J. ENVIRONMENTAL SYSTEMS, Vol. 13(3), 1983-84

INFORMATION RETRIEVAL FOR THE PREPARATION OF AN ENVIRONMENTAL IMPACT STATEMENT*

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ABSTRACT

A study of the possible advantages of land use analysis (land indicators) appears to be a necessary preliminary step to the selection of data for acquisition. Researchers who report data on the physical, chemical and biological quality of water always do so with reference to the land in the basin under study. Two pertinent questions which arise are therefore: just how far should this analysis go; and how should results be optimally used to solve problems relating to water quality. This article should therefore be considered as a preliminary study towards the development of an integrated method for water quality data acquisition. The choice of data is approached from the perspective of land use and the way in which the data are to be used.

This paper is intended to give a general idea of the physical and human characteristics of watersheds. This appreciation of a basin constitutes the first step in the determination of the problems of environmental impacts. For the Province of Quebec (Canada) as a case study, this publication provides a list of the main reference documents and sources of data on the physical and human characteristics of basins. At first sight, there is virtually no need to collect additional data for the purpose of preliminary interpretation of water quality data.

Natural resource planning permits the orientation of effects in a direction appropriate for optimizing potential uses. Thus, good planning makes available a body of logical options, as well as knowledge of the consequences of each decision, from which follows a better preparation for future well-being [1]. Situated within the planning process is the step concerning the evaluation of ecological impacts. Insofar as the principle objective of this process is to foresee

*This research was made possible through grants from the National Research Council of Canada (Grant A3711) and the Department of Natural Resources of the Province of Québec (Water Quality Division).

doi: 10.2190/M44Q-MM7Y-30PE-W3L5
http://baywood.com

and to minimize undesirable changes in the environment, one must eliminate, to the extent possible, the economic, social, and political aspects of the project from this type of evaluation. However, these aspects must be considered in planning for the entire project [2]. Thus, those responsible for the evaluation of ecological impacts must assure that promoters take ecological aspects into account in the elaboration of definitive plans in the same way that others watch over economic and political interests.

Different techniques for evaluating ecological impacts have been developed and refined [3-5]. However, the choice of the most adequate technique depends on the quantity and quality of initial data. In order to augment the precision of ecological impact evaluation, it is often useful to concentrate efforts to assembling the most significant data already available. In effect, numerous private and governmental organizations acquire fundamental data on a systemic basis. In the field of water planning, the existing data base may include variable physical factors, notably hydrological and geomorphological data, information on the chemical composition of water and biological data concerning life in waterways, lakes and soil. It may also include economic and social data regarding the influence of communities and economic activities.

This documentation effort must be performed in a detailed fashion given that the following step in the evaluation of ecological impacts involves the extension of sources of the inventoried data and the execution of supplementary analyses. On the other hand, analysis of existing data [6] on physical, chemical, biological, social and economic characteristics enables one to better identify and precisely state the problem. Enlarging the data base permits the extrapolation of present conditions, prediction of future needs and resources, and the elaboration of plans which take into account actual needs and predicted resource availability.

NATURAL ENVIRONMENT: PHYSICAL CHARACTERISTICS OF THE BASIN

Physiography and Relief

Method—The first physical characteristic of a basin to be considered is its physiography. The basin under study will first be marked out on topographical maps to a scale of 1:250,000, and then to a scale of 1:50,000 for greater precision [7-10]. The basic reference documents listed in Table 1 will then be used to determine for each basin the area [11], the minimum, maximum and average altitudes, the gradients, and the percentage of the area covered by woodlands, marshes, lakes, man-made works, and so forth [12]. A plan of the hydrological system will then be prepared and the length of the river and its principal tributaries measured. Following this, the lengthwise profile of the river and its principal tributaries will be drawn, with points of interest such as rapids, falls, dams, and lakes. In the highlands, the principal springs will also be indicated.

Table 1. Fields of Expertise of Government Agencies and Organisms Which Should Be Used in the Review

Physiography and Relief

Ministry of Energy, Mines and Resources of Canada [7, 8]
Ministry of Lands and Forests of the Province of Québec [9, 10]
Ministry of Natural Resources of the Province of Québec [11]
Institut national de la Recherche scientifique (INRS-Eau) [12]

Geology

Ministry of Natural Resources of the Province of Québec [14-17]
Ministry of Energy, Mines and Resources of Canada [18-20]
Institut national de la Recherche scientifique (INRS-Eau) [21, 22]

Pedology

Ministry of Agriculture of the Province of Québec [23]

Weather

Ministry of Natural Resources of the Province of Québec [24-28, 31]
Environment Canada [29, 30]
Institut national de la Recherche scientifique (INRS-Eau) [12]

Vegetation

Canadian Land Inventory, Land Capability for Forestry Maps [33]
Ministry of Lands and Forests of the Province of Québec [34]
Institut national de la Recherche scientifique (INRS-Eau) [12]
Department of Northern Affairs and National Resources [36]

Hydrology

Ministry of Natural Resources of the Province of Québec [41-43, 45]
Ministry of Environment of the Province of Québec [44]
Hydro-Québec [47, 48]
Environment Canada [12]

Population

Statistics Canada, *Census of Canada—population* [55]
Québec Bureau of Statistics [56, 58]
Ministry of Lands and Forests of the Province of Québec [57]
Institut national de la Recherche scientifique (INRS-Eau) [62-64]

Urban Problems

Québec Bureau of Statistics [60]
Institut national de la Recherche scientifique (INRS-Eau) [65, 66]
Ministry of Natural Resources of the Province of Québec [68]
Québec Water Engineering Association (AQTE) [69]

Agriculture

Institut national de la Recherche scientifique (INRS-Eau) [62-64]
Canada Land Inventory [70]
Québec Office of Planning and Development (OPDQ) [71]
Statistics Canada, *Census of Canada—population* [72]
Québec Bureau of Statistics [73]
Ministry of Agriculture of the Province of Québec [74]

Industry

Québec Bureau of Statistics [75]
Scott's Industrial Directory [76]
Statistics Canada
Institut national de la Recherche scientifique (INRS-Eau) [61, 86]

Recreation

Canada Land Inventory [78, 79]
Ministry of Tourism, Hunting and Fishing of the Province of Québec [80, 83]
Québec Office of Planning and Development [81]
Ministry of Municipal Affairs [82]

Relief and water—A brief physiographic description based on contour lines may promote understanding of the river's regime. Altitude plays a leading role in hydrology, determining gradients and the intensity of precipitation [13]. Highlands often receive more precipitation than adjacent lowlands. As a result, they can give rise to more powerful watercourses than plains. The plan of a hydrological system, when related to land forms, is important in the study of flood development and uniformity of input rates.

Geology

Method—The basin's substratum will be classified into geological formations. In Québec province, we count five major geological regions [14-16]. Then the lithological characteristics of the substratum (percentage of igneous, metamorphic and sedimentary rock) and of the cover of shifting deposits (fluvio-glacial, glacial and marine and lacustrine clays) will be determined. In particular, it will be seen whether the basin contains rock that is fairly soluble. Landslides and mining operations will also be indicated.

Geology and water—There is a direct relationship between geological and structural formations and changes in the natural aquatic environment [19]. It is therefore important to know the type of the bedrock, and its physical characteristics (hardness, permeability, porosity) as well as its chemical and mineral composition. Rocks vary greatly in degree of erosion depending on their properties. The most vulnerable rocks are the soft ones, that is, those that contain highly soluble minerals such as calcite, dolomite, gypsum, anhydrite, hematite and pyrite. This is the case with carbonated sedimentary rocks such as limestone. Hard rocks such as crystalline rocks (granite, gneiss, and so forth) will be less sensitive to erosion. They retain only slight quantities of water because of their low porosity, whereas limestone contains numerous fissures that water can penetrate.

Geology and water flow--Geology influences the regime of a watercourse in different ways. However, the most important role of geological formations is the recharge of underground reservoirs. The capacity of certain rock formations for storing groundwater may exercise a regulatory effect on flow, that is, it may reduce high flows and increase low flows.

Geology and the chemical composition of water—Surface and ground water may act as a solvent for rock, a phenomenon partially responsible for the presence of certain constituents in water [21, 22]. For example, sulfates originate in the dissolution of gypsum and anhydrite in groundwater. The dissolution of limestone may lead to high calcium but low fluorine content. On the other hand, the acidity of certain waters might be due to free carbon dioxide from granite or gravel formations. Mineral deposits may also influence the chemical quality of the water; for example, iron ores lead to ferruginous water.

Pedology

Method–On the basis of the maps and reports listed in Table 1, the types of soils within the basin (gravels, sands, loams, clays, organic soils and peat) will be determined, together with their physical and chemical properties. Soil properties are highly conditioned by natural factors such as gradient, plant cover, and the volume and intensity of rainfall. Thus soils are the expression of geological, climatic, and orographic conditions and, as such, act as intermediary between these conditions and the hydrochemical characteristics of water.

Soils and water–As a rule, the characteristics of a region's water are closely linked to the pedological characteristics of the basins in the region. Soils influence not only the subsoil penetration of the water, but also the quality of the ground and surface water. In addition, it is important to be familiar with certain characteristics such as a soil's retentiveness and its ion exchange capacity. The retentiveness of a soil will be determined by its permeability whereas its ion exchange capacity will depend on its physical and chemical composition in terms of sands and organic and inorganic colloids. Inputs of nutrients and other elements from soil are the result of erosion. Erosion causes sedimentation in the bed of the watercourse, and the sediments themselves transport nutrients and other substances.

As a guide in the chemical evaluation of inputs to the aquatic environment from different types of soil, we may mention by way of example that sand-clay soils have a low phosphorus content, sandy soils have a low nitrogen content and clayey soils have a high nitrogen content. Marshy and peat soils yield acidic water loaded with organic matter. From a biological point of view, soil erosion will have different effects depending on the type of material entering the water. A sandy bottom will be sterile and useless to aquatic organisms. Clay particles can be found in suspension and may reduce the fish population. If they coagulate and precipitate, they may cover aquatic organisms and also reduce populations. Colloidal clay along bays may be considered a major factor in pollution.

Weather

Method–The annual rainfall and snowfall in the basin under study will be determined [24]. As regards temperature, the annual mean for the entire basin, the annual fluctuations, the extremes, the number of days with frost, and the dates of the first frost and the spring thaw will be noted.

Climate and water–Climate has a preponderant influence on flow. Flow is conditioned by climatic factors such as the nature, intensity, frequency and seasonal distribution of precipitation, insolation, temperature and wind speed [25, 26, 29].

Temperature–Temperature plays an important hydrological role, because it controls evaporation and snow-melt and snow-melt retention [27, 28].

Precipitation–The average flow of watercourses depends primarily on the average amount of precipitation. Precipitation over the basin's upper level is more abundant than in regions of lower altitude [32]. It is also necessary to consider the snowfall to total precipitation ratio, which influences the flow particularly during spring thaw. Seasonal variations in precipitation determine the river's regime. The main effects of precipitation will be runoff and percolation. The intensity of runoff will increase with the steepness of the gradient and the sparseness of the forest cover. Runoff may lead to soil erosion, that is, the transport of sediments toward the watercourse. As mentioned under "*Pedology*", sediments may act as transporters of nutrients or other substances. As for percolating water, it adds to the groundwater.

Precipitation may influence water quality even more directly. For a region like Québec, the proportion of constituents entering water directly through precipitation may be large; hence the interest of an in-depth study on the quality of precipitation. It has been found that a large proportion of transported dissolved ions originate in precipitation rather than in erosion. Moreover, the majority of transported sulfates, chlorides and nitrates, may well come from precipitation. Also found in rainwater are fine solid, mineral or organic particles resulting from scavenging of suspended dust particles.

Vegetation

Method–The percentage of the basin's area covered by forest will be determined, together with the nature of the forest (mixed, boreal, arctic), its density, and the main species of flora. In Québec, forest areas are usually located at the headwaters of basins [35, 37].

Vegetation and water–Vegetation has as much an influence on flow as on the quality of water resources [38]. It also exercises controls on erosion and helps to diminish flooding and moderate discharges.

Precipitation–According to Kittredge [39], the presence of forest cover can have an orographic effect and increase precipitation up to 3 percent compared to barren terrain. Forests retain a large portion of water during heavy rainfalls, whereas, on barren terrain, almost all the precipitation becomes runoff, carrying the superficial soil layer into waterways. In forest, water infiltrates slowly upon attaining the soil, after which it reaches the water table and regularly feeds surface waters.

Forest species–Different forest species have varying influences on the interception of rain. According to Molchanov [40], the spruce possess the greatest interception capacity (37%) while that of the oak is 13 percent and that of the aspen 11 percent.

Water quality—With respect to the effect of vegetation on water quality, it may be mentioned that with few exceptions, the streams and rivers in wooded areas are relatively free of suspended particulate matter. It is in forest regions that the lowest losses in nutrients are registered; losses may be two to three times lower than those in farm areas and grasslands. Water coming from a forest contains less ammonia than water from cultivated land; unlike the latter, water from forestland is drinkable, without prior treatment, under normal conditions. This illustrates the important role played by the forest in water purification.

Hydrology

Method—On the basis of the *List of Stations and the Hydrological Directory*, the hydrometric stations in the regions concerned will be located [41, 42, 44]. The following information will be obtained for these stations:

- mean annual flow rate and monthly flow for each year;
- maximum and minimum daily flow, year-to-year and for the year considered;
- specific capacity year-to-year.

It is easy to determine the monthly flow coefficients (ratio of the flow for the month considered to the mean monthly flow) that define the river's regime. It is essential to know whether there are outside influences on the flow, on a daily or even a weekly basis. It will be necessary to obtain the operating schedule for the major dams (from *Hydro-Québec*, for example) [47, 48]. The risks and times of flooding will be noted according to the *Bureau of Statistics* reports [46]. It would be a good idea to prepare a complete map of existing hydrometric stations for each basin. In the absence of a hydrometric station, simulation will be used.

Hydrology and water quality—The hydrological characteristics of a watercourse, that is, the variations in its flow and its high and low flow periods, depend on the natural factors discussed above: relief, geology, soils, climate and vegetation. Hydrological characteristics may in turn serve to explain water quality. Thus an intense flow may mean greater dilution of nutrients or it may mean a greater input of suspended solids and sediments into the water as a result of increased erosion. An increase in flow may also indicate a greater self-purification capacity.

HUMAN ACTIVITIES

Population

Method—First an estimate is made of the population of the basin and of each sub-basin. The main urban centers (cities of more than 5,000 inhabitants) and rural areas are identified and an attempt is made to establish population forecasts for the entire basin. Thus, one can evaluate inputs from the population through analysis of domestic sewage (Tables 2 and 3) and inputs from storm runoff (Table 4). This evaluation will be made through theoretical calculations of the per capita nutrient load.

Evaluation of a basin's population—To evaluate a basin's population, all the municipalities within its boundaries must first be identified. Use of the *Department of Lands and Forests Map of Municipal Boundaries* [57, 60] gives a clear picture of the municipalities located within the basin and the area covered by them. The term "municipality" encompasses cities, towns, villages, parishes, townships and unorganized municipalities. The best plan is therefore to take the names of these municipalities and look up their population in the *Canada Census* [55] or the *Québec Bureau of Statistics (QBS) List of Municipalities* [58] with a view to calculating the total population of the basin. The Map of Population Distribution in Québec prepared by the *Institut de Géographie de l'Université Lavel* dates back to 1961, but it gives a good idea of the most densely populated areas and the urban agglomerations within the basin [59].

Population forecasts—For the population forecasts, we have the results of the Population Analyses carried out by the *Demography Division of the Québec*

Table 2. Characteristics of Urban Sanitary Sewage Waters

	Concentration[a]			
	Thomann [49]		Mascolo et al. [50]	
Characteristic	Mean	Maximum	Mean	Maximum
Total solids	800	450-1 200	548	382 - 924
Suspended solids	300	100- 400	---	---
Dissolved solids	500	300- 800	---	---
Conductivity ($mmho\text{-}cm^{-1}$)	---	---	636	520 -1 465
BOD_5	180	100- 450	104	74 - 123
COD	220	120- 580	234	140 - 313
N-organic	20	5- 35	---	---
$N\text{-}NH_4$	28	10- 60	---	---
$N\text{-}(NO_2 + NO_3)$	2	0- 6	0.32	0.1- 0.48
N-total	50	15- 100	---	---
PO_4 ortho	10	5- 25	10.6	9.5- 12.2
PO_4 total	20	10- 50	13.2	11.7- 15.7
Alkalinity ($CaCO_3$)	---	---	---	---
Total hardness ($CaCO_3$)	---	---	---	---
Cl	---	---	66	42 - 90
pH (units)	---	---	7.29	7.0- 7.85

[a]unless otherwise indicated, concentrations are expressed in mg/l

Table 3. Per Capita Inputs of Phosphorus and Nitrogen From Treated and Untreated Domestic Sewage waters [51]

P *(g/cd)*[a]	*N* *(g/cd)*[a]	*Origin and Treatment*
0.65–1.5	--	Untreated sewage in the U.S.A.
1.5	7.4	Madison, Wisc. biologically treated sewage
1.5 -3.7 (2.3)	—	Minnesota untreated sewage
1.8 -4.8	—	Illinois (trickling filters and activated sludge)
4.4	10.3	Wisconsin, Madison, filters
0.9	8.0	
2.0	12.0	
2.4 -2.9	10.0	
1.5	12.0	
2.3	13.0	
--	13.9	
1.65	—	
—	8-15.3	
3.0	12.0	Studies on the Lindth in Switzerland

Mean value and ranges [P:2.18 (0.65–4.8); N:10.8 (5.1–15.3); N/P:4.95]
[a]grams per capita per diem

Bureau of Statistics [60]. These analyses are based on statistical series observed over several years; extrapolations have been based on factors deemed responsible for the secular trend, such as mortality, birth rate, and migration. Population forecasts have been established by county for the years 1976, 1981, 1986, 1991, 1996 and 2001.

These forecasts were established on a county-wide scale, whereas in most cases only parts of counties fall within any one basin. To determine the real population growth in the basin, it would be necessary to apply to each of its municipalities the birth, death and migration rates that have been calculated for the counties in which they are located. Another important variable that should be taken into account is the possible introduction of new industries that may strongly influence the population growth rate of a municipality [1].

Analysis of the population forecasts will allow evaluation of future water needs [61] as well as the quantity of waste [62-64] (nutrients, and so forth) that will be generated by future populations. These forecasts may lead to better water resource management through protection of water quality in the years to come. Water purification plants may be constructed in the areas where the greatest population increases are expected.

Domestic sewage–It is appropriate to link the population study directly to an analysis of domestic sewage. Thus sanitary and combined sewers must be located

Table 4. Characteristics of Urban Stormwaters

Characteristic	Concentration[a]					
	Weibel et al. [52]		*De Filippi and Shih [53]*		*Burm et al. [54]*	
	Mean	*Maximum*	*Mean*	*Maximum*	*Mean*	*Maximum*
Total solids	---	---	2 166	338 -14 600	---	---
Suspended solids	210	5 -1 200	1 697	130 -11 280	2 080	11 900
Dissolved solids	---	---	---	---	---	---
Conductivity (mmho-cm^{-1})	---	---	---	---	---	---
BOD_5	19	2 - 84	19	3 - 90	28	62
COD	99	20 - 610	335	29 - 1 514	---	---
N-organic	1.7	0.2 - 4.8	---	---	1	4
N-NH_4	0.6	0.1 - 1.9	---	---	1	2
N-(NO_2 + NO_3)	0.45	0.1 - 1.7	---	---	---	---
N-total	2.75	---	2.1	0.5- 6.5	---	---
PO_4 ortho	---	---	---	---	0.8	3.4
PO_4 total	0.8	0.07- 4.3	1.3	0.2- 4.5	5.0	16.4
Alkalinity ($CaCO_3$)	59	10 - 210	---	---	---	---
Total hardness ($CaCO_3$)	78	29 - 240	---	---	---	---
Cl	12	3 - 35	---	---	---	---
pH (units)	7.5	5.3 - 8.7	6.5	6.0- 7.2	---	---

[a] unless otherwise indicated, concentrations are expressed in mg/l

and the sewage quantified in each municipality; the population served by each sewer must be estimated [62]. In rural regions, where domestic wastewater is disposed of in other ways (septic tanks, direct dumping into a river), estimates are more difficult to arrive at [63, 64]. However, since the population is less dense, human inputs are less abundant and more diluted.

Specifically Urban Problems

Urban sewers collect storm runoff in addition to domestic and industrial wastewaters. This storm runoff runs along the surfaces of roads, highways and the entire built-up area mainly during storms, rainfall, snowmelt and after street cleaning. Surface runoff may be collected in combined sanitary and storm sewers or in separate sewers. Sometimes runoff is not collected in sewers but flows by natural means into the receiving waters through ditches, street gutters, and so on. For a long time it was believed that water from storm sewers was a great deal purer than water from sanitary sewers. However, studies have shown that, on the contrary, storm sewage contains a great many substances [65, 66] that contribute to urban pollution (Table 5).

Method–To evaluate the impact of urban runoff on the quality of the aquatic environment, studies should be directed toward certain specific points, the main ones being:

- the relationship between the various types of urban land use (residential, commercial, industrial) and the presence of pollutants in runoff;
- the presence of heavy metals in runoff from roads, particularly lead from automobile gasoline;
- the effects on water quality of the salts (sodium chloride and so forth) applied to roads and highways in winter [68].

In order to be able to study all of these factors, it would be advisable to obtain information on the following points concerning municipalities within the basin:

- size of the urbanized (or developed) area within the municipality, and the population density;
- length of paved roads and highways;
- traffic density;
- urban land use: areas covered by residential, commercial or industrial development;
- types of municipal sewers: combined system (storm and sanitary) or separate system;
- topography of towns (number and direction of gradients); runoff in towns located on flat country will not be as intense as that in hilly towns; the latter will also require a greater quantity of road salt in winter;

Table 5. Type and Quantity of Principal Constituents of Urban Runoff [67]

Substance Analyzed	*Mean Values in Runoff from 10 American Cities (Pound/Mile of Roadway)*
Total solids	1 400
Oxygen demand	
BOD_5	13.5
COD	93
Volatile solids	100
Nutritive substances of the primary trophic level	
Phosphates	1.1
Nitrates	0.094
Kjeldahl nitrogen	2.2
Bacteria	
Total coliforms	99×10^9 [a]
Fecal coliforms	5.6×10^9 [a]
Heavy Metals	
Zinc	0.65
Copper	0.20
Lead	0.57
Nickel	0.05
Mercury	0.073
Chromium	0.11
Pesticides	
p, p-DDD	67×10^{-6}
p, p-DDT	61×10^{-6}
Dieldrin	24×10^{-6}
Polychlorinated biphenyls	$1\,100 \times 10^{-6}$

[a] coliforms observed hourly/mile of roadway

- nature and quantity of road salts used by each municipality every winter [68]. In general, sodium chloride is used; however, when temperatures drop below 6°F, a mixture of calcium chloride and sand is used. The quantity of salt used will also depend on weather conditions (depth of snow, temperature), and in addition on topography (gradients) and local traffic density;
- snow disposal sites and methods, the main ones being:
  - –direct dumping into a watercourse (often the case in small towns);
  - –deposit in snow dumps;
  - –removal to a snow melter that drains into a municipal storm sewer;
  - –direct dumping into a municipal sewer;
  - –removal by snow blower to land adjacent to roads, where possible; for example, in residential areas.

For the Province of Québec, part of this information will be found in the reference documents listed in Table 1, in particular the AQTE (*Association Québécoise des Techniques de l'Eau–Québec Water Engineering Association*) inventory [69] and *"Statistical Information–Municipalities of Québec"* published by the *Québec Bureau of Statistics* [58, 60], which contain data on the developed areas of municipalities, the length of sanitary, storm or combined sewerage systems, the total length of public roads, snow removal (miles of roadway cleared), and more. In some cases, missing information can be supplied by municipal engineers who are familiar with snow disposal sites and methods, and so forth.

Agriculture

Method–For a study of a basin's agriculture, data must be gathered on the following subjects:

- location of agricultural zones;
- number and area of farms;
- area occupied by main crops;
- livestock (number and species of farm animals);
- quantity of lime and chemical fertilizers used;
- quantity of pesticides used.

For the Province of Québec, the following sources of information will be consulted: Canada Land Inventory maps showing the Agricultural Potential of Soils [70], the statistics available through the *Canada Census* [72] and the *Québec Bureau of Statistics* [73], and regional studies by the *Québec Department of Agriculture* [74].

Location of the best agricultural zones–The maps of the Agricultural Potential of Soils [70, 71] show the location of those zones with the best agricultural potential. The soils are subdivided into seven classes and thirteen subclasses according to their capacities or limitations with regard to agricultural production. Thus the soils of the first three classes are suitable for ordinary crops under continuous yield, whereas those of class 4 provide poor fertility for farming under continuous yield. Table 6 gives the classification of soils according to their suitability for agricultural production.

Land use and agricultural production–Having located the best agricultural zones within the basin, it is necessary to be familiar with the current use of these lands, that is, the different types of crops and animals raised. The income derived from the various types of farm operations will also provide an idea of the extent of each type of agricultural land use. The *Canada Census* statistics on agriculture [72] may be consulted. These statistics are informative about farm population, number and acreage of farms, agricultural land use (in acres), crops

Table 6. Soil Classification According to Suitability for Agricultural Production

Class 1:	No significant limitation on choice of crop
Class 2:	Minor limitations on choice of crop or need for application of ordinary soil conservation principles
Class 3:	Moderately heavy limitations on choice of crop or need for special conservation methods
Class 4:	Heavy limitations on choice of crop or need for special conservation methods
Class 5:	Very heavy limitations; soils suitable only for the production of hardy forage crops but capable of improvement
Class 6:	Soil limitations extreme; soils unsuitable for any crops other than hardy forage crops and not capable of improvement
Class 7:	Soils unusuable even for hardy forage crops
Class 0:	Organic soils not included in the classification system

Subclasses—Designating Limiting Factors Within Each Class

C:	Unfavourable climate
D:	Undesirable structure or low permeability of the soil
E:	Erosion
F:	Low fertility
I:	Flooding due to watercourses or lakes
M:	Lack of moisture
N:	Salinity
P:	Rocky soils
R:	Solid rock
S:	Unfavourable soil characteristics
T:	Relief
W:	Excess water
X:	Cumulative effect of several minor disadvantages

grown on a large scale (in acres) and cattle and fowl (number of head) on census farms, as well as the value of agricultural products sold, by county or municipality. Most of the census data are compiled by county, but some are available by municipality, so that it is easier to marshall the facts about a particular basin. It should be noted that the census of Canada is held only every five years.

The *Québec Bureau of Statistics* [73] provides approximately the same information on agriculture as *Statistics Canada*, but it also furnishes additional data on plant products; for example, production (in bushels) of field corn and potatoes by county. These statistics, which have been published annually since

1968, have the advantage of furnishing the most recent data every year. In the *Québec Bureau of Statistics* reports, the statistics are published by agricultural region or by county, but more detailed data (by municipality or census district) are available on request.

Use of chemical fertilizers and pesticides—The fact that statistics on the use of chemical fertilizers and pesticides are not always available on a small scale (by municipality) makes it more difficult to estimate the quantities of such products used within a basin. However, *Canada Census–Agriculture* devotes a section to data, by county, on the use of commercial fertilizers on census farms, on the crops fertilized (in acres) and on the value of the commercial fertilizer purchased. Another section furnishes data on crop spraying and dusting on census farms, that is, the area within which soils or crops were sprayed or dusted with chemicals, either to control insects and disease or to kill weeds and scrub. On special request, *Statistics Canada* will provide the latest data by municipality. The *Québec Bureau of Statistics* furnishes information on the quantities (in tons) of fertilizing substances and commercial compounds sold in the Province of Québec by county and by agricultural region.

Overall impact—On the basis of the data gathered, it is possible to evaluate the impact of agricultural activities on water quality [62, 64]. We may suggest at the outset that the latter is greatly affected by three major factors: animal manure, use of artificial fertilizers, and use of pesticides. All the research on agriculture should therefore be oriented toward obtaining the fullest possible information on these three sources of agricultural pollution.

Industry

Method—A complete list of the manufacturing industries within a basin may be easily obtained from the tape version of the *Scott Directory* [76]. The list of the basin's municipalities, drawn up for the population study, may be fed directly into the computer, which will then provide a list of the industries within these municipalities, the products manufactured, the number of employees and any general information such as address, affiliated companies, names of management staff, and so forth. For the Province of Québec, the taped *Scott Directory* has been available since March 1973 and the *Scott Company* can provide programmers for user's convenience.

The list of industries is prepared according to broad industrial classes, which may vary from one basin to another [63]. It also includes the total number of employees per class and per municipality. Through graphic representation, this method clearly illustrates the type of industry that is dominant within the basin. A consumption per employees survey has already been compiled by *Institut National de la Recherche Scientifique* (INRS-Eau) [61] and is available for certain types of industries in gallons per day per employee.

However, these coefficients are very imprecise. For the same type of industry, they depend on such factors as type of process used, the age of the industry and production [77]. To obtain a true picture of industrial consumption within a basin, it is desirable to visit all the major industries (to determine the number of employees, the quality of effluents, or the characteristics of the particular type of industry), and to complete, with the help of competent, well-informed staff members, a questionnaire on water consumption and waste in terms of both quality and quantity. A detailed study of this type conducted on several basins would establish, after correlation, the validity of certain consumption coefficients.

Another way of obtaining these results would be to make major amendments to the *Statistics Canada* questionnaire designed for the annual census of manufacturing establishments and to try to obtain figures on the actual water consumption of the industry and details on its wastewaters. With regard to quantity, the questionnaire is designed in such a way that at least the order of magnitude of consumption is obtained, and these figures may be used for want of a better source of information. However, the industry data have certain limitations, as the desired information is often incomplete or confidential. A detailed inventory of industries within basins is desirable but involves a great deal of work.

Recreation

Method of location of zones with best recreation potential–The approach once again is first to locate within a basin the zones with the best recreation potential. The *Canada Land Inventory* maps [78, 79] showing recreation potential indicate the capacities and resources available in an area for the development of outdoor recreational sites. The land has been classified on the basis of its natural suitability for recreation into seven classes and twenty-five subclasses, the latter corresponding to twenty-five different types of activity such as fishing, bathing, camping, and so forth. Table 7 gives a list of the classes and subclasses for recreational potential. Take for example subclasses A (angling) and B (beach). A rating of 2A means an area could have good fishing potential. Classification 2B means a beach may be exceptional except that swimming is limited by the coldness of the water. With particular reference to beaches, the report entitled Land Potential for recreational purposes [79] provides a table of the limitations on the potential of beaches (Table 8). The *Canada Land Inventory* maps show only the recreation potential of a region, which does not necessarily mean that the region is developed and equipped with recreational facilities.

Existing recreational facilities–The *Department of Tourism, Fish and Game* maps showing Tourist Facilities and Resources in Québec [80], will indicate the recreational activities and facilities within a basin. These maps use appropriate

Table 7. List of the Classes and Subclasses for Recreational Potential

Classes for Outdoor Recreational Potential	
Class 1: Exceptional potential	Class 5: Fairly low potential
Class 2: Excellent potential	Class 6: Low potential
Class 3: Good potential	Class 7: Very low potential
Class 4: Average potential	
Subclasses for Recreational Potential (Symbols)	
A: Angling	O: Terrestrial fauna
B: Beach	P: Rural landscape
C: Canoeing	Q: Unspoiled landscape
D: Deep water along shoreline	R: Rock formation
E: Unusual vegetation	S: Area suitable for skiing
F: Falls and rapids	T: Hot springs
G: Glacier	U: Area for deepwater navigation
H: Historic sites	V: Panoramic view
J: Gathering and collecting	W: Aquatic fauna
K: Area suitable for camping	X: Miscellaneous activities
L: Geomorphological formation	Y: Pleasure boating
M: Cluster of small lakes	Z: Major man-made works
N: Resort	

symbols to represent the various types of accommodation, sports and cultural facilities and points of interest: public beaches, marinas, golf courses, hotels, motels, camping grounds, historic sites, and so forth.

Resorts and camping–The first step is to locate the main resort areas, that is, the areas where cottages, camping grounds, and hotels offering accommodation in the tourist season are found. From the number of cottages, campsites, and so forth, it is possible to form some idea of the seasonal tourist population within a basin.

Beaches and bathing–The *Sanitary Engineering Division of the Department of Social Affairs* has carried out bacteriological analyses of the water at several beaches within the Province of Québec [82]. The beaches studied were subdivided into four classes, A, B, C, and D, according to the coliform bacteria count.

Sports fishing–The first step is to consult the maps of sports fishing potential published by the *Biophysical Studies and Inventories Service of the Québec Planning Development Bureau* [83]. These maps, which are available for every basin in Southern Québec, have been based on the water quality of the rivers and show only the capacity of the water for supporting certain fish species. Table 9 lists the four classes and eight subclasses for fishing potential. The *Department of Tourism, Fish and Game* has published a brochure entitled

Table 8. Limitations on the Potential of Beaches

	0	1	2	3	4	5	6
Water Quality	← normal concentration of algae →		← high concentration of algae →				
	← turbid water → (unpolluted)		← submerged obstacles → (no danger)		← pollution (limitation according to amount and danger)		
		← cold water → (limits swimming)			← cold water → (limits bathing)	← very cold water (prevents use)	
Miscellaneous		← exposed beach → (limitation according to degree of exposure)					
Hazards			← hazardous slopes, currents and underflows → (limitation according to predominance)				
Slopes (general conditions)	8%	less than 1%	10%	12%	15%	over 15%	
Constituent materials (comfort & danger)	pea-sized pebbles on stable clay	← pebbles (according to walking comfort) gravel) →		smooth rock floor	boulder soil uneven rock floor		broken rock of unequal size
Development Zone	many boulders		shifting dunes cover material poor only 50% of zone	very rocky	boulder soil zone of minimum development		
Difficulty of Access	slight	normal	great		very great		
	0	1	2	3	4	5	6

INSTRUCTIONS

1. Establish the value for each limitation.
2. Overall value of limitations:
   - 2 demote by 1 class
   - 4 demote by 2 classes
   - 6 demote by 3 classes
   - 8 demote by 4 classes
   - 8+ seek other possibilities.
3. General instructions only. Do not deduct a whole point for factors found in combination (e.g., exposed beach and very cold water; submerged obstacles and very cold water; submerged obstacles and high algae concentration).
4. *The presence of other recreation potentials may cancel one limiting factor.*

Accès Publics à la Pêche (public access to fishing) [84] in which it lists the fish species found in the province's lakes and rivers. The wildlife service of the same Department can furnish further information on the geographic distribution of the main fish species found in Québec's rivers.

Pleasure boating–The *Department of Tourism, Fish and Game* brochure entitled *Navigation de Plaisance* (Pleasure boating) lists the marinas found in Québec and the services each provides [85].

Recreation and water quality–Since many recreational activities are directly related to the presence of water, the importance of the aquatic environment for recreation cannot be overestimated. Recreation may be a source of nutrients through the temporary increase in the population during vacation periods, particularly during the summer season. To these increased quantities of nutrients

Table 9. Classes for Fishing Potential

	Classes for Fishing Potential of Water
1.	Water with no serious impediment to game fishes. Waters of class 1 are fertile, warm, well oxygenated and free of inorganic turbidity; they are not very deep or else possess adequate shallow zones.
2.	Waters with few impediments to game fishes. Waters of class 2 contain good reserves of nutrients; the slight limitations arise from physical or chemical factors.
3.	Waters with some impediments to game fishes. Waters of class 3 contain relatively low reserves of nutrients; the limitations on the survival of game fishes vary from moderate to serious.
4.	Waters with serious impediments to game fishes. Waters of class 4 contain few nutrients and impose serious limitations on the life of game fishes.
	Subclasses
D	DEPTH–includes limiting factors resulting from average depth, contour of the shoreline and form of the bed.
E	CURRENT–includes irregularity of currents and variations in water level and flow rate.
L	LIGHT PENETRATION–an indicator of inorganic turbidity.
N	NUTRIENTS–insufficient nutrients in the water.
O	OXYGEN–insufficient dissolved oxygen during all seasons of the year. Extreme cases of oxygen deficiency result in the death of fish populations in winter or in summer.
T	TEMPERATURE–surface water temperature too low or unfavourable thermal stratification.
S	SPECIFIC FACTORS–fairly serious limitations due to a single factor or the cumulative effect of two or more unfavourable factors may influence classification. Among these factors are banks that are narrow in comparison to the total area, ion imbalance and certain physical peculiarities, absence of good spawning grounds, for example.

from the domestic waste of cottages, camping grounds and hotels, must be added the hydrocarbons from motorized pleasure craft.

Gasoline-powered motor boats may greatly affect the quality of a watercourse, first by depositing an oil film on the water's surface, which may interfere with oxygen exchange between the atmosphere and the aquatic environment, and also by creating turbulence within the water, which churns up and resuspends bottom sediments. Recreation not only contributes to the deterioration of water quality; it also suffers, in turn, as a result of poor water quality. Apart from the esthetic appearance of a watercourse, which may be greatly affected, some recreational activities such as fishing and bathing may be largely constrained by deteriorated water quality resulting from other human activities (agriculture, industry) upstream.

CONCLUSION

It is essential to examine the physical characteristics of a basin in order to explain and understand the physical, chemical and biological state of the water under natural conditions, that is, in the absence of any human intervention. It will be seen that the physical characteristics of the basin, its relief, geology, soils, climate, vegetation and hydrology are interdependent. Thus the flow rate of a watercourse will very much depend on precipitation, which itself is a function of altitude. All these physical factors affect water quality, although often indirectly, since they act in the first instance on the intensity of flow and regime of the watercourse. However, these factors can, in certain cases, exert a much more direct influence on water quality.

Although the natural characteristics of a basin have a definite influence on water quality, it is human activity which undeniably has the greatest effect on the aquatic environment. Inputs from domestic or municipal sewers, industrial wastewaters, and farm runoff are bound to affect the quality of a watercourse and contribute to its deterioration. In order to evaluate inputs from human activities, the population of a basin must first be estimated and then the main types of land use examined: urban growth, industry, agriculture and recreation.

ACKNOWLEDGMENTS

I thank Miss L. Potvin, University of Québec, for her assistance, as well as the National Research Council of Canada and the Department of Natural Resources of the Province of Québec who supported this research.

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