**	Long	Med
Pervious Pipe System	-decreased runoff quantity to receiving system; increased infiltration	-potential for ground water contamination -potential for clogging -high cost of replacing existing sewer -specific site requirement	-limited use due to local soil conditions **-not recommended , unless local soil conditions suitable for infiltration**	Med	Med

Urban Stormwater Management Alternatives for Shirley's Brook/Watts Creek (Continued)

Stormwater Management	Advantage	Disadvantage	Applicability	Life	Cost	Comments
End of Pipe Control Measures						
Detention/ Retention Facilities (Dry, Wet and Extended detention ponds)	-water quantity control -improved water quality -potential for downstream erosion control -potential for spill control	-potential for sediment re-suspension (dry ponds) -potential for thermal warming (extended detention) -potential for odour, algae, debris and/or mosquitoes (wet ponds) -potential for outlet clogging -not suitable/economical for small areas, wet ponds require more land area than dry ponds, although both are land consumptive	-would improve water quality, the efficiency of ponds in settling pollutants should be studied as it may be difficult to settle the fine clay particles present in the local soils. **-wet ponds recommended for new and retrofit developments for area >10 ha, subject to above**	Long	High	
Underground Storage	-decreased runoff peak -improved water quality	-difficult to keep clean	-generally used as retrofit in existing developed areas where space is at a premium. **- not expected to have wide application in study area**	Long	High	
Artificial Wetlands	-runoff detainment -potential for water quantity control -improved water quality -potential for downstream erosion control -effective for spill treatment	-potential for thermal warming -potential for outlet clogging -potential for mosquitoes -not suitable/economical for small areas -may have plant sustainability problems where road salts are applied -requires significant land area	-would improve water quality, the efficiency of wetlands in settling pollutants should be studied as it may be difficult to settle the fine clay particles present in the local soils. **--recommended for new and retrofit developments for area >10 ha, subject to above**	Long	High	
Infiltration Basins/Trenches	-decreased runoff quantity to receiving system; increased infiltration if allowed to recharge ground water system -improved water quality if collected and discharged	-potential for clogging/ compaction -potential for ground water mounding -potential for ground water contamination -operation/maintenance problems reported -pre-treatment suggested	-would improve water quality, but it could be difficult to settle the fine clay particles present in the local soils. -subject to suitable soils, bedrock and water table conditions **- limited use do to soil conditions in study area**	Short to Med	High	

Urban Stormwater Management Alternatives for Shirley's Brook/Watts Creek (Continued)

Stormwater Management	Advantage	Disadvantage	Applicability	Life	Cost	Comments
		-specific site requirement				
Filter/Buffer Strips	-potential for decreased runoff quantity to receiving system; increased infiltration and evapo-transpiration -runoff detainment -improved water quality -erosion protection	-potential for clogging	-for new or retrofit development areas < 2 ha **- limited use.**	Short	Low	
Oil and Grit Separators	-limited runoff detainment -improved water quality -spill control	-can only control limited areas -not suitable for quantity control -not suitable for soluble pollutants	-mainly suitable for industrial and commercial areas. **-recommended for new and retrofit industrial and commercial area < 2 ha and with other SWM facilities**	Med	Med	

Chris - Comments? for Aug. 26

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1.0 INTRODUCTION

1.1 Background

In 1997, the Regional Municipality of Ottawa-Carlton (RMOC) and the City of Kanata commissioned a study to assess the applicability of the subwatershed planning process to the City's two main drainage areas, Shirley's Brook and Watts Creek Watersheds. Although these are two separate watersheds, in this report, the term subwatershed is used to emphasize the adoption of the Provincial Subwatershed Planning concept. The study concluded that there would be important benefits realized from implementing subwatershed plans for the Shirley's Brook and Watts Creek Watersheds. Because there is a great deal of existing information on the physical, biological and social/cultural features in these watersheds, it was felt that the subwatershed planning process could be focussed and streamlined to take advantage of the existing data and information.

The City of Kanata and the Regional Municipality of Ottawa-Carleton retained Dillon Consulting Limited to prepare a subwatershed plan for the Shirley's Brook and Watts Watersheds to ensure that planning future development proceeds in an environmentally sound manner. The purpose of the plan is to recommend how water resources and related subwatershed features, and ecological functions should be protected and enhanced to coincide with existing and changing land use.

1.2 Subwatershed Study Area

Shirley's Brook and Watts Creek Watersheds are the two primary systems which drain the City of Kanata. Adjacent watersheds include the Carp River and the Jock River, both of which drain into the Ottawa River, upstream and downstream respectively, of the study area. The boundaries of the Kizell Drain have also been included, as it constitutes part of the Watts Creek Watershed. **(Map to go here)**

1.3 Overview of Ecosystem Approach and Subwatershed Planning

The most appropriate framework for natural resource management is the concept of integrated resource management conducted on an ecosystem basis. An ecosystem consists of air, land, water and living organisms, including humans, and the interactions between them. When applied to land use planning, an ecosystem approach provides early and systematic guidance on the interrelationships between existing and potential land uses and the long-term health of ecosystems.

The approach is based on the recognition that environmental systems have limits to the stress that can be accommodated before the ecosystems are degraded or destroyed. It requires ecological goals to be treated equally with, and considered at the same time as, economic or societal goals.

The overall goal of ecosystem based planning is to ensure that ecosystem health/integrity is improved, restored or maintained after proposed changes in land use (e.g. land use and/or environmental management) are made. Accordingly, an ecosystem based approach to land use planning requires that the boundaries for land use planning be based on biophysical boundaries in order to examine the relationships between the natural environment and human activities. One type of ecosystem unit for planning and resource management is the subwatershed. This unit is based on using the hydrologic cycle as the pathway that integrates physical, chemical, and biological processes of the ecosystem.

Subwatershed studies generally embody an ecosystem-based approach to water and land use management using the boundaries of a subwatershed. At this level, subwatershed studies are tailored to the "tributary needs" of the watershed, reflecting a more local scale, and providing detailed guidance on site-specific resource planning issues. By developing a broad understanding of the ecosystem, the subwatershed studies can identify important ecosystem considerations and objectives that can be integrated into land use planning. Planning on a subwatershed basis considers the integrity of the ecosystem, thereby avoiding a piecemeal approach, which only considers the needs of a proposed development.

Subwatershed studies recommend how water resources and related resource features and ecological functions should be protected and enhanced to coincide with existing and changing land use. By allowing environmental objectives to be set at a time when they can be incorporated into land use planning documents, subwatershed studies provide important information to the land use decision-making process. **Subwatershed studies do not determine land use; instead they establish**

constraints, opportunities and approaches for input into the land use planning process. The input of environmental objectives and management recommendations to the land use planning process promotes informed decision-making, resulting in more efficient and effective land use planning.

Current land use planning practice and resource management philosophy embraces the principles of ecosystem based planning using the subwatershed as the logical unit for environmental management. The overall goal of this approach is, to "*protect the quality and integrity of ecosystems, including air, land, water and biota, and to encourage restoration to healthy conditions where that quality has been diminished*" (OMMA 1995). In achieving this goal, subwatershed planning balances environmental protection, conservation and restoration with development and land use to ensure long-term sustainability of the subwatershed and its significant natural features. Subwatershed planning consists of four main tasks:

- development of an understanding of the current subwatershed features (natural and social/cultural) and how they function;
- prediction of current and potential future impacts on the natural environment which may result from land use changes and development;
- recommendation of possible ecological restoration and/or enhancement measures which could improve existing subwatershed features and functions; and
- development of an approach for managing future development in the subwatershed which includes specific policies for natural heritage features and developable areas.

This approach to integrated land use and environmental planning is also consistent with the current *Provincial Policy Statement* which gives significant importance to environmental protection, conservation and sustainability.

The *Provincial Policy Statement* (Province of Ontario, 1996) provides policy direction on matters of provincial interest related to land use planning and development. The Policy Statement is intended to be addressed by municipal planning policies contained in local Official Plans regarding matters of provincial interest. The Province's Policies are principled upon maintaining Ontario's long-term economic prosperity, environmental health and social well-being.

The policies are structured to provide recognition that there are complex inter-relationships among environmental, economic and social factors in land use planning (Province of Ontario, 1996). Of specific relevance to this Study are the policies under Section 2, "Resources" and Section 3, "Public Health and Safety". Specifically, these policies pertain to Natural Heritage (Section 2.3), Water Quality and Quantity (Section 2.4), Natural Hazards (Section 3.1), and Human-Made Hazards (Section 3.2). This Study addresses provincial policy requirements in succeeding sections of the report.

1.4 Purpose of Study

The purpose of this subwatershed planning study is to develop an integrated subwatershed plan covering Shirley's Brook and Watts Creek Watershed study areas. This plan will provide the broad framework and strategy for development in a manner which harmonizes the city's need for housing and services with the need for sustaining the long term health of the environment.

The plan and accompanying report provide appropriate background information to the Regional Municipality of Ottawa-Carlton (RMOC), the City of Kanata, the provincial government and the Mississippi Valley Conservation Authority (MVCA), for the preparation of land use planning and resources development policies and implementation strategies. These policies and strategies can be incorporated into the ongoing update of the Kanata Official Plan (to be completed summer 1999), and/or into municipal policies and guidelines for capital works programs. Future implementation guidelines to be developed from the subwatershed study will, to a great extent, streamline the development approval process which will result in cost savings while ensuring the protection of the local environment.

This study has involved ongoing communication with key landowners/developers within the City of Kanata. Their input has ensured that the strategies and guidelines which have been developed reflect their opinions as well as the agencies and the public, and in keeping with the objective of preservation and enhancement of natural features. A sufficient level of detail and public input into the subwatershed study has ensured that the Phase 1 and 2 requirements of the Provincial Class Environmental Assessment Process are also fulfilled. This approach is in keeping with the RMOC's Master Plan approach recently adopted for their Official Plan and the RMOC's Transportation, Water and Wastewater Master Plans. The use of this approach will reduce the planning efforts required for individual facilities in the future.

The study thus incorporates an ecosystem-based approach to land use planning which uses the Shirley's Brook and Watts Creek Watersheds as the basis to identify important ecological considerations and objectives that can be integrated into this planning process.

The output of this study, the Subwatershed Plan, provides guidance to local and regional authorities in planning future land use development while ensuring the protection, restoration and enhancement of the natural features in the subwatersheds. The Plan will be useful for the review and regulation of individual development proposals at both the Secondary Plan and Draft Plan of Subdivision levels.

1.5 Scope of Study

The scope of work for the Shirley's Brook and Watts Creek Subwatershed Planning Study included the following tasks:

- A review of background information to assess the general characteristics of the natural environmental features, surface water and groundwater regimes in the study area, as well as land use, and to identify information gaps;
- A hydrology study to develop an overall understanding of the surface water regime, including an inventory of hydraulic structures, existing stormwater management facilities, measurements of stream channel dimensions and identification of existing erosion sites;
- A hydrogeology study to develop an overall understanding of the groundwater regime through identification of significant groundwater recharge/discharge areas, measurements of soil permeability and topography and surface drainage features;
- A fluvial geomorphology study to develop an understanding of bedload and stream dynamics and to advise on the status of the watercourses with respect to sedimentation and erosion;
- A fisheries inventory to assess the existing aquatic habitat using the Rapid Assessment Methodology of the Stream Assessment Protocol for Ontario and including recommendations for habitat protection, restoration and enhancement;

- A terrestrial biology inventory of vegetation, wildlife and habitat units (woodlots, shrublands, linkages), agricultural land, identification of any ESAs, ANSIs or provincially significant wetlands;

- A comprehensive data assessment and identification of the significant natural heritage, environmental protection, hazard features, and land use and policy, along with opportunities for protection, enhancement and rehabilitation and constraints to development;

- Mapping of existing features and constraints;

- Identification of subwatershed goals and objectives for the protection, enhancement and restoration of significant natural heritage, environmental protection and hazard features in a framework which also includes land use planning;

- Identification of specific opportunities for protection, enhancement and restoration of environmental features which ensure the long-term sustainability of their attributes, and identify constraints to development by setting realistic subwatershed resource management objectives;

- Determination of the potential impacts on natural features and hydrologic processes resulting from proposed changes in land use (e.g. increased flooding and erosion, water quality degradation, baseflow reduction);

- Identification subwatershed management alternatives and development of a management plan using a consultative process with the public, landowners, government agencies and the municipality;

- Development of an implementation strategy to guide future development by identifying recommended management works, responsibilities and commitments required at subsequent stages of the planning process, the need for future studies, Official Plan Policy changes and required monitoring and maintenance; and

- Identification of the mechanisms to implement the subwatershed management strategy.

2.0 DATA ANALYSIS AND ASSESSMENT: SUBWATERSHED DESCRIPTION

2.1 Introduction

This section provides a description of the existing environmental conditions within Shirley's Brook and Watt's Creek watersheds. This description is based on available background information and data from previous studies as well as fieldwork undertaken as part of this study.

2.2 Climate

The climate of the Shirley's Brook/Watts Creek Watersheds is characterized by the climatic region of Renfrew (Brown, *et al.*, 1980). The July daily maximum temperature average is 27°C, and the January daily minimum temperature average is -16°C. The mean annual frost free period is 130 days.

2.2.1 Precipitation

The average annual precipitation is 711 mm with an average annual snowfall of approximately 1,906 mm (approximately 191 mm water equivalent).

2.2.2 Snowpack

There are no existing snowcourse stations within the Shirley's Brook/Watts Creek Watersheds. Therefore, in order to characterize typical snowpack conditions in the Study Area, data obtained from the Ontario Ministry of Natural Resources' nearby Bells Corners Station was reviewed. The Station, located approximately 10 km southeast of the study area, is maintained by the OMNR and has been in operation since the 1978/79 winter season.

(To be completed.)

2.3 Geology and Hydrogeology

2.3.1 Data Collection

A geological and hydrogeological review of the Shirley's Brook and Watts Creek Watersheds was carried out using available site-specific hydrogeological and terrain analysis studies, regional geologic and hydrogeologic studies, and the Ministry of Environment (MOE) digital water well record database. The MOE digital database contains 276 water well records within the study area. The dates for water well construction date between May 1948 and April 1985. The MOE database is reported to be current as of December, 1997.

Several hydrogeological studies have been completed within the study area, the majority of which have been directed at the Shirley's Brook watershed. Relatively little information concerning groundwater is available for the Watts Creek watershed. The most significant groundwater studies include a Hydrogeology and Development study by Geo-analysis Ltd. (1976) and a Water Resources Study by Raven Beck Environmental Ltd (1994). Both studies identify a number of constraints and recommendations for future development activities, principally within the rural parts of Kanata.

Numerous hydrogeological and terrain analysis reports have been generated in support of on-site service requirements for future subdivision developments. The majority of these studies are also restricted to rural Kanata.

2.3.2 Physiography

Chapman and Putnam (1984) classify the study area to be located in the Ottawa area clay flats physiographic region. On a more local scale, the study area is made up of three distinct physiographic divisions: gently rolling bedrock uplands of the March Highlands along the southwest; a lowlands area along the northeast; and Paleozoic bedrock plains along the southeast and east. The March Highlands are crested by a Precambrian bedrock ridge referred to as the March or Carp Ridge.

The topography along the March Ridge is generally rough and undulating with elevations ranging between 110 and 130 m.a.s.l. Gently sloping Paleozoic bedrock uplands which flank the March Ridge give way to the lowland areas to the northeast. The lowland areas consist of gently rolling plains which vary between 70 and 90 m.a.s.l. The bedrock plains which dominate the southeast portions of the study area vary between 100 and 120 m.a.s.l. Along the east flank of the Watts Creek subwatershed, the bedrock plains extend approximately 1.5 km north of Highway 417 forming a narrow ridge which comprises the east boundary of the Watts Creek Watershed.

The upland areas of the March Highlands and bedrock plains are characterized by numerous bedrock outcrops, relatively thin overburden cover, and local poorly drained wetlands and marshes which act as headwaters to Shirley Brook, its various tributaries, Kizell Drain, and the north branch of Watts Creek. The poor draining wetlands flow into narrow stream reaches within deep channels that have been cut into the ridges. The upper reaches of the south branch of Watts Creek are dominated by a Paleozoic bedrock terrain.

The middle and lower reaches of the subwatershed areas consist of erosional terraces characterized by offshore deep water marine deposits of silt and clay. These lowlands comprise the floor of an abandoned channel of the Ottawa River. Bedrock exposures within the lowland area are numerous owing to terrace cutting effects within the former channel.

2.3.3 Geology

2.3.3.1 Surficial Geology

The surficial geology within the Shirley's Brook/Watts Creek study area has been defined by Richard (1984). The various overburden deposits are somewhat consistent in terms of their type and spatial distribution through the subwatershed areas. The deposit types include: glacial till; Champlain Sea sediments including clay, silty clay, and silt; and post Champlain Sea Sediments including fluvial sands and organic deposits. The overburden stratigraphy, from youngest to oldest, is listed in Table 2.1.

Throughout the study area the unconsolidated surficial deposits (overburden) are for the most part relatively thin. Overburden thicknesses are usually less than 5 metres, and in much of the upper reaches of the watershed areas are less than 1.0 metres. Overburden thickness based on the MOE water well records digital data base is shown in Figure _____ ***(To be provided.)***. The greatest overburden accumulations (>30 m) lie along the east branch of Watts Creek southwest of the Highway 417/Eagleson Road interchange (Patterson, 1980).

TABLE 2.1
SURFICIAL STRATIGRAPHY

Relative Age	Deposit Type
Post Champlain Sea Deposits	Organic Deposits - mainly peat and muck in bogs, fens, swamps and poorly drained areas.
	Alluvial Deposits - medium grained stratified sand with some silt.
Champlain Sea Sediments	Nearshore Sediments - slabs and shingles developed from sedimentary bedrock
	Offshore Marine Deposits - clay silty clay, and silt, commonly calcareous and fossiliferous, upper parts mottled or laminated reddish brown and blue grey. Uniform and blue grey at depth.
	Offshore Marine Deposits - clay and silt underlying erosional terraces. Uniform blue grey including lenses, bars, and channel fills of sand and pockets of non-marine silt deposited during channel cutting.
Glacial Deposits	Till, plain

The upper reaches of the subwatershed areas are dominated by exposed or shallow Precambrian and Paleozoic bedrock. The exposed/shallow bedrock comprises roughly 50% of the Shirley's Brook and Kizell Drain subwatersheds and 35% of the Watts Creek Watershed. Small discontinuous lenses of glacial till, offshore marine clay, and organic deposits occur within local low-lying areas, predominantly within the Shirley Brook Watershed and Kizell Drain Subwatershed where they comprise roughly 10% of the surficial deposits. Where unexposed, the shallow bedrock cover is typically less than 1 metre in thickness and is generally comprised of silt/clay till. The local organic deposits are mainly muck and peat lying in poorly drained areas including bogs, fens, and swamps. These areas account for approximately 5% of the Shirley's Brook Watershed and Kizell Drain Subwatershed.

The middle and lower reaches of the study area are overlain by offshore marine deposits of clay, silty clay, and silt. These deposits are commonly calcareous and fossiliferous and locally overlain by thin sands. Within the lower lying areas, the upper portions of these deposits have been removed to variable depths during channel cutting so that in places the clay is uniform blue-grey. Lenses, bars, and channel infills formed during terrace or channel cutting occur locally within the clay, however, these are generally discontinuous. The offshore marine deposits comprise approximately 25%, 20%, and 15% of the Shirley's Brook, Kizell Drain, and Watts Creek Watersheds, respectively.

East of March Road along the centre line of the lowland area the surficial deposits consist of alluvial sand. The sand deposit is roughly linear in shape measuring approximately 7 km in length by 800 metres in width. The sand consists of a medium grained stratified sand with some silt. Information in the MOE water well database indicates these deposits to be less than 2 metres in thickness. The alluvial sand deposits comprise approximately 10 - 15% of each of the watershed areas.

Minor deposits (<5%) of nearshore marine sand and gravel lie along the southernmost flanks of the Watts Creek Watershed overlying the shallow/exposed Paleozoic bedrock uplands. The surficial geology within the upper reaches of the Watts Creek Watershed is somewhat more varied compared to the other areas and includes exposed or shallow bedrock (10%) offshore marine deposits (15%), alluvial sand (10%), and organic deposits (<5%). The organic and offshore marine deposits typically occupy low lying areas between the exposed bedrock outcrops and ridges.

2.3.3.2 Bedrock Geology

The bedrock geology as defined by Williams (1991) is shown in Figure _____ ***(To be provided.)*** while the bedrock stratigraphy, from youngest to oldest, is listed in Table 2.2

TABLE 2.2
BEDROCK STRATIGRAPHY

Age	Formation	Rock Type
Lower Ordovician	Oxford Formation	Dolostone
	March Formation	Interbedded quartz sandstone, sandy dolostone, and dolostone
Cambro-Ordovician	Nepean Formation	Fine to coarse grained quartz sandstone
	Covey Hill Formation	Fine to coarse grained quartz sandstone and quartz pebble conglomerate.
Precambrian	Undifferentiated	Granite, gneiss, and marble.

Precambrian bedrock outcrops predominate in the upper reaches of the Shirley Brook Watershed and throughout most of the Kizell Drain Subwatershed. The Precambrian lithologies are comprised of crystalline igneous and metamorphic rocks. Rock types present include granite, granodiorite, granitic gneiss, marble, mafic gneiss, amphibolite, monzonite, syenite, and diabase. The Precambrian bedrock unit unconformably underlies all other Paleozoic bedrock units where it is not mapped at the surface.

The Covey Hill Formation occurs as a pavement outcrop in the middle reaches of the Watts Creek Watershed. The unit unconformably overlies the Precambrian bedrock and consists of interbedded non-calcareous quartz-pebble conglomerate and fine to coarse grained quartz sandstone. The sandstone is poorly to well sorted and ranges from light grey to reddish brown to green. The conglomerate ranges from light to dark grey to reddish brown with angular and sub-rounded to rounded clasts.

The Nepean Formation outcrops along the southern and western portions of the Watts Creek Watershed and as a narrow fault block in the northern portion of the Shirley's Brook Watershed. The Nepean Formation conformably overlies the Covey Hill Formation and consists primarily of medium grained, well-sorted quartz sandstone. Fine grained beds predominate in the upper part of the formation and interbeds of quartz pebble conglomerate occur locally.

The March Formation outcrops throughout most of the Shirley's Brook Watershed and as a narrow fault block near the middle reaches of the Watts Creek Watershed. The formation consists of interbedded quartz sandstone, sandy dolostone, and dolostone. This unit conformably overlies the Nepean Formation and is a gradational between the Nepean Formation and overlying Oxford Formation.

The Oxford Formation outcrops in the northern in the lower reaches of the Watts Creek Watershed and along the northeast portion of the Shirley's Brook Watershed. The formation conformably overlies the March Formation and consists of a light to dark grey, thin to thick bedded, sublithographic to fine crystalline dolostone with shale interbeds.

The study area is transected by numerous steeply dipping normal faults and fault zones striking southeast to east-northeast. Formation bedding, normally close to horizontal throughout the Paleozoic units, often dips steeply adjacent to faults and within the fault zones. Fault traces are generally straight, but commonly curve in the vicinity of fault junctions. Throughout most of the study area these faults act as geological boundaries between the various Paleozoic formations, the differing unit exposures and outcroppings resulting from varying fault displacements.

2.3.4 Hydrogeology

2.3.4.1 Groundwater Usage

Owing to the relatively thin and/or low yield nature of much of the overburden deposits, the vast majority (>98%) of the wells within the study are reportedly completed within bedrock. In fact, only 4 of the 276 water wells identified in the study area reportedly obtain water from an overburden aquifer. In all four wells, groundwater is obtained from a basal gravel layer overlain by varying thicknesses of marine clay. These basal aquifers consist of small, discontinuous accumulations with local bedrock depressions.

The vast majority of the water wells were completed prior to urbanization of the study area and are located along the major and minor arteries such as Carling Avenue, Hazeldean Road, Eagleson Road, and March Road. It is likely that many of the wells within the urbanized areas no longer serve a primary use owing to the servicing of these area with municipal water. The rural areas of the Shirley's Brook Watershed will more than likely remain dependent upon groundwater resources, depending upon future municipal servicing initiatives.

Several significant moderate to high yield Paleozoic bedrock aquifer units have been identified in the study area including the Nepean, March, and Oxford Formations (Geo-Analysis, 1976). Well yields for the Nepean and March Formations range from 13 to greater than 50 litres per minute.

The water quality within the Nepean, March, and Oxford Formations is generally potable, however, iron and manganese generally exceed the MOEE Drinking Water Aesthetic Objectives.

2.3.4.2 Groundwater Flow

Groundwater flow within the crystalline Precambrian rocks is restricted to secondary permeability features including fractures and joints. The fractures and joints are typically tight and small. The fracture porosity typically decreases with depth, consequently an increased well depth is likely to result in increased well yields unless permeable faults and/or fracture zones are encountered.

Groundwater flow in the Nepean and March formations occurs through the fractures and joints and through intragranular (primary) porosity. Groundwater flow within the Oxford Formation occurs primarily along fractured bedding planes and bedding joints (Geo-analysis, 1976). The carbonate rock itself is not sufficiently porous to support intragranular flow.

The regional bedrock groundwater flow regime, interpreted from the static groundwater elevations as reported in the MOE water well database is depicted in Figure _____ ***(To be provided.)***. In general, the groundwater flow paths mimic the topography suggesting that groundwater flow in the area is topographically driven. Groundwater flow for the most part is to the northeast towards the local discharge areas, namely Shirley's Bay and the Ottawa River. Variations in the regional groundwater flow regime occur locally. In the upper reaches of the Kizell Drain subwatershed, groundwater flows radially in response to the local topography.

A major linear bedrock groundwater recharge area lies within the March Highlands parallel to and immediately east of the March Ridge within the upper reaches of the Shirley's Brook Watershed. Several smaller bedrock recharge areas lie within the upper reaches and along the east flank of the Watts Creek Watershed where the overburden cover is relatively thin. However, much of the recharge potential within the shallow bedrock regions of the upper reaches of the Watts Creek Watershed has been lost due to urban development. Minor groundwater recharge also occurs along sand units, particularly in the lowland area, however their extent is limited.

Infiltration capacities for the Nepean and March Formations have been estimated at 90 to 135 mm/year (Geo-analysis, 1992). Similar rates of infiltration have been estimated for the Oxford Formation owing in part to solution cavities commonly observed in outcrop exposures.

2.4.4.3 Groundwater and Baseflow

Baseflow is recognized as an important contributor to the biological habitat quality and to the structure of aquatic ecosystems identified in Shirley's Brook, Watts Creek and the Kizell Drain. Groundwater discharge is crucial to the maintenance of baseflow and to buffering thermal changes that could otherwise impact aquatic habitat (MOEE, 1991b). In addition, high baseflow conditions can help assimilate pollutants found in urban storm water, treatment plant effluent and agricultural runoff.

Given the physiography and the nature and thickness of the overburden materials the groundwater discharge (baseflow) contributions to streamflow are anticipated to be relatively minor in terms of quantity throughout the study area. While the volume of baseflow may be low, the contribution to the overall streamflow is significant owing to the relatively low flows.

Throughout most of the study area, stream channels are incised into silt and clay deposits. While various geotechnical studies completed throughout the study area report a relatively high water table throughout these deposits (approximately 1 to 2 metres below grade), the hydraulic conductivities of such deposits are characteristically low and as such lead to relatively low groundwater flow and discharge rates.

A field reconnaissance will be carried out to assess the physical characteristics of the stream channels as well as to establish a preliminary understanding of the groundwater/surface water interaction. Baseflow contributions to streamflow can be assessed through analysis of the streamflow data recorded at the various monitoring stations with the subwatershed areas.

A more accurate assessment of the groundwater/streamflow interaction can be carried out through the installation of seepage meters or mini-piezometers. These devices allow both qualitative and quantitative assessment of groundwater recharge/discharge conditions throughout the stream channel area. Field locations for the installation of seepage meters and/or mini piezometers will be identified during the preliminary field reconnaissance. The data obtained from the field can be used to characterize the groundwater baseflow conditions throughout the subwatershed areas and provide valuable input to the water balance model.

An assessment of the baseflow characteristics for each watershed can be used to evaluate the potential impacts to each watercourse through loss of precipitation infiltration and groundwater recharge as a result of increased urban development.

2.3.5 Surficial Soils

Surficial soils information for Shirley's Brook/Watts Creek Watershed was abstracted from 1:50,000 scale maps, *"Soils of the Regional Municipality of Ottawa Carleton"* (Schut et. al, 1987) and from 1:25,000 scale maps, *"Soils of Gloucester and Nepean Townships, Carleton County"* (Marshall et. al, 1979) prepared by the Ontario Ministry of Agriculture and Food.

The surficial soils within the Shirley's Brook/Watts Creek Watershed vary considerably as series of bands more or less aligned in a north-south direction across the Watershed.

The upper reaches of Shirley's Brook and the Kizell Drain are underlain by Rockland (land unit). Areas mapped as Rockland are characterized by exposures of Paleozoic or Precambrian bedrock constituting 25% or more of the area. Soils are generally well-drained coarse textured soils, less than 50 cm thick (Schut et. al, 1987). Significant areas of marshland occur in depressional areas of these land units, which tend to retain water and impede surface runoff.

The upper-mid reaches of the Shirley's Brook/Watts Creek Watershed west of March Road are dominated by sandy loam or loam soils. Soils with this texture include the Nepean soils among others, which have been developed on sandstone or quartzite bedrock (Schut et. al, 1987). The soils are moderately coarse to coarse textured and typically are less than 30 cm thick. They occur on topography which is very gently sloping ranging from 2 to 5%. The coarse textured soils are well drained owing to their low water holding capacities and relatively high permeability that combine to result in moderate surface runoff rates. Also present in this vicinity, running along March Road, is a band of finer textured, silty clay loam and clay loam deposits associated with the Dalhousie soil association. These soils occupy level or nearly level topography ranging from 0 to 2%. Generally, the soils have high moisture capacity and medium permeability, which may have been significantly reduced due to compaction of heavy farming equipment. Internal drainage may be further slowed by high water table conditions resulting from groundwater discharge and surface runoff. In areas of flat topography, surface runoff is expected to be slow to moderate.

The area between March Road and Fourth Line Road, and progressing further to the east is underlain by a band of coarser textured fine sand or loamy fine sand soils. Soils with this texture include the Jockvale, St. Thomas, Castor and Uplands soils among others. Although the soils have moderate permeability and low moisture holding capacity, they tend to be poorly drained, reflective of higher local watertables caused by impermeable substratum and lateral seepage from surrounding soils (Schut et. al, 1987). In these situations, surface runoff rates are expected to be slow.

The lower reaches, east of Fourth Line Road and extending to the Ottawa River are underlain by heavy clay marine deposits of the Rideau soil association. The soils have a moderately high clay content, which averages 70%. As with the Dalhousie soils, these soils occupy nearly level slopes ranging from 0 to 2%. Rideau soils exhibit poor drainage and tend to be saturated for extended periods during the growing season (Schut et. al, 1987). Consequently, surface runoff is expected to be very slow.

The soils associated with the watercourse systems of Shirley's Brook and Watts Creek (*i.e.*, Eroded Channel) are comprised of undifferentiated material developed on steeply sloping valley side walls; the result of past and present erosion. Texture of the soils is variable and ranges from coarse textured soils on the valley side walls to finer textured soils (clays) on the flood plains. Drainage of the soils is highly variable; from rapid on the steep side walls, to poorly drained on the channel bottoms. Soils situated on the floor of the creeks are subject to stream flooding as well as excess wetness due to high water tables and/or impermeable subsoils.

2.4 Surface Water Quality

2.4.1 Scope of Data Review

To assist in the characterization of water quality conditions, the RMOC, MOE and MVCA were contacted for water quality monitoring data pertaining to the Shirley's Brook and Watts Creek watercourses. Neither the MOE nor the MVCA had recent (i.e. within the last 20 years) surface water quality monitoring data. However, data previously collected and published by the RMOC was obtained and reviewed. Table 2.3 lists the relevant stations on Shirley's Brook and Watts Creek and their associated tributaries, within the watershed, for which surface water quality data was available. The locations of these stations are shown on Figure _____ *(To be provided.)*. reference 2.5.6

TABLE 2.3
SUMMARY OF AVAILABLE RMOC SURFACE WATER QUALITY DATA

RMOC Station		Sampling Period		[1]Parameter Group Analyzed				
Name	Station ID	Starting (Y/M/D)	Ending (Y/M/D)	G	I	N	B	Tr
Shirley's Brook								
4th Line / Hertzberg Rd.	CK5 - 001	93/6/8	97/12/1	x	x	x	x	x
Main tributary to pond (Ottawa Duck Club)	CK5 - 002	93/6/8	94/8/17	x	x	x	x	x
Klondike Rd.	CK5 - 003	93/6/8	94/8/17	x	x	x	x	x
March Rd., tributary west of Solandt Rd.	CK5 - 004	93/6/8	94/8/17	x	x	x	x	x
March Rd., tributary west of Old Carp Rd.	CK5 - 005	93/6/29	94/8/17	x	x	x	x	x
March Rd., tributary west of CK5 - 005	CK5 - 006	93/6/29	94/8/17	x	x	x	x	x

TABLE 2.3
SUMMARY OF AVAILABLE RMOC SURFACE WATER QUALITY DATA

RMOC Station		Sampling Period		[1]Parameter Group Analyzed				
Name	**Station ID**	**Starting (Y/M/D)**	**Ending (Y/M/D)**	**G**	**I**	**N**	**B**	**Tr**
Watts Creek								
Shirley Blvd	CK6 - 001	93/2/7	97/12/1	x	x	x	x	x
Carling Avenue (east)	CK6 - 002	93/2/7	94/12/8	x	x	x	x	x
Burke Rd.	CK6 - 003	93/2/7	94/12/8	x	x	x	x	x
Carling Avenue (west)	CK6 - 004	93/2/7	94/12/8	x	x	x	x	x
Hertzberg Rd.	CK6 - 005	93/2/7	94/12/8	x	x	x	x	x
Legget Rd.	CK6 - 006	93/2/7	97/12/1	x	x	x	x	x
March Rd	CK6 - 007	93/2/7	94/12/8	x	x	x	x	x
Walden Rd	CK6 - 008	93/2/7	94/12/8	x	x	x	x	x
Watts Creek - Connaught Tributary								
Shirley Blvd.	CK6 - 101	93/2/7	94/12/8	x	x	x	x	x
Water Tower Rd.	CK6 - 102	93/2/7	94/12/8	x	x	x	x	x
Watts Creek - Watts Tributary								
CPR	CK6 - 301	93/2/7	94/12/8	x	x	x	x	x
Corkstown Rd.	CK6 - 302	93/2/7	94/12/8	x	x	x	x	x
Hearst Way	CK6 - 303	93/2/7	94/12/8	x	x	x	x	x
North-east branch	CK6 - 311	93/5/31	94/12/8		x	x	x	
South-east branch	CK6 - 321	93/5/31	94/12/8	x	x	x	x	x
Campeau Rd.	CK6 - 331	93/5/31	94/12/8	x	x	x	x	x
Watts Creek - Beaverbrook Tributary								
CPR	CK6 - 401	93/2/7	94/12/8	x	x	x	x	x
March Rd.	CK6 - 402	93/2/7	94/12/8	x	x	x	x	x
Beaverbrook Rd	CK6 - 403	93/2/7	94/12/8	x	x	x	x	x
Watts Creek - Hertzberg Tributary								
Legget Dr.	CK6 - 501	93/2/7	94/12/8	x	x	x	x	x
Hertzberg Rd.	CK6 - 502	93/2/7	94/12/8	x	x	x	x	x

Note: [1] Number and frequency of analyses for parameters in these groups varies.
G: General parameters
I: Major ions
N: Nutrients
B: Bacteria
Tr: Trace constituents (mainly metals)
x: Indicates parameter group available

The data consists of a standard set of parameters (i.e. generals, major ions, nutrients, bacteria and trace constituents) for one site on Shirley's Brook (CK5 - 001) and two sites on Watts Creek (Ck6 - 001 & CK6 - 006) collected on a monthly basis for the period between 1993 and 1997. The remaining data was collected between 1993 and 1994 at 5 sites along Shirley's Brook and its tributaries and at 19 sites along Watts Creek and its tributaries. For the most part, this composite of data covers the same standard set of parameters described above. All data collected represents a mix of dry weather and wet weather conditions.

2.4.2 Surface Water Quality Objectives

Provincial and federal guidelines for possible uses of the surface waters in the study area were used as a basis for assessing surface water quality. These include the use of the water by natural species, for agriculture and for recreation.

The source for the Provincial Water Quality Objectives (PWQO) was:

> *Water Management, Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy (MOEE, 1994).*

The source for the Ontario Drinking Water Objectives (ODWO) was:

> *Ontario Drinking Water Objectives, Ministry of the Environment and Energy (MOEE, Revised 1994)*

The source for the Canadian Water Quality Guidelines (CWQG) was:

> *Canadian Water Quality Guidelines, Canada Council for the Minister of the Environment (CCME, 1990)*

2.4.3 Surface Water Quality Data Review

The RMOC data collected covers a standard set of parameters. The list of parameters is divided into the following categories:

- general chemistry;
- major ions;

- nutrients;
- bacteriological indicators; and
- trace constituents.

A discussion of the parameters and collected data is presented below.

Temperature?

2.4.3.1 General Chemistry

This group of parameters, along with the major ions, describe the principal chemical character of the water and can be used to account for the majority of the dissolved and suspended matter in the water.

2.4.3.1.1 pH

The **pH** of the water indicates the acidic or basic (alkaline) character of water and varies with the partial pressure of carbon dioxide and concentration of algae in the sample.

The hydrogen ion concentration of a solution is reflected by its pH value which indicates its acidic (pH < 7) or basic (pH > 7) character. Depending on the buffering capacity of a natural water, there may be some diurnal variation in pH levels where photosynthetic aquatic organisms such as algae are present.

The pH levels for the Shirley's Brook and Watts Creek watercourses were found to vary between 7.9 and 8.5 for the most part, indicative of slightly alkaline waters within the watershed. The PWQO pH range for the protection of aquatic life is set at 6.5 - 8.5.

2.4.3.1.2 Conductivity

Conductivity is used as a surrogate for Total Dissolved Solids (TDS) and is a measure of a water's ability to carry electrical current. This ability is directly dependent on the amount of ionic species present and water temperature. TDS is related to hardness and alkalinity.

Conductivity reflects the ability of a water to carry an electric current through the variety of types and numbers of dissolved ion species present. Mineralization of rock provides the main source of these ions in natural waters. Some seasonal variation in conductivity may occur as the snowmelt release of sediments and road salt contribute to the overall ion concentration.

Data collected for Shirley's Brook and Watts Creek were generally below 1200 umhos/cm, acceptable for natural waters in this region.

2.4.3.1.3 Alkalinity

Alkalinity is a measure of the capacity of a water to neutralize acids. This is primarily provided by the concentration of ion species such as carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxides (OH^-). No set PWQO value is provided.

Alkalinity values for the subject watercourses were well within the drinking water criteria of 30 - 500 mg/L set by the ODWO, indicative of waters with "normal" alkalinities.

2.4.3.1.4 Total Suspended Solids

Total suspended solids (TSS) measures the amount of particulate matter found in a water sample. High levels of suspended solids may be undesirable for aquatic life, industrial supply and as a source for potable water. As well, high solids concentrations may provide nutrients to microorganisms, causing algae or other aquatic organisms to flourish and deplete dissolved oxygen levels.

Total suspended solids levels were generally higher and exceeded the MNR guideline of 80 mg/L for warm water fisheries at monitoring stations located within the more urbanized areas of the watersheds (i.e. CK5 - 004 on Shirley's Brook and CK6 - 001, 006, 008, 102, 201, 303 and 401 along Watts Creek). Quantify exceedance

2.4.3.2 Major Ions

Along with carbonate and bicarbonate which make up alkalinity, these comprise the bulk of the dissolved material in the water and some of the specific parameters are of regulatory concern. With the exceptions of nitrate and phosphate, the major ions are conservative, *i.e.* their concentrations do not change significantly in physical, chemical or biological processes in water. As such, they can be used to detect gross inputs from human activity.

The major ions for which data was available include: chloride, sulphate, sodium, magnesium, calcium, and potassium. All of these parameters were, for the most part, below criteria levels where criteria levels were available.

2.4.3.3 Nutrients

Concentrations of these substances can reflect agricultural activity, sewage discharges and normal seasonal biological activity in the river and drainage areas. They affect and reflect biological activity in the watercourses, particularly the capacity for algal growth. Algal growth, in turn, affects properties such as pH, dissolved oxygen and alkalinity.

2.4.3.3.1 Nitrogen

Nitrogen is an essential nutrient for plants and animals, and can be found naturally in various forms in the atmosphere, hydrosphere, lithosphere and biosphere. The chemical and physical transformations that nitrogen undergoes within and between these "spheres" is known as the nitrogen cycle. The common forms by which nitrogen may be found in natural waters are discussed individually and include (in order of decreasing oxidation state):

- nitrate;
- nitrite;
- ammonia; and
- organically-bound nitrogen.

Anthropogenic activities such as the burning of fossil fuels, primarily from automobile engines, contribute to atmospheric inputs of nitrous oxides. As well, high nitrogen levels may be expected following the snowmelt periods of early spring.

2.4.3.3.2 Nitrate and Nitrite

Nitrates are primarily derived from atmospheric nitrogen through a sequence of conversions that ultimately result in the complete oxidation of nitrogen compounds to nitrate. Nitrates are found in almost all natural waters at concentrations that do not exceed 5 mg/L (as N), that have not been contaminated. However, concentrations above 2 mg/L (as N) may be indicative of external sources of contamination that may include fertilizers, municipal wastewater, drainage from barnyards, feedlots, septic systems and cesspools.

No PWQO exist specific to nitrate levels, however, the CWQG criteria for aquatic life suggest nitrate levels be maintained so as to "avoid prolific weed growth".

One form in which nitrogen occurs in water is as nitrite, however, unlike nitrate, this is an unstable form and is typically found in very low concentrations in aerated waters.

The data reviewed did not differentiate between nitrate and nitrite compounds as results were presented for all NOx forms. Consequently, no comparative analysis with any of the guidelines is feasible.

2.4.3.3.3 Ammonia

Ammonia/ammonium ion is naturally present in surface waters, and is formed through the microbiological decay of nitrogenous organic matter (plant and animal waste) by a process known as ammonification. It may also be produced by the hydrolysis of urea (a waste product of animal metabolism) and through the reduction of nitrate by certain types of nitrifying bacteria, under anaerobic conditions. The use of inorganic fertilizers high in ammonia, nitrate or both, also greatly contribute to increased ammonia/ammonium ion levels in watercourses intercepting surface runoff and drainage from agricultural lands. Depending on the pH of the water, the ammonium ion may remain in solution (at pH < 7), or it may dissociate into ammonia gas and excess hydrogen ions if the pH rises above seven. As ammonia gas dissolved in water is known to compete for space normally occupied by dissolved oxygen, excessive levels of ammonia gas can be detrimental to aquatic life forms, and result in fish kills.

The data reviewed for the un-ionized portion of total ammonia (calculated using total ammonia, temperature and pH) indicate that the PWQO of 0.020 mg/L for un-ionized ammonia was not exceeded at any of the monitoring stations.

Additionally, where data was available for comparison, the total ammonia CWQG criteria for the protection of aquatic life forms set at 1.37 - 2.2 mg/L was exceeded at three locations (Ck6 - 004, 005 and 006) along the Watts Creek watercourse on October 13, 1994. As these results are out of line with the consistently low levels detected at all other times and monitoring stations, this data should be considered unrepresentative of typical conditions and regarded as an anomaly.

2.4.3.3.4 Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) is commonly used analytically to reflect the degree of nitrogenous matter present in the form of ammonia and all organically bound nitrogen. The normal range for TKN in waters not influenced by organic inputs is between 0.1 - 0.5 mg/L. The data review indicated TKN levels for both watercourses below this criterion.

2.4.3.3.5 Total Phosphorus

Phosphorus compounds are released into natural waters through the erosion and solution of phosphorus containing rocks. It is a constituent of many important biological molecules such as DNA and also found in the membrane structure of cells and in the bones and teeth of animals. Through the decomposition of organic matter (detritus and animal waste), phosphorus is recycled back into a dissolved form available for uptake again by plants and animals. Other significant sources of phosphorus and phosphates in surface waters include fertilizers, domestic and industrial effluents, domestic detergents, agricultural and urban drainage.

Although there is no firm objective for phosphorus, a guideline of 30 ug/L has been set by the Ministry of Environment to avoid excessive plant growth in rivers and streams. Excessive algae or aquatic plant growth is a direct consequence of elevated levels of phosphorous or phosphates in runoff.

Total phosphorus levels generally exceeded the MOEE's PWQG guideline of 30 ug/L at all monitoring stations for both watercourses. High total phosphorus levels are typically tied in with nearby agricultural activities that lead to the interception with watercourses of surface runoff and field tile drainage systems.

2.4.3.4 Bacteriological Indicators

The bacteriological indicators of water quality reviewed in this study provide another measure of surface water quality. Data for the two indicators (*Escherichia coli* and faecal coliform) are of regulatory interest as they reflect waste discharge from human and/or animal sources.

2.4.3.4.1 Escherichia coli (E. coli)

A wide variety of microorganisms are commonly found in water, most being of no health significance. However, since *E. coli* occurs in great numbers in the intestinal tracts of warm blooded animals and is prevalent in faecal matter and sewage, it serves as a good indicator of recent faecal contamination. Though *E. coli* itself is harmless to humans, its presence may be indicative of other pathogens. For this reason, the Ontario Ministry of the Environment has adopted *Escherichia coli* as the indicator of faecal contamination for recreational use of surface water, and has set an objective of 100 *E. coli* per 100 ml. For the most part, the data reviewed indicates an exceedance of this level at all of the monitoring stations. quantify

2.4.3.4.2 Faecal Coliforms

Although new compliance monitoring and enforcement activities of the Ministry are to be based on *E. coli*, Faecal Coliforms can be used to monitor trends where long-term records exist. The former guideline for Faecal Coliforms was 100 counts per 100 mL. Results for Faecal Coliforms show exceedances at all monitoring stations, especially at those within agricultural areas of the watershed.

2.4.3.5 Trace Constituents

Trace constituents are either toxic to a variety of life forms or are aesthetically displeasing. These are found in surface waters as a result of human activity and from natural sources. Modern analytical methods can detect small changes in these constituents from background levels, and along with some trace organics provide a good indication of problematic discharges.

The concentrations of the trace constituents reviewed were generally below the available PWQO. The exceptions were for aluminum, iron, copper, zinc, lead, manganese, vanadium and cobalt.

Based on the data collected, aluminum and iron levels exceeded the PWQO on a number of occasions at just about all the monitoring stations. Sources of aluminum and iron in surface waters include the weathering of rocks, sewage, and industrial wastewater discharges. Iron may also be introduced through the corrosion of iron and steel.

Copper is an essential element in plant and animal metabolism, and is derived from the weathering of rocks. Many industries use copper extensively, resulting in its eventual dispersal in the environment. PWQO exceedances of copper levels were found at very few of the monitoring stations along Shirley's Brook and Watts Creek.

Zinc is an essential element in plant and animal metabolism, however, in animals, it is primarily obtained through dietary sources other than water. Zinc is commonly used in galvanizing and as a constituent of white pigment in paint and rubber, leading to its release to the environment through these applications. Based on the available data, zinc levels generally exceeded the PWQO level for zinc on a few occasions throughout the two watershed areas.

Manganese is a transition element that rarely exceeds 1 mg/L in natural waters. It is an essential macro-nutrient for both plants and animals, however, large doses of manganese in humans can result in liver damage in humans. Although no PWQO criterion exists for manganese, the ODWO criterion of 0.05 mg/L and the CWQO criterion of 0.2 mg/L for irrigation water were generally exceeded at both the Shirley's Brook and Watts Creek monitoring stations.

At trace levels, cobalt is an essential element in plant and animal nutrition. Cobalt levels were found to marginally exceed the interim guideline PWQO of 0.0006 mg/L in a few instances at the Shirley's Brook and Watts Creek watercourses.

2.4.4 Summary of Surface Water Quality Conditions

→ TABULAR FORM (range of data, noting anomalies)

The characterization of the surface water quality conditions within the Shirley's Brook and Watts Creek watersheds is based on long term data collected by the RMOC Surface Water Quality Branch. The data represents a mix of dry weather and wet weather conditions.

In summary, the accumulated data indicates that the watersheds have been impacted by human activities. On a rather consistent basis, total phosphorous, *E. coli* bacteria and faecal coliforms were found at levels above PWQO or the typical ranges described above. These are indicative of agricultural activities which may include fertilizers, manure runoff, livestock wastes, leaching of septic systems and soil erosion which can release these nutrients and bacteria into streams. Continued high levels of organic compounds and nutrients may lead to excessive growths of aquatic plants (*e.g.* algae and macropytes) and ultimately to the depletion of dissolved oxygen in the watercourse. Low DO levels can be detrimental to most native aquatic species.

The elevated levels of sodium, iron, aluminum, cobalt, manganese, zinc and chloride are indicative of inputs from natural weathering of rocks and urban activities such as road salting. These constituents pose no threat to humans for recreational purposes, however excessively high levels may be detrimental to aquatic life.

As indicated in Table 2.3, monthly data between 1993 and 1997 has been collected by the RMOC at a point downstream of all major tributaries (monitoring station CK5 - 001), just prior to discharge to the Ottawa River. This data set reflects the cumulative water quality conditions of the watershed. Additional background data specific to the areas of development would provide a clearer indication of water quality conditions prior to any new development.

Similarly, water quality data has been collected for Watts Creek on a monthly basis between 1995 and 1997 at two locations (CK6 - 001 and CK6 - 006) in the more rural areas of the watershed. This amount of data is sufficient to present background water quality conditions for this watercourse.

Future water quality monitoring programs should broaden the scope of analytical parameters to include oil and grease, total organic carbon (TOC) and biological oxygen demand (BOD) data and field dissolved oxygen measurements to assist in the characterizing of the waters.

2.5 Surface Water Hydrology

2.5.1 Methodology

The surface water hydrology within the Shirley's Brook/Watts Creek Watershed study area was characterized and assessed from a variety of background information sources, field reconnaissance and inventories of hydraulic structures. In addition, both continuous and discrete measurements of streamflows, water and air temperatures were collected. Analytical calculations including hydrologic and hydraulic computer modelling were used to quantify hydrologic conditions in terms of surface water drainage.

The principle watercourse systems identified and assessed in the study area are discussed according to the following groups:

- Shirley's Brook, including two principal (unnamed) tributaries;
- Watts Creek; and,
- Kizell Drain; the main tributary to Watts Creek.

(Note: As data is still to be collected, the following is more of an approach description than a description of existing conditions. It will be completed in September.)

2.5.2 Surface Water Drainage

Surface water drainage in the study area is accomplished through numerous gullies, streams and creeks of varying size and with different characteristics. For each of the principle watercourse tributaries, selected physical and hydraulic characteristics were recorded. In addition both continuous discrete measurements of streamflow and continuous measurements of water temperature were collected during the 3 month monitoring period.

During the May and June, 1998 field reconnaissance, baseflow was identified in the three main watercourses listed above. Many of the numerous other small feeder streams and creeks are expected to convey baseflow during the spring and fall months, but for the most part, were found to be dry during the summer months between rainfall events.

2.5.2.1 Shirley's Brook

reference figure

2.5.2.1.1 Main Branch

At its outlet into the Ottawa River, Shirley's Brook drains a total upstream watershed area of approximately 26 km^2. The main branch of Shirley's Brook begins north of Goulbourn Forced Road. From this location, Shirley's Brook conveys drainage from predominately forested lands and meanders approximately 950 m passing beneath a Power Transmission Corridor at which point it enters the west boundary of the Kanata North Business Park. The Brook continues another 500 m in a northeasterly direction where it is conveyed beneath Hines Road via a galvanized steel culvert. From Hines Road, Shirley's Brook continues northeasterly 200 m where it is conveyed beneath March Road via a concrete box culvert. 500 m downstream of March Road, Shirley's Brook turns abruptly and continues through the Business Park in a northwesterly direction 320 m, where it enters the first of a series of on-line storm water management wet ponds.

The first pond has provision for a high level overflow into a second off-line pond that outlets under Terry Fox Drive via an elliptical galvanized steel culvert. From Terry Fox Drive, the Brook flows 500 m through a straightened reach, passing under Shirley's Brook Drive via a culvert crossing. The culvert directs Shirley's Brook into an on-line storm water management wet pond that services portions of the South March residential subdivision. Exiting the pond, Shirley's Brook flows approximately 450 m through residential and agricultural lands to Klondike Road.

During the May and June, 1998 field reconnaissance, a well flowing under artesian conditions was observed discharging into the Brook approximately 250 m upstream of Klondike Road. The well discharge was significant enough to augment the baseflow in Shirley's Brook.

From Klondike Road, Shirley's Brook continues 300 m through a treed valley where it is joined by Tributary 1. From its confluence with Tributary 1, Shirley's Brook turns abruptly and flows northeast for 1200 m, passing first under the CNR line via a twin cell concrete box culvert and then under Fourth Line Road via a concrete box culvert. Downstream of Four Line Road, the Brook turns northeast and flows parallel to Four Line Road through DND lands for a distance of 2200 m. At this point, the Brook turns due east and meanders 2000 m through a large wetland before its outlet into the Ottawa River.

2.5.2.1.2 Tributary 1

Tributary 1 begins at March Road (East-West) and flows 1900 m southeasterly through agricultural lands as a small creek where it passes beneath March Road (North-South) via a concrete box culvert. From March Road, Tributary 1 continues in a southeasterly direction an additional 900 m where it is joined by Tributary 2. Downstream of its confluence with Tributary 2, Tributary 1 flows 400 m, joining the main branch of Shirley's Brook 300 m north of Klondike Road.

2.5.2.1.3 Tributary 2

Tributary 2 begins as small wetland immediately south of Old Carp Road. After passing beneath Old Carp Road via a corrugated metal culvert, the Tributary crosses beneath Second Line Road and flows 1600 m eastward through agricultural/rural residential lands where it passes beneath to March Road via a concrete box culvert. From March Road, Tributary 2 continues easterly 250 m where it joins the Tributary 1.

2.5.2.2 Watts Creek

At its outlet into the Ottawa River, Watts Creek drains a total upstream watershed area of approximately 14 km^2. Watts Creek originates at Castlefrank Road situated in Katimavik/Hazeldean. From Castlefrank Road, the Creek meanders 1700 m northward through several residential subdivisions passing beneath several roadway culverts that include: Chimo Drive, Katimavik Road and Hearts Way. At this location, Watts Creek is conveyed through the Highway 417/Eagleson Road Interchange a total distance of 700 m to Corkstown Road via several ramp and highway culverts. After passing beneath Corkston Road via a corrugated metal arch culvert, Watts Creek meanders considerably 1700 m through agricultural lands before passing beneath the CNR line via a concrete box culvert. From the CNR line, Watts Creek turns and continues easterly 250 m westerly where it is joined by the Kizell Drain. Approximately 500 m further eastward, the Creek passes beneath another CNR line via a concrete box culvert. At this point, Watts Creek turns and flows north 700 m to Carling Avenue, passing beneath it via a concrete bridge structure. From Carling Avenue, the Creek flows 600 m through Defence Research lands where it is conveyed under Sandhill Road via a concrete box culvert. Continuing northward, Watts Creek meanders considerably for 2000 m passing first under Shirley Boulevard before outletting into the Ottawa River.

2.5.2.3 Kizell Drain

The Kizell Drain system is the second largest tributary discharging to Watts Creek. At its confluence with Watts Creek, the Kizell Drain subwatershed drains a total upstream area of approximately 9 km^2. The Drain originates at the outlet of Beaver Pond which discharges Pond flows via a bottom draw outlet structure into a vegetated ravine gully that has been channelized with quarried stone. From the Pond, the Kizell Drain flows north 350 m passing beneath the CNR line via a concrete box culvert. The Drain then continues northeasterly 1700 m through the Kanata North Business Park passing beneath several roadway culverts that include: Station Road, March Road and Legget Drive. From Legget Drive, the Kizell Drain flows eastward 250 m crossing beneath Hertzberg Road. The Drain continues eastward 500 m passing first under Carling Avenue, then under the CNR line. From the CNR line, Kizell Drain flows the remaining 950 m eastward where it joins into Watts Creek.

2.5.3 Municipal and Tile Drainage Systems

Artificial land drainage through the construction/installation of tile drainage systems is quite prevalent in the mid-reaches of the Watts Creek Watershed. Only a very small parcel of land situated along Fourth Line Road in the Shirley's Brook Watershed has been tile drained. Tile drainage information was abstracted from 1:25,000 scale *"Artificial Drainage System"* maps for the RMOC prepared by the Ontario Ministry of Agriculture and Food (OMAF, Revised 1996).

The majority of tile drained areas within Watts Creek Watershed are located east of Hertzberg Road between Carling Drive/CNR and Corkstown Road. The drains have been installed to drain isolated wet areas of agricultural fields, improve the soil structure and increase crop productivity.

2.5.4 Hydraulic Structures

A complete inventory was compiled of all the bridges, culverts and storm sewer outfalls situated within the Shirley's Brook/Watts Creek Watershed. For each structure, selected physical and hydraulic characteristics were recorded. The following information was recorded:

The physical and hydraulic characteristics

- size;
- shape;
- length;
- material;
- flow depth; and
- observations of flow, erosion and/or structural conditions.

At each location, photographs were taken and an inventory summary sheet completed. ***(To be provided.)***

2.5.5 Streamflows

Streamflows reflect the time variation in discharges and are characterized by their frequency (how often they occur), their duration (how long they last) and their magnitude (how large they are). Streamflows include peak flows generated from surface runoff caused by rainfall and snowmelt events, as well as groundwater discharges that appear as baseflow. An average year may include approximately 40 runoff producing storms (Gehrels and Mulamoottil, 1990).

The entire range (or regime) of streamflows (i.e., their frequency, magnitude and duration) controls many of the natural and ecological functions that occur in the creeks and streams present in the Watersheds. Low streamflows (or baseflow) sustain aquatic and terrestrial ecosystems in periods of no rain or runoff. Moderate streamflows (recurrence interval between 1:0.5 and 1:1.5 years) control the natural evolution of channel shape and form through erosion (MacRae and Rowney, 1992). Seasonal flooding, caused by spring freshets or rainfall storms, serves to infuse floodplains and wetlands with nutrients and sediments, and provides spawning opportunities for some fish species. High streamflows caused by snowmelt events and/or extreme rainfalls events, such as the 100-year event may result in Natural Hazards and a risk to human life and property.

2.5.5.1 Shirley's Brook

Continuous measurements of streamflow were recorded at one location in Shirley's Brook upstream of Fourth Line Road. Data was collected and compiled over the 3 month monitoring period. In addition, bi-weekly spot measurements of flow were collected at the following locations:

- Tributary 1: at March Road;
- Tributary 2: at March Road; and
- Main Branch: at Hines Road.

2.5.5.2 Watts Creek

Continuous measurements of streamflow were recorded at one location in Watts Creek upstream of Corkstown Road. In addition, bi-weekly spot measurements of flow were collected at Carling Road.

2.5.5.3 Kizell Drain

Continuous measurements of streamflow were recorded at one location in the Kizell Drain downstream of Carling Avenue. In addition, bi-weekly spot measurements of flow were collected at the outlet of the Beaver Pond

(Results to be provided.)

2.5.6 Water Temperature

Continuous measurements of water temperature were recorded for 7 locations in the Shirley's Brook/Watts Creek Watershed study area during the monitoring period. The locations included the following:

- Shirley's Brook
  - Main branch @ CNR (upstream of 4th Line)
  - Main branch @ Hines Road
  - Tributary 2 @ March Road

- Watts Creek
  - @ Corkstown Road
  - @ Carling Avenue

- Kizell Drain
  - @ Outlet of Beaver Pond
  - @ Carling Avenue.

Air temperatures, recorded by the Atmospheric Environment Service (AES) at the Ottawa International Airport were also obtained for the same monitoring period to provide a comparison to recorded streamflow temperatures.

Discussion of cool water potential in upper reaches

(Results to be provided.)

2.5.7 Surface Water Use

(To be provided.)

2.5.8 Flood Line Mapping

Flood plain maps delineating the Regulatory Storm Flood Plain along portions of Shirley's Brook and Kizell Drain have been prepared in 1985 by the MVCA (A.J. Robinson & Associates, 1985) as well as Watts Creek (Chrysler & Lathem Ltd, _). The mapping extends along Shirley's Brook from upstream of Goulbourn Forced Road to it's outlet into the Ottawa River; Kizell Drain from upstream of the Beaver Pond to it's confluence with Watts Creek; and, Watts Creek from upstream of Highway 417 to the Ottawa River. In 1989, the previous hydrologic and hydraulic computer models were updated and the flood levels were recomputed to reflect the anticipated urbanization and the planned storm water management facilities with the Watershed.

New flood plain mapping along Shirley's Brook and portions of Watts Creek is anticipated to be conducted in the fall of 1998 (Personal Communications; J. Price, 1998). For the purposes of this Study, the MVCA 1989 mapping was obtained and reviewed to provide insight into the identification of natural hazard areas associated with flooding. In addition, several previous studies were reviewed to assist in the identification of existing flood prone areas resulting from hydraulic deficiencies, such as inadequate channel and/or culvert capacity.

Based on the background review, several flood susceptible areas were identified along Shirley's Brook, Watts Creek and the Kizell Drain. These areas are listed as follows:

2.5.8.1 Shirley's Brook

- Main branch, downstream of Fourth Line Road: out of bank flow due to insufficient channel capacity, proximity of flood plain to Fourth Line Road, and inadequate hydraulic capacity of the DND entrance culvert.

Figure 4

- Main branch, upstream of Fourth Line Road crossing: backwater, north spill zone across Fourth Line Road and south spill across Klondike Road due to inadequate hydraulic capacity of the Fourth Line Road culvert.

- Main branch, upstream of Terry Fox Drive crossing: out of bank flow and southeast spill zone to Kizell Drain due to insufficient channel capacity.

- Tributary 1, upstream of March Road crossing: backwater and overtopping of adjacent farm access road due to inadequate hydraulic capacity of the March Road culvert.

2.5.8.2 Watts Creek

- Main branch, upstream of Sandhill Road crossing: backwater and flooding of agricultural lands due to inadequate hydraulic capacity of the Sandhill Road culvert.

- Main branch, upstream of CNR crossing: backwater and flooding of agricultural lands extending upstream to bike path and second CNR culvert due to inadequate hydraulic capacity of the CNR culvert.

- Main branch, upstream of sewer-laneway crossing: overtopping of sewer-laneway and backwater extending upstream to bike path due to inadequate hydraulic capacity of the sewer-laneway culvert.

2.5.8.3 Kizell Drain

- Upstream of Carling Avenue crossing: backwater and flooding of upstream agricultural lands due to insufficient hydraulic capacity of the Carling Avenue culvert.

- Upstream of Hertzberg Road crossing: backwater and flooding of several buildings, Herztberg Road is overtopped due to insufficient hydraulic capacity of the Hertzberg Road culvert.

- Upstream of Legget Drive crossing: backwater and flooding of upstream agricultural lands due to influence of spill zone from Shirley's Brook.

2.5.9 Hydrologic Modelling

Hydrologic computer modelling of the Shirley's Brook/Watts Creek Watershed was conducted to characterize the existing '*local*' hydrologic regime. In addition, existing land use condition peak flows were determined to provide the basis of comparison for the future land use development scenarios. In this way, potentially adverse surface water impacts could be identified and assessed as part of the technical assessment of hydrologic process and natural systems.

The modelling included specific emphasis on the main watercourses associated with Shirley's Brook, Watts Creek and the Kizell Drain and includes both continuous and single event modelling, which are discussed below.

Continuous hydrologic computer modelling was conducted for the Shirley's Brook/Watts Creek Watershed. By simulating the response of the receiving watercourse continuously, year-round, the dominant hydrologic processes such as rainfall, snowpack accumulation, snowmelt, infiltration and runoff could be represented in the time series of predicted streamflows. Continuous simulation allows for the detailed accounting of antecedent soil moisture conditions, important for the prediction of runoff peak flows and volumes. Since continuous simulation uses actual long-term historic meteorologic data, the unique temporal variations inherent in the precipitation and temperature sequences are preserved. In this way, predictions of the various hydrologic responses unique to the Shirley's Brook/Watts Creek Watershed can be reproduced more accurately and more characteristically, resulting in a better basis for quantifying and evaluating potential surface water impacts arising from development or other changes in land use.

2.5.9.1 Methodology

The continuous modelling was carried out using the QHM computer model. The model, a predecessor to the original QUALHYMO model developed in 1983, was designed as a simple seasonal continuous water quantity/quality simulation model for lumped application in urbanizing Ontario river basins (Rowney and MacRae, 1992). QHM is a hydrologic computer model that can continuously simulate the rainfall/snowmelt-runoff processes from both rural and urbanized basins. The program responds to a time series input of precipitation and temperature and produces an estimate of the time-history of runoff (hydrograph). The runoff hydrographs determined by the model are a function of the precipitation data and the physical characteristics of the basin such as drainage area, slope, soil type and land use.

The QHM model included the entire Shirley's Brook/Watts Creek Watershed, including storage and channel routing elements to simulate the hydrologic response of Shirley's Brook, Watts Creek and the Kizell Drain, as well as Beaver Pond and several existing storm water management ponds. The model's snowpack accumulation and melt routines were calibrated using collected snow survey data from the MNR Bells Corners Station. Streamflow data collected during the monitoring phase of this study were used to calibrated the soil moisture and runoff routines. Once calibrated, continuous simulations using hourly precipitation and temperature data were conducted to generate a continuous time series of streamflow estimates (hydrographs). A complete discussion of the QHM modelling methodology, including the various model parameters, assumptions, calibration results and findings is given in Appendix _.

2.5.9.2 Results

(To be provided.)

→ used to model pre-development (water quality?? calibrated ~~based on KMQE results~~ calibrated based on monitored runoff flows in the creeks?)

2.6 Stream Morphology

(To be completed by JP.)

2.7 Aquatic Resources

2.7.1 Overview

Shirley's Brook, Watts Creek and Kizell Drain constitute the scope of the aquatic resources investigated for this study. An overview of the study area and the sampling sites is presented in Figure _____ ***(To be provided.)***. The work involved assessing the integrity of the ecosystem through assessment of the fish and benthic invertebrate communities as well as habitat. Relative numbers and diversity of both fish and benthic invertebrate species were calculated ***(To be completed)***. This information was related to stream habitat which was characterized using Version 2.1 of the Stream Assessment Protocol (OMNR 1998). In addition, information on the watersheds was obtained from a number of relevant agencies.

2.7.2 Stream Assessment Protocol

Stream assessment was conducted using the Rapid Assessment Methodology of Version 2.1 of the Stream Assessment Protocol (OMNR 1998). The protocol is a full and quantitative assessment and includes characterization of fish communities, nutrient analysis using characterization of benthic macroinvertebrate communities, thermal stability, surrounding features and channel structure. The Rapid Assessment Methodology used for the Shirley's Brook/Watts Creek Subwatershed Study was developed specifically for this type of large scale study.

Site selection parameters were chosen based on land use and the presence of surface water. A total of six parameters were developed and four sites for each parameter were sampled.

Thus a total of 48 sites were sampled for both subwatersheds. Detailed mapping of the study area was used for site selection. All sites were chosen at random, and prior to conducting field surveys. All sites were at least 40 metres in length. If, during field work a site was found to have surface water present when none was anticipated, this site was assessed and added to the parameter where surface water was present to increase its precision. Assessments were not conducted following storm events as baseflow conditions are inconsistent for 24 hours after rainfall.

2.7.2.1 Habitat Assessment

In applying the Rapid Assessment Methodology of the Stream Assessment Protocol, the following information was recorded to assess fish habitat:

- water velocity
- substrate type(s)
- surrounding land use
- stream morphology
- channel width (minimum and active)
- water depth.
- riparian vegetation
- bank stability
- instream cover
- presence of other flora/fauna species

Physical and chemical parameters were recorded using flow monitors, temperature loggers and other necessary equipment. This information can be found in Sections 2.3.4 (Hydrology) and Section 2.4 (Surface Water Quality). Photographs were also taken at each site.

Clarify which data collected as part of this study.

2.7.2.2 Benthic Invertebrate Collections

(To be completed.)

2.7.2.3 Fish Communities

Fisheries evaluation methods followed guidelines and procedures presented in Version 2.1 of the Stream Assessment Protocol. Fish collections were conducted with MNR staff using a backpack electrofisher. A total of twelve stations *(to be completed)* were sampled along approximately 50 metres of the watercourse. All fish were enumerated, identified to species and released at point of capture with the exception of those unidentifiable in the field. One sample of each of these was bagged and returned for laboratory identification.

2.7.3 Fish Communities and Habitat Characteristics

With the completion of field work, habitat and fish community data were summarized using the habitat database program of the Stream Assessment Protocol.

The fish community summary provides information with respect to size class and abundance. Fish habitat was also classified based on the Fish Habitat Conservation and Protection Guidelines for Developing Areas (OMNR, 1994) and the Habitat Conservation and Protection Guidelines (DFO 1994). The guidelines are presented below with modifications to reflect their application to the aquatic habitats and stream conditions present in the Shirley's Brook/Watts Creek Watershed. ***Guidelines to be included.***

The summary of habitat data provides a means for comparison of developed, undeveloped and agricultural areas. Each of the physical characteristics mentioned in the preceding section were quantified and the percentage of each was calculated. Thus a measure of habitat stability and channel structure is obtained and together with the fish community information provides an indication of productive capacity of each watercourse.

2.7.4 Fish Communities

2.7.4.1 Shirley's Brook

Fish collections were conducted on June 29 and ...., 1998. In addition, readily available background information on the upper and lower reaches of Shirley's Brook was reviewed (Dillon 1997a and 1997b). A total of 10 fish species were collected during the electrofishing program. Results can be found in Appendix ...... Additional fish species that have been captured in the lower reaches of the watercourse but not collected during this survey include: northern pike (*Esox lucius*), walleye (*Stizostedion vitreum vitreum*), largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*), American eel (*Anguilla rostrata*), pumpkinseed (*Lepomis gibbosus*), rock bass (*Ambloplites rupestris*) and logperch (*Percina caprodes*). Some of these species have been reported from the area near Shirley's Bay (Dillon 1997) and others near the mouth of Shirley's Brook (MNR 1992). Overall, Shirley's Brook can be considered a warmwater, tolerant stream. No rare, threatened or endangered species were collected from the creek.

The upper reaches of Shirley's Brook supported moderate species diversity with 7 of the 10 species captured during the survey. All species captured are tolerant of degraded conditions with the exception of the bridle shiner which shows intermediate tolerance. Three of the species captured are carnivorous feeders and the remaining four species are omnivores, which represents a reasonable trophic balance. A stream not impacted by development will support a fish community which consists of a majority of herbivorous species, some omnivores, as well as the presence of several predator species. All sampling conducted in these upper reaches was in undeveloped areas in the south branch of Shirley's Brook. The north branch contained no surface water in the upper reaches at the time of the survey. ***(Further sampling to be conducted.)***

Sampling in the middle and lower reaches included one each of the undeveloped, developed and agricultural sites. ***(Further sampling to be conducted in August.)*** Diversity in both the developed and undeveloped sites was low with a total of only two fish species captured. Both species (common shiner and bluntnose minnow) are omnivorous and tolerant of degraded conditions. No fish were captured at the agricultural site. Water temperature at these sites ranged from 25 -28°C at time of sampling.

2.7.4.2 Watts Creek and Kizell Drain

A tolerant warmwater fish community inhabits Watts Creek and Kizell Drain. The fish species captured were tolerant with the exception of the fantail darter which was captured at both the developed and undeveloped sites. The fantail darter is considered intermediate in tolerance of degraded stream conditions and is at the northern edge of its range resulting in a somewhat restricted distribution within Canada. It is primarily carnivorous and is found mainly in gravel bottom streams. All other species captured are omnivorous. Additional species reported from Watts Creek but not collected during this survey, include northern pike, bluntnose minnow, fathead minnow and logperch. In addition, species present in Shirley's Bay (largemouth bass, smallmouth bass and walleye) can be expected in the lower reaches of Watts Creek. Water temperature on the day of sampling ranged from 21-26°C among the sites. No rare, threatened or endangered species were captured.

The developed and agricultural sections of the watercourse exhibited low species diversity, as expected, with four species captured at one of the developed sites (creek chub, brook stickleback, central mudminnow, fantail darter) and two species captured at one of the agricultural sites (common shiner and brook stickleback). Background information (MNR, 1993) supported the current sampling results.

2.7.5 Benthic Communities

2.7.5.1 Shirley's Brook

(To be completed.)

2.7.5.2 Watts Creek/Kizell Drain

(To be completed.)

2.7.6 Habitat Assessment

Fish habitat in the Shirley's Brook/Watts Creek Subwatershed study area was classified based on the habitat types developed by DFO (1994) and OMNR (1994). ***(Note: The habitat classifications will be mapped and summarized in a table indicating rationale and recommendations at a later date.)*** Shirley's Brook and Watts Creek are characterized by a tolerant warmwater fish community which includes fish species such as common white sucker, creek chub and common shiner. Overall species diversity at most sampling locations was low. Water temperatures during sampling ranged from 21-28°C. This is another indication of warmwater fish communities and is likely caused by lack of groundwater discharge, shallow nature of the watercourse, and the presence of wetlands and open areas upstream.

The following sections summarize characteristics of existing fish habitat in Shirley's Brook and Watts Creek according to land use at various locations throughout the study area.

2.7.6.1 Shirley's Brook

Breakdown of land use in the Shirley's Brook subwatershed is as follows:

- agricultural 44%;
- developed 14%; and
- undeveloped 42%.

A total of five agricultural sites in the study area were assessed. Two of the sites were under crop and three flowed through cattle pastures. Lack of channel structure and instream cover and shallow water were observed consistently throughout these sites. This result was expected due to the nature of agricultural drainage systems and the impacts of cattle to streams. The highest degree of degradation was observed throughout the cattle pastures. Pools constituted 70% of the channel structure in these areas, with glides making up the remainder of the channel form. Instream cover was minimal and water depth was consistently below 100 mm (see Table2.4). Substrate was predominantly fines, although bedrock was present at one of the sites. Banks at these sites were mainly stable (56%). Riparian vegetation was minimal or completely absent. The sites which were electrofished have been designated as Type 3 habitat because of the lack of fish species and the severe degradation. **(Note: additional electrofishing to be done in August.)**

Developed sites varied according to residential or industrial activity. Residential areas were likely to have more instream cover and riparian vegetation. Two sites of each type were assessed and both exhibited degraded stream conditions with little channel structure. Substrate through these reaches was predominantly fines, except one site, which was mainly bedrock. Banks were vulnerable/eroding (51%) or stable (49%). The sites which were electrofished have been designated as Type 2 habitat with a further subclassification of low quality because of low species diversity and poor habitat.

Habitat assessment in the undeveloped areas of the watercourse showed a balanced pool-glide-riffle complex in both the upper and lower reaches. Table 2.4 summarizes the habitat assessment data. ***(Note: to be graphed at a later date.)***. The sites contained 60% instream cover which consisted mainly of macrophytes, and substrate consisted of hard-pan clay in the lower reaches and fines with some gravel in the sites located in the upper reaches of the watercourse. Riparian vegetation was abundant at most sites providing temperature moderation as well as a food supply for the resident fish communities. Bank stability was 62% at these sites with minimal erosion. This section of the watercourse has, therefore, been subclassified as moderate quality Type 2 habitat because of the moderate species and habitat complexity.

TABLE 2.4
SHIRLEY'S BROOK HABITAT SUMMARY TABLES
(ALL VALUES ARE PERCENTAGES)

Land Use	Instream Cover		Channel Structure				Depth (mm)		
	Cover	No Cover	Pool	Glide	Slow Riffle	Fast Riffle	0-100	101-200	201-500
Agricultural	20.00	80.00	70.00	30.00	0.00	0.00	99.17	0.83	0.00
Developed	37.08	62.92	60.42	37.92	1.25	0.42	40.83	48.33	10.83
Undeveloped	38.64	61.36	52.27	29.55	18.18	0.00	65.91	27.27	6.82

Land Use	Substrate				
		Bedrock	Fines	Gravel	Cobble
Agricultural	Max	29.71	53.14	12.97	4.18
	Point	28.87	57.74	13.39	0.00
Developed	Max	24.17	66.25	8.33	1.25
	Point	24.58	74.17	1.25	0.00
Undeveloped	Max	59.55	14.61	16.85	8.99
	Point	59.55	31.46	7.87	1.12

Land Use	Bank Stability			
	Eroding	Vulnerable	Protected	Stable
Agricultural	17.27	24.46	2.16	56.12
Developed	36.46	14.58	0.00	48.96
Undeveloped	18.33	8.33	11.67	61.67

2.7.6.2 Watts Creek and Kizell Drain

Breakdown of land use within Watts Creek and Kizell Drain is as follows:

- agricultural 47.1%;
- developed 30.4%; and
- undeveloped 22.5%.

Results from the assessment of channel structure and water depth were inconsistent throughout the agricultural sampling sites in Watts Creek. This variation is largely the result of one of the sampling sites which had received an increase in the amount of stormwater runoff from a nearby development.

The increase in stream gradient as a result of this runoff is reflected in the increased percentage of glides in the channel structure and greater water depth (See Table 2.5.). ***(Note: 1 additional agricultural site to be assessed for greater consistency.)*** All of the agricultural sites assessed were under crop, which is likely the reason for the greater percentage of instream cover (33%) than in Shirley's Brook. Nutrient input and no impacts from cattle crossing have resulted in macrophyte and algae growth. Fines were the dominant substrate, as expected, and 81% of the banks were either eroding or vulnerable to erosion. Channel structure was entirely pools and glides, reflecting the lack of instream structure. The agricultural areas have been classified as low quality Type 2 habitat because of the low species diversity and lack of habitat structure.

Developed areas varied according to industrial or residential development. However, degraded conditions such as channelization, lack of instream structure (25%) and fine substrate were predominant, similar to the agricultural sites described above. The residential developments south of Highway 417 showed varying degrees of degradation ranging from subdivision development which resulted in the replacement of the natural stream bed with cobble, to urban parkland with some riparian vegetation, but unstable banks as a result of mowing to the water's edge. ***(Note: to be electrofished.)*** The reach of Watts Creek which flows through the industrially developed area near March Road has been severely channelized and stormwater inputs have caused bank slumping and erosion. The sites further downstream of stormwater outfalls exhibit more stability and this is reflected in 55% stable banks. Some gravel substrate was observed at these sites which probably provides some habitat for the fantail darter (*Etheostoma flabellare*) which was unexpectedly captured there. The industrially developed sites are classified as low to moderate quality Type 2 habitat. ***(Note: The residentially developed sites will be classified at later date but are likely the same quality habitat.)***

Only 23% of the Watts Creek Watershed is undeveloped and even these areas are somewhat impacted by development, mainly from upstream sources such as the Beaver Pond or the old City of Nepean sewage treatment plant. Nevertheless, the habitat conditions at these sites reflected the buffer strip surrounding them or some degree of recovery. Channel structure showed the presence of pool-glide-riffle complexes, some variation in water depth and the presence of cover. This type of stream profile is instrumental in providing suitable and varied habitat for resident fish communities and high species diversity. The variation in substrate (see Table 2.5) is also a characteristic of more complex habitat. Abundant riparian vegetation at these sites provides temperature moderation and bank stability. A total of 74% of the banks surveyed were either protected or stable. The habitat of the undeveloped sites is classified as moderate quality Type 2 because of the moderate species diversity and the presence of complex habitat. ***(Note: mapping will specify which areas are moderate quality and which are high quality.)***

TABLE 2.5
WATTS CREEK HABITAT SUMMARY
(ALL VALUES ARE PERCENTAGES)

Lane Use	Instream Cover		Channel Structure				Depth (mm)		
	Cover	No Cover	Pool	Glide	Slow Riffle	Fast Riffle	0-100	101-200	201-500
Agricultural	32.50	67.50	41.67	56.67	1.67	0.00	5.83	53.33	40.83
Developed	24.89	75.11	40.61	45.41	13.97	0.00	34.50	54.15	11.35
Undeveloped	30.09	69.91	31.86	53.10	11.06	3.98	13.27	51.33	35.40

Land Use	Substrate				
		Bedrock	Fines	Gravel	Cobble
Agricultural	Max	0.00	68.33	24.17	7.50
	Point	0.00	81.67	18.33	0.00
Developed	Max	0.00	60.42	37.92	1.67
	Point	0.00	85.42	13.75	0.83
Undeveloped	Max	0.00	69.78	19.56	10.67
	Point	0.00	83.56	12.89	3.56

Land Use	Bank Stability			
	Eroding	Vulnerable	Protected	Stable
Agricultural	29.55	61.36	0.00	9.09
Developed	30.21	13.54	1.04	55.21
Undeveloped	10.42	15.63	5.21	68.75

2.7.7 Summary of Findings and Conclusions

2.7.7.1 Benthic Invertebrates

(To be completed.)

2.7.7.2 Fish Communities

1. The fish community found in Shirley's Brook and Watts Creek is characteristic of a tolerant warmwater community.

2. No rare, vulnerable, threatened or endangered species were collected from Shirley's Brook or Watts Creek.

3. Based on existing information, Shirley's Brook, near the mouth, supports a diverse fish community including several sportfish such as northern pike, largemouth and smallmouth bass and walleye as well as American eel.

4. ***Diversity and abundance indices to be calculated and summarized here.***

2.7.7.3 Habitat Assessment

1. Most of the fish habitat in the Shirley's Brook Watershed is classified as low to moderate quality Type 2 habitat. Some sections were classified as Type 3 habitat.

2. Fine substrate and lack of channel and instream structure characterize the developed and agricultural sections throughout Shirley's Brook.

3. Agricultural areas are severely impacted by cattle crossing and grazing.

4. Undeveloped areas exhibit complexity of habitat with instream cover, abundant riparian vegetation and stable banks. These reaches are mainly in the upper sections of the watersheds.

5. Most of the fish habitat in the Watts Creek Watershed is classified as low to moderate quality Type 2 habitat.

6. Agricultural and developed areas exhibit lack of instream and channel structure and fine substrates predominate.

7. Undeveloped areas, although also impacted by upstream development show pool-riffle complexes and abundant riparian vegetation.

Conclusions based on the field assessment indicate that although erosion and lack of structure in portions of the watersheds have resulted in degradation of fish habitat, numerous opportunities for restoration and rehabilitation are present throughout the Shirley's Brook/Watts Creek Watershed. Later sections of this report identify specific areas and recommend actions which will result in the naturalization of many degraded areas. In addition, existing natural areas are specified and preservation methods for these reaches will also be recommended. ***(Note: This is to be completed.)***

2.8 Terrestrial Resources

2.8.1 Introduction

The purpose of this analysis is to describe or characterize the terrestrial natural features (woodlots, wetlands and old fields) within the three watersheds namely Kizell, Watts Creek and Shirley's Brook. To date, many of these natural features have investigated and documented to some degree by the Natural Environment Systems Strategy (NESS) (Geomatics International, 1995) and the Natural Area Data and Evaluation Records (NADER) (RMOC, 1997) for the Regional Municipality of Ottawa-Carleton (RMOC). In general, these vegetation units have been qualitatively described as wet forested (i.e. swamps), dry forested (i.e upland forests), wet non-forested (i.e marshes), dry non-forested (i.e. old fields and scrubland), planted (i.e. plantations) or open water. For the purposes of this study, a more quantitative approach will be taken so that natural feature units within one watershed can be compared with each other as well as units in the other two watersheds.

2.8.2 Data Collection

2.8.2.1 Published Report Review

As mentioned above, many of the natural features have been investigated and documented through the NESS and NADER. At least three areas in the western portion of the general study area have been studied in more detail by D.F. Brunton. These includes the lands around Shirley's Bay including the Connaught rifle ranges (Brunton, 1980), the Kanata Lakes area (Brunton, 1982a) and the South March Highlands area (Brunton, 1982b). These three studies give an excellent account of the plants, wildlife and bird species that are expected to be found in the area as well as their regional status.

Copies of the most recent Forest Resource Inventory (FRI) mapping was obtained from OMNR and analyzed before field investigations began. Forests were divided into three categories based on their size and age characteristics. These are as follows:

(i) Late Successional (60+ years) and > 4 ha;
(ii) Mid Successional (20 to 59 years) > 4 ha; and
(iii) pioneer forest (< 20 years).

The Canadian Wildlife Service was also contacted in order to obtain bird banding data. This information, along with breeding bird status information from Cadman (et al, 1987) is summarized in section X (Data still being collected). Other relevant scientific papers have also been reviewed and these will be cited where appropriate throughout this document.

2.8.2.2 Field Investigations

Field investigations were conducted in mid June, 1998 and more are expected in the early fall. Using a combination of FRI mapping and air photo analysis and field work, areas that had been identified on a large (1:12,500) colour air photo were as possible were visited by walking along hydro, rail and road right-of-ways and conducting spot checks in the natural areas. For each area, notes were taken on the type of woody and herbaceous plants observed, the type of wildlife in the area (based on incidental sightings, scats, tracks, etc.), as well as the degree of human disturbance throughout the area.

It was found that due to the rapid expansion of the Kanata area, many of the forested areas shown on FRI mapping had either been cleared or disturbed in some manner. However, some other natural areas not identified by OMNR mapping were also found.

2.8.3 Data Analysis Methodology

In order to describe the natural features in the study areas on a quantitative basis, a number of existing evaluation methods were examined for techniques and criteria which would evaluate natural areas on an unbiased basis. Documents such as the *Natural Areas Summary Report* (RMOC, 1997), *The Ontario Wetland Evaluation System* (OMNR, 1993) and *The Natural Heritage of Southern Ontario's Settled Landscapes* (Riley and Mohr, 1994) were examined and a Draft Natural Area Summary Report form was developed (see Appendix _____). These evaluation forms are currently being completed for each natural area using the following criteria: size; biodiversity; landscape attributes; seasonal wildlife concentration and potential, hydrological features, interior bird habitat and the condition of the natural area.

In Appendix _____, there is a set of completed forms for all three watersheds. Some information within these draft reports will change pending further field studies and data collection.

A summary of each criterion is as follows:

Size - In general, the larger the wetland or forest, the more likely that it will contain more plant communities and wildlife species. Forests that are larger than 4 ha (assuming a rectilinear shape) will begin to possess interior habitat for more sensitive species (Riley and Mohr, 1994).

Biodiversity - Biodiversity refers to the richness or types of habitat that a natural feature possesses. For example, a recently abandoned agricultural field will posses some habitat for nesting ground birds (eg. eastern meadowlark, savannah sparrow and bobolink) as well as feeding habitat for rabbit, white-tailed deer and groundhog, but overall, habitats such as grasslands have limited potential. Conversely, a mature sugar maple, beech and elm forest can provide multiple habitats for birds and animals that breed, feed and nest at ground level or in the upper canopy.

In this analysis, the biodiversity of an area has been determined by examining Forest Resource Inventory mapping, air photos and conducting field work to determine the age of various forest stands as well as if these areas are in close association with other natural areas such as marshes or swamps.

Landscape Attributes - The landscapes within the study area has changed dramatically in the last decade with farmland or forest giving way to urban development. For example in 1981, the RMOC area had less than 29.4% of their landscape in forest cover, so it is important to establish whether the three subwatersheds are above or below this rate. To measure this aspect, three subcriteria have being used to calculate what the deforestation trends are, and if remediation plans through the use of vegetative corridors or linkages are possible or feasible.

Seasonal Wildlife Concentration and Potential - Some portions of Shirley's Brook and Watts Creek Watersheds are still heavily forested and provide a range of habitats for many different birds and animals. For example, in the Kanata Lakes Area, which includes portions of all three subwatersheds, Brunton (1992a) reported the presence of 70 species of breeding birds, 20 mammals and 14 species of herpetofauna. Therefore, the purpose of this criteria is to list those species of mammals that are likely to breed/feed within the natural feature.

Hydrological Features - The presence or absence of seeps, wetlands and/or a water courses can have a direct effect on the types of flora and fauna in the area. While it was mentioned earlier than an abandoned agricultural field has lower diversity than a established sugar bush, the presence of a abandoned cattle watering hole or wet agricultural drain can gradually attract a surprising number of mammal, bird and plant species as it become naturalized. Therefore, this criteria has been included as the presence or absence of hydrological features within a terrestrial unit does impact on the diversity of an area.

Interior Bird Habitat - Some species of birds such the white and black warbler, the brown creeper and the ovenbird prefer to nest deep within the forest interior as their eggs and fledglings are less likely to be destroyed by opportunistic, predators such as brown-headed cowbirds and grackles. Researchers in the U.S. midwest has estimated that the physical effects of microclimate, noise, sunscald and desiccation can extend into a forest from surrounded cleared areas to a depth 60 to 100 metres (Wilgrove 1987, Harris 1984 in Riley and Mohr, 1994). For this study, any forest over 4 ha which has a rectilinear shape has been examined to see if it possess interior habitat.

Condition of Natural Areas - This criteria was measured using two subcriteria namely, the degree of human disturbance and Site fragmentation. All of the natural areas within the subwatersheds have shown some degree of human disturbance ranging from the creation of trails or dumping of garbage to the widespread clearing of forests and wetlands for agriculture or residential uses. With regard to site fragmentation, many of the larger tracts of forest or wetland have been disturbed locally by the presence of roads, railways and to a lesser degree hydro corridors. However, as the area develops, and linear facilities are expanded, the potential for further fragmentation is a distinct possibility. It should also be noted that the presence of roads and railways through a natural area does increase the incidence of roadkill, and harden surfaces can also create barriers to wildlife travel especially for smaller mammals and herpetofauna (Oxley, et al, 1974).

For each Natural feature Summary Report (see Appendix _____) overall scores have been provided. This information will be important in the latter stages of this project when conservation priorities are being assigned.

2.8.4 Description of Natural Areas for Each Watershed

2.8.4.1 Kizell Subwatershed

The Kizell subwatershed covers approximately 940 ha of which 292 ha (31.1%) is covered in either forest, wetland or exposed rock. The remainder has been cleared for agricultural purposes or for residential/commercial purposes. Within the area, ten(10) distinct natural areas were identified ranging in size from 53.3 ha (K2) to 4.9 ha (K8) (See Figure _____.) ***(To be provided.)***. The majority of natural areas are concentrated within the northwestern portion of the watershed (K1 to K5). These units are within the Kanata Lakes Study Area which was inventoried by Brunton in 1992. This area includes large expanses of upland (dry) forest, lowland (wet) forests, marsh wetland as well as exposed precambrian shield.

In the upland forest of the Kizell subwatershed (and the other two watersheds), typical species within the upper canopy includes sugar maple, beech, white ash, white pine, hemlock and basswood. The shrub layer is composed of saplings of the upper canopy as well as choke cherry, hop hornbeam and hazelnut. The understorey varies according to the degree of sunlight reaching the forest floor, but typical species found here include white snakeroot, cloudberry, white trillium, enchanters nightshade, jack-in-the-pulpit and wild ginger.

In the lowland forest, which also included swamp communities, the upper canopy ranges from pure stands of white cedar or soft maple to a mixed stand of white cedar, alder, balsam fir, poplar, yellow birch, hemlock, willow/dogwood or black ash. The shrub layer is usually composed of saplings of the upper canopy as well as willows, alders and dogwood. The understorey is composed of ferns including maidenhair, sensitive, ostrich as well as typical riparian plants including spotted jewelweed, fringed loosestrife, enchanters nightshade, mosses and lichens.

During field work it was noticed that many of the marsh wetlands had become drier with willows, dogwoods, and stands of reed canary grass and Canada bluejoint (both water tolerant species) becoming established.

The investigation of the other natural areas (K6 to K10) found that they were scattered around the perimeter of the watershed or isolated within newly built developments. While some areas such as K10 and K9 remained relatively undisturbed, others such as K6, located on the south side of Campeau Road opposite the Kanata Lakes Golf Club, had been much larger at the initiation of this study.

Table 2.6 shows the area, scores for the seven (7) criteria and overall scores for the 10 natural areas. The natural areas K1, K2, K4 and K5 located in the northwestern corner of the watershed scored the highest with scores of 216, 224, 193 and 186 respectively. These areas had extensive forest and wetland cover, excellent wildlife habitat potential, a large area of interior bird habitat and a large degree of hydrological activity. These areas also had very little human disturbance including fragmentation.

The area K6 would have scored higher as it had a relatively large area (39.2) ha which is approximately 9.0% of the total forest cover in the subwatershed. However, large portions of this area have been cleared, thus removing important linkages. K10 is also a large wooded area with a good diversity of species, interior bird habitat and hydrological features. However, it is isolated from other larger areas by roads and railways and the potential for expanding linkages is limited.

2.8.4.2 Watts Creek Watershed

The Watts Creek Watershed covers approximately 1452 ha of which 259.4 ha (17.9%) is covered in either forest, wetland or exposed rock. The remainder has been cleared for agricultural purposes or for residential/commercial purposes. Within the area, seventeen (17) distinct natural areas were identified ranging in size from 55.4 ha (W10) to 0.93 ha (W12) (See Figure _____.). ***(To be provided.)*** The natural features are scattered throughout the watershed, but there is a fairly distinct corridor along the eastern side of the watershed. Units within this area include K17 that is at the outlet of Watts Creek along the Ottawa River; W16, W14, W13 and W12 which are located along

TABLE 2.6
SUMMARY TABLE FOR KIZELL WATERSHED

I.D.	Size (Area)	Score	Biodiversity	Landscape Attributes	Wildlife Concentration	Hydrogeological Features	Interior Bird Habitat	Condition of Natural Area	Overall Scores
K1	(47.5)	30	5	92	30	35	10	14	216
K2	(53.3)	30	5	90	30	45	10	14	224
K3	(6.9)	10	3	52	30	22	2	8	127
K4	(49.2)	30	4	70	30	35	10	14	193
K5	(47.4)	30	5	70	30	30	10	11	186
K6	(39.2)	10	3	67	30	35	10	8	163
K7	(2.7)	5	1	5	18	0	0	0	29
K8	(4.9)	10	1	15	18	0	0	0	44
K9	(12.9)	10	2	47	30	45	2	8	144
K10	(28.0)	10	3	52	30	30	10	11	146

Range Road along Watts Creek; W11, W10 located along Watts Creek between Carling Ave. and Highway 417 and W5, W4 and W3 which are located between Highway 417 and Robertson Road. The largest unit (W10) is located approximately 1.8 km east of Eagleson Road on the west side of the CNR tracks and north of westbound Highway 417. This unit is the hub of the corridor as it is relatively undisturbed and has a diversity of habitats including upland forests, wetlands, rocky outcrops and regenerating grasslands. This area also has headwater tributaries for Watts Creek, and contributes 21.4 % of the forest to the watershed. W11, the next largest totalling 34.0 ha, is located directly north and has the same conditions as W10. Both units are dominated by sugar maple, bitternut hickory, basswood, white ash and white pine that are approaching 75 years of age.

The units W12, W13, W14, W16 and W17 are located along Watts Creek and all are dominated by water tolerant species such as red maple, silver maple, trembling and large-toothed aspen as well as white cedar. While some of these natural areas do not appear on Forest Inventory mapping, these scrub communities do offer important habitat to wildlife that live along this watercourse. W17 is especially significant, as it is located at the outlet of Watts Creek at the Ottawa River. This community is dominated by a mature silver/red maple swamp that periodically becomes flooded as the Ottawa River water levels rise.

Units W5, W4 and W3 are located within or near the Energy, Mines and Resources complex, north and south of Timm Road. These areas have been disturbed in the past by light agricultural activity (i.e. pasture) and contain scattered stands of white cedar, white birch, white elm and poplar species. Some isolated wetland swamps are also within W5 and W3 and these are dominated by white cedar, poplar and silver maple.

The other units in the watershed are scattered throughout the watershed and are isolated with residential developments (W1, W2, W6,) or in agricultural fields (W7, W8, W9, W15). With exception of W1 which is 21.7 ha in size and does have interior bird habitat, the others are less than 10 ha in size and have limited features.

Table 2.7 shows the area, scores for the seven (7) criteria and overall scores for the 1 natural areas in the Watts Creek Watershed. W10 had the highest overall score of 224, followed by W17, W14, W11 and W3 with scores of 180, 173, 172 and 154 respectively, all these areas had high landscape attributes meaning that they were in close proximity to other natural area, and/or they contributed a large portion of forested land to the watershed and/or they had strong linkages with other natural areas. The areas W4, W5, W9 and W16 scored over 100 points, with scores of 127, 127, 126 and

TABLE 2.7
SUMMARY TABLE FOR WATTS CREEK WATERSHED

I.D.	Size (Area)	Score	Biodiversity	Landscape Attributes	Wildlife Concentration	Hydrogeological Features	Interior Bird Habitat	Condition of Natural Area	Overall Scores
W1	(21.7)	10	4	10	21	12	2	4	63
W2	(2.1)	5	1	5	21	12	0	4	36
W3	(25.6)	10	5	55	30	30	10	14	154
W4	(16.5)	10	3	52	30	22	2	15	127
W5	(13.4)	10	3	52	30	22	2	8	127
W6	(4.7)	10	1	35	21	12	0	4	83
W7	(3.3)	5	1	15	24	12	0	0	57
W8	(1.7)	5	1	27	24	2	0	0	63
W9	(9.4)	10	2	57	30	45	10	14	224
W10	(55.4)	30	5	90	30	45	10	14	224
W11	(34.0)	10	3	70	30	35	10	14	172
W12	(0.93)	5	2	27	24	22	0	8	88
W13	(7.0)	10	3	27	21	23	0	8	92
W14	(30.7)	10	3	67	30	50	2	11	173
W15	(4.6)	10	3	27	21	7	0	8	76
W16	(12.5)	10	3	50	24	12	0	14	113
W17	(14.9)	10	4	65	30	55	2	14	180

113 respectively. Some of these areas such as W4 and W5 would have scored higher as they are portions of larger forests. However, when measuring features, only those features that occur within the watershed were counted. Those units with the lowest scores were W2, W1, W6, W7, W8 and W12. Their scores were 36, 63, 83, 57, 63 and 88. Those units including W2, W6, W1 at one time had been part of larger forests which would have interior bird habitat, a number of different vegetation communities and hydrological characteristics. However, because of development in the area, these units now have a high degree of human disturbance and site fragmentation. The units W7, W8 and W12 scored low as they were very small in size and had limited diversity. These units are situated within an agricultural setting and would be easier to enhance or expand in the future.

2.8.4.3 Shirley's Brook Watershed

The Shirley's Brook Watershed covers approximately 2635 ha of which 1063.1 ha (40.3%) is covered in either forest, wetland or exposed rock. The remainder has been cleared for agricultural purposes including pasture land, hay, mixed grain and corn, but many of these areas are now giving way to estate residential or small scale commercial/retail development. Within the area, twenty-six (26) distinct natural areas were identified, ranging in size from 450. ha (S2) to 2.6 ha (S4) (See Figure _____.) ***(To be provided.)***. The two largest units are located on the west side of the watershed and extend west of the western watershed boundary and east to the large hydro corridor. Unit S2 which extends from Old Carp Road south to the CNR tracks and from the western watershed boundary east to the Second Line Road/Goulbourne Road, forms the north half of the South March Highlands area, while S3, S4 and S5 form the southern half.

The eastern portion of S2 and S6 are located on the west and east sides of Goulbourne Road respectively, and form the natural preserve called Trillium Woods Park. Units S8 and S9 are now urban parks known as Morgan's Grant Woods and Klondike Road Park. A field survey of the latter found an interesting diversity of upland sugar maple, white and basswood mixed with a wetter community of white cedar, poplar and silver maple. While this area has been opened up for park land, much of the upper canopy and understorey layers has been preserved, thus keeping many wildlife habitat features intact. Many of the larger, isolated woodlots including S11, S12, S14 and S19 have undergone some degree of disturbance as estate residential and/or large custom built homes have been built within the forest interior. Similar activity is also occurring on the eastern edge of S1.

The natural features that have not been disturbed, apart from farming activity, includes units in the corridor between Fourth Line Road, west to the CNR line. These include units S17, S18, S20, S21, S22, S23, S24 and S25. While most of these units are approximately 5 to 10 ha in size, they do have scores over 100 points which has ben attributed to the presence of hydrologic features as well as the lack of fragmentation and human disturbance. It should be noted that while some of the units such as S24 are bisected by a railway, field investigations found that this line was not very busy, and wildlife including deer, raccoon and groundhogs crossed freely at many points.

Table 2.8 shows the area, scores for the seven (7) criteria and overall scores for the 26 natural areas in the Shirley's Brook Watershed. Unit S2 had the highest score of 425 points and S8 had the lowest with 33. Other areas that had high scores included S1, S3, S6, S13, S24 and S26. As discussed earlier S1, S2, S3 and S6 are located in the western part of the study area and have relatively little disturbance compared to those areas in the east. S13 scored high as it is a relatively large woodlot for this subwatershed, had interior bird habitat and most importantly was influenced by two, first order tributaries. S24 scored high as it had an interesting mix of communities, interior bird habitat and a third order stream flows through it. S26 scored high as it is located at the outlet of Shirley's Brook and would be strongly influenced by the Ottawa River in terms of hydrologic regime and wildlife activity. As this area is relatively undisturbed, it also has a relatively large area of interior bird habitat relative to its overall size.

TABLE 2.8
SUMMARY TABLE FOR SHIRLEY'S BROOK WATERSHED

I.D.	Size (Area)	Score	Biodiversity	Landscape Attributes	Wildlife Concentration	Hydrogeological Features	Interior Bird Habitat	Condition of Natural Area	Overall Scores
S1	(190.7)	50	20	125	30	60	30	14	356
S2	(450.0)	80	34	142	30	95	30	14	425
S3	(64.0)	10	5	55	30	40	10	11	161
S4	(2.6)	5	2	10	21	0	0	14	52
S5	(4.5)	10	2	50	27	12	0	8	109
S6	(41.7)	30	5	50	30	40	10	11	176
S7	(14.9)	10	2	60	30	35	0	8	145
S8	(2.9)	5	2	5	21	0	0	0	33
S9	(10.3)	10	3	50	30	24	2	8	127
S10	(6.1)	10	2	40	27	17	0	8	104
S11	(34.4)	10	5	60	30	23	2	8	138
S12	(39.2)	10	4	60	30	20	2	8	134
S13	(26.3)	10	3	87	30	30	0	8	168
S14	(16.8)	10	2	30	27	0	0	8	77
S15	(18.2)	10	2	50	27	0	0	0	89
S16	(9.4)	10	2	50	30	17	2	11	102
S17	(8.9)	10	2	50	30	13	2	8	115
S18	(4.5)	10	1	27	24	0	0	8	170
S19	(4.8)	10	1	27	24	12	0	4	78
S20	(8.0)	10	2	47	27	8	0	8	102
S21	(7.1)	10	2	50	27	12	0	8	109

TABLE 2.8
SUMMARY TABLE FOR SHIRLEY'S BROOK WATERSHED

I.D.	Size (Area)	Score	Biodiversity	Landscape Attributes	Wildlife Concentration	Hydrogeological Features	Interior Bird Habitat	Condition of Natural Area	Overall Scores
S22	(5.0)	10	2	30	24	0	0	8	74
S23	(10.8)	10	4	47	30	25	2	14	132
S24	(25.5)	10	4	47	30	45	2	14	152
S25	(7.2)	10	1	25	24	0	0	8	68
S26	(49.3)	30	5	47	24	65	10	14	200

2.8.5 Summary

As indicated in the introduction, the analysis of the terrestrial environment has been conducted using a quantitative approach. This approach will be useful in the latter stages of this study when conservation priorities are being assigned.

Riley and Mohr (1994) have indicated that in 1981, the RMOC area only had 29.4% of its land area covered in production and non-production forest. This analysis shows that for the Kizell Subwatershed and the Watts Creek and Shirley's Brook Watersheds, those forested areas are 31.1%, 17.9 and 40.3%. This shows that Kizell and Shirley's Brook still have considerable forest resources, but Watts Creek is approaching critical levels.

The forest/wetland resources within this subwatershed study are located either along the western portion of the study area, along the Ottawa River or along the eastern boundary. Despite the expansion of Kanata and Nepean, these areas still provide a crucial migration corridor for birds and wildlife that travel inland from the Ottawa River.

While portions of the watersheds are being developed, portions of forest are being preserved and being utilized as urban nature reserves. Some of these reserves such as Trillium Woods Park (S6), a proposed 15 acre park south of Kanata Lakes Golf Club (K6), Morgan's Grant Woods (S8) and Klondike Road Park (S9) do contain undisturbed habitat which would be suitable for wildlife such as cottontail, raccoon, skunk, grey and red squirrel and chipmunk. Some of these urban parks (S6),(K6), (W1) and (S9) also contain interior bird habitat.

One trend that seems to be occurring especially in Shirley's Brook Watershed, is the establishment of estate residential developments in the interior of mid-sized, mature sugar maple forests. While this lotting technique does preserve more trees than typical urban, single family densities, it does tend to eliminate interior forest conditions.

2.9 Land Use

2.9.1 General

The Shirley's Brook and Watts Creek Watersheds are mixed use, rapid growth areas which have experienced significant change in the past 30 years. Kanata's growth began in the late 1960s changing this part of former March Township from a rural/agricultural area to an urban community of 50,000 people, including extensive and fast growing industrial areas.

While the two watersheds share this growth and have many common elements, they also have significant differences.

2.9.2 Watts Creek

The Watts Creek Watershed and its major tributary, Kizell Drain, straddle the City of Kanata/City of Nepean municipal boundary. The headwaters are predominantly urbanized at present and will be almost entirely urbanized when the community is fully built out.

Watts Creek's Watershed has an area of 1404 ha. The 511 ha located in the City of Kanata have been developed for primarily low and medium density residential purposes with smaller areas developed for commercial and office uses. The only vacant areas consist of about half of the 203 ha located in the Kanata Town Centre (north and south sides of Highway 417). A substantial part of the Kanata Town Centre is intended to accommodate higher density development.

The 893 ha downstream portion of the Watts Creek Watershed is entirely contained within the National Capital Commission (NCC) Greenbelt. It contains a mix of agricultural, rural and natural areas, as well as a small (89 ha) enclave of government offices.

A list of Regional Municipality of Ottawa-Carleton (RMOC) Official Plan designations and their areas is provided in Table 2.* ***(To be provided.)*** With the exception of the previously referred to undeveloped Town Centre land, the areas listed provide a close approximation of the existing land uses as well. Map 1 shows the RMOC Official Plan designations superimposed on the subwatershed boundaries.

Table 2.*

This watershed is bisected by two major roads - Highway 417 and March Road/Eagleson Road.

2.9.3 Kizell Drain

Kizell Drain has a subwatershed area of 1006 ha and flows into the main channel of Watts Creek south of Carling Avenue on Greenbelt lands. 515 ha are designated General Urban Area in the RMOC Official Plan and are largely developed for low and medium density residential uses. The Kanata Lakes (18 holes on about 70 ha) golf course occupies part of this land. Two of the four neighbourhoods, located in the northwest part of the Marchwood Community, have not yet been fully developed. 8 ha are designated Town Centre and are currently vacant.

The extreme northwest part of the subwatershed is an undeveloped Natural Environment Area (72 ha) which will remain undeveloped as part of Kanata's open space network.

Slightly more than half of the Kanata North Business Park is located in the Kizell Drain subwatershed. It occupies 232 ha in the northerly part of it. These lands are approximately 50% developed at present.

The balance of the Kizell Drain subwatershed area (179 ha) is NCC Greenbelt currently used for and designated rural and agricultural. A few existing single family dwellings are also found in this area. Little future land use change is expected.

March Road bisects this subwatershed area with about 65% located on the west side.

2.9.4 Shirley's Brook

The Shirley's Brook Watershed has a total area of 2669 ha. It is divided into four smaller unnamed subareas. Unlike the Watts Creek/Kizell Drain Watershed, the headwaters are not urbanized and are not contained within the future urban area designated in the RMOC Official Plan. The urban area (comprised of Business Park, General Urban Area and Kanata North Expansion Area) comprises 731 ha, or about 27% of the subwatershed. The southerly (main) branch of the Shirley's Brook Watershed contains most of this urbanizing land. Approximately 30% of this area is developed at present.

The balance of this watershed is comprised of a substantial General Rural Area (970 ha) which is dominated by estate residential and rural residential uses at very low densities. Some infilling could occur in this area. An additional 124 ha is designated Greenbelt Rural, reflecting the NCC's ownership.

Natural Environment Areas and wetlands comprise the balance of the subwatershed, an additional 844 ha.

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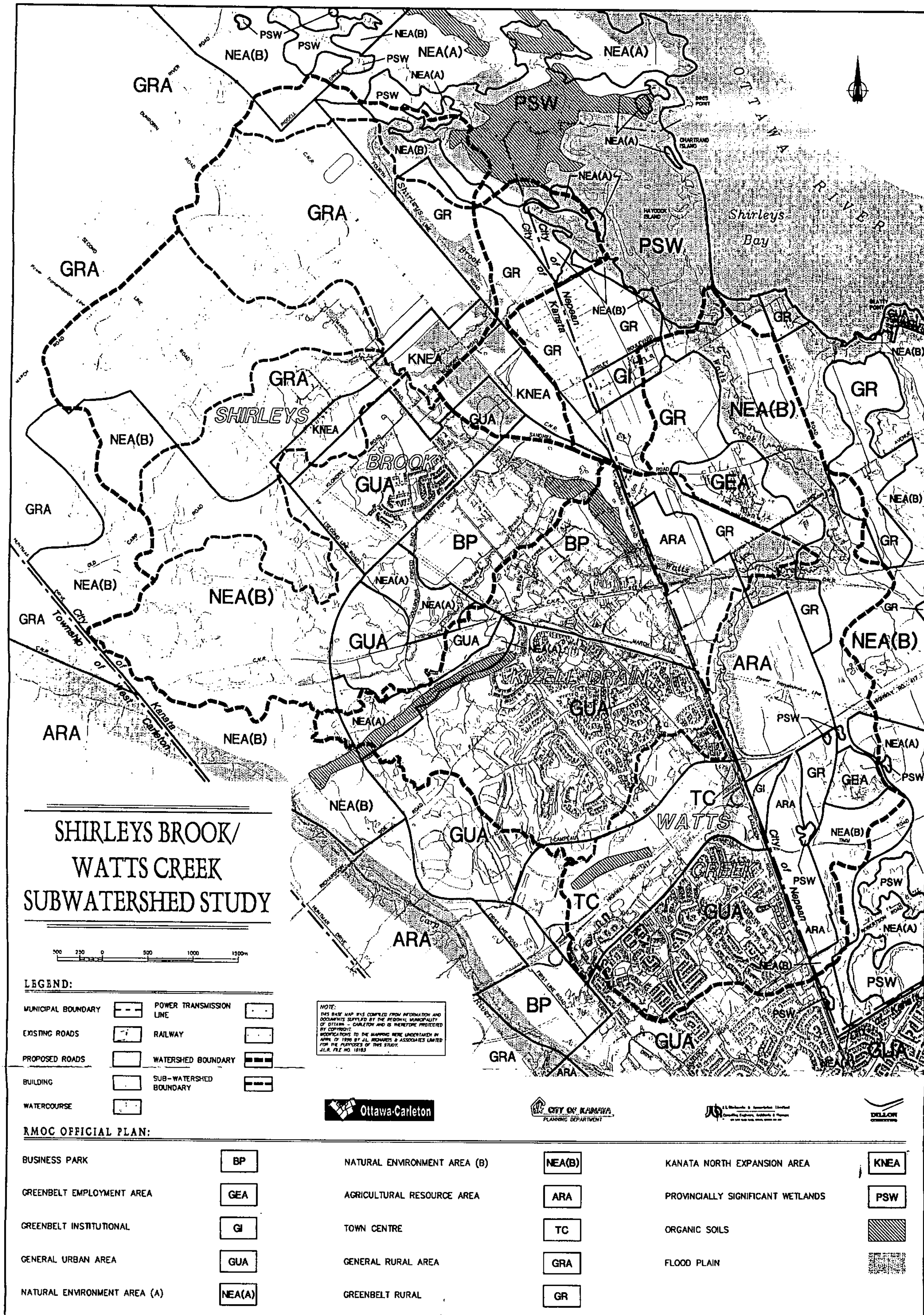
APPENDIX

Distribution of Fish Species in Shirley's Brook According to Land Use								
Common Name	**Scientific Name**	**US1**	**US2**	**US3**	**DS2**	**DS4**	**AS2**	**AS4**
common white sucker	*Catastomus commersoni*	✓				To	To	
common shiner	*Luxilus cornutus*	✓			✓	be	be	
creek chub	*Semotilus atromaculatus*					sampled	sampled	
bridle shiner	*Notropis befrenatus*		✓	✓				
finescale dace	*Phoxinus neogaeus*		✓	✓				
northern redbelly dace	*Phoxinus eos*			✓				
bluntnose minnow	*Pimephales notatus*		✓	✓	✓			
brook stickleback	*Culaea inconstans*		✓	✓				
central mudminnow	*Umbra limi*		✓	✓				
fathead minnow	*Pimephales promelas*		✓	✓				
Total number of fish species		2	6	7	2			0

Distribution of Fish Species in Watts Creek According to Land Use							
Common Name	**Scientific Name**	**US1**	**US4**	**DS1**	**DS3**	**AS1**	**AS2**
common white sucker	*Catastomus commersoni*	✓	To	To			To
common shiner	*Luxilus cornutus*	✓	be	be		✓	be
creek chub	*Semotilus atromaculatus*	✓	sampled	sampled	✓		sampled
northern redbelly dace	*Phoxinus eos*	✓					
brook stickleback	*Culaea inconstans*	✓			✓	✓	
central mudminnow	*Umbra limi*	✓			✓		
fantail darter	*Etheostoma flabellare*	✓			✓		
Total number of species		7			4	2	



MAP 1 RMOC OFFICIAL PLAN