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APPENDIX C
SUBWATERSHED DESCRIPTION

Introduction

This appendix provides information to support the existing conditions description contained in Chapter 3.0. It is broken up into the following Annexes:

- Annex C-1 Climate;
- Annex C-2 Geology and Hydrogeology;
- Annex C-3 Surface Water Quality;
- Annex C-4 Surface Water Hydrology;
- Annex C-5 Stream Morphology;
- Annex C-6 Aquatic Resources; and
- Annex C-7 Terrestrial Resources.

Annex C-1 - Climate

1.1 Climate

The climate of the Shirley's Brook/Watts Creek Subwatersheds 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. The average annual precipitation is 711 mm with an average annual snowfall of approximately 1,906 mm (approximately 191 mm water equivalent).

1.2 Precipitation

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

1.3 Snowpack

There are no existing snowcourse stations within the Shirley's Creek/Watts Creek Subwatershed. Therefore, in order to characterize typical snowpack conditions in the Study Area, data obtained from the Ontario Ministry of Natural Resources' stations at Bells Corners and Huntley, and the Atmospheric Environmental Service station at Ottawa International Airport was reviewed. The Stations are located approximately 10 km southeast, 7 km southwest, and 20 km southeast of the Subwatershed centroid respectively as shown in **Figure C.1**. The Bells Corners and Huntley stations are maintained by the OMNR and have been in operation since the 1978/79 winter season. **Table C.1** summarizes the annual maximum snowpack water equivalent depths and annual snowpack depletion dates.

TABLE C.1
SNOW SURVEY DATA

Year	MNR- Bells Corners				MNR - Huntley				AES Ottawa Int'l Airport			
	Avg. (mm)	Max. (mm)	Date of Max. (m/d)	Date Depleted (m/d)	Avg. (mm)	Max. (mm)	Date of Max. (m/d)	Date Depleted (m/d)	Avg. (mm)	Max. (mm)	Date of Max. (m/d)	Date Depleted (m/d)
85/86	37.7	76.2	03/15	03/23	46.4	81.3	03/15	03/23	33.5	71.1	01/08	03/15
86/87	90.2	152.4	03/01	03/23	87.4	132.1	03/01	03/23	80.4	132.0	03/15	04/01
87/88	37.4	53.3	01/15	03/23	49.5	76.2	01/15	03/23	45.8	76.0	01/01	03/23
88/89	54.6	88.9	02/15	04/01	n/a	n/a	n/a	n/a	38.4	58.0	02/08	04/08
89/90	25.7	45.0	03/01	03/08	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
90/91	50.8	76.2	01/15	03/23	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
91/92	68.6	137.2	04/01	04/08	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Annex C-2 - Geology and Hydrogeology

2.1 Data Collection

A geological and hydrogeological review of the Shirley's Brook and Watts Creek subwatersheds 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 subwatershed. Relatively little information concerning groundwater is available for the Watts Creek subwatershed. 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.

2.2 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 Subwatershed.

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 Geology

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 C.2**.

TABLE C.2
SURFICIAL STRATIGRAPHY

Relative Age	Deposit Type
Post Champlain Sea Sediments	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

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 subwatershed areas are less than (based on the MOE water well records digital data base). The greatest overburden accumulations (>30 m) lie along the Watts Creek southwest of the Highway 417/ Eagleson Road interchange (Patterson, 1980).

The **upper reaches of the subwatershed areas** can be characterized as follows:

- Are dominated by exposed or shallow Precambrian and Paleozoic bedrock that comprises roughly 50% of the Shirley's Brook and Kizell Drain subwatersheds and 35% of the Watts Creek Subwatershed.

- Small discontinuous lenses of glacial till, offshore marine clay, and organic deposits occur within local low-lying areas, predominantly within the Shirley Brook Subwatershed 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 that account for approximately 5% of the Shirley's Brook Subwatershed and Kizell Drain Subwatershed.

The **middle and lower reaches of the study area** can be characterized as follows:

- Are overlain by offshore marine deposits of clay, silty clay, and silt and are commonly locally overlain by thin sands.

- 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 Subwatersheds, 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 subwatershed areas.

Minor deposits (<5%) of nearshore marine sand and gravel lie along the southernmost flanks of the Watts Creek Subwatershed overlying the shallow/exposed Paleozoic bedrock uplands. The surficial geology within the upper reaches of the Watts Creek subwatershed 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.

<u>Bedrock Geology</u>

Bedrock stratigraphy, from youngest to oldest, is listed in **Table C.3**.

TABLE C.3
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 Subwatershed 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 Subwatershed. 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 Subwatershed and as a narrow fault block in the northern portion of the Shirley's Brook Subwatershed. 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 Subwatershed and as a narrow fault block near the middle reaches of the Watts Creek Subwatershed. 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 Subwatershed and along the northeast portion of the Shirley's Brook Subwatershed. 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.

2.4 Hydrogeology

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 Subwatershed 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.

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.

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 Subwatershed. Several smaller bedrock recharge areas lie within the upper reaches and along the east flank of the Watts Creek Subwatershed 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 Subwatershed 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.

<u>Groundwater Discharge</u>

Groundwater discharge 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 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 stormwater, treatment plant effluent and agricultural runoff.

Given the physiography and the nature and thickness of the overburden materials the groundwater discharge contributions to streamflow are anticipated to be relatively minor in terms of quantity throughout the study area. While the volume of groundwater discharge 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.

No areas of significant active groundwater seepage such as upwelling were observed during the course of a field reconnaissance. Minor active groundwater seepage was observed along the west bank of Watts Creek between the Highway 417 off-ramp and Corkstown Road. In this area the banks of the channel are roughly two metres in height and are flanked by a small plateau area. While no groundwater monitors have been installed in this area, the source of seepage appears to be interflow resulting from temporary storage along the flanks of the stream channel following storm events.

Groundwater seepage metres were installed at five stream channel locations throughout the study area to establish the watercourse recharge/discharge characteristics and to quantify the groundwater seepage flux. The metering locations included:

- Watts Creek south of Corkstown Road;
- Watts Creek north of Carling Avenue;
- Kizell Drain east of Herzberg Road;
- Shirley's Brook north of Klondike Road; and
- Shirley's Brook east of CN rail line.

The seepage metres were slowly advanced approximately 10-15 cm into the sediment to ensure an adequate seal. The metres were tilted slightly to allow proper vent functioning. The groundwater seepage flux (discharge) was calculated by measuring the time and the change of water volume in the bag. A decrease in water volume indicates an area of groundwater recharge while and increase in the volume of water indicates a groundwater discharge area.

The baseflow components for each of the watercourses are primarily (>95%) derived from three sources: 1) headwater source areas; 2) on-line stormwater management facilities, and 3) dry-weather flows sourced from storm sewer outfalls.

The results of the seepage monitoring are summarized in **Table C.4**. Projected over the length of their respective watercourses, these seepage rates contribute to baseflows of a volume less than 1 L/sec. These seepage rates are consistent with field observations and those expected given the low permeability nature of the underlying geologic materials and generally shallow channel depths.

TABLE C.4
SEEPAGE MONITORING RESULTS

Monitoring Location	Seepage Volume (ml)	Elapsed Time (min)	Seepage Flux (L/m^2/day)
Watts Creek south of Corkstown Rd.	+58.8	1437	+0.231
Watts Creek north of Carling Ave.	+81.5	1430	+0.322
Kizell Drain east of Herzberg Rd.	+44.0	1685	+0.147
Shirley's Brook west of Klondike Rd.	+40.0	1710	+0.132
Shirley's Brook north of CNR line	+31.0	1440	+0.181

2.5 Surficial Soils

Figure 3.4 (in Chapter 3.0) displays the various surficial soils within the Shirley's Creek/Watts Creek Subwatershed, the characteristics of which are described below. The 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) that 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 that 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. These soils have moderate permeability and low moisture holding capacity.

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.

Annex C-3 - Surface Water Quality

3.1 Water Quality Data

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 C.5** lists the relevant stations on Shirley's Brook and Watts Creek and their associated tributaries, within the subwatershed, for which surface water quality data was available. The locations of these stations are shown on **Figures C2a and C2b**.

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. A summary of the minimum, maximum and average values for a select number of parameters at each of the monitoring stations is presented in **Table C.6**.

TABLE C.5
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
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; Major ions; N: Nutrients; B: Bacteria; Tr: Trace constituents (mainly metals); x: Indicates parameter group available

TABLE C.6
SUMMARY OF HISTORICAL SURFACE WATER QUALITY DATA FOR SELECTED PARAMETERS

Annex C-4 - Surface Water Hydrology

4.1 Surface Water Drainage

The following provides a detailed description of surface water drainage within Shirley's Brook, Watts Creek and Kizell Drain Subwatersheds.

<u>Shirley's Brook</u>

Main Branch

The Shirley's Brook subwatershed drains a total upstream area of 27 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 watercourse continues another 500 m in a northeasterly direction where it is conveyed beneath Hines Road via a 1.85 m x 2.4 m (HxW) galvanized steel plate arch culvert. From Hines Road, Shirley's Brook continues northeasterly 200 m where it is conveyed beneath March Road via a 1.5 m x 3.0 m (HxW) concrete box culvert. Five-hundred metres downstream of March Road, Shirley's Brook turns abruptly and continues through the Business Park in a northwesterly direction 320 m, where it is conveyed under Terry Fox Drive via a 0.9 m x 3.0 m (HxW) concrete box culvert. From Terry Fox Drive, the watercourse flows 500 m through a straightened reach, passing under Shirley's Brook Drive via a twin 0.9 m x 2.0 m concrete box culvert. The culvert directs Shirley's Brook into an on-line artificial wetland 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, where it passes under via a 1.45 m x 3.0 m (HxW) concrete box culvert.

From Klondike Road, Shirley's Brook continues 300 m through a treed valley where it is joined by the two unnamed tributaries. From its confluence with the tributaries, Shirley's Brook turns abruptly and flows northeast for 1,200 m, passing first under the CNR line via a twin 1.45 m x 2.8 m (HxW) concrete box culvert and then under Fourth Line Road via a 2.0 m x 2.75 m (HxW) concrete box culvert. Downstream of Four Line Road, the watercourse turns northeast and flows parallel to Four Line Road through DND lands for a distance of 2,200 m. At this point, Shirley's Brook turns due east and meanders 2,000 m through a large wetland to its outlet into the Ottawa River.

Tributary 1

Tributary 1 originates at March Road (East-West) and flows 1,900 m southeasterly through agricultural lands as a small swale where it passes beneath March Road (North-South) via a 1.1 m x 1.8 m 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, the combined tributaries flow 400 m, joining the main branch of Shirley's Brook 300 m downstream of Klondike Road.

Tributary 2

Tributary 2 begins as small wetland immediately south of Old Carp Road, and passes beneath Old Carp Road via a small diameter corrugated metal culvert. The Tributary flows in a northeasterly direction for 1,250 m where it is conveyed under Second Line Road via a 1.25 m x 0.7 m (HxW) CMPA, and flows 1,600 m eastward through agricultural/rural residential lands where it passes beneath March Road via twin 1650 mm φ CMP culvert. From March Road, Tributary 2 continues easterly 250 m where it joins Tributary 1.

Watts Creek

At its outlet into the Ottawa River, Watts Creek drains a total upstream area of 25 km^2. Watts Creek originates at Castlefrank Road situated in Katimavik/Hazeldean. The main branch of Watts Creek is sourced in the community of Katimavik from a storm sewer outfall located north of Chimo Drive. Several tributaries join the main branch within the community of Katimavik, each of which are also sourced from storm sewer outfalls. At this location, dry weather flow was observed discharging from a storm sewer outfall. Further downstream, several additional storm sewer outfalls were observed augmenting the flow. From Castlefrank Road, the Creek meanders 1,700 m northward through several residential subdivisions passing beneath several roadway culverts that include: Chimo Drive (via twin 1450 mm φ CMP), Katimavik Road (via twin 1650 mm φ CMP) and Hearst Way (via a 2.35 m x 3.75 m (HxW) CMPA). 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, the largest of which is a 200 m long, 2.75 m x 3.8 m (HxW) CMPA. After passing beneath Eagleson Road via a 3.1 m x 4.7 m (HxW) CMPA, and Corkston Road via a 2.75 m x 9.8 m (HxW) CMPA, Watts Creek meanders 1,700 m through agricultural lands before passing beneath the CNR line via a 2.1 m x 2.65 m wood tie box culvert. From the CNR line, Watts Creek turns and continues easterly 250 m where it is joined by the Kizell Drain. Approximately 500 m further eastward, the Creek passes beneath another CNR line via a twin 2100 mm φ concrete pipe culvert. At this point, Watts Creek turns and flows north 700 m to Carling Avenue, passing beneath it via a 4 m high concrete bridge with a span of 10 m. From Carling Avenue, the Creek flows 600 m through Defence Research lands where it is convey under Sandhill Road via a 1.8 m x 5.85 m concrete bridge. Continuing northward, Watts Creek meanders 2,000 m passing under Shirley Boulevard via 2.9 m x 4.3 m CMPA culvert before outletting into the Ottawa River.

Kizell Drain

The Kizell Drain system is the largest tributary discharging to Watts Creek. At its confluence with Watts Creek, the Kizell Drain Subwatershed drains a total upstream area of 10 km^2. The Drain begins at the outlet of Beaver Pond which discharges pond flows via a concrete 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 an 1100 mm φ CMP culvert. The Drain then continues northeasterly 1,700 m through the Kanata North Business Park passing beneath several roadway culverts that include: Station Road (first, via an 1200 mm φ concrete pipe, then entering an 80 m enclosure via a 1300 mm φ CMPA exiting at March Road (via a 1.6 m x 2.45 m concrete box culvert) and Legget Drive (first, via twin 1250 mm φ concrete box pipe, then via twin 1650 mm φ concrete pipe culvert). From Legget Drive, the Kizell Drain flows eastward 250 m to Hertzberg Road where it is conveyed beneath the road via a 2.0 m x 3.0 m (HxW) concrete box culvert. The Drain continues eastward 500 m passing first under Carling Avenue via a 1.2 m x 4.0 m (HxW) concrete box culvert.

In addition to the main branch of Kizell Drain, a significant tributary to the south drains the area of Beaverbrook, originating south of Beaverbrook Road and flows in a northeasterly direction. The tributary passes under Beaverbrook Road via a 1200 mm φ CMP, continuing through Lytle Park to Terron Road where it passes under via a 1.1 m x 1.5 m (HxW) CMPA, through Bethune Park is conveyed under March Road via a 2.5 m x 3.0 m concrete box culvert. The tributary to Herzberg Road passes under the road via a 1900 mm φ CMP, and continues in a northeasterly direction through agricultural lands for 700 m before crossing beneath the CNR line via twin 900 mm φ CMP, then joins into the Kizell Drain.

From the CNR line, Kizell Drain flows the remaining 950 m eastward where it outlets into Watts Creek.

4.2 Streamflow Observations and Temperature Measurements

Streamflow observations were collected over the monitoring period at 9 locations within Shirley's Brook, Watts Creek and Kizell Drain Subwatersheds **(Refer to Figure C.2a and C.2b)**. Average depth, velocity and flow measurements were recorded by the Mississippi Valley Conservation Authority and are summarized on **Table C.7**.

TABLE C.7
SUMMARY OF RECORDED STREAMFLOW OBSERVATIONS

Site Identification and Location	Date of Observation						
Measurements	May 12	June 14/15	June 25	June 28	July 13	August 1	August 13/14
OBS-S1 Shirley's Brook at Hines Road							
Approximate Depth (mm)	200	90	210	n/a	60	60	0
Approximate Velocity (m/s)	0.08	0.01	0.16	N/a	0.05	0.01	0.00
Approximate Flow (L/s)	12	0.5	34	n/a	2	>1	0

OBS-S2 Shirley's Brook Tributary 2 at March Road							
Approximate Depth (mm)	160	115	140	n/a	110	70	0
Approximate Velocity (m/s)	0.10	0.01	0.15	n/a	0.08	0.05	0.00
Approximate Flow (L/s)	10	0.6	13	n/a	5	>1	0

TABLE C.7
SUMMARY OF RECORDED STREAMFLOW OBSERVATIONS

Site Identification and Location	**Date of Observation**						
Measurements	**May 12**	**June 14/15**	**June 25**	**June 28**	**July 13**	**August 1**	**August 13/14**
OBS-S3 Shirley's Brook Tributary 1 at March Road							
Approximate Depth (mm)	n/a	40	90	n/a	48	50	0
Approximate Velocity (m/s)	n/a	0.10	0.10	N/a	0.10	0.05	0.00
Approximate Flow (L/s)	n/a	1	4	n/a	1	>1	0
OBS-S4 Shirley's Brook at Klondike Road							
Approximate Depth (mm)	n/a	40	120	50	20	20	40
Approximate Velocity (m/s)	n/a	0.45	0.33	0.33	0.25	0.30	0.25
Approximate Flow (L/s)	n/a	10	65	15	4.5	5	4
OBS-S5 Shirley's Brook at CN Rail							
Approximate Depth (mm)	n/a	80	n/a	75	70	65	75
Approximate Velocity (m/s)	n/a	0.06	n/a	0.15	0.17	0.12	0.06
Approximate Flow (L/s)	n/a	14	n/a	30	29	20	6
OBS-W1 Watts Creek at Corkstown Road							
Approximate Depth (mm)	n/a	150	200	n/a	100	110	150
Approximate Velocity (m/s)	n/a	0.06	0.50	n/a	0.38	0.25	0.06
Approximate Flow (L/s)	n/a	38	n/a340	n/a	75	72	28
OBS-W2 Watts Creek at Carling Avenue							
Approximate Depth (mm)	n/a	120	320	n/a	230	250	190
Approximate Velocity (m/s)	n/a	0.10	0.33	n/a	0.15	0.20	0.08
Approximate Flow (L/s)	n/a	48	450	n/a	148	225	44
OBS-K1 Kizell Drain at Outlet of Beaver Pond							
Approximate Depth (mm)	300	245	290	n/a	235	240	220
Approximate Velocity (m/s)	0.15	0.09	0.30	n/a	0.11	0.10	0.11
Approximate Flow (L/s)	7	15	61	n/a	17	15	15
OBS-K2 Kizell Drain at Carling Avenue							
Approximate Depth (mm)	n/a	130	300	n/a	250	250	185
Approximate Velocity (m/s)	n/a	0.06	0.15	n/a	0.10	0.15	0.11

Approximate Flow (L/s)	n/a	25	225 E	n/a	80 E	120	45

Notes: 1. n/a represents no measurements available.
2. E represents estimated flow.

The collected streamflow observations were used to confirm results of continuous monitoring data and determine minimum baseflow values for hydrologic modelling as discussed in Section 4.3.
Continuous measurements of stream temperature was also recorded at 7 locations within the Shirley's Brook/ Watts Creek Subwatershed study area during the monitoring period **(Refer to Figure C.2a and C.2b**). The locations included the following:

- Shirley's Brook
  - Main branch @ CNR (upstream of 4th Line) (FM-S)
  - Main branch @ Hines Road (WT-S1)
  - Tributary 2 @ March Road (WT-S2)

- Watts Creek
  - @ Corkstown Road (FM-W7)
  - @ Carling Avenue (WT-W7)

- Kizell Drain
  - @ Outlet of Beaver Pond (WT-K1)
  - @ Carling Avenue. (FM-K1).

Minimum, Maximum and average daily stream temperatures for each location are summarized in **Table C.8.** Collected stream temperature monitoring data was used to assist in the aquatic characterization of the stream systems under current conditions and to determine appropriate aquatic managment targets for future development.

TABLE C.8
SUMMARY OF RECORDED WATER TEMPERATURE MEASUREMENTS

Average Daily Water Temperature (°C)																
Kizell Drain					Watts Creek						Shirley's Brook					
K1		FM-K1			FM-W1			WT-W1			WT-S1			WT-S2		
.[2]	Avg.[3]	Min.[1]	Max.[2]	Avg.[3]	Min.[1]	Max.[2]	Avg.[3]	Min.[1]	Max.[2]	Avg.[3]	Min.[1]	Max.[2]	Avg.[3]	Min.[1]	Max.[2]	Avg.[3]
[illegible]	19.5	9.9	32.4	20.4	8.6	22	14.6				10.3	30.2	19	7.5	28	17.6
[illegible]	21	8.9	35.3	21.9	9.3	23.6	16.2	11	28.6	20.2	10.5	28.5	19.2	8	28.8	20.4
[illegible]	23.2	15.6	32.5	23.4	13.5	26	18.4	15.8	29.8	21.8	15.4	24.8	19.5	12.3	25.4	18.5
[illegible]	24	15.8	33	23.8	13.8	25.5	18.6	16.5	25.5	22.2	13.6	24	19.4	11.3	33.2	17.6
[illegible]	21.9	12.5	33.3	22.4	11.3	24.3	16.9	14.4	28	21.4	12.4	26.9	19.3	9.8	28.8	18.3

Notes:
1 Minimum average daily temperature during month.
2 Maximum average daily temperature during month.
3 Average daily temperature during month.
Toned cells indicates incomplete month.

4.3 QUALHYMO Computer Modelling

Methodology

QUALHYMO models representing the existing and future land use conditions were prepared for the entire Shirley's Brook and Watts Creek Subwatershed Area. The various parameters used to describe the existing land use characteristics of each catchment area are detailed in the QUALHYMO input files included at the end of **Annex C-4**. Descritization of Subwatershed catchment areas are also shown on **Figures 3.6a and 3.6b** in Section 3 of the Report.

Continuous Hydrologic Computer Modelling

Continuous simulation using QUALHYMO was conducted for the Shirley's Brook and Watts Creek Subwatershed for existing and future conditions. The snowpack accumulation and melt routine in the QUALHYMO model was calibrated using 7 years of snow survey data. Once calibrated, continuous simulations using 7 years of recorded hourly precipitation and temperature data were conducted to generate a continuous time series of streamflow estimates (hydrographs). Streamflow data collected during the monitoring period as part of this study was used to calibrate the hydrologic model parameters related to runoff generation.

Streamflow hydrographs were first simulated using the QUALHYMO model based on existing land use conditions in the Shirley's Brook and Watts Creek Subwatershed. Characteristics of the proposed land uses were then input into the model to assess the potential for future changes. Streamflow hydrographs were again simulated and comparisons to existing conditions were made. Characteristics of the predicted streamflow hydrographs were used as the basis for assessing the potential surface water impacts posed by future land use changes. Increases (or decreases) to streamflow peaks and runoff volumes were used as indicators of potential surface water impact.

Single Event Hydrologic Computer Modelling

Single event hydrologic computer modelling of the entire Shirley's Brook and Watts Creek Subwatershed Area was conducted using the same QUALHYMO model setup used for the continuous simulation, run in *event-mode*. As with the continuous modelling, single event runoff hydrographs were first simulated using the QUALHYMO model based on existing land use conditions. Characteristics of the proposed land uses were then input into the model. Runoff hydrographs were again simulated and comparisons to existing conditions were made.

The QUALHYMO input parameters for both existing land use conditions and assumed future land use conditions, together with the methods used to derive the values, are discussed as follows.

QUALHYMO Model Input Parameter: Existing Land Use Conditions

i) Climatic Data Files

Continuous Data

Precipitation

A continuous precipitation data file was developed using hourly precipitation data from the nearest Atmospheric Environment Service (AES) meterological station located at the Ottawa International Airport. To provide for a 7 year time span of continuous simulation, data was obtained for the 1985 to 1992 period.

Missing data was infilled using daily precipitation data from the same station. The daily precipitation values are distributed using a standard 4 hour storm distribution (20%,40%,20%,20%). As well, the daily precipitation totals are compared with the hourly data to ensure that the daily, monthly and annual precipitation totals were preserved.

Temperature

A temperature data file for the same period as the precipitation file was developed using hourly temperature data also from the AES meterological station located at the Ottawa International Airport. QUALHYMO only reads the temperature data for the winter season of each year from November 1 to May 31. To facilitate this program requirement, the temperature data from June 1 to October 31 for each year is removed from the file.

Missing data was infilled using linear interpolation to estimate any missing values.

Single Event Data

Design Storms

The design storm hyetographs for the 2, 10 and 100-year return periods were developed using rainfall intensity-duration-frequency data from the AES meteorological station also located at the Ottawa International Airport. The station maintains over 30 years of record.

The Soil Conservation Service (SCS) Type II distribution was used to distribute the rainfall intensities over a 12 hour storm duration. A storm duration of 12 hours was used because it exceeds the time of concentration of the basin, is sufficient to examination of the attenuation effects of storage elements and has been adopted by the MVCA in previous studies within the Subwatershed. A time step of 60 minutes was used for the discretization of the design storm to be consistent with the model input requirements.

ii) Subwatershed Discretization

Delineation of the Subwatershed and catchment area boundaries for existing land use conditions was based on a review and interpretation of the following information:

- detailed topographic mapping, prepared by RMOC and the City of Kanata;
- 1:2000 scale Floodplain Mapping of Shirley's Brook, Watts Creek and Kizell Drain prepared for the MVCA;
- 1:10,000 scale OBM topographic mapping, prepared by the MNR;
- Colour air photo mosaic of the Study Area;
- 1:25,000 scale *"Artificial Drainage Systems"* maps prepared by OMAF;
- 1:50,000 scale topographic mapping prepared by Environment Canada;
- Miscellaneous road and highway plan and profile drawings; and,
- Field reconnaissance conducted during the Spring 1996.

Catchment Areas (DA)

Areas for each of the delineated drainage/catchment areas within the Subwatershed were measured using the detailed topographic mapping supplemented by 1:10,000 scale OBM mapping, air photos and field reconnaissance.

Impervious Area Fraction (FRIMP)

The percentage of impervious area is used to distinguish between pervious areas (grass or vegetation) and impervious areas (*e.g.* paved roads, sidewalks and rooftops) associated with urban areas. Areas with high percentages of impervious area generally produce higher peak flows and larger runoff volumes than natural areas.

Impervious area percentages (expressed as a fraction) were determined from examination of existing land uses in the Subwatershed. Sources used included aerial photos, Official Plan land use schedules and zoning documents, topographic mapping, background reports and field reconnaissance.

iii) Impervious Area Component Parameters

Hydrograph Shape Parameters

Unit Hydrograph Type (AA)

For both impervious and pervious areas, the Nash unit hydrograph was used.

Number of Nash Reservoirs (XK)

The number of Nash (linear) reservoirs was initially set at 3 in the model for the generation of the hydrographs. Upon comparison to observed flow data, the number of linear reservoirs was increase to 5 to better match the existing hydrograph shape.

Time to Peak (TP)

The time to peak represents the time from the beginning of rainfall to the peak of the hydrograph and is indicative of the basin's response to storm events. This parameter is based on the physical characteristics of the subwatershed such as length, slope and surface cover. The slope and surface cover determine the velocity at which the runoff will travel and the length over which it must travel determines the time of concentration.

Estimates of the time to peak were determined by first computing a separate travel time for both an overland and a channel component (where applicable) and then adding the respective times together; this established the time of concentration for each catchment area.

For the overland component, the U.S. Soil Conservation Service (SCS) Upland Method was used to determine the travel time for each sub-area. The required overland flow lengths and slopes were determined from the detailed topographic mapping. Vegetative land use covers used to characterize the hydraulic resistance to overland flow were obtained from interpretation of the air photo mosaic.

Travel times for the channel component were computed from streamflow velocities derived from typical channel cross-sections measured from the detailed topographic maps. The velocities were based on flows approximating bankfull discharge. Hydraulic parameters, such as channel slopes and lengths, were also determined from the topographic maps. Channel roughness coefficients were estimated using information from field investigations, supplemented by the air photo mosaic.

Surface Runoff Parameters

Initial Abstraction (ABSIMP)

Initial abstraction consists mainly of the interception, infiltration and surface storage of rainfall during the beginning of storm events, before runoff is produced. The primary factors which influence initial abstraction are the native soils, vegetative cover and the extent of surface depressional storage.

For impervious areas, an initial abstraction value of 1.0 mm was used based on background literature.

Volumetric Runoff Coefficient (RIMP)

This parameter controls runoff volume for the portion of impervious areas that is directly connected to the outlet point and was set at 1.0.

Evaporation Correction Factor (CETIMP)

This parameter provides the ability to adjust the amount of evaporative losses from the impervious area initial abstraction parameter and was set at 1.0.

iv) Pervious Area Component Parameters

Hydrograph Shape Parameters

Unit Hydrograph Type (AA)

For both impervious and pervious areas, the Nash unit hydrograph was used.

Number of Nash Reservoirs (XK)

As described under the impervious area parameter, the number of reservoirs was determined based on calibration to observed hydrographs to reflect the actual conditions in the basin. Similarly, determination of the number of reservoirs used for generation of the hydrographs for the pervious areas was based on this method. The pervious areas number of reservoirs value used in the model for each catchment area was set at 1.1.

Time to Peak (TP)

Time to peak estimation for the pervious areas is based on the same method as used for the impervious areas and is described in section iii).

Surface Runoff and Soil Moisture Storativity Parameters

Surface runoff from pervious areas is affected by a number of factors including soil moisture storage (which reflects the infiltration capacity of the soil), initial abstraction and evaporation. To incorporate this factors into the runoff generation process, QUALHYMO employs a modified Soil Conservation Service (SCS, 1975) method for computation of direct runoff. The model takes into account variations in initial abstraction and antecedent moisture conditions by linking precipitation inputs to a time dependent soil moisture storage recharge function that is associated with the SCS method. This results in an infiltration based approach that considers soil recharge and depletion through sub-surface flow, evapotranspiration and deep groundwater losses. The model uses soil moisture storage (S) or storativity, which is related to the standard SCS curve number (CN) as the indicator of the runoff potential of an area. The CN, and hence S is used to determine the percentage of rainfall that becomes runoff. The curve number is a function of land use, soil type and antecedent moisture conditions.

To establish upper and lower boundary condition values for the model variations in storativity, CNs were first calculated as follows.

Land use conditions for the Subwatershed were determined primarily from aerial photography and field reconnaissance, supplemented by review of the *Agricultural Land Use Systems* mapping (OMAF). Curve numbers for each of the catchment areas were computed by calculating a weighted CN based on the relative proportions of the different land use and soil types within each sub-basin using the runoff curve numbers summarized in **Table C.9**.

TABLE C.9
RUNOFF CURVE NUMBERS

Land Use	Runoff Curve Number (AMC II)						
	A	AB	B	BC	C	CD	D
Agriculture	63	69	74	78	81	83	85
Woodland/Scattered Shrub Area	36	48	60	68	73	76	79
Open Space/Grassland	49	59	69	74	79	82	84

Note: AMC II refers to average antecedent moisture condition.

The storativity was then calculated by transforming the computed CN values using the following relationship:

$S = 25400/CN - 254$ where S is in mm

Minimum and Maximum Soil Storativity (SMIN, SMAX)

The upper and lower boundary condition values for the model variations in storativity; *minimum* and *maximum soil storage* were then calculated using the following relationships:

$SMAX = S_{(AMCI)}/0.85$, and

$SMIN = 0.15(SMAX)$

Initial Abstraction (ABSPER)

Given the many actors that affect the amount of initial abstraction available for pervious areas, it generally is a difficult parameter to estimate correctly and is best determined by calibration.

For this study, rain gauge data and observed flow data were used to determine the amount of rain (*i.e.*, initial abstraction) that fell prior to runoff. Only rain events preceded by dry weather for 24 hours or more were used to estimate this parameter to ensure that the response was not accelerated due to wet antecedent conditions. Initial abstraction values of 9 mm for Shirley's Brook, 5 mm for Watts Creek and 7 mm for Kizell Drain were determined for the pervious areas within the Study Area.

Other Soil Moisture Accounting Parameters (SK, APIK, API, CETPER)

Soil moisture accounting is achieved through various parameters in addition to those discussed above that are used by the model to:

· control the rate of change in soil moisture *(API/S Variable, SK*);
· account for previous or initial conditions as a result of rainfall or snowmelt (*Starting Antecedent Precipitation Index, API*);
· determine the memory of the system, the recovery rate after an event (*API Calculation Parameter, APIK*);
· determine the rate of evaporation that will affect the initial abstraction (*Evaporation Correction Factor, CETPER*).

The Initial Antecedent Precipitation Index was initially set to an assumed value. During model simulations, this value converges to the appropriate API value after an elapsed time. The other variables listed above were initially set to an assumed value and confirmed through comparison of the observed and simulated hydrographs.

v) Baseflow Parameters

Minimum Baseflow (BASMIN)

Minimum baseflow rates, which are generally constant throughout the simulation period were determined based on continuous streamflow monitoring data and observations collected throughout the monitoring period. Minimum baseflows were distributed to each catchment area using a weighted-area average combined with field observations.

Baseflow Generation and Groundwater Storage Parameters

Baseflow in excess of the minimum baseflow is generated in QUALHYMO as a function of the basin area, the volume of water available for baseflow in groundwater storage, the rate of outflow, and the losses to deep groundwater storage. Mass balance of the groundwater storage available for outflow (baseflow) is treated as a single linear reservoir with inflow essentially being the difference between precipitation and runoff, less any losses to initial abstraction.

The *Initial Soil Moisture Content (SVOL)* or volume of the groundwater reservoir is initially set to an assumed value, as this volume is normally unknown. The model will converge to the appropriate volume and baseflow rate some time after the simulation is started.

In the absence of infiltration, the outflow rate is averaged over the time step based on the *Baseflow Recession Constant (SLOSK1)*, which controls the rate of outflow from the reservoir during dry periods. The *Baseflow Reduction Factor (SLOSK2)* adjusts the baseflow rate by accounting for the losses to the deep groundwater storage. These parameters were set by comparing the observed and simulated hydrograph recessions curves.

Depletion of the groundwater, or the rate of outflow, varies depending on the retention properties of the soil. The baseflow rate increases as water above the groundwater table, 'gravity water', is more abundant, at or above the *Soil Moisture Field Capacity (SFIELD)*. As soil moisture depletes below the field capacity through evapotranspiration processes and lack of infiltration, there is a progressive increase in the retention capacity of the soil, and thus, the baseflow rate decreases. The volume of the groundwater reservoir declines until the gravity water is depleted and the soil has reached the *Soil Moisture Wilting Point (SWILT)* at which the rate of outflow from the reservoir as baseflow is equal to the minimum baseflow specified.

The soil moisture wilting point and field capacity are set based on the soil type and root zone depth typical for the soil type and the flora occupying the area.

The rate of decrease in the baseflow to the wilting point, where baseflow is at the minimum, can be adjusted using the *Baseflow Calibration Factor (BFACR)*. Evapotranspiration rates can be adjusted using the *Evapotranspiration Correction Coefficient (CET)*. For this study, both parameters are given the default value of 1.0 since the recession limb of the hydrographs generated are consistent with actual observations.

vi) Snowmelt Parameters

When ambient air temperatures rise above a base temperature at which precipitation falls as rain and any accumulated snow pack begins to melt, snowmelt amounts are calculated and added to the rainfall, if any, and used to generate the runoff hydrographs. The Reduced Heat Budget temperature index method for determining snow pack and snowmelt, adopted for this study, has been found to provide good estimates of snow pack accumulation and melt.

This method uses the mean temperature per time step and *Monthly Snowmelt Factors (CMELTF)*, determined by comparison to observed snow pack and seasonal melt rate analysis, to generate the snow pack and melt. The *Initial Snow Pack Depth (PACDEP)* is assumed to be 0.0 mm, allowing the model to converge to a value based on the temperature and precipitation conditions. The temperature at which snowmelt begins *(Base Melt Temperature, BASET)* and temperature at which precipitation will fall as rain *(Precipitation Base Temperature, PSTATE)* are determined based on observed data and are normally set at or near 0°C.

Snowmelt Calibration Parameters

Numerous other parameters which play a part in the snow accumulation and melt routines were determined through the snow pack calibration process. These parameters account for factors including:

- *Wet Day Calibration Factors (COEFD, COEFE)* to account for the heat content in the rain to slightly modify the melt factor;

- *Upward and Downward Heat Flux Factors (ALPHAA, BCOEF)*, and *Soil Thermal Conductivity vs. Depth (XKL)*, to account for long wave radiation, geothermal inputs and vegetative cover; and
- *Thermal Insulation Factor (XNCOEF)* for the snow pack.

vii) Model Calibration Data

The snowpack accumulation and melt routine in the QUALHYMO model was calibrated using 7 years of snow survey data. The results of the calibration are shown on **Figure C.3**. The calibration showed good agreement between the observed and predicted snowpack depths. This confirmed that the model parameters reflected the Subwatershed snow accumulation and melt characteristics, with only moderate adjustment in parameterization.

Calibration of the QUALHYMO model parameters was undertaken using the 3 months of streamflow data collected during the monitoring period. Calibrations involved adjusting key model parameters such as the Number of Nash Reservoirs (n) and the Time to Peak (Tp) until a match between the observed and modelled runoff hydrographs was attained. Continuous rainfall data recorded at the RMOC March Road Pumping Station station were used in the model simulations

The results of the calibration for Shirley's Brook, Watts Creek and Kizell Drain are shown on **Figures C.4, C.5 and C.6** respectively. The calibration showed good agreement between the observed and predicted hydrographs. This confirmed that the model parameters reflected the Subwatershed rainfall-runoff characteristics, with only moderate adjustment.

viii) Hydrologic Routing

Hydrologic routing is the method by which the movement of water down streams and valleys is predicted. The resulting peak flow attenuation of the runoff hydrograph is a function of the travel time of the reach and the available storage in the valley.

The hydraulic characteristics of the watercourses, including the cross-section data, slope and routing distances, were computed from measurements using the detailed topographic mapping, supplemented with MVCA Floodplain Mapping and field survey where required. Locations of the channel overbanks and flow resistance (Manning's n) were estimated using topographic mapping, aerial photography and field reconnaissance. Generally, one typical cross-section was used to represent the relevant channel reach for each catchment area. The information was input into the hydrologic model and the inflow (upstream) hydrographs were routed using the kinematic approximation of the program.

ix) Detention/Retention Storage

The presence of detention/retention storage within the conveyance system can result in considerable attenuation (*i.e.* peak flow reduction) of the runoff hydrograph. This is because the runoff volume of the hydrograph is temporarily detained over a longer time period resulting in a lowering of the peak flow. The resulting peak flow attenuation is a function of the runoff hydrograph volume and the discharge-storage characteristics of the storage element. Types of storage includes detention elements that are normally dry, such as roadway embankments, and retention elements that are normally wet, such as lakes and ponds.

The attenuation effects associated with the retention storage of both the Beaver Pond located in the upper reaches of Kizell Drain and the Duck Pond located adjacent to the DND lands were modelled in QUALHYMO. The discharge-storage characteristics for storage elements were determined from previous detailed studies, supplemented with field measurements. The information was input into the hydrologic model and the inflow (upstream) hydrographs were routed using the Storage-Indication Method of the program.

QUALHYMO Model Input Parameter: Future Land Use Conditions

The various parameters used to describe the future land use characteristics of each catchment area are detailed in the QUALHYMO input files included at the end of **Annex C-4**. Descritization of Subwatershed catchment areas are also shown on **Figures 3.6a and 3.6b** in Section 3 of the Report.

i) Climatic Data Files

Continuous Data

Precipitation and *Temperature* files for continuous simulation of future conditions were the same as those used for existing conditions.

Single Event Data

The *Design Storm* hyetographs for the 2, 10 and100-year return period events were the same as those used for existing conditions.

ii) SubwatershedDiscretization

Area delineation for future land use conditions was based on the same hydrologic model used for existing conditions, but with specific catchment areas further discretized and/or revised to reflect differences in future land use. Modelling changes were based on a review of the following information:

- Official Plans for the Regional Municipality of Ottawa Carlton, and the City of Kanata; and
- Numerous development proposals within the Study Area.

Impervious Area Fraction (FRIMP)

Values of percent imperviousness associated with future land uses were estimated based on a review of the RMOC Official Plan. **Table C.10** lists the values of percent imperviousness estimated for each land use density.

TABLE C.10
PERCENT IMPERVIOUSNESS ASSOCIATED WITH FUTURE LAND USE

Land Use	Percent Imperviousness (%)
Rural Residential	25
Urban Residential	35
Commercial / Industrial	65
Kanata Town Centre	65
Institutional	45
Other (Highway 417, Large Parking Facilities)	50

iii) Impervious Area Components

Hydrograph Shape Parameters

The Unit Hydrograph Type (AA)

The Nash unit hydrograph used for existing conditions was kept the same under future conditions.

Number of Nash Reservoirs (XK)

The number of Nash reservoirs used for existing conditions was kept the same under future conditions.

Time to Peak (Tp)

For areas subject to new development, the time to peak values were recomputed using the methodology as described under existing conditions.

Surface Runoff Parameters

Surface runoff parameters assumed for impervious areas for existing conditions have remained the same for future conditions.

iv) Pervious Area Component Parameters

Hydrograph Shape Parameters

The Unit Hydrograph Type (AA)

The Nash unit hydrograph used for existing conditions was kept the same under future conditions.

Number of Nash Reservoirs (XK)

The number of Nash reservoirs used for existing conditions was kept the same under future conditions.

Time to Peak (Tp)

For areas subject to new development, the time to peak values were recomputed using the methodology as described under existing conditions.

Surface Runoff and Soil Moisture Storativity Parameters

Minimum and Maximum Soil Storativity

The runoff curve numbers for the pervious component of the areas subject to development were kept constant, equal to the values used in the existing condition hydrologic model, therefore, minimum and maximum soil storativity values did not change.

Initial Abstraction (ABSPER)

Initial abstraction values were kept the same under future land use conditions.

Other Soil Moisture Accounting Parameters

Various parameters used for soil moisture accounting in the model, discussed under existing conditions, were kept constant for the future conditions model.

v) Baseflow Parameters

The *Minimum Baseflow* values and parameters that affect baseflow generation (groundwater reservoir outflow) from the existing condition model were kept constant in the future condition model.

vi) Snowmelt Parameters

Parameters that control the snow accumulation and melt routines were kept constant in the future condition model.

Annex C-5 - Stream Morphology

5.1 Introduction

The science of fluvial geomorphology studies the form of watercourses and the processes responsible for creating that form. The most important processes are the movement of sediment and the movement of water through the drainage system. At the coarsest scale, controls and modifying factors that influence processes operating in the drainage basin are identified. Morphometric analyses of the drainage basin, conducted at an intermediate scale, quantify various properties of the drainage area that yield insight into the character and efficiency of water and sediment movement through the subwatershed. At the finest scale, field investigation of reaches along the main channel examines the physical characteristics of the watercourse's form, yielding insight into its function within the drainage basin.

Understanding of channel form and function can be drawn upon to develop guidelines for proposed land use changes that ensures long-term stability of a reach. Because fluvial geomorphology concerns itself with watercourse processes and its interaction with the environment, results usually permit integration with aquatic habitat and stormwater management objectives in the development of landuse guidelines. Further, field data collected during the study to characterize the existing morphology of channel reaches provide baseline or reference conditions to which future monitoring activities can be compared.

5.2 Basin Analysis

Geology and climate exert the principal controls on the function and form of a drainage basin. The controls of geology and climate are modified by other factors present in the subwatershed. In general, geology affects the drainage pattern, the volume and properties of sediment supplied to the channel, and the erosion and transport potential of the watercourse.

The main source of sediment for the channel originates from regions of the subwatershed that are overlain by glacial till and lacustrine sediments. Low relief and proximity to Shirley's Bay contribute to the poor drainage in the lowest region of Shirley's Brook and is indicated by large areas of wetlands within this area. The Precambrian bedrock (granite, gneiss and marble) that is exposed in various parts of Kizell Drain and the middle to upper regions of Shirley's Brook is resistant to erosion and therefore does not constitute a major source of sediment. The shallow overburden, coupled with the exposed bedrock, depressional topography, contributes to the poor drainage of these regions and is expressed through the presence of bogs and marshes.

Climate controls the volume of water delivered to the drainage basin and the shape of the annual hydrograph. The annual hydrograph is characterized by high flow events in the spring resulting from snowmelt while low flow conditions characterize winter and summer. Most of the precipitation in the basin is due to convection and frontal air mass activity, producing rainfall events in the fall and summer.

Elements within the subwatershed can modify the characteristics of the drainage basin that are controlled by geology and climate. These elements include beaver activity, riparian vegetation and surrounding land use. Modifying effects of riparian vegetation include the ability to protect the channel banks, resulting in narrower, but deeper channels than would normal be expected given flows produced from the upstream area. This is especially true in meadows, where the root density from grasses and sedges is greater than roots from mature trees. Land use in the basin primarily effects the hydrologic cycle, by influencing the amount of runoff, infiltration and evapotranspiration. Ponds situated upstream of beaver dams are areas of deposition while the increased carrying capacity of a watercourse downstream of the beaver pond increases erosion. Beaver activity modifies the drainage process and may cause shifts in channel pattern. Changes in landuse and riparian vegetation within the basin and especially along the stream corridor can affect the intricate functions between the channel and its floodplain, as well as the primary functions regarding the movement of water and sediment.

5.3 Morphometric Analyses

Morphometric analysis involves the quantification of various properties and characteristics of the drainage basin. These analyses provide insight into the pathway, and efficiency of water and sediment movement through the drainage basin. All measurements were made using 1:10,000 mapping and are quantified in **Table C.11**. Given the scale of the map used, it is likely that some ephemeral and small streams are not indicated on the maps thereby biassing the values for some of the parameters.

TABLE C.11
MORPHOMETRIC PARAMETERS

Parameter	Shirley's Brook	Watt's Creek*	Kizell Drain
Drainage Area (km^2)	27	25	10
Drainage Density (km^2/km^2)	1.47	1.32	1.60
Relief Ratio (m/m)	0.0108	0.0132	0.0077
Average Bifurcation Ratio	3.6	4.0	7.0
Sinuosity (m/m)	1.29	1.32	1.16

*Includes Kizell Drain.

Drainage density is a direct function of geology and climate and represents the average area drained per unit length of channel. The low drainage density values for all three subwatersheds indicate that the surface geology is resistant to erosion and/or have a large infiltration capacity. However, a more likely explanation for the low values, especially in the Watt's Creek basin and Kizell Drain basin, is the loss of surface channels that have been replaced by storm sewers, due to urbanization. The storage of water in bogs, lakes and wetlands in both the upper regions of Kizell Drain and in the lower regions of Shirley's Brook is another likely explanation for the low drainage density values.

The average steepness of the drainage basin is represented by the **relief ratio**. This value provides a general measure of the relative sediment supply that may be produced within the subwatersheds (Chorley, 1969) as well as the general dynamics of the watercourse. Because published relations of sediment delivery to the channel are based on concave longitudinal profiles, they may not represent the relative volume of sediment delivered to the creeks since the escarpment causes a knickpoint in their longitudinal profiles. Nevertheless, the relief ratio does provide an indication of the energy of the stream which has implications on erosion potential and sediment carrying capacity. The values for both Shirley's Brook and Watt's Creek are very high, indicating that sediment supply to these watercourses would be substantial.

The rate, at which a stream divides, influencing the pattern of sediment delivery and the shape of the hydrograph, is quantified by the **bifurcation ratio**. Values between 3 and 5 are typical for areas in southern Ontario with glacial deposits. (Chorley, 1969). Elongation of a drainage basin will increase the ratio, as is the case for Kizell Drain.

Sinuosity represents the ratio of channel length per unit length of valley. As such, it represents the degree of meandering. Channel straightening for the purposes of irrigation or containment in urban settings reduces the sinuosity of a watercourse. For this reason, as shown on **Table C.11**, the sinuosity within Kizell Drain is lower than for Shirley's Brook. Although the upper reaches of Watt's Creek are urbanized, the extensive lengths of downstream channel within open space helps to maintain some of the natural sinuosity.

5.4 Reaches

To examine the function of watercourses in a subwatershed, the main channel of a drainage network is divided into reaches. Reaches are identified on topographic maps and air photos as lengths of the channel, which display similar and physical characteristics, such as sinuosity, valley gradient, landuse, and relation between channel and valley form. Once identified, historical analyses of reaches are conducted to examine both landuse and channel changes. The results of these analyses, in conjunction with a rapid stream assessment of the reaches in the field, guide the detailed field work that assesses the function of a watercourse throughout its drainage basin.

Tables C.12, **C.13** and **C.14** describe the general physical characteristics of Shirley's Brook, Watt's Creek and Kizell Drain. The data tabulated below provides baseline information with respect to channel length, sinuosity, valley gradient and Rosgen classification of the channel within each reach. The Rosgen classification values are based on a Level I, which uses map data to evaluate basic plantform features (Rosgen, 1996). This classification provides a means of standardizing the reaches and permits comparison between other basins, as well as long-term monitoring.

From **Table C.12**, which summarizes the reach data from Shirley's Brook, several trends are observed. First, the gradient values are steeper within the middle and upper reaches of the basin, which likely is due to the influence of the underlying bedrock. Second, there are several reaches which appear to be degraded, due to the low sinuosity values, indicating some straightening and probable confinement. These reaches are classified as either an 'F' or 'G'.

Table C.13 contains the data on the reaches from Watt's Creek. There are fewer reaches for Watt's, as no tributaries where included. The shortest reach, located approximately at the middle of the basin, is a very steep portion of channel, which appears to cross an escarpment in the bedrock. As demonstrated in the classification, the reaches of Watt's Creek are quite diverse, with some of the changes in channel form occurring over a ver short distance. This pattern is likely due to the modifying effects of beaver activity and land use change. As with Shirley's Brook, there are several reaches which appear abnormally straight and are classified as either a 'F' or 'G' type channel. The reaches in Kizell Drain, described in **Table C.14**, have generally a low gradient and low sinuosity, which are likely the product of urbanization.

TABLE C.12
REACH INFORMATION FOR SHIRLEY'S BROOK

Reach	Length (m)	Gradient (%)	Sinuosity	Rosgen Class.
Shirley's Bay -E. of 4th line	1080	0.41	1.29	C
E. of 4th line - W. of DND	1230	0.02	1.01	F
W. of DND - 4th line	1350	0.27	1.20	C
4th line - W. of CN line	1030	0.14	1.42	E
W. of CN line - confluence with trib.	515	0.29	1.20	C
Confluence with tributary - Klondike	360	1.55	1.24	B
Klondike Rd. - E. of Legget Dr.	1940	0.06	1.14	C
E. of Legget Dr. - Hines Rd.	790	0.65	1.10	C
Hines Rd. - W. of Hines Rd.	490	1.28	1.26	C
W. of Hines Rd. - Hydro Corridor	380	1.79	1.36	B
Hydro Corridor - CN rail	730	1.06	1.40	C
CN rail - E. of Goulbourn Forced Rd.	1450	0.41	1.19	C
N. branch, tributary confluence - E. of March Rd.	990	0.96	1.04	G
N. branch tributary confluence - 2nd Line Rd.	1995	1.13	1.08	B

TABLE C.13

REACH INFORMATION FOR WATT'S CREEK

Reach	Length (m)	Gradient (%)	Sinuosity	Rosgen Class.
Shirley's Bay - north edge of DRE	1720	0.39	1.40	E
N. edge of DRE - N. of Sandhill Rd	400	0.10	1.04	F
N. of Sandhill Rd - Carling Ave	1875	0.29	1.36	C
Carling Ave - S. of northern CN line	1100	0.17	1.24	C
S. of Northern CN rail line - Kizell confluence	630	0.34	1.45	E
Kizell confluence - W of bicycle path	760	0.45	1.09	F
W. of bike path - bottom of ravine	650	0.11	1.41	E
Bottom of ravine - N. of hydro lines	195	5.15	1.18	B
N. of hydro lines - Hwy 417 Eagleson North exit	1570	0.13	1.26	C
Hwy 417 Eagleson N. exit - S. of Katimavik Rd.	1390	0.76	1.05	F

TABLE C.14
REACH INFORMATION FOR KIZELL DRAIN

Reach	Length (m)	Gradient (%)	Sinuosity	Rosgen Class
Watt's confluence - S. of Carling Ave	970	0.11	1.15	F
S. of Carling Ave - N. of Legget Dr.	1140	0.22	1.11	C
N. of Legget Dr. - E of Mitel Parking	390	0.44	1.15	C
E. of Mitel Parking - E of Legget Dr.	320	0.22	1.39	C
E. of Legget Dr. - March Rd.	490	0.67	1.09	F
March Rd. - Walden Rd.	1200	0.89	1.26	C
Walden Rd. - E. of Goulbourn Forced Rd.	1870	0.34	1.15	C

5.5 Historic Analyses

Historical land use and channel changes were evaluated using 1975 and 1996 air photos. Due to the scale of the air photos (1975 – 1: 15,000; 1996 – 1: 11,276), changes in channel width could not be reliably quantified, nor could specific areas of channel erosion and deposition be identified. The channel pattern is sometimes obscured by riparian and surrounding vegetation on the air photos preventing the measurement of channel length or observance of channel pattern changes.

The historic analysis of the three subwatersheds indicates that the landuse in Shirley's Brook has changed very little since 1975. Road construction and channel crossings characterize the change that has occurred in the upper regions of the Watt's Creek Subwatershed. Since 1975, urbanization has increased throughout the Kizell Drain Subwatershed. Channel straightening has increased and is likely a function of urbanization and development. One consistent observation for all basins, is the increase in terrestrial vegetation, especially the maturity of wooded areas.

Tables C.15, **C.16** and **C.17** provide a summary by reach of channel changes and land use changes.

TABLE C.15
LAND USE AND CHANNEL CHANGES BETWEEN 1975 – 1996
FOR SHIRLEY'S BROOK

Reach	Channel Changes	Land Use Changes
Shirley's Bay -E. of 4th line	Meander cut-off	No change
E. of 4th line - W. of DND	Decr. in wavelength	Incr. woodland density Some residential
W. of DND - 4th line	Addition of one irrigation canal	Road added
4th line - W. of CN line	Not available	Incr. woodland density
W. of CN line – confluence with tributary	Incr. radius of curvature, smoother pattern	Incr. riparian vegetation Channelization of watercourse
Confluence with tributary - Klondike Rd	None observed	Slight increase in residential housing
Klondike Rd. - E. of Legget Dr.	Straightening	Channelization, large increase in residential housing
E. of Legget Dr. - Hines Rd.	Decr. Sinuosity	Commercial development
Hines Rd. – W. of Hines Rd.	Not available	Incr. woodland density
W. of Hines Rd. – Hydro transformer station	Decr. Sinuosity	Channel realignment
Hydro transformer station - CN rail	Meander cut-off, channel straightening, channel splitting	Incr. woodland density
CN rail - E. of Goulbourn Forced Rd.	Decr. Sinuosity	Incr. woodland density
N. branch, tributary confluence - E. of March Rd.	Decr. Sinuosity	Residential development
N. branch tributary confluence - 2nd Line Rd.	Not available	No change

TABLE C.16
LAND USE AND CHANNEL CHANGES BETWEEN 1975 – 1996
FOR WATT'S CREEK

Reach	Channel Changes	Land Use Changes
Shirley's Bay - north edge of DRE	Incr. radius of curvature at mouth	Incr. woodland density
N. edge of DRE - N. of Sandhill Rd	None observed	Incr. woodland density
N. of Sandhill Rd - Carling Ave	Add two irrigation canals	Residential development, road lengthening

Carling Ave - S. of northern CN line	Meander bend development	Incr. woodland density, minor road constructed
S. of Northern CN rail line - tributary confluence	None observed	No change
Tributary confluence - W of bicycle path	None observed	Road crossing, road close to watercourse
W. of bike path - bottom of ravine	None observed	Road close to watercourse
Bottom of ravine - N. of hydro lines	None observed	Decr. orchard area
N. of hydro lines - Hwy 417 Eagleson North exit	Straightening, widening, channel splitting	Road crossings, decr. orchard area
Hwy 417 Eagleson N. exit - S. of Katimavik Rd.	Straightening	Road crossings, urbanization

TABLE C.17
HISTORICAL LAND USE AND CHANNEL CHANGES BETWEEN 1975 – 1996 FOR KIZELL DRAIN

Reach	Channel Changes	Landuse Changes
N. of bike path - S. of Carling Ave	None observed	Slight incr. in woodland density, road crossing
S. of Carling Ave - N. of Legget Dr.	Increase in width near commercial property	Incr. commercial landuse
N. of Legget Dr. - NNW of Legget Dr.	Increase width?	Incr. commercial landuse
NNW of Legget Dr. - E of Legget Dr.	Decrease gullies and tributaries entering channel	Incr. woodland density
E. of Legget Dr. - March Rd.	None observed	Major road crossing, incr. commercial landuse
March Rd. - Walden Rd.	Channel culverted	Incr. commercial landuse, major and minor road crossing
Walden Rd. - E. of Goulbourn Forced Rd.	Lake drainage	Incr. residential landuse, road crossing

5.6 Erosion

Channel bank erosion is a process that occurs in most natural watercourses. When changes in the flow or sediment regimes occur, or when the platform of the watercourse has changed through natural or human influences, then excessive stream bank or bed erosion can occur. To identify sites along the drainage network where erosion is occurring, several methods are used. Air photos are examined, a rapid stream assessment is completed and detailed field work is undertaken. Through map work and air photo analyses, reaches were identified for all three subwatersheds. Given the limitations of scale on both the map and the aerial photographs, specific areas of erosion and subtle changes in stream characteristics cannot be readily identified. For this reason, a rapid stream assessment technique (RSAT) was applied to the main drainage channel within each subwatershed. The visual assessment of the main channels that are part of the drainage network allows identification of areas of erosion and instability. Further, this technique permits an evaluation of the appropriateness of map defined reach-boundaries. Results of the RSAT are used to guide the location of detailed field work, and also applied in the interpretation of the geomorphic relations based on the detailed field measures.

Rapid Stream Assessment Technique

As part of the rapid stream assessment technique, parameters pertaining to the channel's form and function, sediment characteristics, riparian vegetation, and aquatic habitat are scored based on a numeric scale. In addition to this scoring, measurements are made of these parameters which are useful descriptors of the reaches (e.g. bankfull width, substrate sediment and bank material). The scores for each of the parameters are tabulated and the sum is indicative of channel stability. A RSAT score of 50 represents a pristine channel that has no disturbances. The rankings of channel stability are as follows:

- Low: a score of less than 20: usually due to poor channel definition
- Moderate: a score between 20 and 35: a defined channel with some form of disturbance
- High: a score greater than 35: good channel stability.

Results of the RSAT scores obtained for the main channel in each of the subwatersheds are presented in **Tables C.18, C.19 and C.20**. Copies of the field data sheets are provided in **Appendix H**.

TABLE C.18
RAPID STREAM ASSESSMENT SCORES AND CHANNEL STABILITY CLASSIFICATIONS IN SHIRLEY'S BROOK

Reach	RSAT Score	Channel Stability
Shirley's Bay -E. of 4th line	N/A	N/A
E. of 4th line - W. of DND	27	Moderate
W. of DND - 4th line	26	Moderate
4th line – W. of CN line	32	Moderate
W. of CN line – confluence with trib.	19	Low
Confluence with tributary – Klondike	28	Moderate
Klondike Rd. - E. of Legget Dr.	21	Moderate
E. of Legget Dr. - Hines Rd.	22	Moderate
Hines Rd. – W. of Hines Rd.	28	Moderate
W. of Hines Rd. – Hydro Corridor	28	Moderate
Hydro Corridor - CN rail	16	Low
CN rail – E. of Goulbourn Forced Rd.	20	Moderate
N. branch, tributary confluence - E. of March Rd.	14	Low
N. branch tributary confluence – 2nd Line Rd.	N/A	N/A

TABLE C.19
RAPID STREAM ASSESSMENT SCORES AND CHANNEL STABILITY CLASSIFICATIONS IN WATTS CREEK

Reach	RSAT Score	Channel Stability
Shirley's Bay - north edge of DRE	N/A	N/A
N. edge of DRE - N. of Sandhill Rd	N/A	N/A
N. of Sandhill Rd - Carling Ave	29	Moderate
Carling Ave - S. of northern CN line (Carling Ave) (S. of rail line)	33 28	Moderate Moderate
S. of Northern CN rail line – Kizell confluence	31	Moderate
Kizell confluence - W of bicycle path	25	Moderate
W. of bike path - bottom of ravine	24	Moderate
Bottom of ravine - N. of hydro lines (150 m upstream of scarp)	38 27	High Moderate
N. of hydro lines - Hwy 417 Eagleson North exit	23	Moderate
Hwy 417 Eagleson N. exit - S. of Katimavik Rd.	25	Moderate

TABLE C.20
RAPID STREAM ASSESSMENT SCORES AND CHANNEL STABILITY CLASSIFICATIONS IN KIZELL DRAIN

Reach	RSAT Score	Channel Stability
Watt's confluence - S. of Carling Ave	21	Moderate
S. of Carling Ave - N. of Legget Dr.	23	Moderate
N. of Legget Dr. - E of Mitel Parking	19	Low
E. of Mitel Parking - E of Legget Dr.	24	Moderate
E. of Legget Dr. - March Rd.	15	Low
March Rd. - Walden Rd.	21	Moderate
Walden Rd. - E. of Goulbourn Forced Rd.	24	Moderate

Results of the rapid stream assessment show that the majority of the channel reaches in each subwatershed are moderately stable. One notable observation or trend, is that low channel stability values are typically found in recently urbanized areas, where some direct human modification of the channel has occurred. Specifically, this is often a result of channel straightening as well as the presence of numerous culverts and crossing structures. An exception are the reaches within Watt's Creek, which could be explained by the large open areas surrounding the channel and the relative older age of the urbanized area, whereby the channel has already undergone some adjustment.

Several site-specific features which would produce a lower RSAT score, include reaches in agricultural areas, where the channel has been straightened and/or livestock have accessed the stream, resulting the bank erosion and loss of in-stream structure. Another site-specific feature are beaver dams, which on the short term and affect sediment transport and stability at the local scale.

Field Investigation

Figure C.7a and 7.b illustrates the identified erosion sites. The erosion sites identified during application of the rapid stream assessment technique coincide with low entrenchment ratios. The low entrenchment values typically correspond to areas of increased residential and commercial development towards the middle portions of the drainage system (see spacing and position of streets on the figures). When the entrenchment and width/depth ratios are low, any flow greater than the channel forming discharge or bankfull flow cannot spilling onto its floodplain. Since the energy of the flow is not dissipated through floodplain spillage, the energy remains in the channel thereby increasing the erosion pressure on the channel bed and banks. For this reason, increased evidence of erosion is expected along reaches of channel in which the entrenchment and width/depth ratios are low.

As noted elsewhere in this document, the surficial geology of the subwatersheds consist of till and ponding is not uncommon. From these facts it follows that the substrate materials of the channel bed are fine grained. This observation was made during the RSAT and during the detailed field investigation of selected reaches. The cohesiveness of channel bed material has implications for the erosion potential of the stream banks. That is, when the bed of the watercourse is resistant to erosion, then a larger portion of the energy contained in the flow is directed to the banks. As a consequence, undercutting of the banks will occur which may lead to greater bank failures.

5.7 Detailed Field Work

Based on results of all the analyses completed, five reaches were selected for detailed field investigations and long-term monitoring, and five additional reaches were selected for monitoring purposes only. In total, 2 field sites and 2 monitoring sites are situated in each of Shirley's Brook and Watts Creek and 1 field and 1 monitoring site are situated in Kizzel Drain. Each of the reaches included in the field investigation or monitoring program represent areas in which erosion is occurring, natural channel adjustments are being made or the channel appeared to be relatively stable. The purpose of selecting the reaches in different settings is to gain a broad, general understanding of the different functions that the channel serves within each of the subwatersheds and the processes that are occurring in the drainage network.

As part of the field investigation, information is collected pertaining to the cross-sectional shape, the sediment characteristics, and the longitudinal profile of the channel. This information is summarized and is used in quantitative analyses of channel stability, hydraulic geometry, and erosion potential. Data summaries identifying the variables measured, and the corresponding reach averaged quantities for the field work undertaken, are provided in Appendix B. Summaries of significant geomorphic variables are presented in **Table C.21** and some of these are given a spatial context with respect to the longitudinal profile of the channel in **Figures C.8 – C.10.**

Table C.21 Summary of significant geomorphic variables based on results of detailed field investigations in each of the three subwatersheds.

TABLE C.21
GEOMORPHIC VALUES SUMMARY

	W. of DND – 4th line	**E. of Legget Dr. – Hines Rd.**	**N. of Sandhill Rd. – Carling Ave.**	**Bottom of ravine – N. of hydro lines**	**E. of Mitel Parking – E. Of Legget Dr.**
Length Surveyed (m)	151	189	145	160	134
Avg. bankfull width (m)	3.77	3.04	7.04	4.03	3.70
Avg. Bankfull depth (m)	0.39	0.37	0.44	0.38	0.31

Entrenchment ratio	1.87	2.51	1.54	1.70	8.54
Substrate D50 (mm)	0.0020	0.0038	0.0020	0.2090	0.0034
Substrate clay: silt:	55.6 15.6	41.7 31.7	50.0 20.4	7.5 1.4	40.0 48.0
Number of banks undercut (%)	90	60	20	40	50
Dominant bank material	silt, clay	silt, clay	silt, clay	fine sand, silt	silt, clay

The geomorphic data presented in **Table C.21** and **Figures C.8-C.10** demonstrate that many natural processes occur within each of the drainage networks. That is, the downstream increase of channel width and depth is common in natural systems and reflects the increased volume of water that occupies the channel as a function of an increase in drainage area in the downstream direction. A downstream increase in entrenchment ratio is expected since the river valley typically opens towards the mouth of the river and, in the Shirley's Brook and Watts Creek subwatersheds, these areas are undeveloped.

Geomorphic data of Shirley's Brook demonstrate several different trends (**Figure C.8**). The increasing trend of channel width in the downstream direction (towards Shirley's Bay) is observed on most rivers and is a function of channel modifications to accommodate the flow supplied from tributaries and upstream drainage areas. As the river approaches residential and commercially developed areas (note the spacing of roads), the entrenchment of the channel decreases markedly and the channel width/depth ratio (W/D ratio) increases. Low entrenchment values indicate that the river will not spill onto its floodplain during high discharge events (often a consequence of channel incision in natural stream systems). When the water is thus contained within the channel, the energy of the flow is not dissipated onto the floodplain, thereby increasing the energy of flow through the channel, and increasing the potential for erosion. It is interesting to note the close correlation between low entrenchment values and the erosion sites on the geomorphic summary for Shirley's Brook. The generally fining downstream sequence of channel bed material is part of a natural process of sediment sorting.

Geomorphic data of the tributary of Watts Creek that is situated in Kizzel Drain also show several trends **(Figure C.9)**. The downstream increase in channel width is part of a natural downstream change in channel configuration that is a function of the increased volume of flow that fills the channel (a function of an increase in drainage area). Changes in the channel width/depth (W/D) ratio occur when the relative erodibility of the channel bed and banks change. Larger W/D values signify erodible banks whereas small W/D values signify cohesive or non-erodible banks. Spatial variation in channel entrenchment is noted on the geomorphic data summary implying a wide variation in the relation between the river and its floodplain/valley walls. When entrenchment values are low, water is contained within the channel during flood events increasing the energy and erosion potential of the flow. While much of the channel bed material is fine grained along the tributary's length, an increase is observed towards the confluence. This increase may be a function of local geology and of changes in channel gradient.

Various observations regarding the geomorphology of Watts Creek can be made using the information provided on the geomorphic summary for Watts Creek **(Figure C.10)**. As for Shirley's Brook and the tributary of Watts Creek, a downstream increase in channel width is expected. Of interest is the decrease and constancy of channel width upstream of the southern CN Rail line. In this region (note the longitudinal profile of the channel), the river flows through a steep landscape in a ravine. Such conditions are often associated with narrower channels. The entrenchment values tend to be low around the channel crossings. The higher erosion potential associated with low entrenchment values is evident in the occurrence of erosion sites near these channel crossings. Variation in the channel width/depth ration (W/D) is a function of the surficial geology of the area. The generally large bed material of the channel is linked to both the longitudinal profile of the channel (i.e. the gradient of the channel) and to local geology. Furthermore, the occurrence of large bed material near road crossings may be an artifact of road building activity in which the channel was affected.

5.8 Monitoring Stations

In total, ten monitoring cross-sections were established within the subwatersheds. Five of these cross-sections are positioned in reaches wherein detailed field work was conducted and the remainder were positioned at other locations within the subwatersheds. The purpose of these monitoring sites is to measure changes to the cross-sectional shape of the channel and to quantify erosion rates of bank materials after the passage of bankfull discharge events. Local datum points have been installed at each of the monitoring sites to ensure that the spatial position of the channel cross-section is replicated.

In addition to quantifying erosion rates and changes in cross-sectional channel configuration, it was also the intent of the study to obtain measurements of bedload transport during high flow discharge events at these monitoring sites. Unfortunately, given the lack of significant rainfall events in the Ottawa region during the 1998 fall and winter seasons, such data could not be collected.

Annex C-6 - Aquatic Resources

6.1 Review of Background Information

Available background information on Shirley's Brook, Watts Creek and Kizell Drain was obtained and reviewed from the following sources:

- Ontario Ministry of Natural Resources, Kemptville District - Daryl Seip, Jim Niefer;
- Ontario Ministry of Natural Resources, Ontario Fisheries Information System - Trish Chen;
- University of Ottawa - Benoit Lalonde;
- Regional Municipality of Ottawa-Carleton, Surface Water Quality Branch - Stuart Dean; and
- City of Kanata - Stu Moxley.

Information was also obtained from previous studies completed by Dillon Consulting Limited in the area (e.g. Terry Fox Drive Class Environmental Assessment).

6.2 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 three parameters were developed and four sites for each parameter were identified. The three parameters used were: agriculture, developed land, and undeveloped land.

Thus a total of 12 sites were identified for each subwatershed. In addition, four dry sites were assessed with respect to substrate and bank condition to provide information for the upper reaches of Shirley's Brook. Detailed mapping and air photos of the study area were used for site selection. All sites were chosen at random, and prior to conducting field surveys. Some designations were changed or sites added to the program if land use was found to be different from the mapping. All sites were at least 40 metres in length. Assessments were not conducted following storm events as baseflow conditions can be inconsistent after rainfall.

<u>Habitat Assessment</u>

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 3.5 (Hydrology) and Section 3.4 (Water Quality). Photographs were also taken at each site.

<u>Benthic Invertebrate Collections</u>

Benthic invertebrates were collected using the 'kick and sweep' method. This method involves the use of a net approximately 1 metre wide, which is placed in a riffle, on the substrate. An area of substrate (1 m^2) upstream of the net is disturbed ('kicked') and any cobble is cleaned. All material is washed into the net, removed and examined thoroughly. A subsample of 100 invertebrates is identified and recorded on data sheets. The absence of riffles at the developed sites of both subwatersheds prevented samples from being collected. In addition, all agricultural sites in the Shirley's Brook Subwatershed were dry at the time of sampling. These limitations to the sampling program actually provide some information about the sites, and are explained in the Data Analysis section.

Sampling for this portion of the protocol was conducted August 27-29, 1998. One sample from each subwatershed and each land use type was collected and the Hilsenhoff Index for organic pollution was calculated. This calculation is based on the biodiversity of the sample, and the pollution tolerance of the species collected.

<u>Fish Communities</u>

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 six stations were sampled, each of which encompassed approximately 50 metres of the watercourse. In addition, information from collections conducted by MNR staff was used. 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.

The aquatic sampling sites are shown on **Figure C.11**.

6.3 Fish Communities and Habitat Characteristics

Fish habitat was 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 Subwatershed.

Type 1

This habitat is defined as "critical" habitat which requires a "high" level of protection from the effects of development. These habitats generally have high productive capacity and/or provide important habitat for various life stages of fish. Examples of Type 1 habitat include:

- spawning areas for significant fish species (e.g. northern pike);
- significant migration routes for cold water species;
- essential nursery areas;
- highly productive feeding areas (e.g. wetlands); and
- habitats supporting endangered, threatened or vulnerable species (as designated by the Committee on the Status of Endangered Wildlife in Canada).

Type 2

This habitat requires a "moderate" level of protection and includes areas utilized by fish for feeding, growth and migration which, while important to the fish stock, are not considered critical. Habitat falling into this classification is usually abundant. Examples of Type 2 habitat include:

- feeding areas, particularly for adult fish;
- areas of unspecialized spawning habitat, such as that used by many minnow species; and
- pool-riffle-run complexes.

Type 3

Habitats requiring "minimal" protection are defined as Type 3. This habitat generally has a low productive capacity and does not contribute significantly to fish production, or may not have reasonable potential for enhancement or restoration. This can include, but is not limited to, habitat that has already been degraded by human activities. Examples of Type 3 habitat can include:

- ravine gullies and high gradient streams;
- highly altered watercourses or portion of a waterbody which is artificially hardened and polluted; and
- municipal drains and/or artificially created drainage swales.

6.4 Benthic Communities

<u>Shirley's Brook</u>

A summary of the benthic invertebrate sampling program is presented in **Table C.22**. Results are discussed in the main body of the text (Chapter 3.0).

TABLE C.22
SUMMARY OF BENTHIC INVERTEBRATE SAMPLING PROGRAM
(% OF SAMPLE)

Invertebrate Taxa	Watts Creek WA1	Watts Creek WU4	Shirley's Brook SU2
Oligochaeta (segmented worms)	0.99	0	0.93
Hirudinea (leeches)	6.93	0	0
Amphipods (scuds)	73.27	0	0.93
Isopoda (aquatic sowbugs)	7.92	0	0
Chironomidae (blood worms)	1.98	0.99	1.87
Simuliidae (black flies)	0	17.82	0
Tipulidae (crane flies)	0	0	0.93
Ephemeroptera (mayflies)	0.99	0.99	0
Coleoptera (beetles)	0.99	0.99	0.93
Trichoptera (caddisflies)	2.97	76.24	0.93
Gastropoda (snails)	2.97	0	0

Decapoda (crayfish)	0.99	2.97	0.93
Platyhelminthes (flatworms)	0	0	92.52
Hilsenhoff Score	**6.25**	**4.28**	**5.92**

6.5 Fish Communities

Shirley's Brook

Fish sampling was conducted on June 29 and August 27-28, 1998. In addition, background information on the upper and lower reaches of Shirley's Brook is readily available (Dillon 1997a and 1997b) and electrofishing from sampling conducted by OMNR staff in 1998. A total of 13 fish species were collected during the electrofishing program. Results can be found in **Table C.23**. 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 (OMNR 1992).

TABLE C.23
DISTRIBUTION OF FISH SPECIES IN SHIRLEY'S BROOK

Common Name	Scientific Name	SA1	SU1	SU2	SU4	SU5	SD2	SD3
Central Mudminnow	*Umbra limi*				_	_		
White Sucker	*Catostomus commersoni*		_	_				
Northern Redbelly Dace	*Phoxinus eos*		_		_	_		
Finescale Dace	*Phoxinus neogaeus*				_	_		
Bridle Shiner	*Notropis bifrenatus*		_		_	_		
Common Shiner	*Luxilus cornutus*		_	_			_	
Blacknose Shiner	*Notropsis heterolepis*		_					
Bluntnose Minnow	*Pimephales notatus*		_		_	_	_	
Fathead Minnow	*Pimephales promelas*				_	_		
Creek Chub	*Semotilus atromaculatus*		_					
Banded Killifish	*Fundulus diaphanus*		_					
Brook Stickleback	*Culaea inconstans*		_		_	_		
Fantail Darter	*Etheostoma flabellare*		_					

Total Number of Fish Species		0	10	2	7	7	2	0

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 (*Etheostoma flabellare*) 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. Results of the sampling program can be found in **Table C.24**. Water temperature on the day of sampling ranged from 21 to 26^{o}C among the sites. No rare, threatened or endangered species were captured.

TABLE C.24
DISTRIBUTION OF FISH IN WATTS CREEK

Common Name	**Scientific Name**	**WA1**	**WU3**	**WU4**	**WD3**	**WD5**	**WD6**
Central Mudminnow	*Umbra limi*		_		_		
White Sucker	*Catostomus commersoni*	_	_				
Northern Redbelly Dace	*Phoxinus eos*		_				
Finescale Dace	*Phoxinus neogaeus*						
Bridle Shiner	*Notropis bifrenatus*						
Common Shiner	*Luxilus cornutus*	_	_			_	_
Blacknose Shiner	*Notropsis heterolepis*						
Bluntnose Minnow	*Pimephales notatus*	_		_	_		
Fathead Minnow	*Pimephales promelas*						
Blacknose Dace	*Rhinichthys atromaculatus*	_					
Creek Chub	*Semotilus atromaculatus*	_		_			
Banded Killifish	*Fundulus diaphanus*						
Brook Stickleback	*Culaea inconstans*	_	_	_	_	_	
Fantail Darter	*Etheostoma flabellare*		_		_		
Total Number of Fish Species		6	6	3	4	2	1

6.6 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). 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 to 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.

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.

Shirley's Brook - Habitat Assessment

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

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

A total of four agricultural sites in the study area were assessed. Two of the sites were or had been under crop and two 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 graphs below). Substrate was predominantly fines, although bedrock was predominant at one of the sites (SA3). Channel 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.

Developed sites varied according to residential or industrial activity. Residential areas generally 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 (SD2). 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. 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.

The following graphs provide a summary of Bank Stability, Overhead Cover and Channel Structural for Shirley's Brook.

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 agricultural sampling sites in Watts Creek were similar to Shirley's Brook (see figures below). Both of the agricultural sites assessed were under crop. A combination of nutrient input and absence of impacts from cattle crossing have resulted in some macrophyte and algae growth. Fines were the dominant substrate, as expected, and over 80% of the banks were either eroding or vulnerable to erosion. Channel structure was entirely pools and glides, reflecting the lack of instream structure. One of the agricultural areas (WA1) has been classified as medium quality Type 2 habitat because of the fish community present and in spite of lack of habitat structure. The other site was classified as low quality Type 2.

Developed areas exhibited a predominance of degraded conditions such as channelization, lack of instream structure (25%) and fine substrate, 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. The reach of Kizell Drain 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 (WD1 and WD2) 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.

Only 23% of the Watts Creek Subwatershed 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 were exhibiting 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 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.

The following graphs provide a summary of Bank Stability, Overhead Cover and Channel Structure for Watts Creek/Kizell Drain.

Annex C-7 - Terrestrial Resources

7.1 Introduction

The purpose of this analysis is to describe or characterize the terrestrial natural features (woodlots, wetlands and old fields) within the three subwatersheds namely Kizell, Watts Creek and Shirley's Brook. To date, many of these natural features have been 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 subwatershed can be compared with each other as well as units in the other two subwatersheds. A description of the scoring system is provided in Section 7.3.

7.2 Data Collection

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 (1980) were 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).

Field Investigations

Field investigations were conducted in mid June and September 1998 and 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 visited where possible 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.

7.3 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 E**). These evaluation forms were 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.

A summary of each criterion is follows. This section also describes the scoring mechanism for each criterion.

<u>Size</u> - In general, the larger the wetland or forest, the more likely that it will contain more plant communities and wildlife species. According to Riley and Mohr (1994), conservation priorities should be assigned to woodlands that are old growth and mid to late successional naturally occurring forest ecosystems and are large enough to support forest interior habitats. However, smaller sized woodlots should be retained in cases where they provide a crucial link between one natural area and another.

In determining the scoring for the size component, the criteria were based on Mohr and Riley (1994). Woodlot sizes were categorized as follows:

- Other Woodlands (less than 4 ha);
- Micro Woodlands (4-40 ha);
- Meso Woodlands (40-100 ha);
- Meta Woodlands (100-400 ha); and
- Mega Woodlands (more than 400 ha).

Initially, in the Shirley's Brook and Watts Creek subwatershed study, other woodlands (less than 4 ha) were to be given a score of 0 points, but based on field investigations these woodlots did provide a habitat function and in some cases provided linkage functions. Therefore, these woodlots scored 5 points.

Micro woodlands received 10 points as any woodland larger than 4 ha can have a forest interior (assuming a rectilinear shape and is not less than 100 m in any direction). It is noted that forests that are larger than 4 ha (assuming a rectilinear shape) begin to possess interior habitat for more sensitive bird species such as the northern waterthrush, Nashville warbler, ovenbird and veery. From initial secondary source investigations, this forest group would have received at least 20 to 25 points. However, it was found through field work that many of these micro woodland had limited to no interior forest as estate residential development had occurred throughout these woodlots. It should be noted that the majority of forests within the three subwatersheds (i.e. Kizell (55%), Watts Creek (70%), Shirley's Brook (77%) were within this category.

For the meso woodlands, a score of 30 points was assigned as these forests can have a forest interior of at least 19 ha assuming that there is a relatively undisturbed interior. It was determined that at least one of this forest group is contained in each of the subwatersheds.

For the remaining two forest groups, only two such forests are found in the study area. Both of these forests are found in the western portion of Shirley's Brook. The difference in scoring for these two forests (50 versus 80) was to reflect the large difference in size (190 ha versus 450 ha).

<u>Biodiversity</u> - 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 the Shirley's Brook and Watts Creek subwatershed study, the biodiversity of an area was 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. In designing the scoring for biodiversity, the scores were based on the number of communities that could be determined on the FRI air photography and through field investigations (where possible). While the biodiversity criterion normally would be considered a highly important criterion, the limitations in gaining field access to all of all natural areas reduced scores attributable to it. It should be noted that many aspects of biodiversity are reflected in the other criteria so that biodiversity "issues" were considered overall. It was therefore determined that the scoring of this criteria would be based on the number of general communities (i.e. old field, wetland) found in the natural area.

Landscape Attributes - The landscapes within the study area (particularly Watts Creek Subwatershed) has changed dramatically in the last decade with farmland or forest giving way to urban development. In 1981, the RMOC area had less than 29.4% of their landscape in forest cover (Riley and Mohr, 1994). To establish whether the three subwatersheds are above or below this rate, three subcriteria were used to calculate what the deforestation trends are, and if remediation plans through the use of vegetative corridors or linkages are possible or feasible.

The intent of the subcriteria *"Percentage of land within 1 km that is covered by forest/wetland",* was to determine if a natural area is isolated or in close proximity to other areas. Those natural areas that had less than 20% of land within 1 km covered by forest/wetland received 2 points or less as these areas were in urban situations and enhancement and connectivity potential were nil. Conversely, areas that had 50% or more land within 1 km covered by forest would have potential for linkage possibilities.

The subcriteria *percentage of the natural forest cover within the watershed*, was considered to be more important than the first subcriterion. It provides an indication as to the importance of the feature with respect to its size in the context of all other natural areas within the subwatershed.

The last subcriteria, *Terrestrial linkage present and type*, refers to existing hedgerows and watercourses/valleylands that have the potential to link one natural area to another. The terrestrial components within stream floodplains are usually the last remaining green space in urban situations. Therefore, the presence of a watercourse was given a score of at least 20 points as this linkage would expect to remain despite urban development pressure. Hedgerows were given a score of at least 10 points as even a single row of trees along a unmaintained fenceline can provide habitat for many forms of plants and animals.

Seasonal Wildlife Concentration and Potential - Some portions of Shirley's Brook and Watts Creek Subwatersheds 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 criterion is to list those species of mammals that are likely to breed/feed within the natural feature.

In the scoring of this criterion, the point allocation was similar to that of biodiversity. While most natural areas were visited at least once, the recording of wildlife was based on incidental sightings or other evidence (feeding damage, dens, scats, etc.). In general, small isolated woodlots would provide habitat for grey squirrel, chipmunk, raccoon, skunk and cottontail rabbit. Therefore these natural areas would receive15 points (5 species x 3 points) even if the wildlife had not been observed during the field check. In those areas where a watercourse flowed through a natural area, certain species including muskrat and beaver (only where feeding damage) would be added, and thus a higher score.

Hydrological Features - The presence or absence of seeps, wetlands and/or a watercourses 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 becomes naturalized. Therefore, this criteria has been included as the presence or absence of hydrological features within a terrestrial unit can be an influence on the diversity of an area.

In the scoring allocation of this section, the presence of seeps received 1 point/seep. This is because some seepage areas found in the spring are dry by late summer or a heavy spring runoff would create a higher potential for seeps lasting longer in the spring than in other years. For the scoring of presence of streams, this was based on if the stream order (i.e. first order to third order). In most cases, higher order streams would have a higher density of species and generally be more established.

For wetlands, the scoring allocation was similar. Isolated wetlands received only 5 points whereas wetlands associated with rivers scored 20. This is because isolated wetlands are generally more common and have lower density than palustrine or riverine wetlands.

<u>Interior Bird Habitat</u> - Some species of birds such the white and black warbler, brown creeper and 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.

As indicated in the size criteria, the larger the size of the forest (or natural area), the more likely it is to have interior bird habitat.

As noted in the size criteria, most natural areas within the three subwatersheds are within the 4 to 40 ha range. However, from field review and air photo interpretation, many of the forest interiors have been damaged by residential development. For the point allocation in this criteria, the range is 0 to 30 points.

<u>Condition of Natural Areas</u> - This criterion 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. For this reason, no areas received a full 10 points. In most cases, 4 to 7 points were awarded for this criterion based on the degree of disturbance. 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. Again no area received 10 points as every natural area visited does have some type of site fragmentation. It should also be noted that the presence of roads and railways through a natural area does increase the incidence of roadkill, and 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 E**) overall scores have been provided. This information was considered in developing conservation priorities.

7.4 Designation of Natural Areas

Kizell Subwatershed

Table C.25 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 subwatershed scored the highest with scores of 216, 224, 194 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.

TABLE C.25
NATURAL FEATURE SCORES FOR KIZELL DRAIN SUBWATERSHED

(1 page)

The area K6 would have scored higher as it had a relatively large area (39.2) ha which is approximately 9% 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 natural areas by roads (Carling Avenue) and the CNR tracks. There is some potential for expanding linkages if along the Watts Creek floodplain.

Watts Creek Subwatershed

Table C.26 shows the total area, scores for the seven (7) criteria and overall scores for the 17 natural areas in the Watts Creek Subwatershed (see **Appendix E** for individual summaries). 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 subwatershed and/or they had strong linkages with other natural areas. The areas W4, W5, W9 and W16 scored 127, 127, 129 and 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 subwatershed were counted. Those units with the lowest scores were W2, W1, W6, W7, W8 and W12. Their scores were 36, 63, 88, 56, 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.

TABLE C.26
NATURAL FEATURE SCORES FOR WATTS CREEK SUBWATERSHED

(1 page)

Shirley's Brook Subwatershed

Table C.27 shows the area, scores for the seven (7) criteria and overall scores for the 26 natural areas in the Shirley's Brook Subwatershed (see **Appendix E** for individual summaries). 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. Area 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. Area S24 scored high as it had an interesting mix of communities, interior bird habitat and a third order stream flows through it. Area S26 scored high as it is located at the mouth 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.

One trend that seems to be occurring especially in Shirley's Brook Subwatershed, 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, it does tend to eliminate interior forest conditions.

TABLE C.27
NATURAL FEATURE SCORES FOR WATTS CREEK SUBWATERSHED

(2 pages)