A METHODOLOGY FOR SELECTING WATER QUALITY SAMPLING SITES MINIMALLY IMPACTED BY HUMAN ACTIVITY IN THE GANARASKA RIVER BASIN OF SOUTHERN ONTARIO

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December 1991

Abstract

This paper outlines a methodology to select "least impacted" water quality monitoring sites within river basins, using the Ganaraska River Basin as a case study. The methodology consists of five phases of analysis. (1) Preliminary Site Selection: Topographic and land use maps were evaluated to select potential monitoring sites, which appeared "minimally impacted" by human activities. (2) Field Reconnaissance: After the potential sites were selected, a field reconnaissance was conducted to verify the land use observed on the maps and to assess the morphological and hydrological characteristics of the sites to determine how appropriate they were for sampling purposes. The Upper Ganaraska Sub-basin was found to be the "least impacted" during the field reconnaissance, and the 24 potential sites selected through map evaluation were reduced to 3 final candidates. (3) Representative Sub-basin Determination: Each of the sub-basins were then evaluated to determine which sub-basin was the "least impacted", using a ranking scheme based on potential impacts caused by human activities. (4) Detailed Investigation of the Ganaraska River Basin: A detailed investigation of the Ganaraska River Basin was conducted to assess the dominant soil and physiography types, and the degree of forest cover within the basin. (5) Detailed Site Investigation: The final step was to evaluate and rank the three final sites, on the basis of how representative they were of the Ganaraska River Basin. Factors considered were: the the size of the tributary basin, soils, geology, physiography, and land use characteristics. Results indicate that site U2, in the Upper Ganaraska Sub-basin, is the "best suited" and most representative site for water quality monitoring with respect to the "least impacted" criteria. Site U1 is the second most suited site.

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1.0 Introduction

Water quality monitoring networks in Canada have normally been established based on site, chemical, or watershed specific requirements. Results have been used to assess surface water compliance, to forecast long-term trends, and to calculate loadings in specific areas. Problems may occur if data from networks are used to assess problems on a regional or national scale, since results can only be extrapolated for areas within the vicinity of the sites (Ongley, 1986).

To date, no theoretical foundation has been established for the design of a regional and national scale network in Canada (Ongley, 1986). There is a need for the establishment of a water quality monitoring network which can provide baseline water quality information to monitor aquatic ecosystem more accurately, and manage, and conserve them more efficiently for the longterm (Ongley, 1986).

But monitoring programs need to clearly specify their objectives, their needs, and how the data will be applied, to efficiently ultilize valuable resources. As well, the clear identification of goals allows managers, planners, and scientists to intelligently and objectively establish, or reduce monitoring networks, in a rational and effective manner (Perry et al., 1984).

A national design strategy for a the establishment of a baseline water quality network or National Reference Network (NRN) in Canada, using ecologically representative locations has been proposed (Warry, 1990) with the following objectives:

1) to provide a national description of current water quality conditions which are ecologically representative;

2) to define longterm changes in these waters; and,

3) to identify, describe, and explain, if possible, factors controlling observed quality conditions and their changes.

The first stage of the strategy is to determine the most important issues affecting water quality. This was done by selecting an issue-based or stress-based focus for the monitoring. The types of issues identified were "least impacted" conditions, agricultural eutrophication, pesticides, urban eutrophication, industrial contaminants, long range airborne pollutants, and resource extraction and development (Warry, 1990). This creates a clear objective for the NRN and establishes a framework for simple and systematic implementation.

The second stage is selecting the scale of resolution. In the case of the "least impacted" issue, this was done using the Ecological Land Survey Classification System to select representative ecodistricts within an ecoregion (Warry and Hanau, 1991). This limited areas which have to be investigated based on homogenous climatal, physiographical and biological characteristics.

The third stage, and the focus of this report, is to develop and describe a suitable methodology for selecting representative water quality sampling sites in a watershed, that are minimally impacted by human activity. The Ganaraska River Basin has been used as a case study to test the methodology. Once sampling sites are located, water quality network stations will be established and data will be collected for three to four years. This data will be compared with stations in other ecoregions to determine whether there are significant differences in water quality, that is, whether ecoregions have a distinct chemical signature. This information will provide realistic baseline water quality conditions within a given area for the establishment of attainable goals in resource management (Omernick and Griffith, 1991).

2.0 Objective

This paper outlines the methodology used to select the "least impacted" water sampling sites in the Ganaraska River Basin. It is the final component of a three tiered process for the establishment of a baseline water quality Ontario Reference Network (ORN) (see Figure 1). The focus of the report is to select the site that has the suitable sampling characteristics, is the "least impacted", and best represents the Ganaraska River Basin.

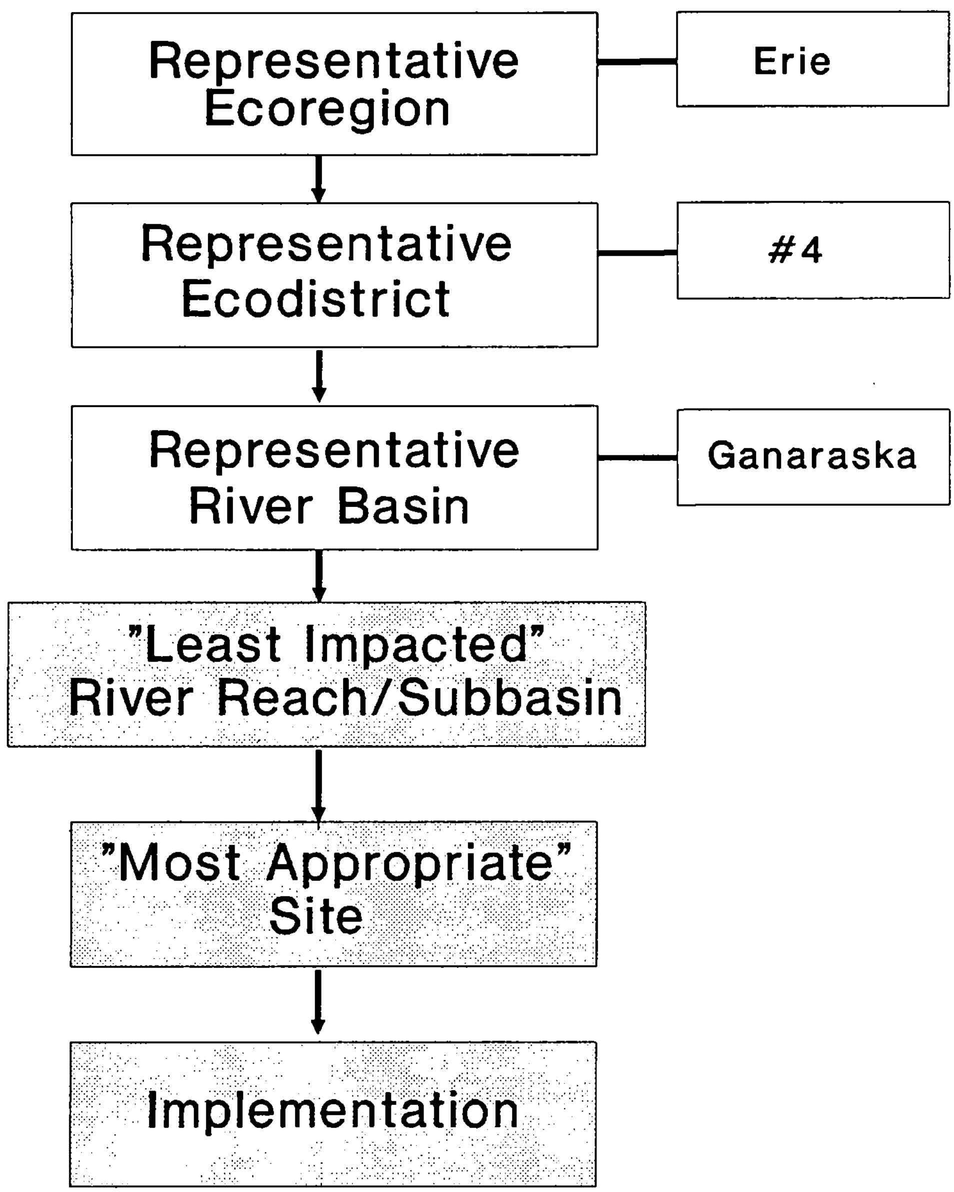
3.0 Description of the Ganaraska River Basin

3.1 Location and Land Use

The Ganaraska River Basin is located in south-central Ontario, north of Port Hope on the northern shores of Lake Ontario. The basin occupies an area of 291km^2 (Geomatics, 1991) (see Figure 2) and is comprised of two major streams - the Ganaraska and the North Ganaraska. Both of these streams flow from the south edge of the Oak Ridge Moraine (GRCA, 1983).

90% of the Ganaraska River Basin lies with Ecodistrict #4 of the Erie Ecoregion (Wickware and Rubec, 1989). The remaining 10% of the river basin is located in Ecodistrict #3 of the Hurontario Ecoregion (Wickware and Rubec, 1989). The study conducted by Warry and Hanau (1991) indicated that Ecodistricts #1, #2, and #3 had the most potential to be representative of the Erie Ecoregion. Ecodistrict #4 was not chosen, however, it was recognized as an ecologically distinct ecodistrict within the Erie ecoregion that warrented ORN implementation. A site in Ecodistrict #4, coupled with a site located within Ecodistricts #1, #2, or #3, would best represent the diverse characteristics within the Erie Ecoregion, as opposed to having a single site.

Figure 1: Logic for the Establishment of the Ontario Reference Network Water Quality Sampling Sites



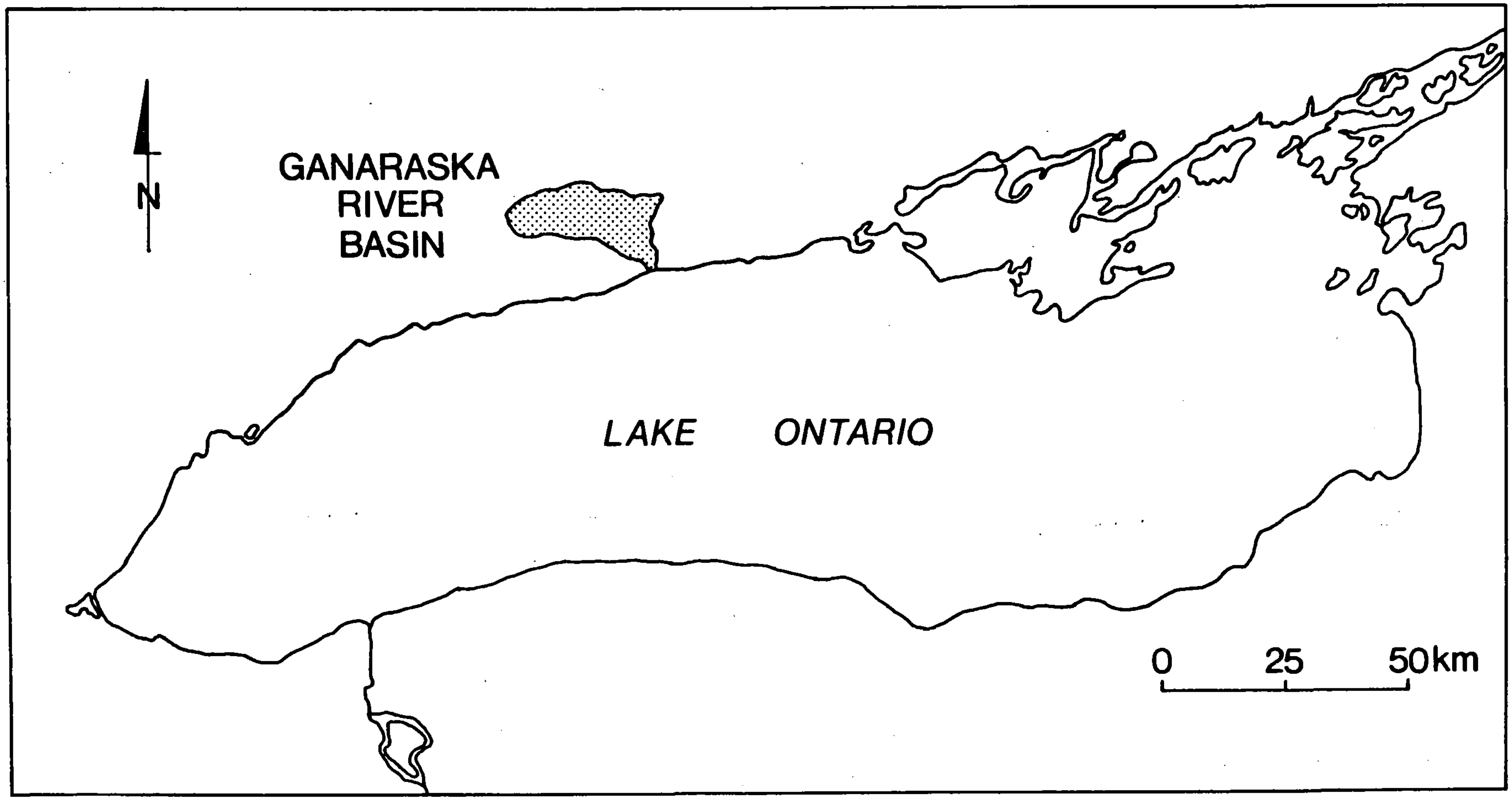


Figure 2 Location of Ganaraska River Basin

Agriculture is the most prominent land use in the Ganaraska River Basin (47%); row crops, pastures, and field crops are commonly observed (see Table 3 and Appendice). In the northern extent of the river basin, large areas of mixed hardwood forests exist as a result of intensive reforestation efforts by the Ganaraska Region Conservation Authority to control erosion and flooding problems (OMNR, 1976). Six small communities are found in the central part of the watershed. But the only significant population centre in the watershed is Port Hope, located at the mouth of the Ganaraska River, with an approximate population of 10,000 (OMMA, 1989).

3.2 Climate

The Ganaraska area experiences a temperate climate characterized by warm summers and mild winters, with a mean annual temperature of 7.2°C (GRCA, 1983). The area has a long growing season with approximately 145 frost-free days per year (GRCA, 1983). The mean annual precipitation is 850mm, and the mean annual snowfall is 1700mm, with slight variations due to topographic differences between the northern and southern parts of the watershed (GRCA, 1983).

3.3 Geology and Physiography

The underlying geology of the river basin is composed of Paleozoic consolidated limestone and shales (OMNR, 1985). The uppermost bedrock formation consists of limestones of the Trenton and Black River groups originating from the Middle Ordovician period (GRCA, 1983).

The area's physiography is characterized by steeply rolling hills and deeply cut river valleys of the Oak Ridge Moraine, located in the northern part of the basin (OMNR, 1976). The Oak Ridge Moraine, classified as a kame-moraine, is characterized by knobby hills and irregularly stratified sand and gravel deposits (GRCA, 1983). The ground moraine, located on the southern slopes of the Oak Ridge Moraine, has clay to boulder sized deposits, composed of dense limestone till from the Trenton and Black formations (GRCA, 1983). Drumlins are interspersed throughout the undulating hills of the Oak Ridge Moraine's southern slopes (OMNR, 1976). The Iroquois Lake Plain, formed by a glacial lake which preceded the present Lake Ontario, consists of clay, silt, and sand deposits of lacustrine origin (GRCA, 1983). The Iroquois shoreline is located 7 to 12km north of Lake Ontario, with a beach of associated bars and scarps composed of silt to gravel of varying depths located at 170m in elevation (GRCA, 1983). Organic deposits are located in areas where there is poor drainage at or near the surface (GRCA, 1983). This is especially common in depressions and areas adjacent to streams (GRCA, 1983).

3.4 Soils

The Grey-Brown Podsolic Great Group dominates the Ganaraska River Basin (SRI, 1960). Bookton, Fox, Granby, Guelph, and Honeywood soil families exist in the river basin, composed of fourteen soil series, ranging from poor to good drainage, and very fine sandy loam to sandy loam soil textures (SRI, 1960). The soils are derived mostly from limestone till, glacio-fluvial deposits, deltaic or outwash materials, and lacustrine materials. Other materials, such as marsh and muck, comprise a very small proportion of the parent material for these soils (GRCA, 1983).

3.5 Hydrology

The Ganaraska River has a moderate weighted slope of 4.09m/km falling 183m along its 31km course (GRCA, 1983). The North Ganaraska River, the largest tributary, has a gentle weighted slope of 2.28m/km over its 15.5km course (GRCA, 1983). Approximately 66% of the precipitation falling on the the Ganaraska drainage basin becomes runoff at Port Hope. The North Ganaraska, with gentler slopes and better defined wooded valleys, has a runoff value of 46%, indicating greater soil permeability and lesser degree of urbanization and agricultural activity (GRCA, 1983). Table 1 provides a water yield summary of the Ganaraska River Basin (OMNR, 1976).

Table 1: Hydrology Information of the Ganaraska River Basin

Station Location	River Name	Drainage Area (sq cm)	Mean Annual Runoff (cm)	Mean Annual Precip (cm)	Runoff/Precip
@ Port Hope	Ganaraska River	261.6	54.7	83.0	.659
Near Dale	Ganaraska River	243.5	43.3	83.0	.522
Near Osaca	Ganaraska River	67.3	51.5	83.0	.620
Near Osaca	N. Ganaraska River	38.9	38.1	83.0	.459

Groundwater is a major source of rural water supply in the Ganaraska River Basin for both domestic and agricultural uses (OMNR, 1976). Water is obtained by using dug and drilled wells (OMNR, 1976).

The Ganaraska River Basin has wetlands scattered throughout, which play an important role in water storage, water quality maintenance, and flow maintenance especially during the summer months. As well, the lakeshore marshes serve as nurseries for some warm water fish species. Wetlands are prone to being drained for agricultural lands, and are often impacted by livestock access, and recreation use. At the moment, the impacts on the Ganaraska's wetlands are minimal (GRCA, 1983).

3.6 Dominant Forest Cover and Fisheries

The Ganaraska River Basin lies within the Deciduous and Great Lakes-St. Lawrence Forest Regions, which consist of combinations of hardwoods, mixed hardwoods, and mixed conifer stands (GRCA, 1983). The primary tree cover is composed of beech, sugar maple, and oak (Wickware and Rubec, 1989). Agreement Forests are scattered throughout the northern extent of the river basin, composed mainly of white pine, planted during the 1940's to control soil erosion and flooding problems. Woodlands Improvement Act Lands are also interspersed throughout the river basin to minimize runoff and erosion (GRCA, 1983).

The Ganaraska River Basin hosts a variety of both cold and warm water species (GRCA, 1983). The cold water species, Rainbow Trout, Brown Trout, and Pacific Salmon, play an important role in supporting the area's sport fishing industry. Despite the overall good quality of the fisheries in the area, dams, marginal temperatures, sedimentation of spawning beds, and sedimentation from streambank and runoff erosion are constant threats to the cold water fishing industry.

4.0 Methodology

Five phases of analysis were undertaken to determine the "least impacted" water quality sampling sites. These were:

(i) preliminary site selection;
(ii) field reconnaissance to verify site appropriateness;
(iii) representative sub-basin determination;
(iv) detailed investigation of the Ganaraska River Basin; and,
(v) detailed potential site investigation.

4.1 Preliminary Site Selection

The first stage in the site selection process was to identify all sites meeting the criteria as being the "least impacted" in the river basin. Preliminary site selection was completed using 1:50,000 National Topographic Series Maps (DENR, 1978, 1984, 1985). The Ganaraska River Basin and boundaries were outlined on the topographic maps by examining the contour lines. Then, all potential sites were identified using the following criteria:

1. Sites should have minimal human impacts upstream;

2. Site location should encompass enough tributary coverage for adequte representation of the basin; and;

3. Sites must have easy road access year round.

The watershed area for each site was then estimated. Twenty-three potential sites watershed areas were found to range from 4 to 62km^2 (see Table 2 and Figure 3).

Table 2: Preliminary Site Selection for Potential Water Quality Sites in the Ganaraska River Basin

Sub-basin	Proposed Sites	Area (sq km)	Area of Sub-basin (%)	Coverage Basin (%)
1 Upper Ganaraska	U1	17	26	6
	U2	26	40	10
	U3	6	9	2
	U4	10	15	4
	U5	9	14	3
	O3	62	96	23
2 Poplar Hill	P1	7	16	3
	P2	26	59	10
	P3	6	14	2
	P4	9	20	3
	GP-Geomatics	4	9	1
3 North Ganaraska	N1	5	8	2
	N2	21	33	8
	N3	15	23	6
	N4	8	12	3
4 Rossmount	R1	10	47	4
	R2	14	65	5
	R3	17	79	6
5 McBurney's Hill	M1	4	20	1
	M2	4	20	1
	M3	3	15	1
	M4	16	78	6
	M5	17	83	6
6 Middle/Lower Ganaraska	L1	4	8	1

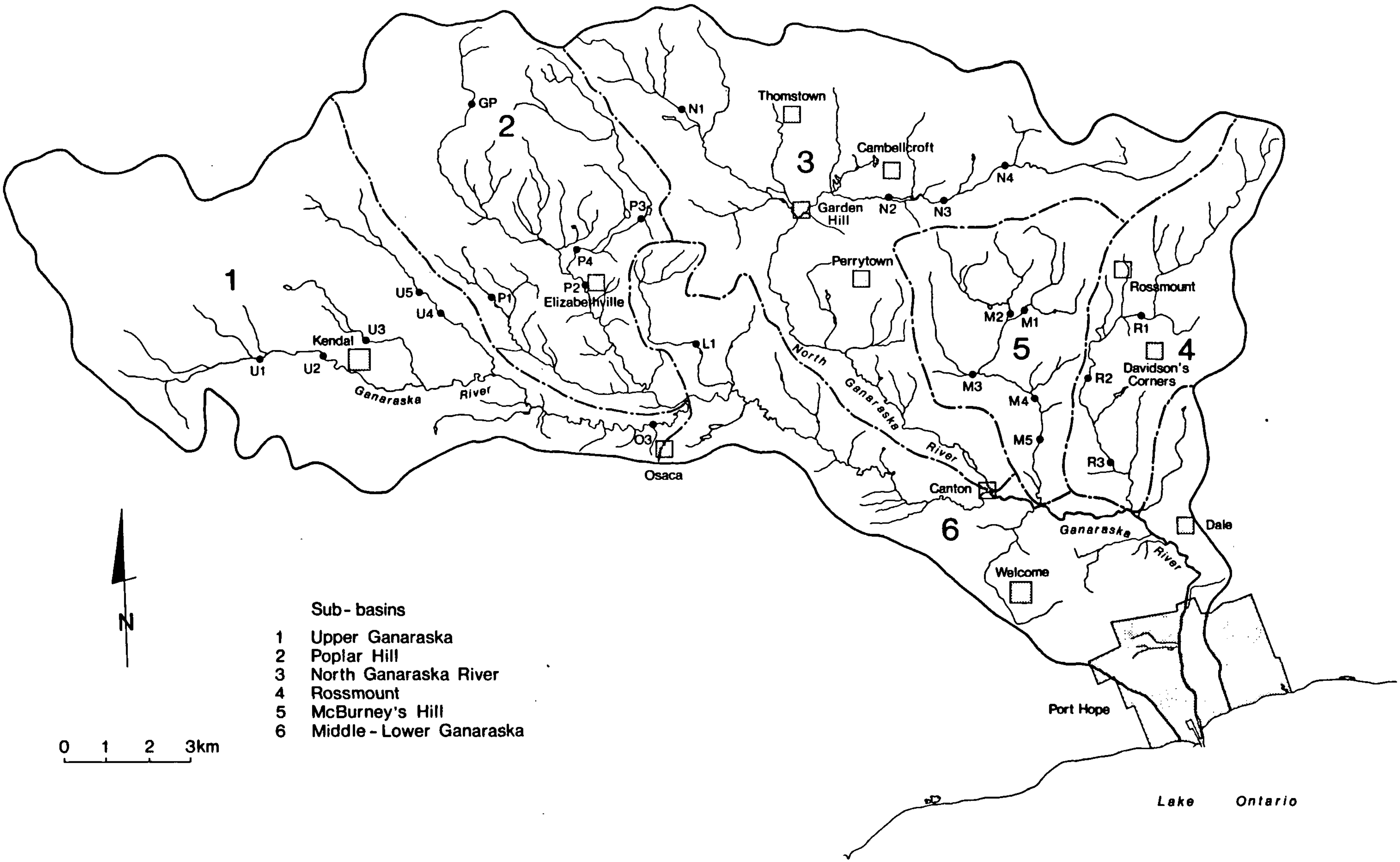


Figure 3 Potential Site Locations Based on Preliminary Map Evaluation

4.2 Field Reconnaissance

The second step in the site selection process was to visit each of the potential sites to determine its suitability for sampling. Each of the sites identified on the topographic maps was assessed with respect to: site access, stream width, water depth, flow, water clarity, stream bed morphology, and hydro availability. Details were recorded and are presented in the Appendice. In addition to an assessment of the streams, surrounding land use was noted, so that it could be compared with map inventories. These land use observations will also be used to locate sites for the investigation of other issues, such as agricultural eutrophication.

After completing the field reconnaissance, only 3 of the 24 potential sites were considered. All three sites, (U1, U2, O3), are located in the Upper Ganaraska Sub-basin (see Figure 4). Some of the reasons for eliminating potential sites are as follows:

1) poor visual water quality (high turbidity and algal growth);
2) insufficient water depth (the water sampler requires a minimum stream depth of 12 inches);
3) insufficient streamflow;
4) streambanks with fine silts and fine organic material (fine particulate matter can be easily stirred up while wading in the stream and may contaminate water samples); and,
5) unsafe stream access.

4.3 Representative Sub-basin Determination

The main criteria for network establishment, is that the sites, and the tributary basin area they lie within, must be representative of the watershed in terms of soil type, physiography, area of coverage, and land use. But practical considerations such as the cost of hydrometric station installation, and longterm land use trends along streambank and upstream areas also need to be addressed. In some cases, these factors are subjectively evaluated when the final selection is made.

4.3.1 Land Use

The third step in the analysis is to determine the most representative and "least impacted" sub-basin in the Ganaraska River Basin with respect to land use. The basin boundaries were outlined on agriculture land use maps (OMAF, 1982a, 1982b, 1983) and percent area of coverage of specific land uses were estimated by basin and sub-basin (see Table 3). A ranking system was used to rate each sub-basin with respect to the overall coverage of a specific land use, and its water quality degradation potential. For example, corn and row crops have a greater potential for surface water contamination due to a high erosion potential (ie. exposed soil), high fertilizer application rates, and pesticide runoff. A sub-basin was rated "2" if it was the best candidate with regard to the land use activity (most preferred), "1" represented the second most preferred (intermediate), and "0" for the least preferred (see Table 4). This method was very subjective, but it provides a quantitative measurement of land use activities, and potential water quality impacts for each sub-basin. Results indicate that the Upper Ganaraska sub-basin has the least probability of negative water quality impacts due to land use. Poplar Hill and the North Ganaraska sub-basins ranked second and third respectively.

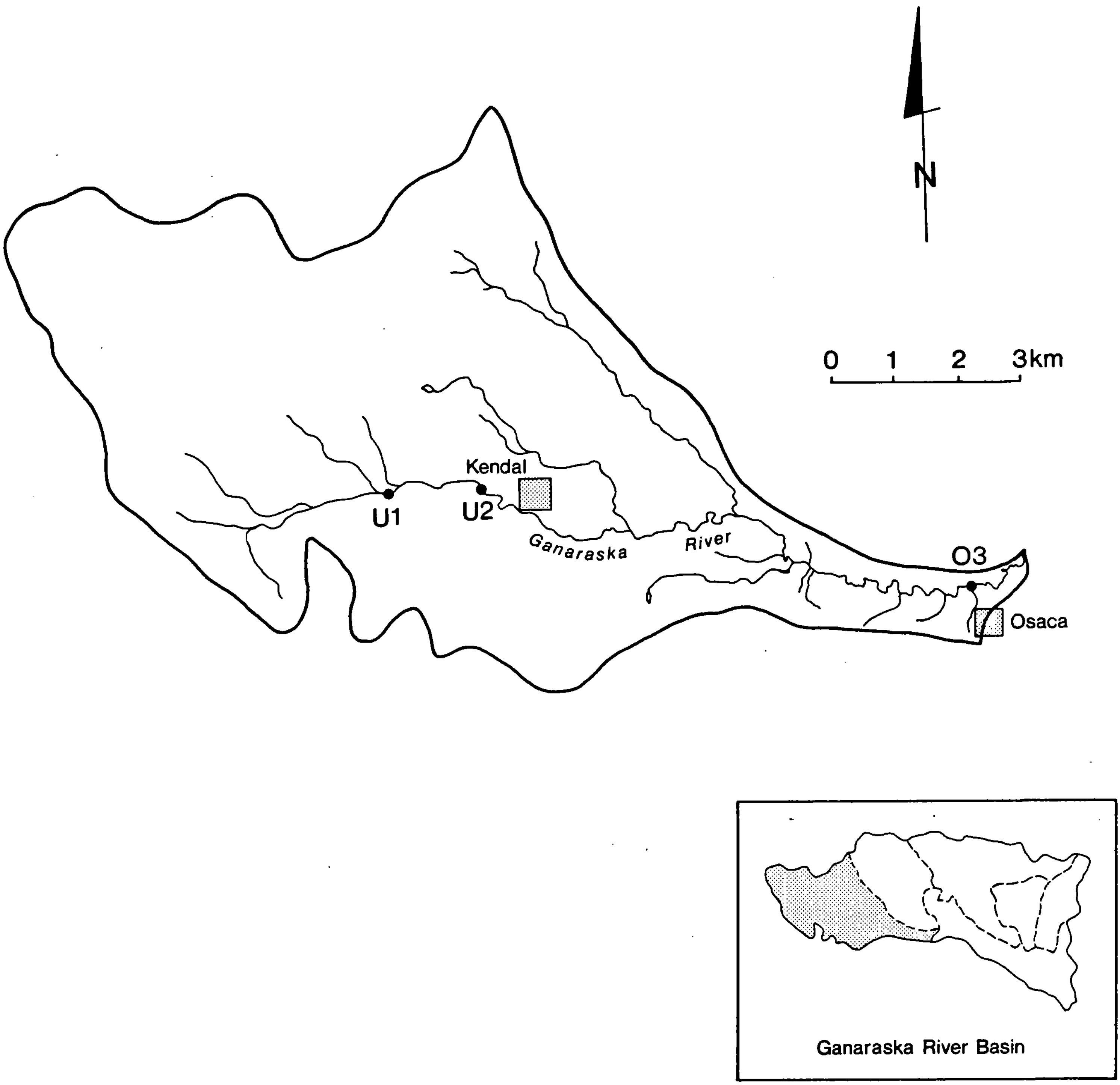


Figure 4 Potential Site Locations in the Upper Ganaraska Sub-basin after Field Reconnaissance

TABLE 3: LAND USES IN THE GANARASKA WATERSHED BY SUB-BASINS AND BASIN

	Sub-basin 1	Sub-basin 2	Sub-basin 3	Sub-basin 4	Sub-basin 5	Sub-basin 6	BASIN
Land Use Categories	Upper Ganaraska	Poplar Hill	North Ganaraska River	Rossmount	McBurney's Hill	Middle/ Lower Ganaraska	GANARASKA
	-------------Percent of Sub-basin and Basin Area---------------						
Built-up Area	1					11	2
Continuous Row Crops	4	7	6	14	7	25	10
Corn System	3	6	16	16	30	8	10
Grain System	1	2	9	18	13	2	6
Grazing System	2	2	2	4		14	4
Hay System	10	9	8	2	18	1	8
Idle Agriculture Land	1	2	2	5	5	6	3
Mixed System	6	5	5	5		4	4
Orchards				1			0
Pasture System	10	7	5			14	7
Recreation	1					2	1
Sod Farms	2						0
Tobacco System	2	1	2		1	4	2
Woodland	46	50	45	23	20	4	34
Other	11	9		12	6	5	9
Total Area	100	100	100	100	100	100	100

TABLE 4: LAND USE RANKING OF THE GANARASKA WATERSHED TO DETERMINE THE "LEAST IMPACTED" SUB-BASIN

	Sub-basin 1	Sub-basin 2	Sub-basin 3	Sub-basin 4	Sub-basin 5	Sub-basin 6
Amount of Land Use Activity	Upper Ganaraska	Poplar Hill	North Ganaraska River	Rossmount	McBurney's Hill	Middle/ Lower Ganaraska
Corn	2	1	0	0	0	1
Forest Cover	2	2	2	1	1	0
Grain	2	2	1	0	0	2
Grazing	1	1	1	1	2	0
Row Crops	2	1	1	0	1	0
Urbanization	2	2	2	2	2	0
Total	11	9	7	4	6	3

2 = most preferred
1 = intermediate
0 = least preferred

4.4 Detailed Investigation of the Ganaraska River Basin

The fourth step in the site selection process is to determine which of the sites, after the field reconnaissance, is the best suited for baseline monitoring based on physiography, soils, forest cover, and upstream land uses.

4.4.1 Physiography Analysis

The Ganaraska River Basin boundary was traced onto a physiographic map (Chapman and Putnam, 1984), to estimate the areas of each type of physiography. Sand plains and drumlinized till plains are the most dominant physiography types in the Ganaraska River Basin (Table 5).

Table 5: General Physiography in the Ganaraska River Basin

Physiography Type	Area (%)
Sand Plains	42
Till Plains (Drumlinized)	30
Kame Moraines	16
Clay Plains	8
Drumlins	4
Total	100

4.4.2. Soil Analysis

The Ganaraska Watershed general soil types and series were summarized by Richardson (1946). For the purposes of this report, the fourteen soil series which exist in the Ganaraska River Basin were generalized into five soil types: limestone tills, fluvio-glacial tills, deltaic outwash materials, lacustrine, and miscellaneous. The percentages of the soil types within the entire river basin, and each of the site tributary basins were calculated (see Table 6). All three sites consist of mostly limestone till and fluvio-glacial till which are considered to have high and medium susceptibility to water erosion, respectively.

Table 6: Generalized Soil Types in the Ganaraska River Basin and Site Tributary Basins

Soil Types	Entire Basin (%)	U1 Basin (%)	U2 Basin (%)	O3 Basin (%)
Limestone Till	41	44	35	41
Fluvio-Glacial Till	24	48	55	37
Deltaic/Outwash Materials	20	0	0	10
Lacustrine Materials	7	0	0	1
Miscellaneous	8	8	10	11
Total	100	100	100	100

4.4.3 Forest Cover

The total forest cover within each of the site tributary basins was calculated using the National Topographic Series Maps (DEMR, 1978, 1984, 1985) (see Table 7). The site with maximum forest cover is likely to have the least amount of human activities that would impact upon water quality. Site U2 had the highest amount of forest cover of the three tributary site basins.

Erosion along streambanks is also of concern, since it affects turbidity and overall water chemistry. River reaches with forest cover were measured and compared to the total tributary length to determine the percentage of the river which is buffered (DEMR, 1978, 1984, 1985) (see Table 7). Although the differences between all three sites are minimal, the tributary of site O3 had the greatest amount of buffering by forest cover.

Table 7 Forest Cover Characteristics (in Percent)

Forest Cover Characteristics	U1	U2	O3
Tributary Area with Forest Cover	44	**51**	46
Tributary Length with Forested Buffer Strip	72	75	**76**

4.5 Potential Site Analysis

After the field reconnaissance, the three sites in the Upper Ganaraska sub-basin (U1, U2, and O3), were considered to be satisfactory. With respect to the land use criteria used in this study, the Upper Ganaraska sub-basin is the "least impacted" of all the sub-basins (see Table 4). Significant amounts of forest cover are located in the northern parts of the sub-basin in the Oak Ridge Moraine and along the stream reaches (DEMR, 1978). This forest cover is important, because it serves as a buffer to minimize soil erosion, and other agricultural impacts along the streambanks. The field reconnaissance survey noted corn, soyabean, pasture and livestock production as the dominiant agricultural land uses. Kendal, with a population of 170, is the only community located in the sub-basin and homes have septic tank systems. This is a concern in terms of the potential for leaching of nutrients into the water course.

Each of the potential sites were described and evaluated in terms of sampling suitability and the degree to which they represent the Ganaraska River Basin. The factors considered were physiography, soil, adjacent and upstream land use, area of the site tributary basin, erosion potential and stream morphology. The individual site evaluations are descriptive highlights of the characteristics of each site. In the final analysis, a ranking scheme was employed to quantify each of the factors for the sites (Table 8). A score of "2" was given to the site which was considered the best candidate for a given factor (most preferred); "1" represented the second most preferred (intermediate); and "0" was the least preferred.

TABLE 8: RANKING OF THE PROPOSED SITES IN THE GANARASKA RIVER BASIN

Ranking Criteria	-----Potential Sites-----		
	U1	U2	O3
Agricultural Land Use	2	2	0
Forest Cover (Tributary Area)	1	2	1
Forest Cover (Buffer Zone)	1	2	2
Potential for Upstream Influence	2	2	0
Representative Physiography	2	2	2
Representative Soils	2	0	0
Site Erosion Potential	0	2	2
Suitability of Site for Sampling	1	2	2
Tributary Basin Area	0	1	2
Tributary Basin Erosion Potential	1	1	2
Urbanization	2	2	0
TOTAL	14	18	13

2 = most preferred
1 = intermediate
0 = least preferred

4.5.1 Site U1 Characteristics

Total Basin Area of Tributary	17km2
Creek Width	6m
Maximum Creek Depth	46cm
Creekbed Material	Stony bottom with fine sand
Physiography	Till Plains (drumlinized)
Soil Type on Site	Otonabee loam steep phase - limestone till
% of Tributary Buffered	72
% of Tributary Area Forested	44
Site Erodibility Potential	High
Tributary Basin Area Erodibility	Medium to High

Overall, U1 ranked second in terms of being suitable as a potential network station (see Table 8). This site was representative of the Ganaraska River Basin in terms of physiography and soil type, but since U1 is contained within the tributary area of U2, it is less preferred because of its smaller tributary basin area (see Figure 5). The soils within the tributary basin are primarily composed of limestone and fluvio-glacial tills, which have medium to high water erodibility (GRCA, 1983). Site U1 has the Otonabee loam steep soil phase, which has a high susceptability to erosion (GRCA, 1983), making this site less desirable. There is a log upstream of the road which is creating a pool deep enough for sample collection. It appears stable, but there is the risk of it being washed downstream, which would make the creek too shallow for sampling. In addition, there is a derelict dam downstream, and if it fails, it may cause the water level to drop too low for sampling. See Appendice for a more thorough site description of U1.

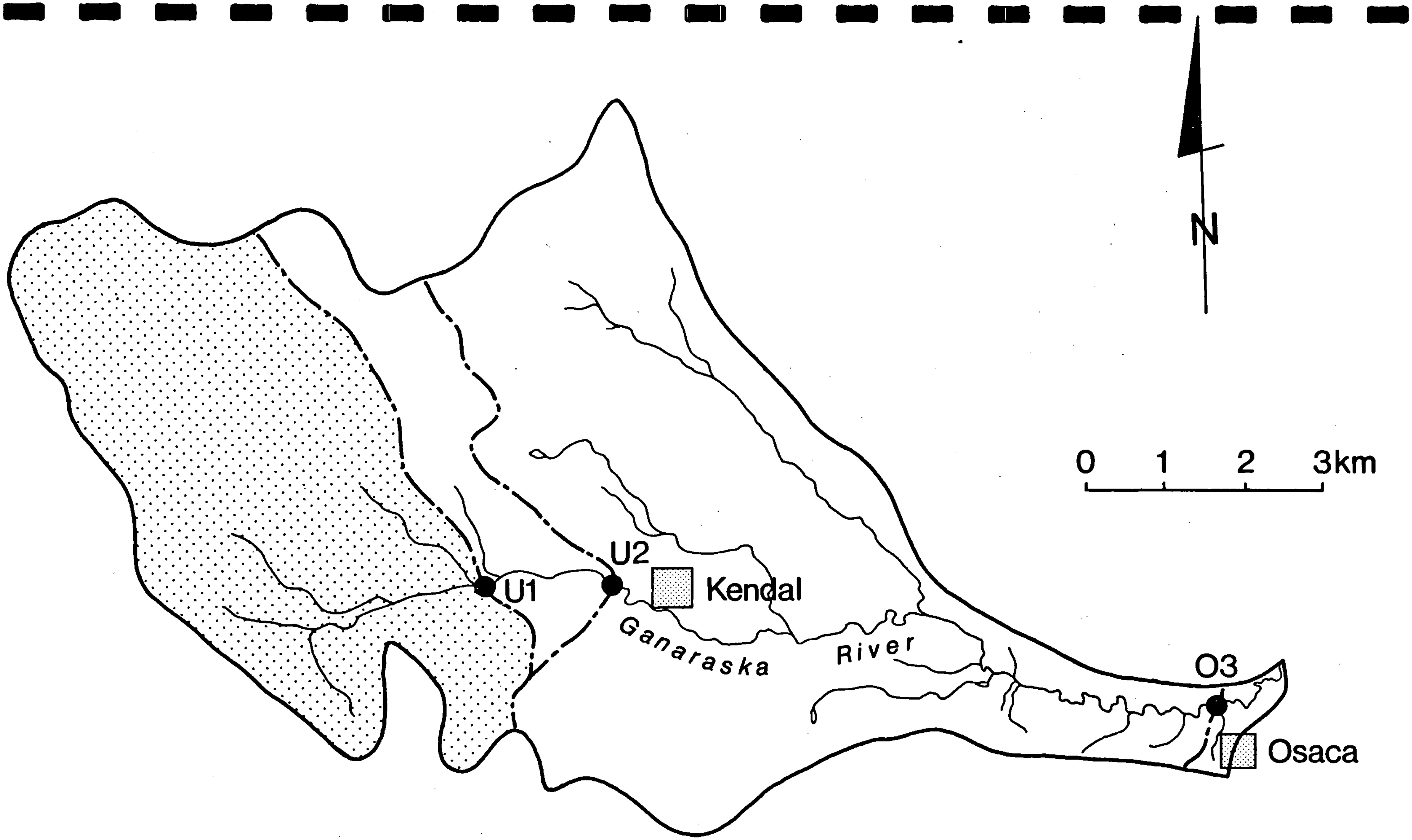


Figure 5 Location and Tributary Basin of Site U1

4.5.2 Site U2 Characteristics

Total Basin Area of Tributary	26km2
Creek Width	6m
Maximum Creek Depth	61cm
Creekbed Material	fine silt along streamside, boulders along the side of stream, stream bottom sandy
Physiography	Sand plains
Soil Type on Site	Muck
% of Tributary Buffered	75
% of Tributary Area Forested	51
Site Erodiblity Potential	Low
Tributary Basin Area Erodibility	Medium to High

U2 is ranked as the best site for station implementation (see Table 8 & Figure 6). Good water flow, depth, and minimal upstream impacts place this site ahead of the others. The muck soil type is characteristic of areas along stream beds and depressions, and it has a relatively low erodibilty potential. The soils within the tributary basin are primarily composed of limestone and fluvio-glacial tills which have medium to high erodibility (GRCA, 1983). Sparse pockets of minor erosion, livestock production, and corn crops were observed in the upper reaches of the sub-basin, however, the site's favourable sampling characteristics, high amount of forest coverage, large tributary basin, and low site erodibility potential, are the overriding strong points. See Appendice for a more thorough description of site U2.

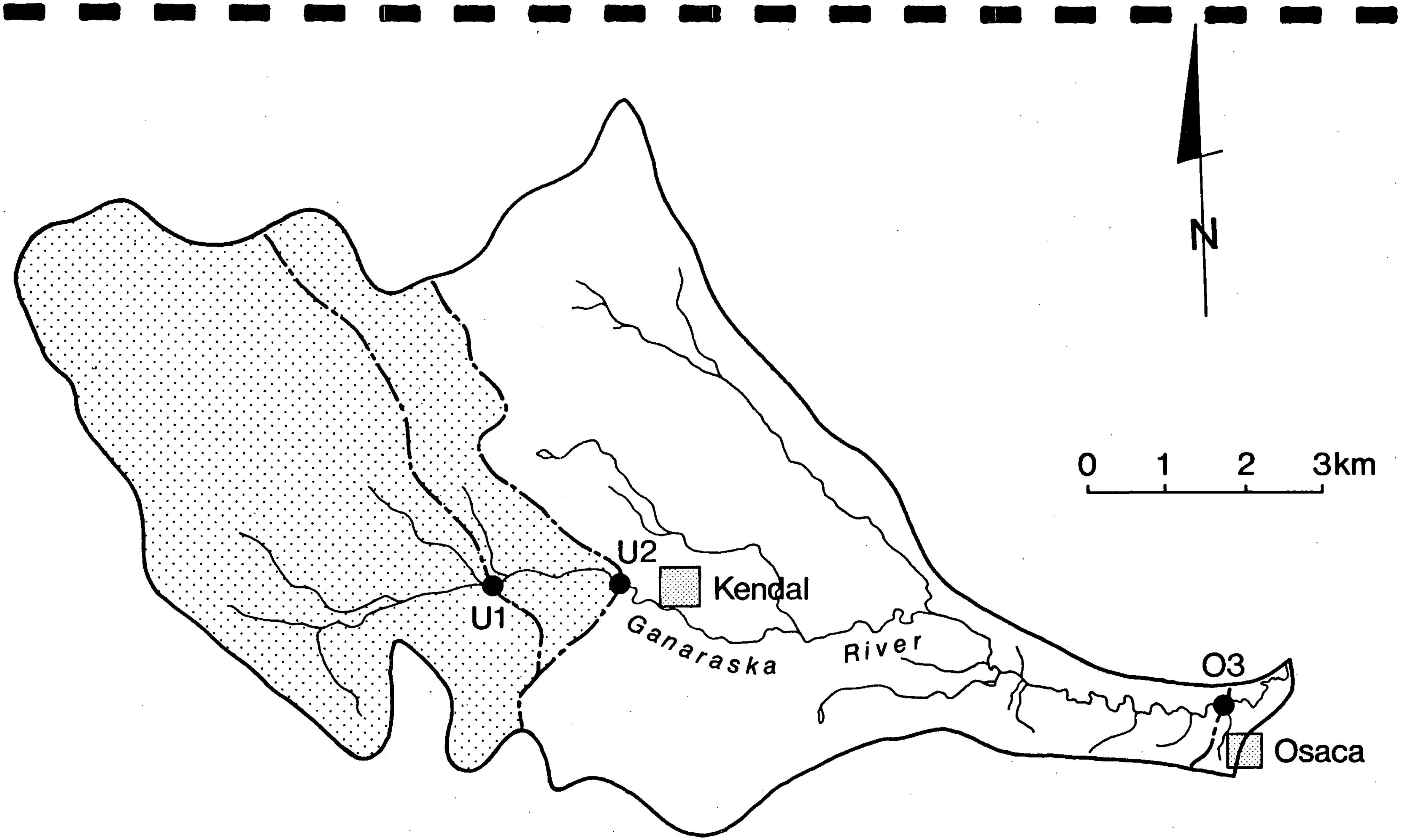


Figure 6 Location and Tributary Basin of Site U2

4.5.3 Site O3 Characteristics

Site O3 is 1/2km^2 upstream of Water Survey of Canada hydrometric station 02HD003.

Total Basin Area of Tributary	62km2
Creek Width	6m
Maximum Creek Depth	61cm
Creekbed Material	sandy bottom with rocks along streambanks
Physiography	Sand plains
Soil Type on Site	Bottom Land
% of Tributary Buffered	76
% of Tributary Area Forested	46
Site Erodibility Potential	Low
Tributary Basin Area Erodibility	Medium to High

Overall, site O3 ranked third in terms of being suitable as a potential station (see Table 8 & Figure 7). This site had favourable characteristics with respect to stream bed morphology, tributary basin size, and low site soil erodibility. The soils within the tributary basin are primarily composed of limestone and fluvio-glacial tills, which have medium to high erodibility (GRCA, 1983). Site O3 is downstream from the community of Kendal, which relies on septic tank systems; this may have an impact upon water quality. As well, site O3 has a greater degree of corn and livestock production upstream. Tobacco curing houses were noted slightly upstream from site O3, and tobacco is still being grown in the vicinity. Tobacco crops may have a significant impact upon water quality, since nitrogen and phosphorus based fertilizers are commonly used (OMAF, 1988).

Site O3 has a hydrometric station nearby, which would greatly reduce sampling start-up costs. Although this site also has favourable sampling characteristics, the large basin area of the tributary has too many confounding factors which may affect baseline water quality. See Appendice for a more thorough description of site O3.

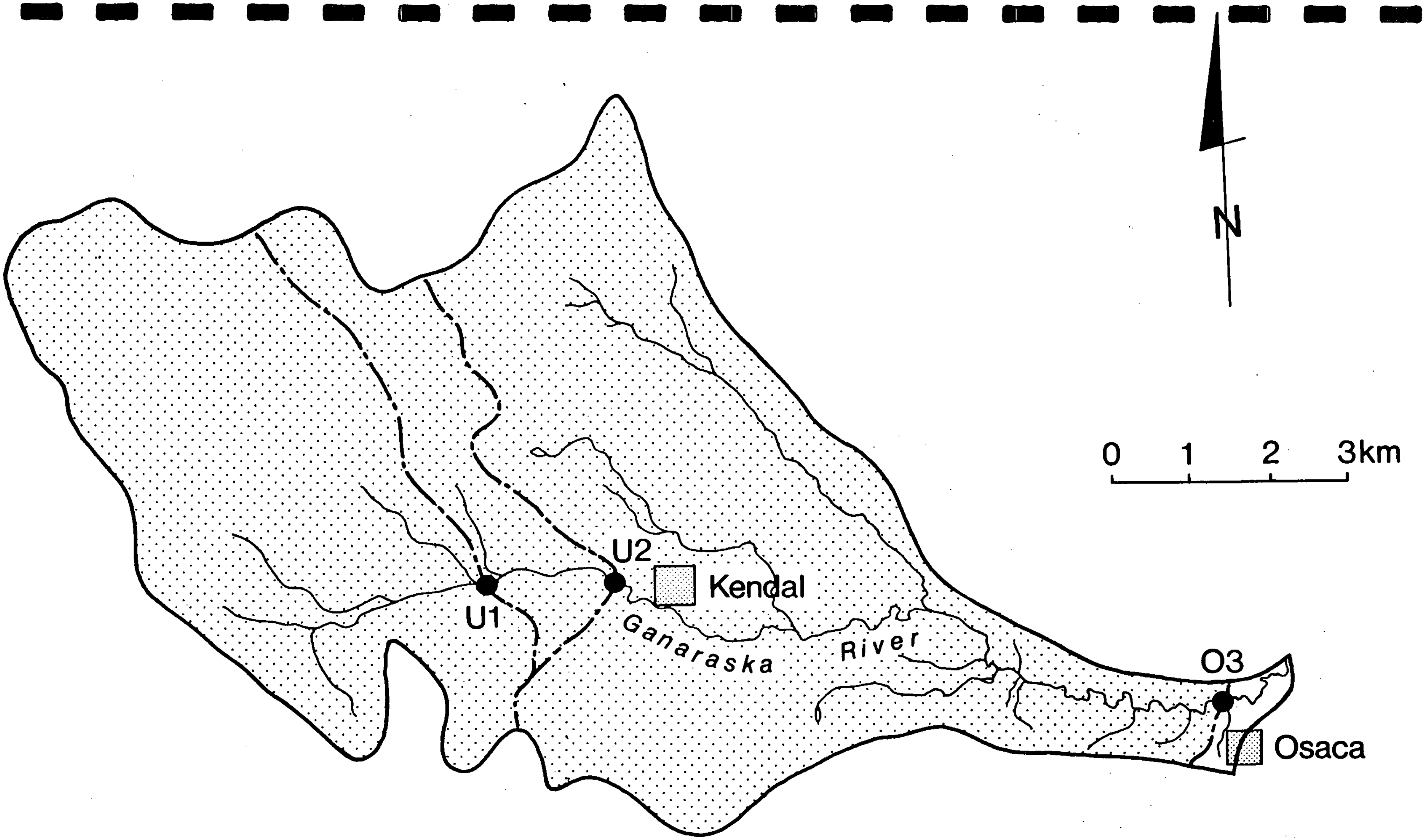


Figure 7 Location and Tributary Basin of Site O3

5.0 Additional Comments

Watson (1980) and the Ganaraska Region Conservation Authority (1983) conducted water quality surveys in the Ganaraska Watershed. Samples were collected during the summer months from 10 sites located throughout the watershed. The study by Watson was conducted for the months of June, July, and August 1980, and an average of 29 samples were collected per site. Sites of interest from both studies are as follows (see Figure 8 and Table 9):

Table 9: Selected Sampling Site Locations and Descriptions from the Watson and GRCA Studies

Site No.	Site Name	Sub-basin Location and Description
1	Port Hope CA	Middle/Lower Ganaraska
3	Forest Centre	Poplar Hill, Ganaraksa Conservation Authority Forest Centre
4	Dell	Poplar Hill, Upper part of
7	S. Osaca	Upper Ganaraska, Hydrometric Station
8	N. Osaca	Upper Ganaraska, Hydrometric Station
10	N. Kendal	Upper Ganaraska
11	S. Kendal	Upper Ganaraska

A summary of the the water quality analyses is presented in Tables 10 & 11. The Dell and Forest Centre stations are located in the upper reaches of Upper Ganaraska and Poplar Hills sub-basins in heavily forested areas, thus resulting in the lower average water temperatures (Table 10) - they are the least impacted relative to the other sites due to their remoteness as indicated by the low fecal coliform counts (Table 10). These sites had significantly better water quality than the other sites, but they were not rejected as potential sites for ORN due to their small tributary basins. In GRCA study (1983), the North Osaca station, which is not influenced by the town of Kendal, had lower fecal coliform values than the South Osaca station, which includes possible influences from the town (Table 11). In the Watson study (1980), the North and South Osaca sites experienced the same fluctuations in fecal coliform counts, suggesting the same type of agricultural practices in the vicinity (Figure 9). All the sites can be compared to Port Hope CA, which is the furthest downstream. Based on this information, it is likely that human activities downstream of the town have an impact on the water quality at site O3 (South Osaca). Since U2 is upstream from Kendal, and experiences minimal land use impacts, it will be a better site.

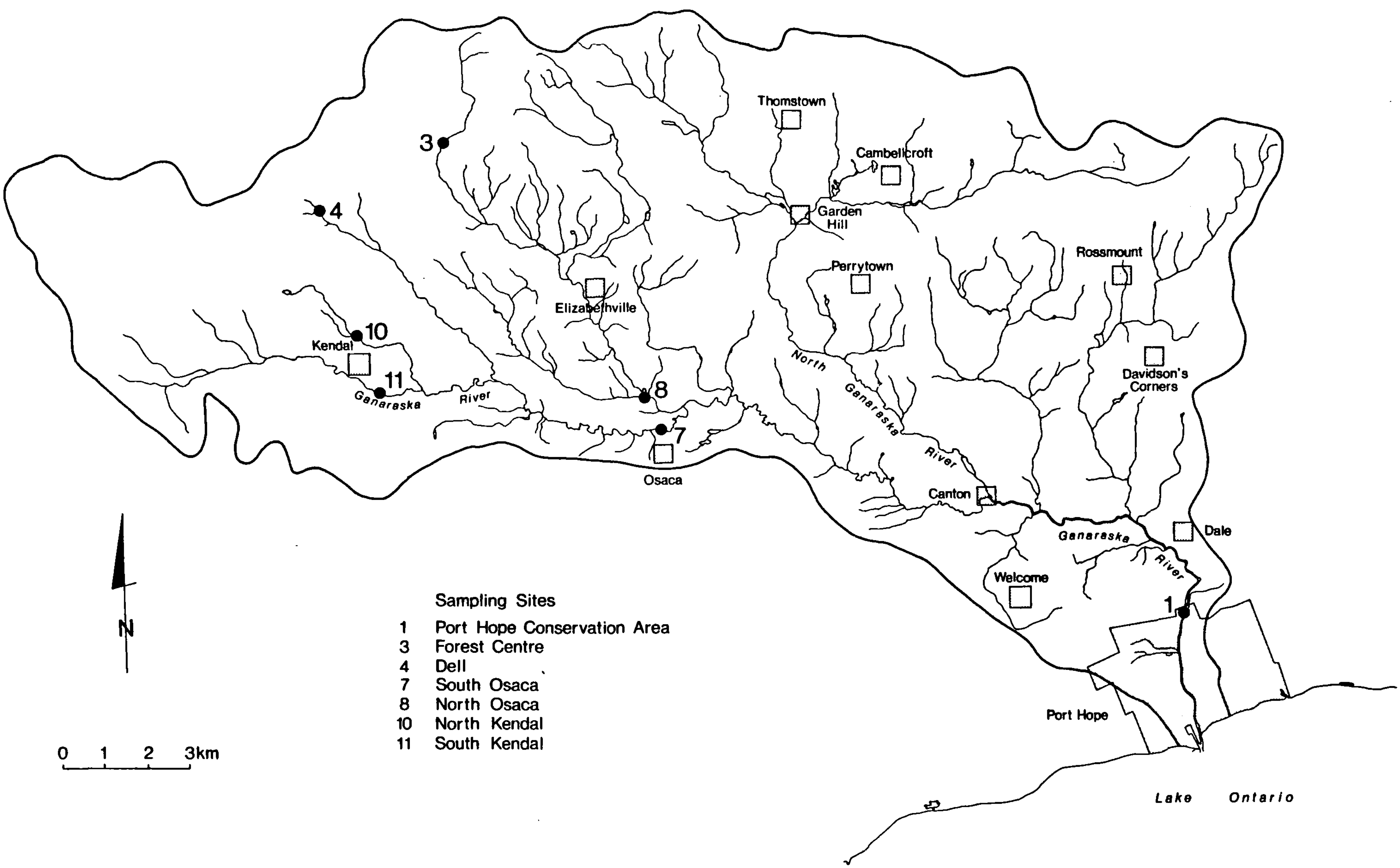


Figure 8 Sampling Site Locations for Watson and Ganaraska Region Conservation Authority Studies

Table 10: 1980 Water Quality at Selected Sites in the Ganaraska River Basin

	SITES				
Quality Criteria	**Port Hope**	**Forest Centre**	**Dell**	**South Osaca**	**North Osaca**
Average Water Temperature (°C)	17.0	7.6	8.6	16.0	15.2
Average Total Coliform (/100ml)	873	7	14	330	339

Source: Watson, 1980

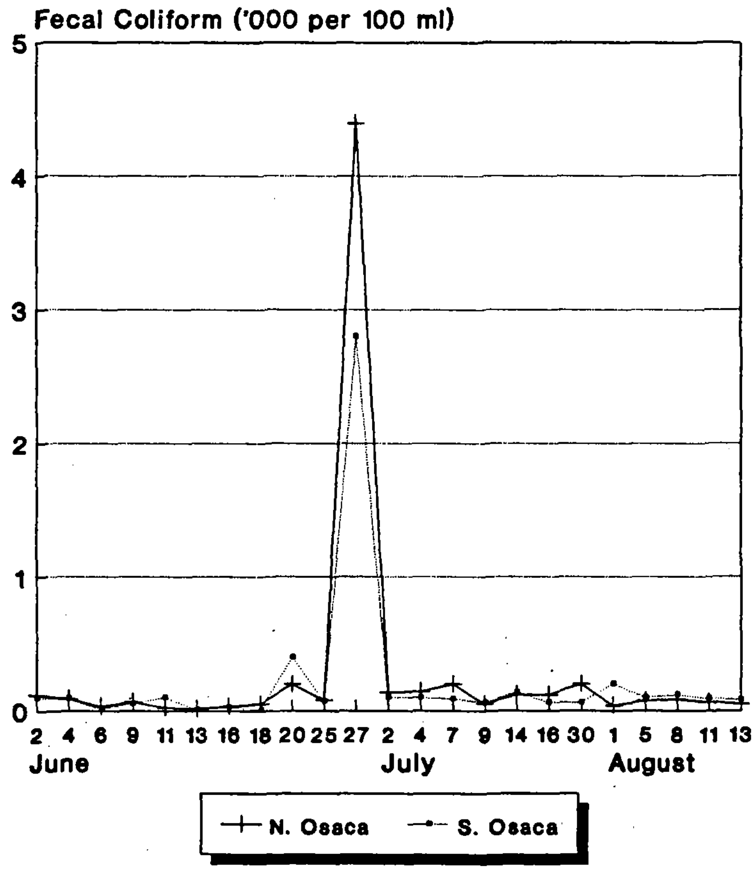
Note: The values are averaged from 29 samples per site collected between June, July, and August 1980.

Table 11: 1983 Water Quality at Selected Sites in the Ganaraska River Basin

Quality Criteria	1 **Port Hope CA**	2 **Forest Centre**	3 **Dell**	4 **South Osaca**	5 **North Osaca**	6 **North Kendal**	7 **South Kendal**
Avg Water Temp (°C)	18.3	8.5	8.8	16.4	16.3	14.7	15.4
Minimum	24.5	-	-	21.4	19.6	-	-
Maximum	14.1	-	-	13.8	12.5	-	-
pH	7.5	6.9	-	7.5	7.5	7.5	7.5
Acidity	13.1	-	-	12.4	12.0	10.6	12.5
Alkalinity	205.3	173.3	-	208.4	208.3	198.3	210.6
Dissolved O_2	8.4	11.4	-	9.9	9.4	9.9	9.7
CO_2	11.5	-	-	12.1	11.9	10.6	12.2
Hardness	206.8	171.0	-	212.7	183.3	225.2	231.1
Fecal	**372.0**	**7.0**	**13.0**	**210.0**	**147.0**	**72.0**	**382.0**

Source: Ganaraska Region Conservation Authority, 1983

Figure 9: North and South Osaca
Fecal Coliform Levels



Source: Watson, 1980

6.0 Conclusion

This report proposed a methodology for establishing water quality sampling sites which are the "least impacted" by human activity in the Ganaraska River Basin. This is the last stage of a three tiered process, for the establishment of an Ontario Reference Network to monitor baseline water quality conditions. The establishment of an ecologically defined baseline water quality network will have many advantages. The most important is the ability to provide baseline water quality information from which other stresses such as agricultural eutrophication and pesticide runoff can be compared against. In turn, this will assist in the placement of a limited number of network stations within provinces and across Canada. Other benefits include:

1) A cost savings due to a reduced number of network stations (costs of hydrometric station construction, labour, shipping, and analysis costs);
2) A formalized national approach for assessing baseline water quality;
3) A consistent national database of baseline water quality information;
4) A water management tool geared towards the specific climatic, physical, geomorphological, and biological conditions unique to a particular region;
5) A mechanism to check the effectiveness of water resource management strategies and regulation policies; and,
6) A baseline network can be used to measure and assess the magnitude of water quality stresses caused by human activities on an ecoregional basis.

The study indicated that sites U1 and U2 are in close contention as the most suitable water quality sampling site for the Ganaraska River Basin, representing ecodistrict #4 in the Erie ecoregion. Site U2 contains sufficient area, has favourable site characteristics, and is less impacted that site U1. Site U1 contains a smaller area than site U2, has favourable site characteristics, though it is slightly more impacted. Site O3 is located further downstream, and represents an area almost three times the size of site U2. Site O3 has suitable sampling characteristics, but it may experience influences from the community of Kendal. In addition , it has a higher degree of agricultural activities in the tributary basin. The study completed by the Ganaraska Region Conservation Authority (1983) infers that sites below Kendal have significantly higher fecal coliform levels than the sites upstream from Kendal.

7.0 Recommendation

Site U2 is the most preferred site for ORN establishment in the Ganaraska River Basin; site U1 is the second most preferred site. This decision is supported by the GRCA (1983) study which suggest that there are significantly higher fecal coliform counts at sites below Kendal.

Acknowledgement

Special thanks to Bob McCrea and John Struger for their helpful comments, insights, and suggestions for this report.

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Appendice

Field Reconnaissance Notes for the Ganaraska River Basin

Date of Survey: September 20, 1991

Weather: Sunny with intermittent cloud cover, occasional light rain in the afternoon, cool.

Surveyors: John Fischer, Mei-Ching Tsoi

Sub-basin 1 - Upper Ganaraska

The upper reaches of the sub-basin 1 has significant amounts of forest cover still intact. The types of land use observed on this sub-basin includes: hay fields, soyabeans, corn, pastures, and some livestock. Some erosion was observed along hilly areas. Overall, agriculture land uses such as row crops, plowing, and grazing were the least intense in the Upper Ganaraska Sub-basin. The only community in the sub-basin, Kendal, is not highly developed, consisting of farms and houses located at a concentrated junction. All possible sites downstream were considered suspect due to potential impacts from septic tanks.

Site Assessments

U1

Upstream: The streambanks are wooded. It is 20ft wide and 1 1/2ft deep under the bridge. Stream bed consists of stoney bottom with fine sand and some very fine organic silts. There is a 2ft deep hole located close to bridge which is easily accessible. Hydro is available on site. There is a log blocking the stream channel upstream which creates a 2 1/2ft deep hole with a gravelly bottom and good flow. The log dam appears to have been there for a long time.

Downstream: Water has a maximum depth of 1ft deep. Bottom consists of fine sands and very fine organic silts. There is a derelict dam 100m downstream which controls the present level of the upstream water. If it fails, the water level downstream will drop considerably. Land use consists of forest and fields along the streambanks.

U1 Conclusion: U1 upstream site was considered to be a potential site due to its favourable site characteristics, water depth and flow, and its location; it is located in relatively high reaches of the basin. As well, since the upper part of the basin has the least intensive farming as compared to other sub-basins, it is the least impacted area in the entire river basin.

U2

Upstream: Hydro is available. The stream is 20ft wide and 2ft deep with good water flow. At about 10ft away from the bridge, the water is 3 1/2ft deep with a rocky and solid bottom. The streambanks are forested (buffered). There were very fine silts and very fine organic silts located along the streambanks. The stream bottom is sandy and there are boulders along the side which serve as a standing spot for easy sampling access. A fish (8 to 12in in length) was sighted in the stream, indicating a healthy aquatic environment.

Downstream: The stream is 20ft wide and 1ft deep and the bottom is silty, which is not suitable for sampling.

U2 Conclusion: U2 upstream site was considered to be the most favourable site of the entire river basin. It is located in the upper reaches of the least intensively farmed sub-basin. The land use along the tributary consists of wooded areas, corn, hay, fields, and small amounts of livestock grazing. Site U2 encompasses more forested areas (51%) than that of site U1 (44%). Moreover, U2 is further downstream, thus incorporating greater reaches of the sub-basin for sampling purposes. The stream flow characteristics and the boulders located along the upstream stream bed offer superior water sampling criteria than that of U1.

U3

Upstream: There is severe erosion on hillside. The stream is too shallow.

Downstream: The stream is 5ft wide and 8in deep with sandy bottom

U3 Conclusion: The stream is inadequate for sampling due to insufficient water and depth.

U4

Upstream: The stream is 8ft wide and 1 1/2ft deep with rocky, gravelly, and silty bottom. Hydro is available. Water depth is marginal.

Downstream: Water is only 4in deep, too shallow.

U4 Conclusion: U4 downstream is too shallow for sampling. The upstream, however, can be sampled, although it is not considered to be the best site.

U5

Upstream: There is no forest cover with fields running all the way up to the streambed. The creek is 3ft wide and only 6in deep. The flow is insufficient for sampling.

Downstream: The stream is 10ft wide and 2ft deep. There is a good ledge with rocks along the side for standing. The bottom is gravelly with some rocks. The streambank consist of stones, pebbles, and some silt. The area has difficult access since a private property sign is posted, and the area has been fenced off.

U5 Conclusion: The upstream site is inadequate for sampling purposes. Though the downstream site has sufficient depth and flow, it is discounted due to access difficulties as well as being located on the downstream side of the road.

O3 - Hydrometric Station

O3 is slightly upstream 1/2km west of the Environment Canada hydrometric station.

Upstream: The stream was 20ft wide and 2ft deep with a sandy bottom and clear water. There are lots of rocks along the streambank to step onto to collect samples. The streambank is forested and appears to have minimal disturbance. Many fish approximately 1ft in length were spotted in the stream.

Downstream: Water was 2ft depth as well.

03 Conclusion: The site was considered to be a candidate for a sampling site because it fulfills all the physical criteria as a potential sampling site. The disadvantages with this site is that it is downstream of the community of Kendal and there are some agricultural activities (i.e. corn, row crops, livestock, tobacco) upstream which may impact water quality.

Sub-basin 2 - Poplar Hill

The upper reaches of Poplar Hill Sub-basin consists of forested area. The Ganaraska Conservation Authority Forest Centre is located in the northern extent of the sub-basin. Poplar Hill has a higher level of agriculture activity than the Upper Ganaraska Sub-basin. The activities consist of grazing and row crops. Intermittent forest cover does exist throughout the Poplar Hill Sub-basin, but it is less dense than the Upper Ganaraska Sub-basin. The water of all the streams surveyed in sub-basin 2 appeared murky. Erosion due to agriculture activities may be causing the degradation of the water quality in the Poplar Hill Sub-basin. The Poplar Hill Sub-basin may have suitable sampling sites for the examination of the agricultural eutrophication issue, due to the variety and intensity of farming activities in this area.

<u>Site Assessments</u>

P1

Upstream: Stream is 4ft wide with a water depth of 4in. Inadequate stream flow for sampling purposes.

Downstream: The stream is 15ft wide and 3ft deep at a deep hole, but there is lots of very fine silts on the stream bottom. Close to the culvert, the water level is only 6in to 8in deep with a sandy bottom.

P1 Conclusion: The upstream site is discounted due to insufficient stream flow and depth. The downstream site is not adequate due to the large amount of very fine silts.

P2

Upstream: There is a lot of livestock activity within the vicinity. As well, there is a lot of very fine organic silts along stream bottom. The water appears very murky.

P2 Conclusion: Due to the livestock activity and overall water quality, this site was excluded as a potential sampling site.

P3

Unable to find site; stream must have been very small and intermittent.

P4

The site was located in a marshy area. The water appeared very murky and had a distinct odour. Overall not a good site for sampling purposes.

04 - Hydrometric Station

Cannot locate station structure. The stream has a sandy bottom but it is too small for sampling.

GP - Geomatics Proposed "Pristine" Site

The site proposed in the Geomatics report is located in the northern parts of the Poplar Hill Sub-basin approximately 1km due northeast of the Ganaraska Forest Center campsite. The proposed site is only accessible by a hiking trail. No on-site assessments were made.

Geomatic Site Conclusion: The site is not suitable due to difficult access and the tributary's small area coverage ($4km^2$).

Sub-basin 3 - North Ganaraska

The North Ganaraska Sub-basin exhibited the most intense level of agriculture activities with extensive parcels of land devoted to corn, soyabeans, grazing, and other row crops. There are some idle fields and forested land scattered throughout the sub-basin, although the amount is smaller than that of the Upper Ganaraska Sub-basin. Two significant communities, Campbellcroft and Garden Hill, are located within the North Ganaraska Sub-basin. Potential sites have been selected upstream from these communities to avoid any urban influences. North Ganaraska Sub-basin may provide an ideal location when examining the agricultural eutrophication issue due to the variety and intensity of farming activities in this area. At Garden Hill, between the reservoir and the bridge, cattle were observed having free access to the stream bed.

Site Assessments

N1

Upstream: The stream is 6ft wide with a small hole almost 1 1/2 ft deep. The bottom is sandy, so this hole may fill in with time. The water is clear. There is livestock activity upstream.

Downstream: The water depth was only 4in deep.

N1 Conclusion: Although there is presently enough water to sample from the upstream site, the streambed morphology may change over time and the livestock should be avoided.

N2

Corn was planted right up to the streambanks. As well livestock (horses) has access to the water. The site was discounted due to livestock impacts and agricultural runoff potential.

N3

Upstream had murky water. Downstream had very fine organic silt bottom and insufficient flow. This site was discounted due to poor water quality and insufficient flow.

N4

Insufficient water flow to warrent sampling and the water appeared murky. There was ponding behind the culvert and a flow regulator was installed on private property on the upstream side. This site was discounted due the lack of water flow and poor water quality.

Sub-basin 4 - Rossmount

The Rossmount Sub-basin had land use similar to McBurney's Hill Sub-basin. Only pockets of forest cover remain with corn and hay fields being predominant. Overall the Rossmount Sub-basin did not provide any suitable sites due to the small size of the creeks. All the creeks identified as potential sites had insufficient flow for sampling.

Site Assessments

R1

The creek was too small to sample.

R2

Upstream: The site has extremely difficult access. The creek is 3ft wide and 4in deep. The water was clear. Hydro is available.

Downstream: There is a hole with 20ft diameter that is deep enough to sample. The terrain is extremely steep, however, which makes it too dangerous to carry sampling equipment to the site especially in the winter.

R2 Conclusion: The site is too dangerous to sample due to difficult access and was rejected due to safety concerns.

R3 - also Geomatics Proposed Eutrophicaton Site

Upstream: The stream is 5ft wide and only 4in deep with a low flow and silty bottom.

R3 Conclusion: The stream is not suitable for sampling due to insufficient flow and depth.

Sub-basin 5 - McBurney's Hill

McBurney's Hill is similiar to the Rossmount Sub-basin in that it has a high level of agricultural activity when compared to the North Ganaraska. There are only small pockets of forested areas remaining within the sub-basin and large areas of the basin consist of corn fields. Less dominant land uses include pastures and hay fields. Overall, many of the creeks are too small and too murky to sample. The poor water quality is likely a reflection of the agricultural activities in the sub-basin.

<u>Site Assessments</u>

M1

The creek was too small; it was almost ditch-like.

M2

There was insufficient water and it appeared murky.

M3

There was insufficient water and a well used pasture upstream. It is quite likely there would be manure runoff into the stream.

M4

Upstream: Hydro is available. The stream had a 10ft wide pool above the bridge, which was 3ft deep, and had a silty bottom. The water was stagnant, but some small fishes were sighted.

Downstream: The stream was 15ft wide and 4in deep. The water appeared to be stagnant.

M4 Conclusion: The poor flow and silty bottom excludes this sampling site.

M5

The site was too steep for safe access and there was all kinds of garbage on the creek banks.