THE ONTARIO RURAL BEACHES STUDIES:

IMPLICATIONS FOR REMEDIAL STRATEGIES

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ABSTRACT

The ten-year Ontario Rural Beaches Studies were initiated as a result of poor bacterial or chemical water quality at numerous public swimming beaches throughout Southern Ontario. The studies are developing comprehensive Clean Up Rural Beaches (CURB) Plans for watersheds upstream of problem beaches.

Preliminary results indicate that, for phosphorus control, the most cost-effective practices are target soil erosion control programs and milkhouse wastewater treatment. For bacteria control, restriction of livestock from streams, repair of faulty septic systems and improved manure spreading practices are the most cost-effective solutions.

Present programs to reduce environmental impacts of agricultural activities should be modified to reflect these findings.

BACKGROUND

In Ontario, the Ministry of Health monitors water quality at most public beaches to ensure suitability for swimming. If several consecutive water samples exceed 100 fecal coliform bacteria or 1000 total bacteria per 100 mL. of water, the beach is placarded as a warning to the public. In addition, beaches are sometimes placarded due to high turbidity and more frequently due to heavy algal growth, particularly dense blue-green algal blooms resulting from nutrient enrichment.

In 1983, approximately 10% of 1,300 provincially-monitored beaches failed to meet swimming criteria for at least 10% of the swimming season. When this situation began to repeat itself in 1984, the provincial cabinet recommended that funds be allocated and action be taken to improve beach water quality.

By 1985, the Ontario Ministry of the Environment (MOE) had allocated study funds over a ten year period and analyzed the problem beaches and categorized them into four lists:

1. beaches where the source problems were known and capital works expenditures were required as a major portion of the solution.
2. beaches where innovative technical solutions could be attempted.
3. beaches where the main pollution sources were urban.
4. beaches where the main pollution sources were rural.

This paper will address only the latter category dealing with beaches that are downstream of predominantly rural watersheds. This program has become known as the Rural Beaches Program.

Administrative Organization

There are 38 Conservation Authorities (CA's) which carry out conservation and water management activities on a watershed scale. These authorities can provide a focus for direct local input to problem resolution. On this basis, MOE decided to carry out its beaches programs through agreements with CA's. Because of the widespread nature of the problem and the difficulty of deploying sufficient staff to track down the sources, this regional approach also has advantages in terms of efficiency in program delivery and resource requirements.

The MOE maintains financial and technical input to the conservation authorities through a committee structure as outlined in Figure 1. The **"Rural Beaches Program"** staff of each conservation authority involved are under the technical direction of a local steering committee chaired by MOE and workshops organized by the Provincial Committee. Typically, the local committees also include representation from the Ontario Ministry of Agriculture and Food (OMAF), the Ministry of Natural Resources (MNR), County Medical Officers of Health, Farmer Organizations, County Planning Departments and the Conservation Authorities, themselves. The conservation authorities hire and directly supervise the staff.

The MOE chairmen of each of the local committees sit on the Provincial Planning and Advisory Committee (PPAC) which apportions the funds to each study area and oversees the whole program. Representation on this committee includes MOE, OMAF and MNR and chairmanship is by the Water Resources Branch of MOE.

Supporting work of a research nature or of general value to the program is directed by the PPAC and some is funded through the MOE's Research Advisory Committee.

Study Watersheds

The number of studies undertaken varies each year. Depending on the size of the watershed and its complexity, individual studies vary in duration from 2 to 5 years. As studies are completed, new studies are initiated. Figure 2 indicates the watersheds which have been investigated and those which are in progress as of May, 1989.

Study Objectives

The objective of the Rural Beaches program is to develop a course of action leading to the maintenance or restoration of acceptable water quality at problem beaches. Recommended actions will include both measures for specific beaches and broader scale Provincial measures based on cumulative results of component studies.

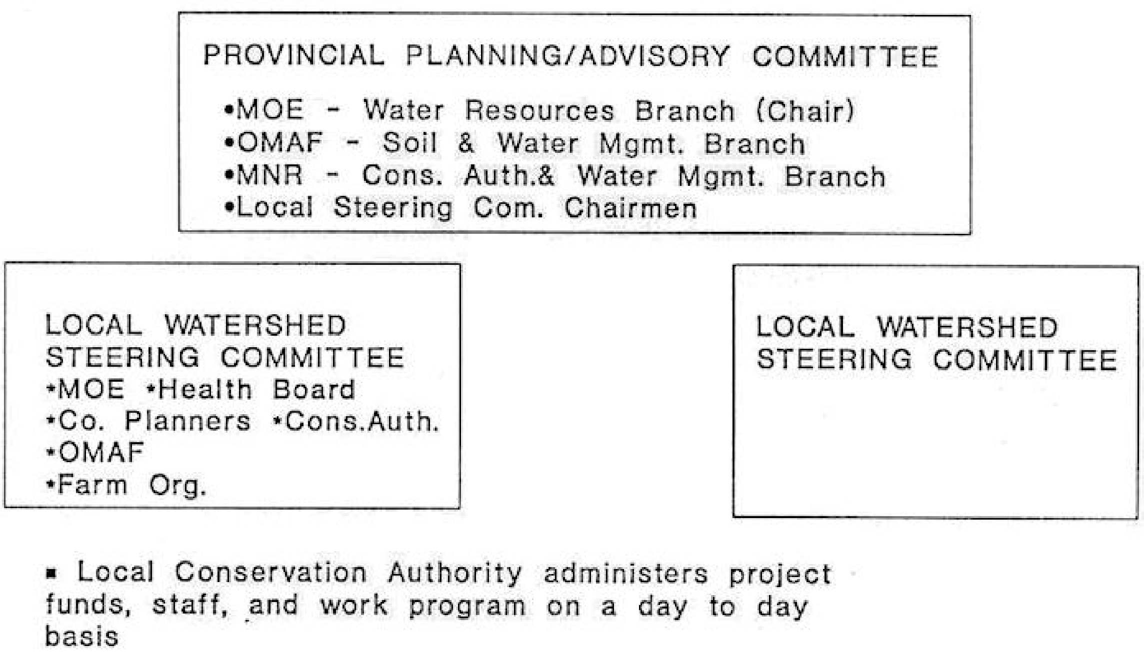

Figure 1: Rural Beaches Strategy: Administrative Organization

The objective of each component watershed study is to develop a Clean Up Rural Beaches (CURB) plan specific to the watershed upstream of the problem beach. The CURB plan is developed, in part, through the application of basic modelling techniques to arrive at remedial strategy options and respective cost estimates for each problem beach.

THE CURB WATERSHED ASSESSMENT MODEL

Ontario's Provincial Water Quality Objectives establish concentrations, or in the case of bacteria, density limits for specific water uses such as drinking or swimming. Concentrations at a particular location result from the combined effect of upstream source loadings and loss mechanisms en route to the sampling point. Hence, to evaluate the relative significance of individual source types impacting on beaches in this study, estimates of individual components of the total loading must be made.

For both bacteria and phosphorus, this involved examining the runoff concentrations and volumes of each contaminant source as well as the proportion of this runoff which enters the stream systems (overland or field delivery ratio). The sources were further categorized into continuous and pulse inputs. Continuous inputs are those which usually occur daily and are independent of rainfall events while pulse inputs result from specific runoff events or spills.

Table 1 lists the continuous and pulse inputs considered by the project teams. The general equations used to estimate source magnitude and delivery to the surface water system from each source are shown. The constants for each of the equations were based on methodologies researched and developed within and outside the study areas [1] and further refinements by Beaches Program staff based on local data and conditions. Collection and use of local data for source concentrations and volumes was encouraged and comparisons made between project areas. Local surveys provided an inventory of such information as principal farm-type, number and type of animals, location, proximity of barnlot/feedlot to a watercourse, remedial practices, cattle access details, etc.

In the studies described subsequently, "bacteria" refers to either *E. coli* or the broader group of fecal coliform bacteria. These are considered "indicator" types, since the presence of these bacteria at high enough densities is likely correlated with the presence of pathogenic species of micro-organisms.

After having computed pollutant loads delivered to streams, in-stream delivery processes were taken into account to estimate loads delivered to the downstream beaches of interest. Bacteria and phosphorus were handled very differently in this regard.

In the case of phosphorus, 100% in-stream delivery to the beach was assumed. This is recognized as an over-simplification in view of the physical, biological and chemical activity which may take place along a stream reach. Nonetheless, excessive phosphorus inputs to a stream will have negative impacts whether in-stream enroute to a downstream beach or at the beach itself and whether during the same season of source input or much later as it becomes biologically available. It is recognized that this simplification may result in over-estimates of cost-benefit ratios, at least for the short-term.

Modelling of bacterial transport is much more complex than phosphorus because bacteria are living organisms whose reproductive and mortality rates are governed by environmental factors. Loss rates in the water column combine the processes of deposition, adsorption, death and inactivation.

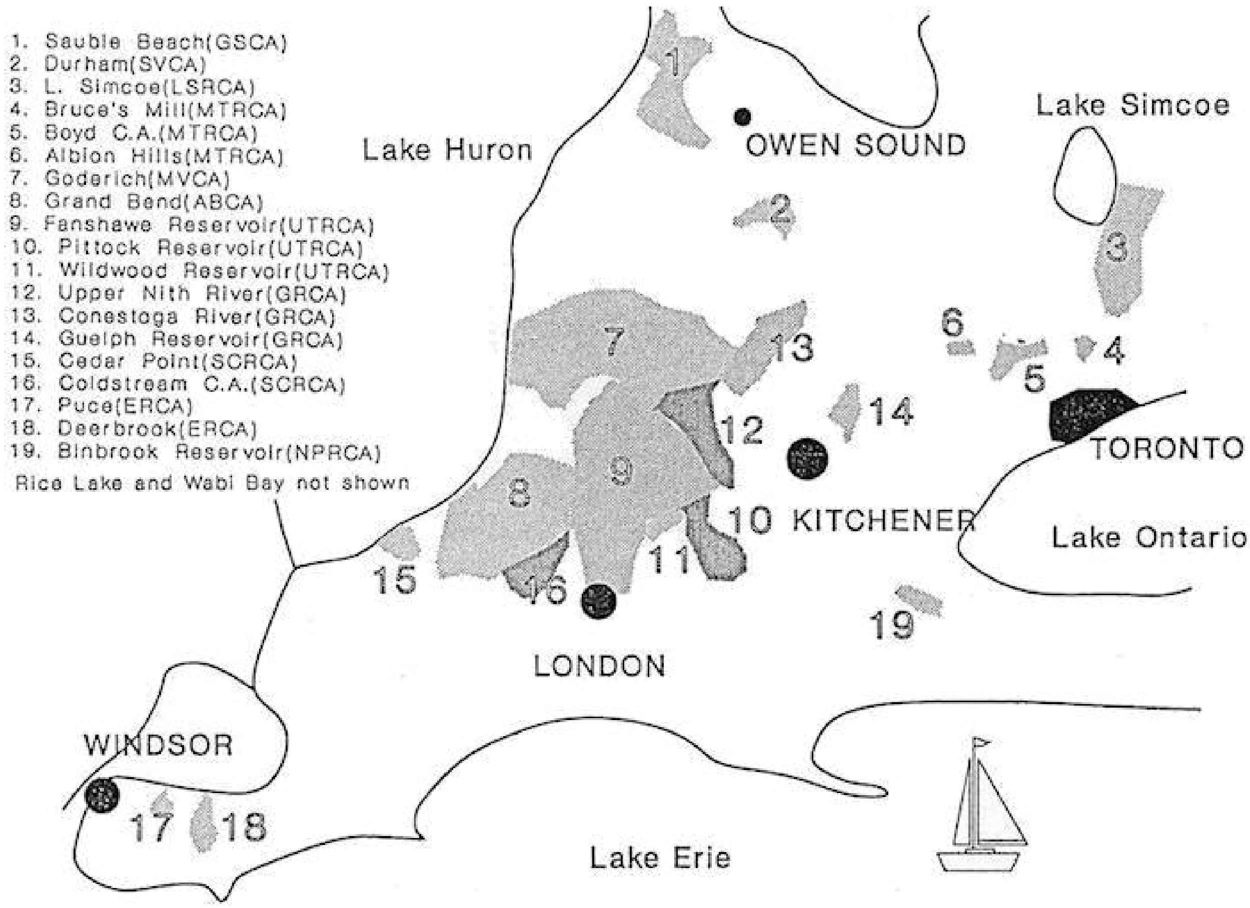

Figure 2: Watersheds Studied Under the Rural Beaches Program

Table 1: CURB Model

CONTINUOUS

Livestock access

	# of farms x	#/defecation(kg/)	prob of defc^n x	# of waterings x	days of access x	% of day x	# of animal units
fecal coliforms	Survey	8.90E+08	0.18	2.50	180.00	Survey	Survey
total phosphorus	Survey	1.20E-03	0.18	2.50	180.00	Survey	Survey

Milkhouse

	# of farms x	volume /day x	#/litre x	discharge days x	growth
fecal coliforms total	Survey	Survey	2000	365	500
phosphorus	Survey	Survey	35		

Unacceptable Septic systems

	# of homes x	1/person x	people/house x	#/1 (kg/) x	% faulty x	discharge days
fecal coliforms	Survey	137.00	3.10	1.00E+07	0.30	365.00
total phosphorus	Survey	137.00	3.10	3.00E-05	0.30	365.00

PULSE

Manure/Feedlot	# of problems x	#/ha-mm (kg/) x	storage area(ha) x	rainfall(ha-mm) x	delivery
fecal coliforms	Survey	5.00E+09	Survey	600	0.70
total phosphorus	Survey	0.25	Survey	600	0.70

Manure Spills/Discharges

	# of problems x	volume/spill (L) x	#/litre(kg/)
fecal coliforms	MOE Estimate	MOE Estimate	1.80E+07
total phosphorus	MOE Estimate	MOE Estimate	5.00E-04

Manure Spread Total Produced

Vol. Produced * 5.0e+11 (#/m^3)

Vol. Produced * 0.662 (kg/m^3)

winter	total x	% vol. produce x	operators spread x	amount spread x	delivery to stream x	storage survive x	field survive
fecal coliforms	above cal^n	0.25	0.47	0.75	0.016	1.00E-02	3.40E-02
total phosphorus	above cal^n	0.25	0.47	0.75	0.016		

Manure Spread

summer (too many AU/acre)	total	(vol. left - minus access) x	op. overspread x	amount overspd. x	delivery to stream	field +stor. survive
fecal conforms	4.49E+17	4.09E+17 see	0.05	0.25	0.016	3.40E-04
total phosphorus	5.95E+05	5.42E+05 above	0.05	0.25	0.016	

Sewage - 1988 conditions

fecal coliforms	MOE Estimates
total phosphorus	MOE Estimates

Urban Non-Point Source

	area(ha) x	rain (m^3/ha) x	#/m^3(kg/)
fecal coliforms	County Health Unit	2845	1.10E+07
total phosphorus	County Health Unit	2845	9.00E-05

Erosion

	crop area(ha) x	load(kg/ha)
fecal coliforms	N/A	N/A
total phosphorus	County ag stats	0.23

adapted from UTRCA CURB Plan (1989)

In several of the study areas, experiments were conducted to examine rates of bacteria mortality within the water column and in the sediments of lakes and streams. The results of these studies together with literature values have been documented in an unpublished report, [2]. Generally, when bacteria are removed from their original environment and enter the water column of an open stream or lake, a net decrease in density occurs over time. The net rate of mortality varies with stream or lake conditions, particularly sunlight, turbidity and temperature.

During rainfall events, a decay rate for bacteria was used which was lower than the rate used for continuous (dry-weather) bacteria input. This is because bacteria loss due to mortality and settling is offset to a considerable extent by resuspension from the stream bed of viable, previously input bacteria. River and Lake die-off rates were also differentiated. An example of the numbers used in the Upper Thames River Conservation Authority CURB Plan is shown in Table 2 [3]. Each study team incorporated the empirical values [2] which were judged to be most suited to its watershed conditions.

These mortality rates were combined with the estimated travel times from each subwatershed to the beach and the estimated number of bacteria entering the subwatershed stream according to the standard decay function:

$$\mathbf{N = N_o\ (10)^{-kt}}$$

where

- **N** is the estimated number of bacteria which reach the beach.
- $\mathbf{N_o}$ is the estimated number of bacteria entering the stream at the source.
- **k** is the decay rate.
- **t** is the travel time from the source to the beach.

Costs of Remedial Practices

The current unit capital costs for remedial practices were estimated based on figures from the Ontario Ministry of Agriculture and Food [4] and internal data of the Upper Thames River Conservation Authority and Maitland Valley Conservation Authority. Annual costs were estimated based on a zero-discount rate.

In comparing costs for various manure storage structures (ie. earthen, open concrete and covered concrete), the annual amortized cost combined with operation and maintenance costs were similar. The initial capital outlay, however, which often is of greater impact to an operator, varies significantly for the 3 alternatives.

Table 2: Calculated Dieoff Rates for Fecal Coliforms in Fanshawe, Pittock and Wildwood Reservoirs

Reservoir	Dieoff Rates (log/day)	Travel Time High Flow [1] (hours)	Travel Time Low Flow [2] (hours)	Dieoff High Flow [1] (log/day)	Dieoff Low Flow [2] (log/day)
Fanshawe					
River	0.22	12	36	0.11	0.33
Lake	0.5	6	24	0.125	0.5
			Total	0.235	0.83
Pittock					
River	0.22	6	24	0.055	0.22
Lake	0.5	6	24	0.125	0.5
			Total	0.185	0.72
Wildwood					
River	0.22	4	16	0.037	0.147
Lake	0.5	12	48	0.25	1
			Total	0.287	1.147

[1] pulse input conditions
[2] continuous (daily) input conditions

adapted from UTRCA CURB Plan (1989)

MODEL RESULTS

The resultant bacteria load estimates were not originally anticipated to quantify the measured bacteria loadings in the stream, but rather to examine the relative impacts of various source types and locations on the problem beach. However, when the predicted bacteria loads in three separate subwatersheds of the Upper Thames River Watershed were compared to respective measured values, they were within an order of magnitude [3].

Similar results were found for the three stations compared in the Maitland River study area [5]. These are shown in Figure 3. The predicted bacteria loads ranged from approximately 33% to 67% of the measured load estimates. This is considered acceptable since all potential sources were not necessarily included in the model.

Of particular interest were the following findings:

Dominant Sources

Continuous sources such as faulty septic systems and cattle access to streams which occur during wet or dry weather conditions are the largest influencing factors for bacterial quality, both in-stream and at the beach in most watersheds.

Table 3 indicates that low flow sources in several study watersheds are estimated to account for 70% to 80% of the bacteria load to the beach with septic systems accounting for 27% to 77% of the total beach load and livestock access to watercourses accounting for 3% to 30% of the beach load.

A large proportion of the annual phosphorus load is also attributable to continuous low-flow sources. Approximately one third of the total phosphorus load to Pittock and Wildwood Reservoirs can be attributed to milkhouse waste effluent, while in Fanshawe reservoir, one upstream food processing plant, together with milkhouse wastes accounts for one third of the total phosphorus load as documented in Table 4. The largest single source of phosphorus, however, is agricultural soil erosion which is an event-flow input accounting for approximately one half of the average total annual phosphorus loads.

Impact of Source Proximity to Beach

Initial modelling assumptions about net bacteria mortality rates have led to the result that subwatersheds which are closer to the beach are likely to have a much greater bacterial impact at the beach than headwater subwatersheds. This is very evident when bacteria-load reductions per-remedial-dollar-spent are compared for a watershed in close proximity to a beach (travel time=0.4 days) and a headwater watershed of the same beach (travel time = 7 days) in Figure 4. Generally most remedial measures are more effective by 1 or 2 orders of

magnitude at reducing bacteria loads to Goderich Beach when installed on the small lakeshore watersheds compared to installation on the most distant upland watershed.
However, preliminary Ontario research results are now indicating that traditional laboratory techniques using colony growth/plate count methods may be over-estimating the mortality rates of bacteria, because colonies do not develop from temporarily sterile organisms, [7]. If this proves to be true, proximity may be less significant than shown by the model results.

Relative Cost Effectiveness of Remedial Practices

Generally, the practices which are most prevalent and impactive on water quality are also those which are the least costly and therefore the most cost-effective to improve. Tables 3 and 4 respectively indicate that faulty septic systems and livestock access to streams account for approximately 70% of bacteria loads while milkhouse waste effluent and soil erosion account for up to 90% of phosphorus loads.

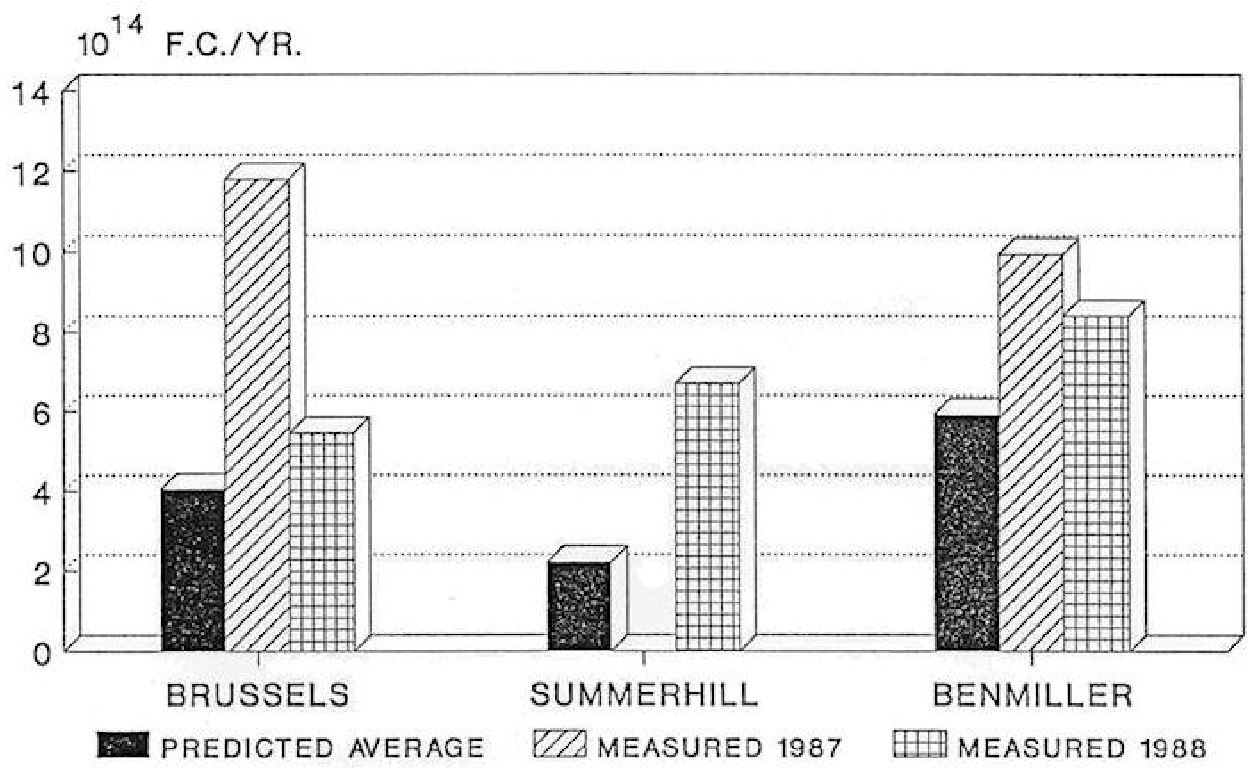

Figure 3: Predicted vs Measured Annual Bacteria Loads

Table 3: Total Annual Fecal Coliform Load at the Beach: Continuous Low-Flow vs. Event-Flow Sources

	Continuous Low-Flow Sources					Event-Flow Sources*					
	Livestock Stream Access	Milk house Wastes	Unaccept Septic Systems	Industry Discharge	TOTAL LOW-FLOW	Manure/ Feedlot Runoff	Manure Spills/ Discharges	Manure Spreading	Sewage Treatment Plant Effl.	Urban NPS	TOTAL EVENT FLOW
Goderich Beach (L. Huron)	12%	1%	66%	- -	79%	1%	<1%	16%	1%	2%	21%
Fanshawe	19%	<1%	27%	38%	84%	2%	2%	1%	3%	9%	16%
Pittock	30%	1%	46%	-	77%	3%	3%	<1%	13%	4%	23%
Wildwood	16%	5%	49%	--	70%	2%	10%	9%	--	9%	30%
Ausable-Bayfield (L. Huron)	3%	<1%	77%	--	80%	1%	- -	19%	- -	<1%	20%

* Note: Agricultural Soil Erosion was not considered, although it could contribute F.C. in event-flows.

Table 4: Total Annual Phosphorus Load

	Continuous Low-flow Sources					Event-Flow Sources						
Watershed	Livestock Stream Access	Milkhouse Wastes	Industry	Unaccept. Septic Systems	TOTAL LOW-FLOW	Manure/ Feedlot Runoff	Manure Spills/ Discharges	Manure Spreading	Sewage Treatment Plant Effl.	Urban NPS	Agric. Soil Erosion	TOTAL EVENT FLOW
Fanshawe	1%	15%	15%	5%	36%	2%	- -	1%	10%	1%	50%	64%
Pittock	2%	33%	- -	11%	46%	3%	- -	3%	3%	<1%	43%	52%
Wildwood	<1%	33%	- -	5%	38%	<1%	- -	3%	- -	<1%	58%	62%
Ausable-Bayfield	2%	3%	- -	40%	45%	<1%	- -	19%	2%	<1%	34%	55%

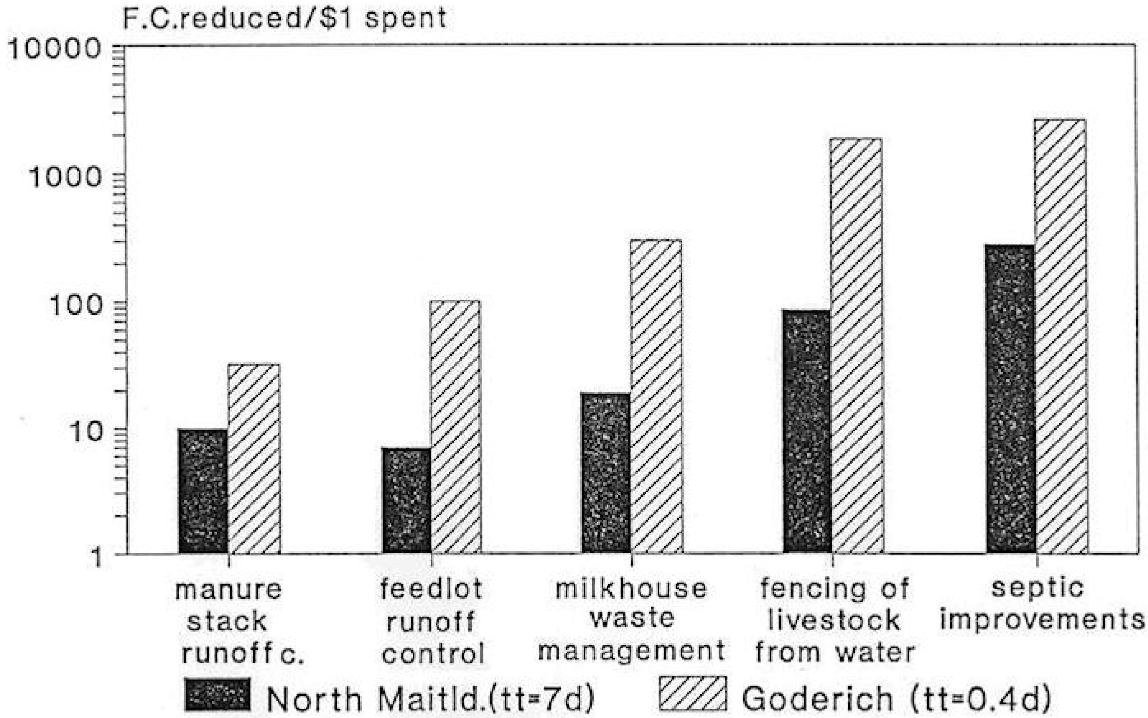

Figure 4: Effect of Bacteria Source Proximity on Cost-effectiveness of Remedial Practices

For bacteria load reductions, the most cost-effective measures, generally, are repair of faulty septic systems, and fencing of livestock from streams. However, travel time from the source to the beach in question can have a significant impact as shown in Figure 5. In fact, based on the model results for the watersheds documented in Figure 5, repair of septic systems and livestock access control in watersheds with travel times exceeding 6 days becomes less cost-effective than milkhouse waste treatment for bacteria control in a watershed with a less-than-2 day travel time. A survey conducted in the Maitland study area determined that available storage capacity was not necessarily a consideration when spreading manure in winter, [5]. Hence, avoidance of winter-spreading may also be a cost-effective measure.

Unfortunately, these most cost-effective solutions for bacteria control have few direct benefits to agricultural production and hence require some persuasive action by governments.

For phosphorus load reductions, control of milkhouse waste effluent, improvement of industrial discharges and erosion control (only if targeted) are the most cost-effective solutions. Figure 6 documents the findings of the Upper Thames River Conservation Authority regarding the relative annual costs per unit phosphorus reduced for various best-management practices in the watersheds upstream of Fanshawe, Pittock and Wildwood Reservoirs of the Thames River system.

Impact of Other Local Conditions

It is evident in Figure 5 that local factors other than travel time can also affect the cost-effectiveness of remedial practices by at least an order of magnitude.

Agricultural intensity is one such factor. For example, it is far more cost-effective to fence 60 cattle out of a ½ km. long stream than to fence 20 cattle out of a 2 km. long stream.

Other local influencing factors are variability in stream exposure to sunlight and turbidity (which affects bacteria mortality rates), the magnitude, distribution and delivery to the stream of sources within the subwatershed, and the drainage density.

IMPLICATIONS OF STUDY RESULTS ON GOVERNMENT POLICIES

The study findings provide several useful insights for provincial non-point source policy development in the areas of:

1. prioritization of the types of practices to be encouraged,
2. where they should be encouraged, and
3. the means required to encourage these practices in terms of regulatory enforcement versus various levels of incentives.

Targeting Priority Practices

Historically, in Ontario, it has been deemed politically sensitive to provide incentives or regulations for remedial practices in only certain geographic areas. A recent program which did so, resulted in a considerable number of public complaints.

The findings of the preceding analysis indicate, however, that consideration should be given to targeting priority practices which achieve similar pollutant load reductions as some of the practices which have traditionally been encouraged through grants, but at only 1% to 10% of the cost per unit pollutant reduction.

The high priority measures suggested for bacteria control are:

1. restriction of livestock from streams, and
2. repair of faulty rural septic systems.

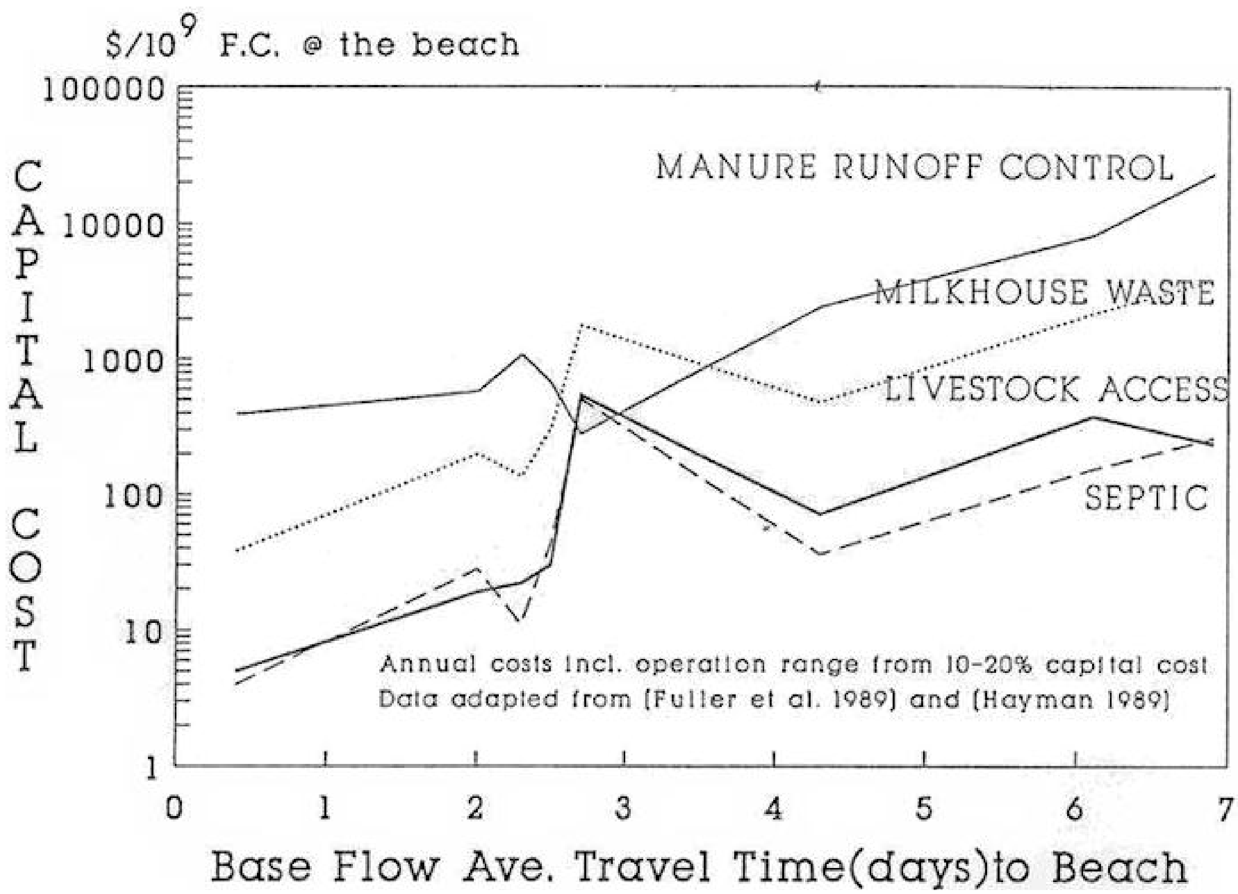

Figure 5: Cost Effectiveness of Practices vs. Travel Time

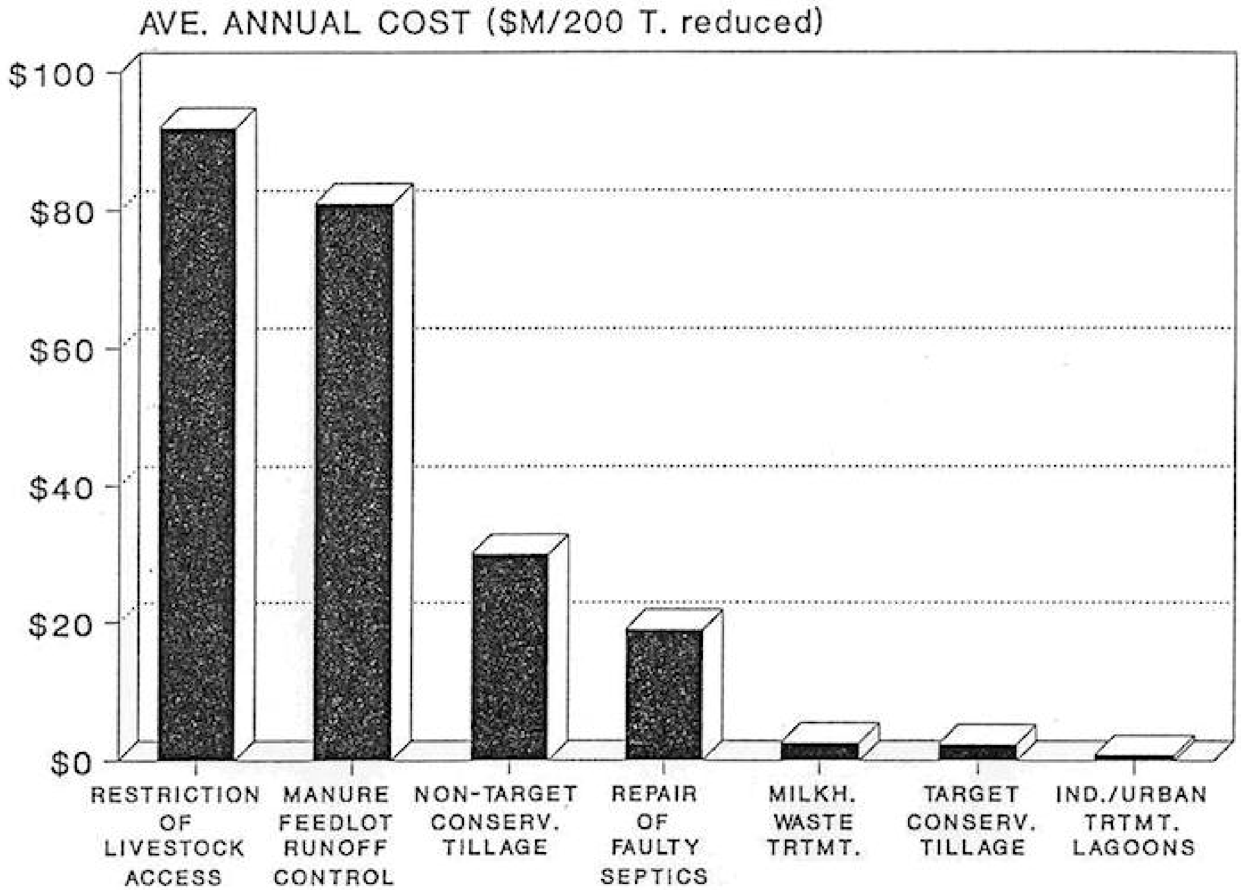

Figure 6: Relative Cost-Effectiveness of Phosphorus Management Practices

For phosphorus control, the measures suggested are:

1. conservation tillage, (targeted to the most erodible slopes only), and
2. milkhouse waste treatment/storage.

Targeting these <u>practices</u> (and inherent topographical features for conservation tillage) should result in a program which is ten to one hundred-fold more cost-effective in terms of unit of pollutant reduced per dollar spent while recognizing political sensitivities. These priority practices also happen to address the most prevalent problems in each watershed.

This is not meant to detract from other potential abatement measures which could be necessary for in-stream water quality. However, emphasis on the more cost-effective practices could have some obvious benefits, particularly at the downstream beaches.

Education / Incentives versus Regulations

Presently, faulty septic systems and discharge of milkhouse wastewater to streams are prosecutable offences under provincial statutes.

Realistically, however, the extent of the potential problems and the lengthy prosecution process make enforcement extremely impractical. Besides, with good management being an essential ingredient for most rural non-point source abatement measures, enforcing non-voluntary participation would be counter-productive at this time. Conformity should perhaps be an eventuality as proper practices become the noun. Hence, an incentive-based remedial program is envisaged together with an extension/ education program.

Unfortunately, the most cost-effective practices for water quality maintenance are those which have little direct benefit to the farm operation or rural dwelling.

Therefore, practices such as milkhouse waste treatment and/or storage, repair of faulty septic systems, and perhaps restriction of livestock from streams will likely require enhanced subsidies. Alternatively, compliance of milkhouse waste, septic, and stream watering systems should be pre-requisite to receiving grants for the less cost-effective practices which have traditionally been eligible for non-conditional grants.

Proactive Targeting

In addition to the targeting of priority practices, a further means of targeting, while respecting political sensitivities, is to proactively approach landowners only in the specific watersheds upstream of problem beaches armed with subsidies and educational materials through direct contact and mailings.

Based on the findings presented in this paper, it would be prudent to initially promote the identified high priority practices in watersheds which are in close proximity to the affected beach.

Some latitude would be essential to the local program staff such that practices which are promoted are geared towards the particular downstream problem or potential problem.

Analysis such as that shown in this paper should be done for each sub-watershed upstream of a problem beach so that the relative impacts of each source are well understood. It was evident from the model application that local agricultural intensity, as well as stream conditions which affect bacteria mortality, can also have considerable impact on the cost-effectiveness of certain remedial practices, potentially raising or lowering it by an order of magnitude.

These local influences speak strongly for an individual watershed approach specific to the problem beach rather than a generic provincial formula for abatement.

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