AGRICULTURE CHEMICALS AND WATER QUALITY IN ONTARIO

Proceedings of a workshop sponsored by the Ontario Water Management Research and Services Committee (O.W.M.R.S.C.)

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PREFACE

The impact of intensive agricultural practices on surface and ground water quality is a major concern in Ontario. Soil erosion and structural deterioration has resulted in sediment and nutrient loading of surface water. The application of agricultural chemicals, particularly nitrogen and pesticides, has resulted in increased incidence of ground water contamination. In response to this concern the Ontario Water Management Research and Services Committee (OWMRSC) organized the workshop titled "Agricultural Chemicals and Water Quality in Ontario" held on November 17- 18, 1989 in Kitchener, Ontario.

The purpose of the workshop was to provide an opportunity for agencies involved in water quality issues to present an overview of present and future programs, identify areas where additional research and service programs are needed, and to provide participants an opportunity for information exchange and technology transfer. Thirteen speakers representing the federal, provincial, and university sectors addressed general, monitoring, and research programs focusing on surface and ground water quality problems in Ontario. There were 81 registered participants representing federal and provincial agencies, universities, private industry, and grower organizations. Included in these Proceedings are transcripts of the speaker's presentations and a compilation of participant's comments and recommendations.

J. A. Stone, Chairman
O.W.M.R.S.C.

TRANSCRIPTS OF WORKSHOP PRESENTATIONS

AGRICULTURAL WATER QUALITY PERSPECTIVES IN ONTARIO I.

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ABSTRACT

There are many water quality issues in Ontario which are directly linked to agricultural activities. The major issues are related to water supply, sediment, nutrients, agricultural wastes, bacteria, and pesticides.

Ontario is committed to improving water quality in international and national agreements. In light of these agreements and growing public concern over water quality, the Ministry of Agriculture and Food (OMAF) is taking the necessary steps to minimize and ameliorate the impact of agriculture on water quality. OMAF's strategy is composed of five components: cooperation, financial assistance programs, extension, education, and research.

INTRODUCTION

Interest in sources of pollution from agricultural areas has increased substantially **in** recent years as discharges from municipal and industrial sources have come under increasing control. Modern agricultural practices employ techniques which involve the use of fertilizers, pesticides, irrigation systems, improved drainage, and confined poultry and livestock operations. A possible consequence is the increased potential for water quality degradation of surface and ground water.

Within agriculture, both point and non-point sources of pollution can be theoretically identified. Agriculture, however, is usually considered in the non-point source category because agricultural pollution comes mainly from gross soil erosion and surface water runoff. Other sources include eroding ditch banks, natural subsurface drainage, and illegal connections of septic and milkhouse wastes to tile systems.

The quality of agricultural runoff reflects the type of soluble material with which the water comes in contact and the suspended material it carries. Major pollutants from agricultural lands include sediment, nutrients, animal wastes, pesticides, and bacteria.

WATER QUALITY ISSUES RELATED TO AGRICULTURAL ACTIVITIES

At present, there are a large number of water quality issues in Ontario which are directly related to agricultural activities. The following is a summary of the major issues.

ISSUES RELATED TO WATER SUPPLY

- contamination of surface and ground water by agricultural chemicals and bacteria,
- water well contamination due to spills, poor location, poor construction and maintenance, and
- contamination of agricultural ponds.

ISSUES RELATED TO SEDIMENT

- impacts on fish habitat,
- contamination of surface waters associated with pollutant transport,
- impacts on water supply intakes, and
- management of soil resources.

ISSUES RELATED TO NUTRIENTS

- contamination of surface and ground waters,
- phosphorus loadings to receiving waters,
- nitrate contamination of aquifers,
- transport and fate of nutrients, and
- management of nutrients.

ISSUES RELATED TO AGRICULTURAL WASTES

- cattle access to streams,
- treatment systems for milkhouse wastes,
- disposal of domestic waste and septage,
- aquaculture effluents and their impacts on water quality, and
- management of manure, aquaculture effluents, and milkhouse and domestic wastes.

ISSUES RELATED TO BACTERIA

- contamination of surface and ground waters,
- human and livestock health,
- beach closings, and
- management of bacteria associated with agricultural activities.

ISSUES RELATED TO PESTICIDES

- contamination of surface and ground waters,
- fate and transport of pesticides,
- pesticide residues in food, and
- disposal of pesticide containers.

ONTARIO'S COMMITMENT TO CONTROL AGRICULTURAL POLLUTION

Ontario's commitment to protect our environment and water resources from the impacts of agricultural non-point source pollution is strongly linked to the large number of studies which have been carried out by various government agencies and research institutions. Results from these studies have sharpened our awareness of the key issues of agricultural pollution, increased our understanding of the difficulties we are facing, and strengthened our commitment to bring this pollution under control. This awareness has led to a number of international and national agreements to improve water quality in general, and rural water quality in particular.

THE CANADA-UNITED STATES GREAT LAKES WATER QUALITY AGREEMENT

In 1972, Canada and the United States signed the Great Lakes Water Quality Agreement requiring both Federal Governments to reduce phosphorus loads to the Great Lakes. In response, major municipal programs with expenditures totalling over $8 billion, industrial controls, and phosphate limitations on detergents did produce a reduction, and in some areas a reversal of the eutrophication process in the Great Lakes Ecosystem.

Article V(d) of the 1972 Agreement called on both Canada and the United States to undertake measures for the abatement and control of pollution from agriculture, forestry and other land use activities, including:

- measures for the control of pest control products with a view to limiting inputs into the Great Lakes System;

- measures for the abatement and control of pollution from animal husbandry operations, including encouragement to appropriate regulatory agencies to adopt regulations governing site selection and disposal of liquid and solid wastes in order to minimize the loss of pollutants to receiving waters; and

- advisory programs and measures that serve to abate and control inputs of nutrients and sediments into receiving waters from agricultural, forestry and other land use activities.

In 1978, the Agreement was revised to address the new environmental challenge--toxic substances. The revised Agreement expressed, for the first time, the principles of virtual elimination and zero discharge of persistent toxic substances. Among other things, Article V was revised and renamed as Article VI. The revised Article expanded on the above items and recommended:

- to strengthen research and educational programs to facilitate integration of cultural, biological and chemical pest control techniques;

- to strengthen educational and technical assistance programs to enable farmers to establish waste utilization, handling and disposal systems; and

- to implement measures to control soil losses from urban and suburban as well as rural areas.

In 1987, the Agreement was further revised. Article VI now requires the appropriate agencies to establish and maintain inventories of pest control products used in the Great Lakes basin. In addition, Article VI requires further non-point source programs in accordance with the new added Annex 13.

The purpose of Annex 13 is to "...delineate programs and measures for the abatement and reduction of non-point sources of pollution from land use activities". Among other things, Annex 13 requires the Parties to:

- identify land-based activities contributing to water quality problems;
- identify, preserve and, where necessary rehabilitate significant wetland areas; and
- conduct surveillance, surveys and demonstration projects.

THE CANADA-ONTARIO AGREEMENT RESPECTING GREAT LAKES WATER QUALITY (COA)

Ontario is committed to control agricultural pollution under the Canada-Ontario Agreement Respecting Great Lakes Water Quality, to which the Minister of Agriculture and Food is signatory. Under COA, the Government of Canada and Ontario adopted common objectives, and developed and implemented cooperative programs to maintain the aquatic ecosystem in the Great Lakes Basin. COA serves as a focal point for coordinating federal and provincial efforts in meeting Canada's international commitments. In 1984/85 a federal/provincial task force developed a phosphorus management plan for the lower Great Lakes.

The purpose of the plan is to reduce the total loading of phosphorus discharge to Lake Erie by 300 metric tonnes per year of which 200 metric tonnes is attributed to agriculture sources. This plan is being implemented now under the federal-provincial Soil and Water Environmental Enhancement Program (SWEEP).

NATIONAL AGRICULTURE STRATEGY

At the First Ministers Conference in Vancouver, November 20-21, 1986, they agreed upon a National Agriculture Strategy which contained an element on Soil and Water Conservation and Development. The National Agriculture Strategy calls for:

- Establishment of a coordinated soil and water conservation program, adapted to each province, that would provide:

  - awareness and education programs,
  - improved extension and technical advisory services, more on-site demonstrations,
  - additional research as required,
  - improved financial support, and
  - assistance in areas such as soil survey work and infrastructure planning.

- Improvement of federal and provincial coordination mechanisms;

- Provinces to ensure interdepartmental coordination;

- Federal Government to create focal point for coordinating existing and new soil and water activities;

- Reorientation of federal and provincial programs to meet needs;

- Negotiations of federal/provincial agreements to finance and coordinate programs; and

- Establishment of local soil and water conservation and development organizations where appropriate to facilitate farmer's participation and focus local activities.

At present, Ontario and Canada are negotiating an Accord on Soil and Water

Conservation as a first step to implement the National Agriculture Strategy. It is anticipated that the Accord will serve as a framework for future federal/provincial agreements.

OMAF'S STRATEGY TO CONTROL AGRICULTURAL POLLUTION

In light of the international and national agreements and growing public concern over water quality, OMAF is taking the necessary steps to minimize and ameliorate the impact of agriculture on water quality. Because it is next to impossible to collect all agricultural runoff and because it is astronomically expensive to treat it, OMAF believes that the only practical strategy to control agricultural pollution is the one based on techniques that emphasize prevention rather than cures.

OMAF's strategy is composed of five components:

- cooperation,
- financial assistance programs,
- extension,
- education, and
- research.

To implement this strategy, OMAF utilizes the following process:

- identification of the problems;
- consultation and cooperation with government agencies, the farming community and the public at large;
- identification of available options and appropriate solutions;
- development and implementation of necessary educational, technical (extensional) and financial assistance programs;
- promotion of remedial measures that meet the test of being practical, economical, cost-effective, and site specific; and
- conducting the necessary supporting research.

To date, OMAF's adherence to the above strategy appears to bear fruit. OMAF is participating on national, provincial and local committees which deal with issues related to agricultural pollution. OMAF has developed and is administering financial and technical assistance programs designed to minimize agricultural pollution, is providing extension and education to farmers, and is financing relevant research.

COMMITTEES INVOLVED IN CONTROL OF AGRICULTURAL POLLUTION

A number of international, national and inter-agency committees and subcommittees are presently addressing issues related to the control of agricultural pollution. Examples include:

- the IJC Loading and Sources Subcommittee,
- the Federal/Provincial Committee on Soil and Water Conservation,
- the Environmental Monitoring and Modelling Committee under COA,
- the MOE/OMAF Deputy Ministers Liaison Committee,
- the OMAF Water Quality Committee,
- the Interministry Committee on Great Lakes,
- the Interministry Sludge Utilization Committee,
- the Interministry Acid Precipitation Committee,
- the Interministry Committee on Wetlands,
- the MOE/OMAF Pesticide Education Program Steering Committee,
- the OMAF/MOE/MNR/Conservation Authorities Drainage Committee, and
- the Rural Beaches Planning and Advisory Committee.

These committees have completed or are about to complete a number of products which are of paramount importance to our efforts in controlling agricultural pollution. Examples include:

- the Design and Construction Guidelines for Work Under the Drainage Act,
- the OMAF Water Quality Stewardship Report,
- the OMAF/MOE Protocols for Handling Farm Pollution Incidents, and
- the Provincial Policy Statement on Wetlands.

PROVINCIAL PROGRAMS RELATED TO CONTROL OF AGRICULTURAL POLLUTION

The Province of Ontario has introduced during the past few years significant programs which will benefit the farmers as well as improve water quality. The majority of these programs are being administered by OMAF. Others are being administered by the MOE. These programs are:

- Ontario Soil Conservation and Environmental Protection Assistance Program II (OSCEPAP II),
- MOE Enhanced OSCEPAP II Program,
- Provincial Rural Beaches Program,
- Tillage 2000 Program,
- Land Stewardship Program, and
- Food Systems 2002 Program.

In addition, the Province and the Federal Government are cooperating on the implementation of the Soil and Water Environmental Enhancement Program (SWEEP).

EXTENSION PROGRAMS

Agricultural extension and program delivery are provided by OMAF staff at the local county or district level. These staff work directly with farmers and provide technical advice on farm drainage, water supply, erosion control and manure management.

EDUCATION PROGRAMS

OMAF operates five colleges of agricultural technology, offering two-year diploma courses in various facets of agriculture, agribusiness, livestock and food. Soil conservation and water management are part of the curriculum.

In addition, training courses on soil conservation are being provided to farmers under the Land Stewardship Program. Land stewardship ethic is a compulsory component of every course. Other components include soil degradation; fertilizer, manure and pesticide management; and water quality.

RESEARCH

The Agricultural Research Institute Of Ontario has responsibility over the expenditure of OMAF research funds for agriculture, veterinary medicine, and consumer studies.

The research funding for the year 1987-1988 was over $41 million. Additional funds are being made available for the fiscal year1988-1989 through the Land Stewardship Research Program and Food Systems 2002 Program.

Agricultural research within OMAF is carried out by the Agricultural Laboratory Services, the Economics and Policy Coordination Branch, and the five colleges of agricultural technology. Extensive agricultural research is also being carried out and funded by OMAF at the University of Guelph.

Water management research needs are identified by the Soil, Water, and Air Research and Services Committee of the Ontario Agricultural Services Coordinating Committee. In 1987-1988 a large number of research projects are being conducted in the areas of agrometeorology, streamwater management, land use, and soil management.

FUTURE CHALLENGES

The control of agricultural non-point source pollution is a long-term battle which requires long-term commitment by all of us. In this decade we have achieved a great deal of progress towards improving agricultural water quality, but too many challenges still lie ahead. I am sure that we will successfully overcome these challenges provided that we have the will, the perseverance, and the required resources.

Many gaps exist today which require attention. The following is an attempt to identify the major gaps:

ENVIRONMENTAL EFFECTIVENESS OF VARIOUS TECHNIQUES TO CONTROL AGRICULTURAL POLLUTION

Most research has been concerned with the effects of various practices on soil fertility or with runoff from only small plots. Little documented information is available on the effectiveness of various techniques for reducing non-point agricultural pollution. What is the phosphorus reduction value of a fence or a buffer strip? Carefully planned research is needed on the effect of the best management practices on nutrient and pesticide losses from large agricultural watersheds.

SOIL DEGRADATION

Soil degradation continues to be a problem in Ontario. It is important to define the allowable soil working parameters, which reduce or eliminate soil degradation effects, in terms of compression and shear loading; particle sizes; working depth; soil moisture; and crop and soil type.

NUTRIENTS

Bench mark data are required for the development of maximum nutrient applications for all crops grown on all major soil types.

There is a need to develop guidelines for maximum nutrient applications allowable for each crop in Ontario on all major soil types.

There is a need for the development of guidelines for land-livestock ratios to ensure land bases are available to safely dispose of manure.

There is a need for the development of critical levels of row crops for each watershed or county, depending upon soil conditions and crop type.

Evidence suggests that soil tests are good predictors of phosphate fertilizer requirements to give highest economic yield. We have to encourage farmers to base their phosphorus fertilizer application on soil tests.

Unlike phosphorus, nitrogen soil tests have proven unsatisfactory for field crops in Ontario. Farmers should be encouraged to base their nitrogen fertilizer applications always on the type of crop to be grown, the amount of manure applied, and legume content of forage or green manure crops.

PESTICIDES

The high costs of pesticides and their potential effect on the environment and human health, make it imperative that existing application methods be refined.

Pesticide container disposal is a troublesome problem for farmers and regulatory agencies. Mechanisms should be developed by government and industry to allow for safe disposal.

The continued development and use of water-soluble packaging that dissolves with contents in spray tanks should be encouraged.

There are in existence today a number of computer models of various levels of complexity. Our experience with the Nissouri Watershed Study on the transport and environmental fate of atrazine indicates that these models cannot effectively be used until and unless we know the impact of a given practice on key model parameters under Ontario conditions. Therefore, research in this area is urgently required.

GROUND WATER

Stories about individual water well contamination by bacteria, nitrogen, or pesticides are being brought to our attention on a regular basis. We do not know, however, the extent, type, or severity of ground water contamination in rural Ontario. A lot of detective work in this area is necessary.

A need exists for a provincial survey to assess the extent and severity of ground water contamination in rural areas to identify:

- which chemicals exist in ground water, in what concentrations, and by what means they are reaching the ground water,
- persistence and solubility of agriculture chemicals under various soil and geologic conditions, and
- areas with problems or potential problems.

A need exists to disseminate as widely as possible information on agricultural chemicals and their potential impact on ground water quality to farmers and farm organizations.

A need exists to provide technical guidance and/or financial assistance to help farmers protect their ground water supplies.

CONCLUSIONS

Agriculture, as all the other sectors of the economy, depends on high quality water resources. The pervasive nature of non-point source pollution dictates that considerable cooperation is needed among federal, provincial, and local agencies, farming organizations, interest groups and the public at large. All users of water resources must work together to conserve these resources for future generations.

As part of its societal obligations, OMAF should promote agricultural practices which are environmentally sound and which maintain the viability of the agriculture industry. OMAF should provide leadership for the stewardship of agricultural soil and water resources, and should continue to provide technical and financial assistance to producers to meet the environmental challenge.

AGRICULTURAL WATER QUALITY PERSPECTIVES IN ONTARIO II.

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ABSTRACT

In 1978, the International Joint Commission adopted the 'Ecosystem' approach framework to current and proposed non-point source (NPS) pollution programs in the basin. Integrated resource management on a watershed basin is one manifestation of this approach which is being adopted by many agencies. The development of remedial action plans (RAP's) for some of the Areas of Concern is one example of the application of the principles of integrated watershed management.

In several of the RAP watersheds and other priority areas, agriculture is seen as a major contributor to the pollution problem. The question is posed as to whether viable agriculture and high water quality can co-exist in the same watershed. Watersheds such as the Saugeen River basin show alarming declines in water quality in the last 15-20 years which can be related to increasing intensity of agriculture.

Annex 13 of the revised Great Lakes Water Quality Agreement calls for further reductions in NPS pollutant loadings, particularly by toxic contaminants and also calls for the development and implementation of watershed management plans for priority areas. Programs which further promote low impact agriculture, such as SWEEP (Canada-Ontario Agreement on Soil and Water Quality Enhancement) and Food Systems 2002 (Ontario Ministry of Agriculture and Food) will contribute towards achieving the Agreement's objectives.

PRESENTATION

Since Mr. Singer and I are from different agencies with different mandates, you might expect to hear quite different views on agriculture in the environment.

However, it is interesting that our two agencies viewpoints have as much in common as they do these days. Part of the reason we are finding more in common is because, as we carry out more studies and research together, we are building a truer picture of the physical, chemical, and biological processes and the environmental impacts involved. And as we at MOE have become more involved in applied research, in IPM and in grants and demonstrations with farmers we have become more knowledgeable about farm level issues.

In short, we are beginning to see things from a broader perspective closer to the ideal of an ecosystem approach which the International Joint Commission (IJC) has adopted. In fact, since many of the programs in which our two ministries are involved are related to work under the Great Lakes Water Quality Agreement (GLWQA), an ecosystem approach is appropriate. As many of you know, the IJC adopted the Ecosystem approach in 1978 and all agreements since then reflect this view.

'Ecosystem' as defined by the IJC, is a flexible term applying to a water body, a river basin, the Great Lakes or any convenient unit within which exchanges of materials take place between living and non-living parts. IJC emphasizes that the ecosystem perspective that they use includes man and his activities.

To reduce the impact of man's activities, and take action leading to high water quality will require application of the principles of integrated watershed management. The integration required is on the government level. The GLWQA & COA, with their ecosystem perspective, will take us absolutely nowhere unless local governments also adopt the principles and act accordingly.

It is worth noting in passing that the Remedial Action Plan (RAP) teams which are addressing the 17 Areas of Concern in the Canadian Great Lakes are making good progress in achieving this sort of integration. These teams involve stakes-holders, i.e. industries, government officials, public interest groups and resource users of all types, in developing decisions on both water quality goals and remedial plans for their particular watershed and area of concern. MOE takes a lead role in RAP's and will certainly play a key role in integrated watershed management in the future.

Generally in this province, intensive agriculture and good water quality have not co-existed. Is such a state possible: that is, can we have viable, profitable agriculture and good water quality throughout the same watershed? In southwestern Ontario, only streams in Bruce and Grey Counties and parts of Huron meet our Provincial Water Quality objectives for phosphorus. Two-thirds of the region's surface water does not.

There are also some worrisome trends concerning nitrate-N in parts of these counties, such as in the Saugeen River. Downward trends in water quality are well correlated with increases in row crop production in these areas. In Huron County, for example, corn production acreage has doubled since the early 70's, and this parallels a decline in water quality.

According to our policies we should be taking steps to prevent the downward trend in quality in these areas from continuing. We have already completed a study of water quality issues in the Saugeen R. Basin to identify key issues and we will be initiating a more detailed study in the near future which it is hoped will ultimately lead to an integrated resource management plan for that basin.

We must proceed on a number of fronts; first we have to deal with a number of chronic problems of the more controllable type such as illegal waste discharges, drainage, and runoff from manure sources.

On another front the whole area of low input agriculture and the more environmentally sound management practices that it applies are very promising. But in addition to these approaches we will require better planning of land and water uses on a river basin scale if we are to meet high expectations for water quality.

Some of the work we are engaged in is helping to advance our understanding of processes at the watershed scale. One of the objectives was to evaluate the feasibility of using watershed modelling to predict the environmental fate of agricultural chemicals and the effects of conservation practices on their movement and losses. The model proved powerful in its capability to simulate chemical behaviour in water and soil on a watershed scale and it warrants extensive further application.

To me, one of the most important applications of this model could be its utility in addressing some of the questions which are likely to arise concerning how pesticide behaviour changes under no-till, minimum or conservation tillage practices. Models such as this are extremely valuable tools to use in the planning and regulatory aspects of pesticide management and are a good example of the application of an ecosystem perspective applied on a watershed scale.

In another project, we are also involved, along with Agriculture Canada and the Water Survey of Canada in water quality and quantity monitoring of several small watersheds in southwestern Ontario which have been established under the Soil and Water Environmental Enhancement Program (SWEEP). SWEEP, is a $30M program running to 1993 funded by Agriculture Canada and OMAF and supported by the Federal and Provincial Environmental agencies. One of the goals of the program is to reduce phosphorus loading from cropland sources in the L. Erie basin by 200 metric tonnes/year.

Under one of the SWEEP sub-programs, called the Pilot Watershed Program, 3 pairs of agricultural watersheds of about 400 ha. in size were established in SW Ontario. Farmers in one of each pair of watersheds will convert to conservation tillage and cropping practices while farmers in the other watershed will maintain the current practices. MOE and Environment Canada will be monitoring the resulting impacts on water and developing models to assist in understanding the behaviour and effect of individual components of these systems. MOE and Agriculture Canada will be looking in some detail at surface and subsurface transfer of chemicals and at the effects of specific practices associated with particular soils and cropping systems. The principle water quality parameters to be measured are phosphorus, suspended sediment and nitrogen. Selected pesticides will be regularly monitored for in order to account for changes to practices which result in differences in the timing, placement and amounts of pesticide utilized.

All of these efforts just described and others in which Agriculture Canada and Environment Canada are involved are taking place on a watershed scale and address the question of how changing agricultural practices, such as conservation tillage, interact with other variables in the system.

In terms of our future involvement with other non-point source programs (NPS), such as I have described, you might say we have already received our marching orders in the form of the new Annex 13 of the revised GLWQA. This part of the agreement delineates programs and measures for the abatement and reduction of non-point source inputs of phosphorus, sediments, toxic substances and microbiological contaminants. This is an extension of what we have been doing under the Federal-Provincial phosphorus control program in conjunction with SWEEP.

Annex 13 requires us to develop and implement watershed scale plans which include provisions for <u>regulation</u> of non-point sources, and for the identification of priority areas and implementation schedules. Under Annex 13 we will also have to establish demonstration watersheds to evaluate the effectiveness of strategies which promise reductions of loadings of bacteria, pesticides and nutrients.

I think that the concept of 'low input agriculture' has a lot of potential in this regard. Low input agriculture is agriculture which has reduced dependence on inorganic fertilizers and pesticides, replaced by intensive recycling of nutrients within the farm. It is a system of farming which takes into account biological cycles of crop pests and has regard for farm economics. Programs such as Tillage 2000 and the Technology Evaluation and Development program of SWEEP are already making progress in this direction. G. Driver and W. Findlay will describe these programs later in the workshop. In the future, we will also be looking for less chemical dependent agriculture through integrated pest management and the development of biological and other non-chemical pest and weed control techniques.

Recently the Premier announced a comprehensive pesticide and pest management program known as Food Systems 2002 which will be implemented by the Ministry of Agriculture & Food. W. Roberts will be making a presentation on that program later this morning.

MOE, through its Research Advisory Committee and OPAC, currently allocates about $400K/year to pesticides research which has 3 objectives:

(1) to find alternative pesticides to replace those deemed environmentally hazardous
(2) to determine potential environmental hazards of pesticides currently in use and
(3) to find methods to reduce pesticide inputs to the environment.

This brings me to the end of my talk, and in closing, I'd like to return to the question I asked earlier: can a viable agricultural exist alongside water resources of high quality? Realizing that one of the goals of this workshop is to develop recommendations on research and program needs, I will just close by saying that I trust we will come up with recommendations that will lead to developing strategies that make that scenario achievable.

RESEARCH IMPLICATIONS OF THE REVISED GREAT LAKES WATER QUALITY AGREEMENT 1987

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The Governments of Canada and the United States have entered into Water Quality Agreements to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. The revised Agreement of 1987 recognized the need to strengthen efforts to address the continuing contamination of the Ecosystem with particular emphasis on persistent toxic substances. Further, it was acknowledged that many of these toxic substances enter the Great Lakes System from the air, from groundwater infiltration, from in-place sediments and from runoff of non-point sources. To address the continuing contamination problem the Agreement acknowledges the need for further research and program development to enable effective actions to be taken. This paper will present the implications of the Great Lakes Water Quality Agreement (1987) for agricultural research programs in Canada.

The responsibilities and functions of the International Joint Commission relate primarily to an assessment of the effectiveness of the programs and other measures undertaken by the Parties (Canada and the USA) and by the State and Provincial Governments pursuant to the 1987 Agreement. The actual implementation of the Agreement recommendations is the responsibility of the Parties and State and Provincial Governments.

The programs and measures that are to be implemented in accordance with the Agreement are identified in Article VI and associated Annexes. There have been six new Annexes added to the revised Agreement (1987) that may have program and research implications to Agricultural agencies. The following subjects are addressed in these new Annexes:

- remedial action plans for Great Lakes areas of concern,
- pollution from nonpoint sources,
- contaminated sediment, airborne toxic substances (including pesticides),

- pollution from contaminated groundwater, and
- research and development.

Each of these Annexes delineates programs and control measures that the appropriate Federal, Provincial and State agencies have been committed to implement.

The research and development Annex delineates research needs to support the achievement of the goals of the Agreement. Specific research requested includes the following topics that should be of concern to agricultural research:

a. Determine the mass transfer of pollutants between the Great Lakes Basin Ecosystem components of water, sediments, air, land and biota, and the processes controlling the transfer of pollutants across the interfaces between these components in accordance with Annexes 13, 14, 15 and 16;

b. Develop load reduction models for pollutants in the Great Lakes System in accordance with the research requirements of Annexes 2, 11, 12 and 13;

c. Determine the physical and transformational processes affecting the delivery of pollutants by tributaries to the Great Lakes in accordance with Annexes 2, 11, 12 and 13;

d. Determine cause-effect inter-relationships of productivity and ecotoxicity, and identify future research needs in accordance with Annexes 11, 12, 13 and 15.

The need to coordinate the programs and research of agricultural agencies in response to the Great Lakes Agreement is becoming apparent with increasing involvement of agricultural agencies in Great Lakes Basin water quality issues.

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TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM OF SWEEP

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INTRODUCTION

The Soil and Water Environmental Enhancement Program (SWEEP) is a $30 million federal-provincial agreement, designed to improve soil and water quality in southwestern Ontario. The program has two interrelated purposes: to reduce phosphorous loadings to Lake Erie from cropland runoff; and to improve the agricultural productivity of southwestern Ontario by controlling soil degradation which contributes to water pollution. Several sub-programs have been established within SWEEP, one of which is the Technology Evaluation and Development (TED) sub-program.

The TED component is centered at the Federal Research Station, Harrow, and is being managed by Ecological Services for Planning Ltd. (ESP) of Guelph. TED is directed at field level evaluation of existing technologies, particularly development of new conservation methods under commercial farm conditions. The workplans support several activities: 1) farm management systems; 2) cropping strategies; 3) tillage options; 4) fertility management; 5) pest control; 6) water management; and 7) problem/process understanding.

COMPLETED RESEARCH PROJECTS

A REVIEW OF FARM BASED SOIL CONSERVATION RESEARCH AND DEVELOPMENT

<u>Objective:</u> To provide information on conservation farming practices currently being tested by farmers and to document the problems encountered through

the testing of various technologies.

Output: Data on machinery use and modifications; methods of weed and pest control; use of cover crops, crop rotations, land residue management; problems encountered, reasons for choosing the various technologies; suggestions for research that could be addressed in the TED program.

STRUCTURAL DEGRADATION - PILOT STUDY

Objective: To assess the degree and extent of subsoil compaction on lowland clays in Southwestern Ontario.

Output: Compiled data from surveyed farms: farm size, rotation used, crop, type and yield, fertilization (method, timing, rate), tillage, equipment (size, specifications), compaction perception by farmer, use of manure, soil type, drainage class, soil moisture, penetrometer resistance, strength of ped separation, soil structure, earthworm numbers, bulk density, pore volume class; correlation of parameters to define relation of cropping and tillage to subsoil compaction and to yields; related to soil models.

IN PROGRESS RESEARCH

MANAGEMENT OF FARM VARIABILITY

Objective:

(a) To determine variations in crop yield response to soil landscape variability under different tillage and relate to crop yield response and intrinsic soil properties; determine relative rates of soil erosion and phosphorus delivery on various landscape positions; devise strategies to manage farm field variability under different soil conditions and

(b) to determine causes of severe erosion observed on shoulder slope positions in complex topography and establish the extent to which conservation systems will reduce erosion.

Output: Crop yield, leaf number, height, growth stage dates, emergence and population counts, surface residue cover, weed counts (T2000); crop rotation, equipment, fuel consumption, herbicides and pesticides, seeding rates, (T2000); classification of landform groups to distinguish topographic parameters which define distinct landform elements; grid sampling of yield, soil, and landform parameters, tissue testing and soil fertility; assess soil water regime; soil erosion and P using Cs^{137} method; classify management areas.

COVER CROP MANAGEMENT - HURON AND MIDDLESEX

Objective: To determine the type, establishment method, and killing method of cover crops and the effect of cover crops on yield response, weed pressure, harvesting, and related management operations.

Output: Height of cover crop at various dates, percent residue cover, live plant escapes; main crop - plant emergence, plant height at various times, silking date, grain yield, grain moisture; soil - texture, fertility, air temperature, precipitation.

COVER CROP MANAGEMENT - OXFORD, WATERLOO, WELLINGTON

Objective: To evaluate cereal, grass and legume cover crops in certain corn-soybean-winter wheat rotations.

Output: Cover crop biomass and establishment, percent regrowth, ground cover; weed growth and biomass; crop yields, heading dates.

MODIFICATIONS TO THE MOLDBOARD PLOUGH

Objective:

(1) To determine the effect of shape of moldboard and type of plough on the amount of cereal and/or grain corn residue cover left on the soil surface at various times in the growing season.

(2) To prepare preliminary recommendations on the adjustments and specifications of moldboard plows for optimizing residue management potential.

Output: Using 5 moldboards of different shapes and types; identify moldboard and plough specifications and adjustments, soil texture and moisture at treatment, soil surface residue in fall prior to treatment, in early spring and after planting.

NO-TILL DRILLING OF SOYBEANS

Objective: To determine whether use of more aggressive coulters will improve performance and ability of the drill to plant no- till soybeans.

Output: Soybean performance - seed germination, rate of emergence, final plant stand, harvested yield.

MACHINERY MODIFICATIONS AND PRACTICAL TIPS

Objective:

(1) Outline practical considerations a farmer makes when choosing and implementing a conservation tillage system and

(2) document previous and current applications of conservation tillage techniques.

Output: Topic pamphlets: identification of problems and solutions of soil degradation; general perspective of conservation tillage; choosing the right system; managing machinery, tips and economics for (a) no-till corn and beans; (b) no-till cereals and solid seeded beans; (c) ridge tillage for corn and beans and (d) minimum tillage.

CORN HYBRID TESTING AND SPLIT APPLICATIONS OF NITROGEN

Objective:

(1) To determine whether different corn hybrids will perform similarly on conventional tillage and no-till, and if not, if the response is predictable to plant breeders such that varietal recommendations can be made according to tillage;

(2) to determine whether the application of a portion of N at planting will affect yield of corn; and,

(3) to determine the optimum quantity of N.

Output: Corn performance - seed germination, rate of emergence, rate of seedling growth, biomass accumulation, flowering date, plant height, grain moisture at harvest, yield; rainfall records; corn with N (no-till) -parameters which are influenced by early or delayed application of N; ie. rate of seedling and early growth (rate of biomass accumulation), leaf tissue samples at flowering for total N, yield. Soybeans with *N* (ridges) - as per corn with N.

OPTIMAL WEED CONTROL STRATEGIES

Objective: Determine predominant weed species (minimum till vs conventional); phenological development of weeds relative to timeliness of control; effect of crop residues on effectiveness of herbicide treatments or required change in timing of residue type as a result; assess effect of changes in soil properties and environmental conditions on choice of weed control strategies; develop and test additives to herbicides; assess cost/benefit of more promising weed control strategies.

Output: Weed counts x weed species, seed weights, crop stand and yield, crop injury; information regarding more difficult to control perennials, winter annuals, and new species; herbicide rates and interaction, timing.

CONTROL OF PROBLEM WEED SPECIES

Objective: To determine problem weed species in long term conservation tillage; determine timing of phenological stages of problem weeds by crop, soil type and geographic region; determine phenological stages where weeds are susceptible to control; devise weed control programs which do not depend on tillage as a major control; examine effectiveness of proposed weed control.

Output: Species list; abundance according to number of years in tillage, weeds previous years, pattern of herbicide use, crop and rotation system, soil and climate; weed phenological stage correlated with growth stage of crop, tillage, soil, climate, region, control measures used; estimate reproductive potential of weeds in various tillage systems; determine chemical control systems available by discussion with experts and by reading labels; identify effect of mechanical damage at different development stages re: survival and changes in phenology (greenhouse); identify promising weed control strategies.

LAND RESHAPING ON LOWLAND SOILS

Objective: To develop a method for measuring phosphorus movement rates under different water management practices; monitor P, crop yields, and management requirements of field.

Output: monitor tillage, fertilization, compaction, crops, weed control, yields, quantity and quality of water runoff.

EFFECTS OF TILLAGE ON THE QUALITY OF SURFACE AND SUBSURFACE WATER

Objective: To establish effect of no till, ridge-till and conventional tillage on water losses; to quantify total P, total dissolved P, orthophosphate, and herbicides in surface and subsurface runoff.

Output: Continuous monitoring of runoff and tile; P and herbicide analysis in water samples; estimates of runoff volumes from surface and tile discharge; precipitation records.

EFFECTS OF TILLAGE ON THE QUALITY OF SURFACE AND SUBSURFACE WATER; UPLAND

Objective: To determine the quantity and quality of water moving to tile drains and as overland runoff under no-till and fall moldboard plough tillage; determine mechanisms responsible for changes in surface and subsurface water loss; identify potentially negative impacts of conservation tillage and possible prevention.

Output: Data on phosphorus and soil loss during rain events; rainfall simulation at harvest, after fall ploughing, and the following spring for P and sediment loss total P, dissolved P, organic P, nitrates; field solute flux to assess the effect of tillage on subsurface movement of chemicals, dominance of macropores; evaluate the importance of macropores, and the effective water filled porosity contributing to subsurface water flux; in Year 3 of study, hydrological measurements from undisturbed cores - moisture retention, hydraulic conductivity, texture, bulk density, horizonation.

THE EFFECT OF TERRACES ON PHOSPHORUS MOVEMENT

Objective: To develop and test a comprehensive methodology for evaluation of the impact of erosion control structures on the loss of phosphorus from rolling crop lands.

Output: Monitor quantity and quality of water leaving structure; water samples analyzed for total P and total suspended solids; particle size distribution of soil samples and of composite samples taken in sediment basin to estimate portion of clay which passes through the structure; recommend instrumentation.

THE EFFECT OF ORGANIC MULCHES ON SOIL MOISTURE REGIME

Objective: to measure soil moisture, soil and leaf temperature in organically mulched and unmulched soybean crops on light, medium and heavy textured soils; to develop a numerical model that links soil moisture under mulch to climatic data; to investigate the effect of management of mulch to optimize soil moisture regime for, and minimize interference with, subsequent crop production.

Output: Soil moisture, weekly and after rain; hourly air temperature, humidity, radiation, wind; soil temperature; bean growth - height to tip of apical bud, number of leaves, number of axillary branches, percent emergence, time to first flower, time to first pod formation, final yield including number of pods, number of seeds, seed weight, seed protein.

EFFECT OF MANAGEMENT ON SURFACE HYDRAULIC PROPERTIES

Objective: To test a new field portable, tension infiltrometer; compare with standard, more intensive lab measurements of hydraulic properties from field cores; compare measurements to runoff characteristics of soils under two tillage management systems, using rainfall simulation and two design storms; develop a standard field methodology for assessing the effects of management on surface hydraulic properties.

Output: Two soil types, clay and loam, under three management systems, no-till, fall moldboard, pasture or forest: measure surface infiltration rates, and compare to pore size distribution, sorptivity and hydraulic conductivity; examine surface runoff generation under simulated rainfall (2 sites, 2 tillage systems); evaluation of field method vs lab methods of measurements for evaluation effects of management on surface hydraulic properties.

ALLELOPATHIC EFFECTS; CAUSES AND REMEDIES

Objective: Determine effects of residue types and placement on phytotoxin production; determine effect of soil climate and chemistry on phytotoxin production and crop yields; determine residue management to minimize yield reduction; determine crop sensitivity to phytotoxins.

Output: Plant and soil samples (field) - organic acids, emergence rate, plant population, tillering, above ground biomass, grain yields; soil samples (lab) - phytotoxins (aliphatic and aromatic acids). rate of movement of phytotoxins, size, rate and distribution of residue, extent of decomposition of residue; effect of lime, N and P, calcium peroxide as a seed coating.

MONITORING AND EVALUATING THE EFFECTS OF SUBSOILING

Objective: To understand how and under what conditions submulch cultivation may be done and to determine its effectiveness and longevity on 13 farms.

Output: Detailed mapping of sites to describe soil uniformity, degree and depth of compaction, drainage, topsoil thickness; penetrometer resistance, bulk density, field moisture; cropping history; particle size, organic matter, nutrients, crop yields; farmer observations re: weed growth, ponding, erosion.

ACKNOWLEDGEMENT

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TILLAGE 2000

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THE CHALLENGE

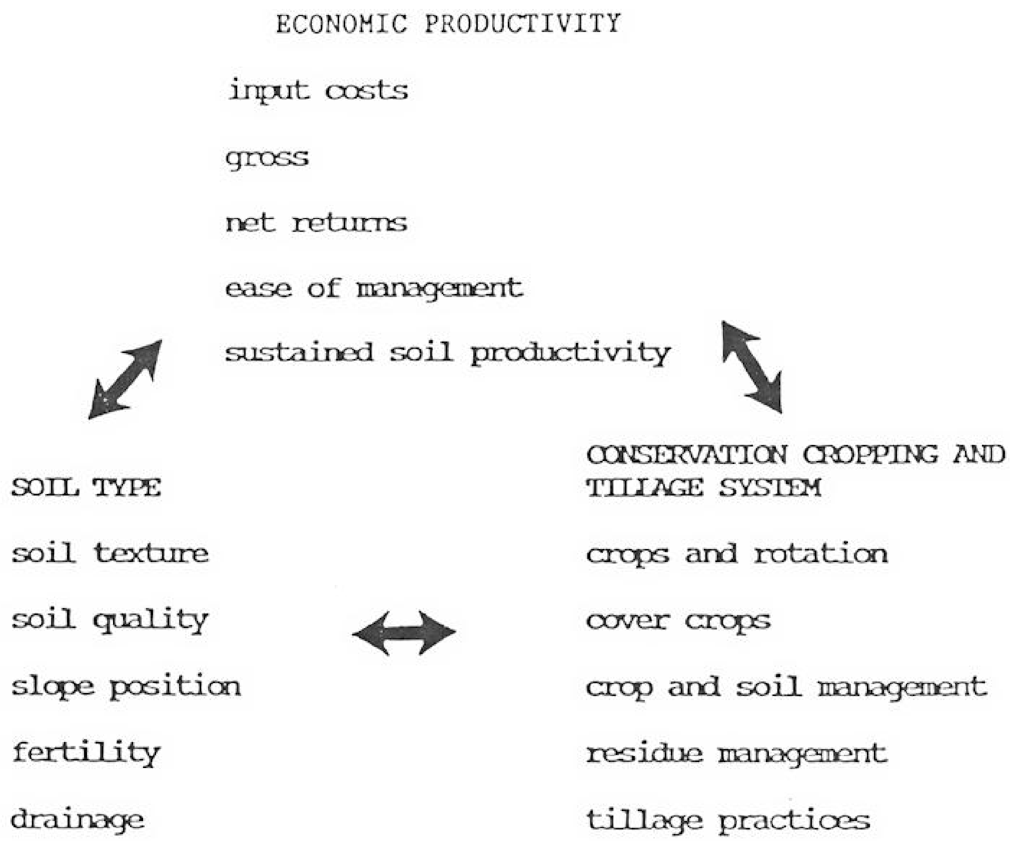
"To develop and evaluate conservation farming systems for specific soil types which maximize economic productivity and minimize soil degradation". That was and continues to be a big challenge, but one that is providing rewards and results. Historically, thousands of on—farm plots have been monitored in Ontario, unfortunately many lacked in design and management and rarely could the data From one be compared to others. T-2000 makes comparisons possible.

THE CONCEPT / OBJECTIVE

The main objective of Tillage 2000 is to develop and evaluate conservation farming systems for specific soil types, which maximize economic productivity and minimize soil degradation. The project will be conducted for at least five years on up to 40 farms across the province. Farms have been selected, with crop rotations and tillage treatments established.

Tillage 2000 is unique to soil conservation in Ontario by virtue of its methodology and process: the project includes both a research and demonstration component within an economic farm unit framework; the process is both investigative and developmental over several years. The program will introduce concepts of conservation systems to a larger number of farmers and provide a way to distribute known information and experience through field scale demonstration.

A viable conservation farming system must consider not only the cropping and tillage program, but also the soil resource and economic net returns. Tillage 2000 studies the relationships among these components as illustrated below:



Tillage 2000 is also a developmental process on each project farm. Conservation tillage systems that are not meeting expectations on a project farm are modified the following year to improve performance: successful components, unique to similar projects at other locations, are incorporated - as well as any ideas the cooperator may have to improve the system.

The farmer provides land, machinery and basically all the production inputs. Outside agencies provide technical help, to advise, monitor, harvest, sample the soil, calculate the results and to communicate with the cooperating farmer.

A paired sampling design was established on each of the field scale study sites because of the interaction between tillage and soil landscape on measured crop yield. Each study site has two field scale treatments, a conservation and conventional tillage system. The long axis of each plot was selected so that the major soil landscape units in the field would be split (paired) by the two tillage systems. Within each major soil landscape unit, permanent paired benchmark plots were established for collection of data from each tillage system. Three or four different soil landscape units were usually established at each study site. Thus, at each Tillage 2000 site there were approximately 2 tillage system, 3 or 4 soil landscape units per tillage system, replicated 2 to 4 times, which resulted in 18 to 32 benchmark sites.

MONITORING PROGRAM

TILLAGE AND CROPPING SYSTEM

For each treatment, information regarding field history and major aspects of operation were recorded. These included, crop rotation, type and use of equipment, estimated fuel consumption, applied herbicides and pesticides, seeding rates and date, applied fertilizer, and rainfall during the growing season. Machine harvest yields were obtained from each field treatment. Grain yield was measured from a strip within each field with a weigh wagon or its equivalent.

BENCHMARKS

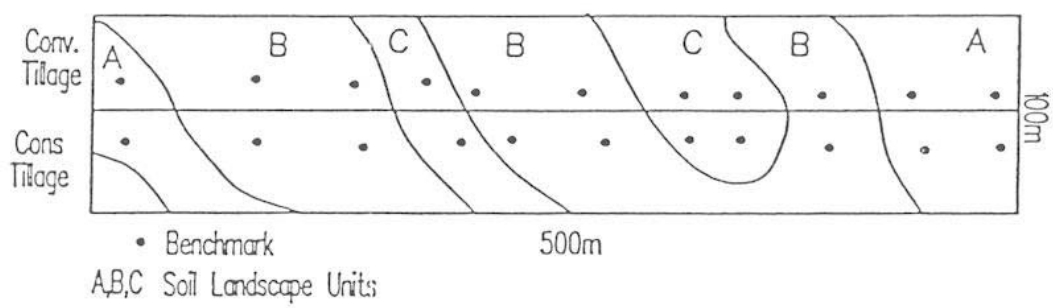
To establish the validity of the pairing of the benchmarks between treatments and to examine the integration between tillage, soil landscape, and crop yield, a detailed characterization of soil and topographic properties was undertaken in 1986. Undisturbed cores were taken to a depth of approximately 1 meter at each benchmark for some of the sites with a Giddings hydraulic sampler. The cores were sliced according to soil horizons and the samples saved for chemical and physical analysis. A grid of elevation readings were taken around each benchmark location for calculation of topographic parameters such as slope percent and length.

T-2000 AFTER 3 YEARS

- has a high profile with some researchers, writers, extension people and farmers
- provides good data which can be used effectively
- has shown that each site requires considerable time by the farmer and the extension staff
- still is strongly supported by the farmer cooperators - they like it!
- has enough data to do a complete analysis and make valid comparisons
- has people/researchers asking to use the sites to add new dimensions to the research
- has demonstrated that this type of project can work very well; cooperation by all parties is essential

FIELD PLOT DESIGN

Comparing the productivity of different tillage systems is complicated by variations in climatic conditions from year to year. Thus comparison should be made over a number of years of observation. In addition, specific combinations of soil and topography called soil landscape units can significantly influence crop growth and yield within a field.



Typical field plot design

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The detailed analysis will continue to take place over the life of the project.

EROSION

A subset of the permanent benchmark locations are being sampled in detail for measurement of a naturally occurring soil tracer, ^{137}cesium. The soil tracer is found only in the plough layer and will not move by leaching or be taken up by plants. Thus ^{137}cesium will move from a site only if the soil it is attached to also moves. Thus, the loss of ^{137}cesium from a benchmark location is directly related to the loss of soil from erosion. Soil samples will be taken in the 1987 growing season and again at the end of the project. The change in ^{137}cesium will be used to examine the interaction between topography, soil, and tillage system on erosion.

WHY SUCCESSFUL?

- Everyone benefits. The farmer refines his new technology on his farm, data is available, the soil conservation advisor gains experience in applying the technology.

- Other farmers seem to appreciate the data that has been collected in this manner.

- Cooperators get profile from publicity.

- Data is gathered on a variety of soil types and thus provides information that is usable in many situations.

- Data is available for specific sites for 3 years and this provides a useful information/history base for additional research.

- A core of cooperators is developing considerable expertise in conservation systems.

1987 HIGHLIGHTS

- The average conservation tillage yield index (conservation yield/conventional yield x 100) for all crops was 99.5 in 1987 and 97 in 1986.

- No-till corn grain yields in 1987 were on average equal or higher than conventional tillage yields.

- No-till corn grain yield response to applied N fertilizer (28% liquid N knifed in) was significantly different than conventional tilled yield response.

- Average production costs (dollars per bushel) were 9.5 % lower for no-tillage compared to either moldboard or minimum tillage systems. Net return (profits) to land, management, and risk was $7.50 per acre greater for the conservation tillage compared to conventional tillage system.

- For 250 acres of grain corn production the no-till system required an average of 65 hours less pre-harvest time than either moldboard or minimum tillage systems.

- Average surface residue cover after corn was 65%, 34% and 15%, for no-till minimum till, and moldboard plough, respectively.

- Changing the tillage system significantly altered the type of weeds and weed pressures indicating an integrated weed program has to be included in any tillage comparisons.

- I look forward to the highlights of the 1988 report which should be available in early 1989."T-2000 and its Effect on Awareness of Conservation Tillage" by K. Zimmerman, D. Blackburn, J. Shute, and R. G. Kachanoski.

I would like to refer to this report briefly for several reasons. The fact that this report exists indicates that someone has an interest in T-2000. The results are interesting from this comparison of 16, T-2000 cooperators and a random sample of 107 other farmers. Clearly they are different in many characteristics. I do not have the time to delve into this. I would like to quote from the report an interesting overview of what motivated these farmers to cooperate:

"The factors that motivated the demonstration farmers to participate in the Tillage 2000 program were varied. The majority wanted to experiment with and/or learn as much as possible about conservation tillage, and ranked this reason as "very important" (44 percent) or "moderately important" (19 percent). One-quarter of the demonstration farmers mentioned that they knew that someone was needed as a cooperator in their area, and felt they had a responsibility to participate. Another one-quarter were personally contacted, either by Tillage 2000 staff or conservation authority staff, and asked if they would participate in the program. In rank order, the remaining reasons given were: connections with the Soil and Crop Improvement Association (three respondents); previously practiced some conservation tillage (three respondents); concerned about preserving agricultural land for the future (two respondents); and the adverse effects of conventional tillage (one respondent).

Overall, the cooperators exhibited the conventional characteristics of innovators. This was displayed through: their desire to experiment and gain new knowledge; their sense of responsibility about participating in the program; their connections with other organizations; and the fact that they were well known enough in their communities to be personally contacted by Tillage 2000 staff."

Herein lies the secret to the success of this project - the cooperators. I have every reason to be optimistic for the next 2 years of this project. We are just beginning to accumulate sufficient data so that it can be interpreted and extended. The real benefits of this work of many people are just around the corner. The payoff should start in 1989.

FOOD SYSTEMS 2002 - AN UPDATE

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FOOD SYSTEMS 2002 is a new program announced by the Ministry of Agriculture and Food in January, 1988.This program was initiated to address many critical issues pertaining to pest control which currently face the agricultural industry, these being:

- environmental and health concerns
- resistance to pesticides
- an ever changing pest complex
- dramatic reduction in the availability of new chemical pesticides
- lack of viable non-chemical alternatives
- reduction in research emphasis on pest control

It has long been recognized that the continued intensive use of pesticides has serious limitations and hazards. Problems such as chemical persistence, acute and chronic toxicity, and bioaccumulation are not new. These terms were emphasized in the early 1960's by Rachael Carson in Silent Spring. Almost 30 years later many of the same concerns have come back as key issues in the political arena. In 1987, in Ontario, environmental and health concerns were the number 1 political issues. In the current political campaign these same issues are a continued high priority.

In relation to agricultural pesticide usage, we are faced with increased regulations and a much more educated and concerned vocal consumer and public. FS 2002 is designed to address many of these concerns.

The objective of FS 2002 is a 50% reduction in the use of pesticides over the next 15 years while still maintaining efficient sustainable agriculture. This does not mean we are planning to do away with chemicals but rather put more emphasis on environmentally-sound pest control methods.

FS 2002 is not a new idea. OMAF has been involved in Integrated Pest Management (IPM) Programs since 1969. IPM is a philosophy of crop protection that has been defined as a multi-disciplinary, ecological approach to pest management which utilizes a variety of control techniques compatible in a single coordinated pest management system. It does not attempt to eradicate pests, but rather to maintain pest populations below thresholds that cause economic damage.

Its primary goal is not the elimination of pesticides but the selection of the best control stratagems to produce a stable agroecosystem.

Ontario peach growers were the first commodity group to implement this philosophy for pest control. IPM was quickly expanded to include crops including apples, onions, carrots, grapes and pears. By 1985, IPM was implemented on a provincial basis on the above crops and was widely accepted by Ontario growers. IPM has been directly responsible for a decreased pesticide load of 25-40% in the environment. This reduction translates to a net savings in pesticide costs of $100/ha. at the grower level. Moreover, these figures do not in any way demonstrate important benefits to our environment.

FS 2002 is a well coordinated approach to the pesticide issue. The program involves three major components, these being: education, research, and field delivery. The total budget for the first 5 years of the program is $10million.

The EDUCATION component involves a total of $1 million over 5 years. This component is also based on past experience in the field. The Ontario Pesticide Education program (OPEP) was initiated in 1981 as a cooperative program involving the pesticide industry, the MOE and OMAF. Initially, this program was designed to address voluntary certification for aerial applicators and pesticide vendors. Under the new program emphasis will be placed on educating and certifying growers regarding the safe use and handling of pesticides. Our goal is to train some 35,000 - 40,000 growers over the next 5 years. This component is being coordinated through the Ridgetown College of

Agricultural Technology. In 1987-88 a pilot program involving 1,500 growers was carried out. Plans are well underway to expand this program to train 10,000 growers in 1988-89. Although at the present time, this program is voluntary, the writing is on the wall, and many grower groups are in support of and requesting mandatory certification. It is anticipated that after the initial emphasis on grower certification that education will also be directed towards the general public with emphasis on consumer education regarding wise and appropriate chemical usage in food production.

In 1988, a full-time coordinator was hired to operate this program. Approximately 300 grower courses will be run across Ontario in 1988-89. Trained individuals will be hired on a per diem basis to deliver these programs. OMAF has accepted the responsibility of training the growers, but it will be up to the MOE to develop the legislation and regulations for mandatory certification.

The second component of FS 2002 is RESEARCH. Research was the driving force behind the initial IPM programs. Today, agriculture is on the threshold of significant advances in biotechnology, many of which will be directly applicable as non-chemical alternatives to pest control. Possibilities include biogenetic engineering, pheromone disruption techniques, new chemistry, etc.

New research thrusts are required within the Ministry, such as:

- research into developing new technology to detect chemical residues in food
- research on the fate of pesticides in the environment
- new methods to detect new chemical residues
- new research into spray application technology
- systems analysis approach to pest management

In addition to the above, FS 2002 has also committed $800,000/year for the first 5 years for solicited research. In other words, OMAF is buying and funding research. The field delivery component and the various research committees will help identify research gaps that can be filled with research dollars. The research fund is designed to address both short-term as well as long-term research. Who can apply? - any organization such as Agriculture Canada, Universities, private organizations, private sector groups or individuals. At the present time, the main emphasis has been placed on literature searches to better define which directions we should pursue at this time.

The criteria established at this time for proposals include:

- non-chemical alternatives to pest control
- development of systems approach to crop pest control
- pesticide efficacy testing
- pesticide application technology

This fund will be controlled through the Agricultural Research Institute of Ontario via transfer payments. This means that we will direct research funding as it directly applies to FS 2002.

The final component of FS 2002 is FIELD DELIVERY. At present, IPM programs are only available for 6 commodities in Ontario. Under FS 2002 an additional 11 new full-time Pest Management Specialists will be hired to develop and implement IPM programs for an additional 19 commodities. In 1988, four new people were hired in the following locations and associated with the crops as listed:

- Clarksburg - apples, strawberries, asparagus
- Centralia - field corn, cereals
- Centralia - rutabaga, muck vegetables
- Vineland - greenhouse floriculture

In 1989, we plan to add another 5 positions throughout Ontario.

The duties of the Pest Management Specialists would include:

- to conduct feasibility studies, organize on-farm demonstrations and delivery IPM programs to growers.
- to develop and modify monitoring techniques, economic thresholds and methods of measuring climatic indices.
- to develop strategies for selection and timing of pest control options, such as timing of application, selection of IPM-specific pesticides, non-pesticide alternatives, etc.
- to monitor shifts in the pest complex (i.e. pests, newly-developed pesticide resistance and the presence of beneficial parasites and predators.

The Ontario Ministry of Agriculture and Food believes that this new program along with our other new initiatives such as Land Stewardship will ensure that Ontario remains in the forefront of agriculture in terms of high quality food production while demonstrating our commitment to a healthy environment.

FOOD SYSTEMS 2002 - AN ECOLOGICAL SYSTEMS APPROACH TO SUSTAINABLE CROP PRODUCTION

PESTICIDE MONITORING OF GROUNDWATER

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ABSTRACT

Since 1984 MOE has conducted pesticide monitoring programs of sensitive groundwater environments in predominantly corn and potato-growing areas in Southern Ontario. The programs are of 2 distinct types.

The first involves the sampling of domestic wells located in shallow sandy or fractured bedrock aquifers. The following pesticides have been analysed for: aldicarb in Alliston and alachlor, metolachlor and triazines province-wide. Except for Alliston, sampling of domestic wells has been undertaken either weekly or every two weeks. Samples are analysed for pesticides as well as total and fecal coliforms, and once each month a sample is taken for major ion chemistry including nitrate.

Since stricter sampling protocols were established in 1986, pesticides have been detected in shallow wells in sand plain areas. Atrazine and its metabolite d-ethyl atrazine, are the most commonly found triazine pesticides at levels up to 17.2 µg/L. The Ontario interim maximum acceptable concentration for total atrazine is 60 µg/L. Wells showing persistent levels of pesticide also show indications of other types of contamination such as: nitrate, chloride, sodium, potassium and total and fecal coliform bacteria.

The second type of program involves detailed monitoring of piezometers adjacent to cultivated fields where pesticides are applied. The MOE has two such monitoring programs. One is located in the shallow sand aquifer at Alliston and the other is in the shallow sand aquifer of the Caradoc/Bothwell sand plain between Bothwell and Strathroy.

At Alliston, 15 piezometers were installed in 1985, in nests of 2 or 3 at 6 sites downgradient from fields where aldicarb has been applied in the past. Piezometers have been sampled 2-4 times each year for aldicarb and major ions. Aldicarb has been detected in some monitoring wells at generally low levels of <2.0 ppb.

In the Caradoc/Bothwell sand plain 29 piezometers were installed in 1988 at 7 sites, in nests of 2 or individually. Piezometers are sampled weekly for triazine pesticides plus metolachlor and monthly for major ions. Five sets of soil samples, taken at shallow depth have also been analysed for pesticide. Atrazine and its breakdown product d-ethyl atrazine have been detected at 6 of 7 sites.

MOE SURFACE WATER QUALITY MONITORING PROGRAM

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ABSTRACT

The Ministry of the Environment (M0E) is responsible for the protection of surface water quality for aquatic life, recreation, and water uses. The primary concerns confronting the Ministry are maintenance of water quality at or better than the provincial water quality objectives and regulating and controlling point-source and diffuse-source pollutants.

To address these concerns, the MOE has in place several monitoring programs: Provincial Water Quality Monitoring Network Program, Great Lakes Surveillance Program, Drinking Water Surveillance Program, Inland Lakes Program, Biomonitoring Program, Acid Precipitation in Ontario Study Program and the Municipal and Industrial Strategy for Abatement Program. This report will deal only with the Provincial Water Quality Monitoring Network Program (PWQMN).

The PWQMN program comprises a Routine Monitoring Program (RMP), an Enhanced Tributary Monitoring Program (ETMP) and Complementary Programs. The RMP manages 740 monitoring sites sampled on a monthly basis, and addresses 90 parameters including physical, chemical, nutrients, microbiological, metals and trace chemicals, in addition to numbers of industrial organics and groups of pesticide residues. The data provide for spatial mapping of water quality affected area, degree of exceedances on PWQO, problem identification, and areas where serious attention may be required. The ETMP addressed more frequent sampling at 17 Great Lakes' tributaries with emphasis on loadings for total phosphorus and nine toxic contaminants.

Corollary to the ETMP are bedload and suspended sediment samplings at the 17 ETMP sites to detect sediment absorbed and particulate pesticides and other trace chemicals; and a MOE/OMAF-Laboratory study to scan for detection of 52 pesticide residues at three Great Lakes tributaries: Grand, Thames and Saugeen. In addition, there are other complementary intensive studies, such as, the 3-year study on pesticide and nutrient fate and transport from an agricultural watershed, which includes evaluating the effects of agricultural practices on pesticides runoff losses. Research studies deal with impacts of agricultural tile drainage on flow and tile drainage influence on pesticides and other contaminants removed from watersheds. There is also significant monitoring involvement in River Basin Studies.

INTRODUCTION

Based on the nature of variation in water quality conditions in the water bodies in Ontario, the Ministry of the Environment (MOE) has to satisfy many requirements so that a range of water quality issues can be addressed. Some of these requirements are maintenance of the ambient surface water quality conditions to equal or better than the provincial water quality objectives, reduction in diffuse-source pollution, assessment of quality relative to the uncertainties inherent in sources of pollution and variation in streamflows; and also, the appropriate use of the information relative to the specified program objectives.

From the monitoring perspectives the MOE addresses water quality concerns through its ability to provide surveillance, detecting trends and by identifying water quality problem areas; and the ability to assess responses of the river systems relative to pollution abatement programs; and being able to predict changes in quality in view of future developments in agriculture and industry.

The MOE has several wide-scale water monitoring programs, such as, the Provincial Water Quality Monitoring Network Program (PWQMN), the Great Lakes Surveillance Program, Inland Lakes Program, Biomonitoring Program, and the Acid Precipitation in Ontario Study Program. In addition, there are, effective pollution control measures for point-source discharges such as the Municipal and Industrial Strategy for Abatement Program; and MOE participation in developing measures to reduce and control diffuse-source pollution with other Ministries. The purpose of this presentation is to describe the structure of the PWQMN programs and to give a status of the programs and the extent of benefits the programs provide to the Ministry and public.

PWQMN PROGRAMS

The PWQMN comprises a Routine Monitoring Program (RMP), an Enhanced Tributary Monitoring Program (ETMP), and Complementary Programs including Intensive Study, Research and Basin Study. The PWQMN programs are extensive, in that, they are provincial, monitoring quality in rivers, lakes, watercourses and outlets of lagoons and other open water bodies. A wide range of parameters have been addressed by this program. These include physical, nutrients, chemicals, (organic and inorganic), heavy metals, trace metals, radiochemical; and pesticides. The sampling frequencies are carried out on a routine monthly basis, with enhancement in the ETMP. The PWQMN programs have a large data repository, providing information to the Ministry, other Ministries and the public.

ROUTINE MONITORING PROGRAM (RMP)

The objective of the RMP was to provide baseline water quality data, mainly for surveillance purposes. The size of the network is 740 monitoring sites. These sites are located in strategic geographic locations based on expected agricultural and industrial sources of pollution. A numerical distribution-based on the station specification is shown in Table 1.

It should be noted that emphases are on industrial and municipal pollution sources, surveillance and regional assessments. Other interests are agricultural sources, loading estimates for the International Joint Commission (IJC); and monitoring in specific areas for fish protection, water uses and recreation.

The PWQMN data base is used for different purposes. For example, the degree of spatial extent of a parameter on a provincial basis can be mapped, to give for example, spatial views of phosphorus and nitrate-nitrogen in the province. In addition, the number of times a parameter exceeds the provincial water quality objectives, based on the sampled information, can be assessed. Trends in parameter concentrations are of particular importance to the Ministry, because they give a sense of an increase or a decrease in quality over time. An increasing trend often indicates an emerging problem area. A typical trend curve for total phosphorus in the Grand River is shown in Figure 1.

A similar trend curve is shown for nitrates in Figure 2. A degree of control may be sensed for total phosphorus, because of the ongoing large scale IJC phosphorus reduction program measures to combat the increasing use of phosphorus products. The nitrate curves, on the other hand, have shown some increase in concentration over time.

An inventory of pesticides and industrial contaminants for all the monitoring samples encountered in the program since 1979-87 was assessed. Values were derived for number of samples with concentration less than the laboratory detection limits and number of samples with concentrations greater than the detection limits. It was observed that from the samples collected, only small percentages have been greater than the detection limits. The pesticide group (parameters) described included carbamates (8), chlorobenzenes (12), chlorophenols (4), organochlorines (23), organophosphorus (19), phenoxy acids herbicides (10), and triazines (10). Concentrations observed at above the detection limit were below the objective levels for those parameters with guidelines.

ENHANCED TRIBUTARY MONITORING PROGRAM (ETMP)

The objective of the ETMP was to detect contaminants and to provide tributary loadings to the Great Lakes, as a contribution to the IJC Water Quality Board report. Seventeen large tributary mouths are monitored in the Great Lakes basin. As described, the sources of pollution are industrial, municipal, urban and agricultural; while the sampling frequency is 40 to 100 samples per year.

Total phosphorus loadings into the Great Lakes is the IJC's primary concern. Contributions to the lakes during the period 1980 to 1987 are shown in Figure 3. The tributary contributions amount to approximately 75% of the total loadings to the lakes. As expected, the greatest loadings were contributed by the Lake Erie and Lake Ontario basins. Lakes Superior and Huron basins' contributions appeared to he consistent over the years in the order of 500 metric tonnes per year.

The greatest sampling frequency in the ETMP provides data which could be used to get a sense of the performance of the system in satisfying water quality objectives. This was assessed to determine how reliable the system is in satisfying the objectives, how quickly the system can recover, once failure occurred, in terms of a defined resiliency; and the significance of the consequences of failure described under vulnerability. A typical performance evaluation for total phosphorus was carried out for Grand River basin. It was observed, that at the objective level of 0.03 mg/L, the reliability was low (less than 5%) and once failure occurred, the failure condition remains in place for a long time. Vulnerability was also high, in that, a major economic effort would be required to remove phosphorus from the system to bring it back to the required objective level in the long term.

A greater degree of assessment can be made on frequency of detection for pesticides and industrial organics (Table 2). In addition, more reliable estimates of pesticide loadings (e.g. atrazine) could be determined (Figure 4). An increasing trend in loadings was observed over the years for atrazine in these basins.

COMPLEMENTARY PROGRAMS

The objectives of the complementary programs were to initiate intensive studies and research and to support basin studies. A recent intensive study on pesticide fate and transport provided a suitable management tool to predict pesticide (atrazine) and nutrient losses from watersheds. In addition, this tool was used to get a sense of how conservation management practices may affect pesticide losses from the watershed.

Research studies, which are ongoing, include evaluation of the impact of agricultural tile drainage on flows, sediment, nutrients and pesticide losses from watersheds.

As a regular practice the PWQMN is involved with river basin studies, such as TAWMS, Saugeen; and the RAP activities.

PWQMN PROGRAM BENEFITS

The PWQMN database is essential to resources and project planning because it provides suitable background and baseline information for these purposes. A major importance, based on the observed trends and exceedances of objectives, is that quality problem areas are identified, thereby, setting up a basis for research to address areas of concern. The network also provides a basis where large-scale issues on provincial water quality protection can be addressed, enabling answers to critical decision-making policy problems. In addition, to the primary purpose of surveillance, there are immediate assessments which can be made on the system response to ongoing abatement measures. The background information supports pollution control, regulation and enforcement; and provides records of detection of pesticide residues and other contaminants. Another benefit is the dissemination of information to the public through request, summary data, and interpretive reports.

FUTURE INITIATIVES

A number of developments are anticipated for the PWQMN programs. These include a reevaluation of the network in line with new Ministry perspectives; an expansion of the enhanced monitoring program to address more toxic contaminants and pesticides in concerned areas; expanding research in transport of toxic contaminants; and the development of pesticide screening models and technology transfers.

CONCLUSION

The PWQMN is one of several monitoring programs being carried out by the MOE to address surface water quality in the province. The PWQMN comprises a Routine Monitoring Program (RMP), an Enhanced Tributary Monitoring Program (ETMP) and Complementary Programs of Intensive study, Research, and Drainage Basin Studies. The RMP is used to provide provincial mapping of parameter concentrations, percentages exceeding the provincial objectives, trends and an inventory on provincial monitoring of pesticides and industrial organics.

The ETMP is used to describe contaminant loading intensities into the Great Lakes and the extent of the tributary system performance. More detailed detection of pesticides and loading estimates are also determined. A typical intensive study on pesticides, described the atrazine runoff losses from a watershed; and the effectiveness of a management model in predictions and simulation exercises. The research program is investigating the effects of agricultural tile drainage on streamflow and its impacts on sediment, pesticide and nutrient losses. The PWQMN supports basin studies and RAP activities through routine monitoring, baseline data, and interpretive analysis.

Future initiatives envisaged are a network evaluation and an expanding enhanced monitoring program to address several issues, such as, pesticide and other toxic substance monitoring and transport modelling. Benefits to the Ministry and other agencies include support to resources and program planning, research, abatement, surveillance, regulation and enforcement. In general, the PWQMN data repository provide information to the public through data dissemination and interpretive quality reports.

Table 1. PWQMN station specification.

Sources/Protection	No. of Sites	Percent
Industrial	80	10.8
Municipal	181	24.5
Surveillance	180	24.5
Urban	20	2.7
Agricultural	55	7.4
Fish Protection	18	2.4
Regional Assessment	131	17.7
Mixture (Water Supply, Recreation, extractive, IJC, others)	75	10.0

Table 2. Pesticides and PBC's frequency of appearance at the mouth of three river basins: 1981 and 1985.

	Frequency of appearance						
	Grand R		Saugeen R		Thames R		Total
Contaminants	(no.)	(%)	(no.)	(%)	(no.)	(%)	(no.)
(mg/L Level)							
2,4-D	9	8.7	8	5.7	61	29.9	78
dicamba	4	3.9	3	2.1	37	18.1	44
dichlorprop	1	1.0	1	0.7	16	7.8	18
2,4-DB	0	0	0	0	3	1.5	3
mecoprop	2	1.9	1	0.7	10	4.9	13
MCPA	1	1.0	0	0	4	2.0	5
EPTC	0	0	1	0.7	0	0	1
alachlor	3	3.2	1	0.7	11	5.4	15
atrazine	86	90.5	89	62.2	200	99.0	375
cyanazine	8	8.4	5	3.5	32	15.8	45
metolachlor	4	4.2	2	1.4	15	7.4	21
metribuzin	0	0	0	0	6	3.0	6
simazine	0	0	1	0.7	6	4.0	8
diazinon	0	0	0	0	1	0.5	1
malathion	0	0	0	0	1	0.5	1
(ng/L level)							
t-DDT	1	1.0	1	0.7	3	1.5	5
dieldrin	0	0	3	2.1	13	6.5	16
endosulfan	5	4.8	0	0	9	4.5	14
HE	16	15.2	5	3.6	33	16.4	54
PCBs	9	8.6	9	6.4	9	4.5	27

no. -- number of samples identified

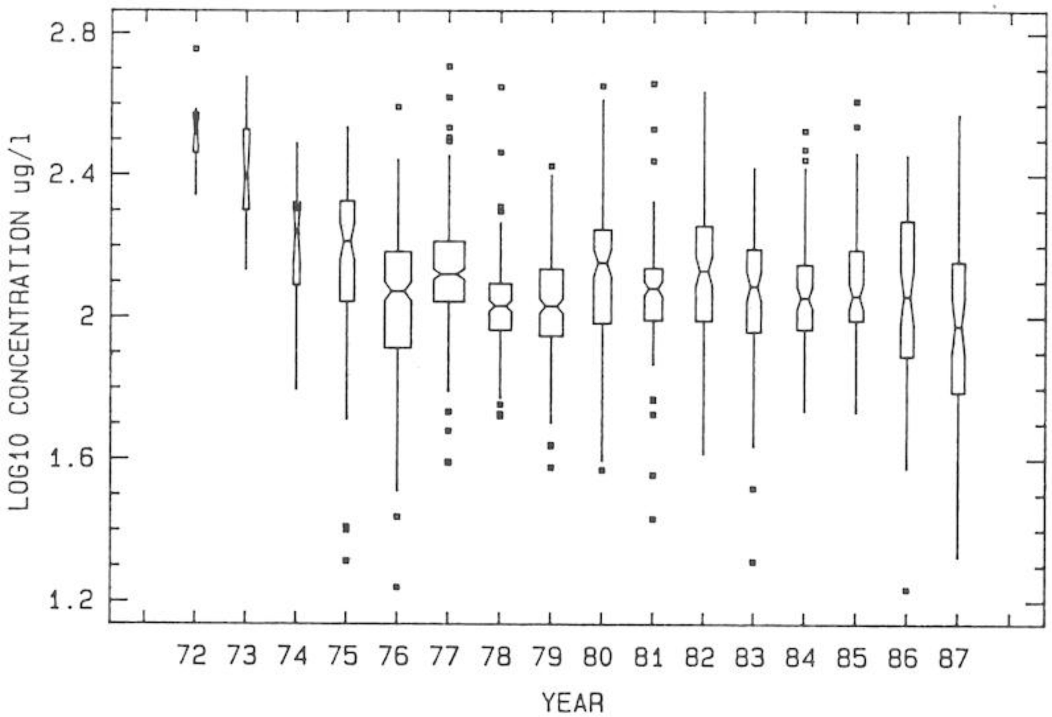

Figure 1. Total phosphorus trends, Grand River at Dunnville, 1972-87.

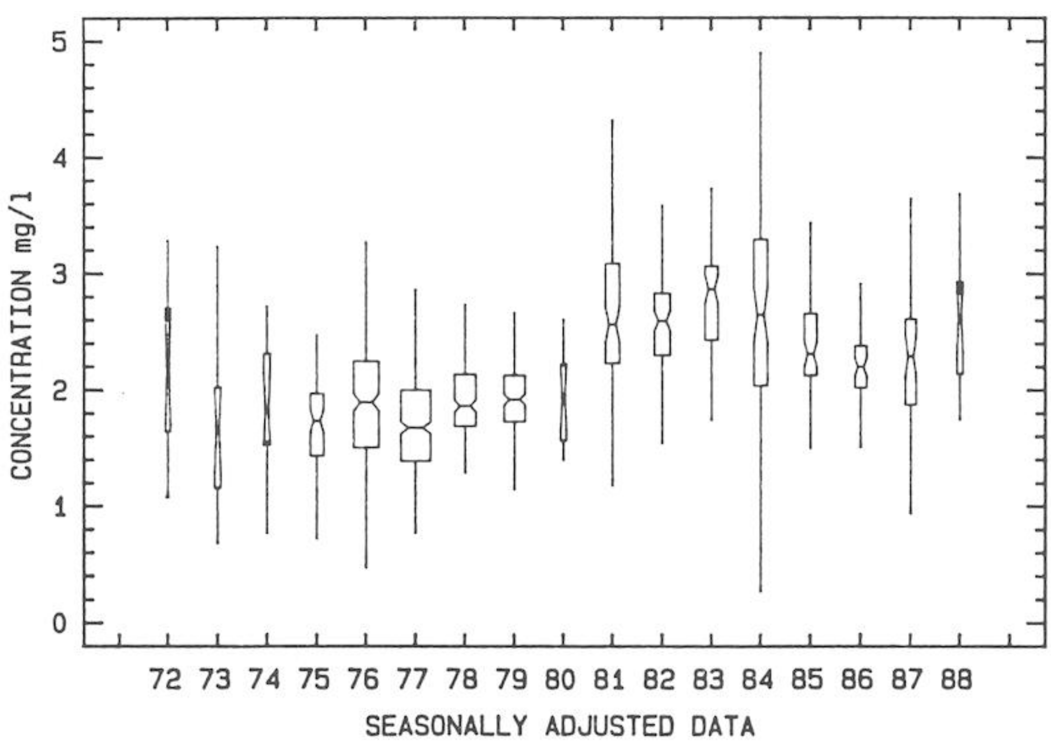

Figure 2. Total nitrate trends, Grand River at Dunnville, 1972-88.

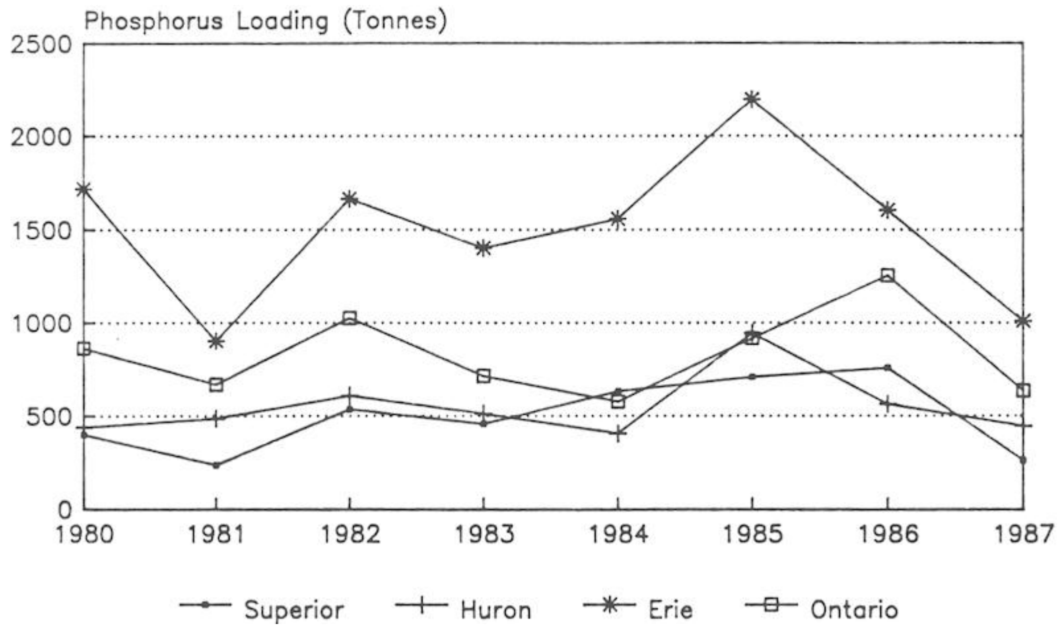

Figure 3. Tributary phosphorus loadings into the Great Lakes, 1980-1987.

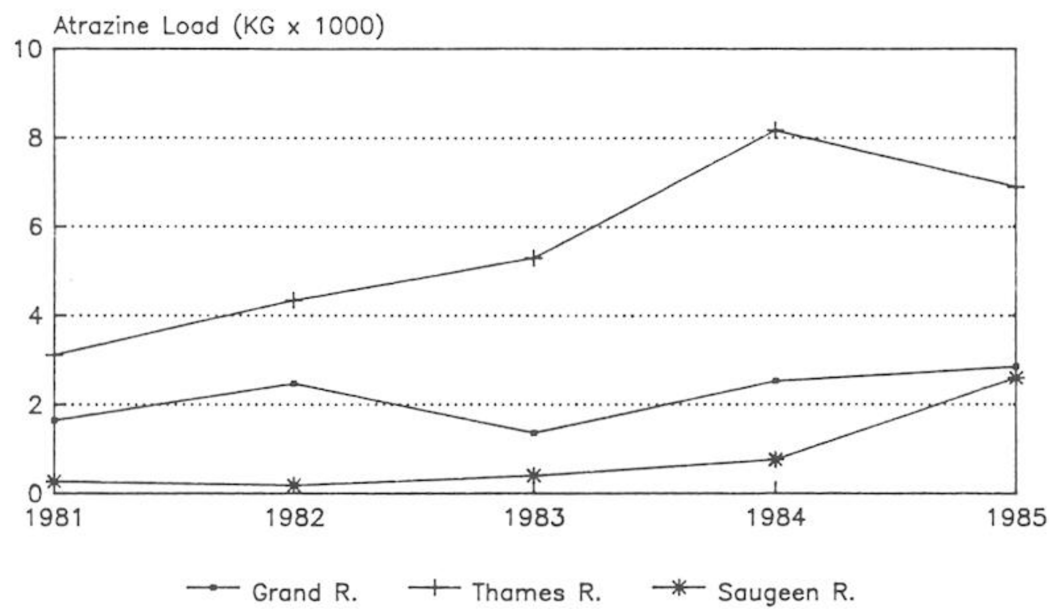

Figure 4. ETM atrazine loading, 1981-1985.

PESTICIDE ANALYSIS AND WATER QUALITY STUDIES

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The Provincial Pesticide Testing Laboratory, as part of Agricultural Laboratory Services Branch, Ontario Ministry of Agriculture and Food, has an objective to provide a world class chemical analytical laboratory service together with interpretation and advice on pesticides and toxic contaminant residues and metal content in food, feed, and the environment to government agencies, the farm community, the food industry and the general public. Another objective is to provide a resource group of expertise to the Ministry, the Government and society on issues dealing with pesticides, toxic contaminants, metals and nutrients with respect to foodlands, the consumer, and the environment.

There are four main activity areas: research, monitoring and surveillance, investigational, and service. The laboratory endeavors to maintain a balance between these four areas, however, ad hoc issues often swing the balance to one area or another. Often a specific issue, such as contamination of well water, can result in an increase in all four areas. For example, studies into the fate and persistence of herbicides and their mode of entry into water is research, determining the extent of well contamination is monitoring, examination of the causes in specific cases can be investigational, and the analysis of water samples for concerned citizens is service. Due to the flexibility of the staff and programs, on-going changes in the thrust within these four areas evolve in response to major issues or problems.

The laboratory has an analytical capability of over 300 different pesticides, metabolites or pollutants and will analyze almost any substrate. In 1987-88, 16,653 samples were analyzed and this represented 28,314 analyses. Of these samples, 1,112 (6.5%) were water.

Two classic studies conducted by the laboratory set the stage for many of the current research programs on pesticides in well and surface waters. "Herbicide Contamination and Decontamination of Well Waters in Ontario, Canada, 1969-78" focused on modes of contamination of wells and remedial measures. The three-year IJC study "Stream Flow Quality - Pesticides in Eleven Agricultural Watersheds in Southern Ontario, Canada, 1974-1977" detailed contamination of surface waters by pesticides.

Ongoing studies monitor the Grand, Saugeen and Thames Rivers for pesticides, the Dresden water treatment plant (raw and treated water) for herbicides, numerous wells across the province either weekly or as a one-time spot check, as well as investigations into well and pond contamination. Persistence of pesticides in soil and water is studied to assist in modelling runoff of pesticides and to make recommendations to farmers.

Investigations of suspected pesticide contaminations of rural Ontario wells and ponds indicate a large number of water sources become contaminated due to spills, spray drift or surface runoff water carrying pesticides into these waters. In 1985, monitoring of 351 wells susceptible to contamination showed 52% of the wells exceeded guidelines established by Health and Welfare Canada; up to six pesticides were found in some wells and residues > 500 µg/L were observed. In 1986, seasonal monitoring of 37 properly constructed and maintained wells indicated 4 (11%) were frequently contaminated whereas 20 (54%) had an occasional residue and 13 (35%) indicated no herbicide; residue concentrations were generally low (<5µg/L). Most high concentrations of contaminations result from carelessness or misuse of pesticides near the well whereas low level contaminations resulted from runoff into poorly constructed wells or through groundwater contamination. In many cases the contaminations were self-induced with the leading causes being due to back-siphoning, overfilling the spray tank, spilling of concentrate and washing equipment too close to the well or other water source. Atrazine, a widely used herbicide in the production of corn, was the most frequently found contaminant. A random sampling of 350 other wells between 1984 and 1988 confirmed these general trends. Other herbicides and a few insecticides were also detected.

In the last few years, extension programs, factsheets and grower certification programs have stressed protection of farm water supplies and offered good management practices and remedial measures. Grant monies (i.e., OSCAPAP II) have been made available to assist with this protection. During this period, the incidence of well contaminations has appeared to decline, however, the severity of contaminations, when they have occurred, have not changed. Continued educational and awareness programs are required on the safe use and management of pesticides and to protect the environment. Improvements in well and pond construction and maintenance are needed to prevent direct entry of pesticides into these water sources. In addition research programs are required to better assist growers in selecting and using pesticides while monitoring programs must be continued to ensure water quality objectives are met and new contaminations are not occurring.

NITRATE CONTAMINATION OF GROUNDWATER IN SOUTHERN ONTARIO: A HYDROGEOLOGIC PERSPECTIVE

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ABSTRACT

Over the past twelve years the Department of Earth Sciences at the University of Waterloo has participated in several studies dealing with the occurrence and transport of nitrate in groundwater.The results show nitrate to beubiquitous in unconfined aquifers in areas of intensive agricultural production, with concentrations ranging from below the drinking water limit (10 mg/L NO_3-N) to in excess of 50 mg/L NO_3-N. There is little question that agricultural fertilizer is a major contributor to the elevated nitrate values. Concentrations are highly variable in space, both in the horizontal direction and particularly in the vertical direction.This variabilityprovides convincing evidence that in some hydrogeologic environments, nitrate is chemically active. In particular, denitrification has been shown to be an active process in areas with shallow water tables (less than about 2 m below ground surface), while if the water table is at greater depth, denitrification appears to be of lesser importance. A recent study showed the presence of labile organic carbon below the water table to be the controlling factor on the occurrence of denitrification.The results suggest that enhancedtransport of organic carbon to the groundwater zone could stimulate denitrification, thus reducing nitrate concentrations in the aquifer.Inorder to pursue this hypothesis, an improved understanding of carbon cycling within the vadose zone is required.

INTRODUCTION

Nitrate is one of the earliest recognized anthropogenic sources of groundwater contamination, with serious concerns being raised in the 1950's and earlier. Recognizing nitrate in drinking water as a potential cause of methemoglobinaemea in infants, drinking water limits have generally been established at 10 mg/L NO_3-N, with no significant change in the limit for the past three decades. Recently however, concern has been raised regarding the formation of nitrosamines (highly carcinogenic) in the body as a result of ingesting nitrate, while (Dorsch *et al.*, 1984) showed a statistically significant increase in the risk of malformations of the central nervous system and musculoskeletal systems of offspring whose mothers' antenatal drinking water contained nitrate at concentrations in the range of about 1 to 3 mg/L NO_3-N.

With increasing population densities and the increased use of agricultural fertilizers, nitrate contamination of shallow groundwater supplies has become more extensive and more severe. For example, many municipal supply wells in Denmark and other parts of Europe show steadily increasing nitrate concentrations since the early 1950's, with many wells now being taken out of production as concentrations surpass the drinking water limit. While the severity of nitrate contamination has been relentlessly increasing, regulatory agencies and the research community have been largely occupied by more recent concerns such as radioactive wastes and hazardous wastes from industrial sources. Clearly it is time that greater attention be focussed on the nitrate problem. Particular areas requiring thorough examination include:

- health effects of nitrate in drinking water
- fate and transport of nitrate in groundwater
- remediation technology
- improved management of agricultural and other sources of nitrate
- point-of-use treatment systems.

In this paper, information concerning the occurrence of nitrate in agricultural watersheds of southern Ontario is reviewed and the results of specific studies to examine the occurrence of denitrification in groundwater are presented.

OCCURRENCE OF NITRATE CONTAMINATION IN AGRICULTURAL WATERSHEDS OF SOUTHERN ONTARIO

The groundwater group at the University of Waterloo has been involved in studies of the occurrences of nitrate in groundwater for about 12 years. The initial study involved a detailed investigation of the occurrence and transport of nitrate in a small agricultural watershed (Hillman Creek) in southwestern Ontario. Unlike most previous studies of a similar nature,nitrate concentrations were not determined from existing wells, but from nests of sampling wells, thus providing an opportunity to observe variations in concentration with depth.

The surficial geologic material was a medium to fine sand underlain by a clay-till. The water table occurred in the sand at a depth varying from about 1 to 4 m below ground surface.Most of the watershed was under intensiveagricultural production with potatoes, tobacco, tomatoes, orchards, and cereal grains as the principal crops.

Observed nitrate concentrations varied between zero and about 60 mg/L NO_3-N. The highest values tended to occur in areas of high fertilizer application; however, there was considerable variation in concentration both areally and with depth. It was clear that large regions of the aquifer were contaminated to levels that were well above the drinking water limit, and agricultural fertilizer was the most probable cause. At most monitoring sites the nitrate concentration was high in the vicinity of the water table, then declined to zero values at depths greater than about 1 to 2 m below the water table. This trend could not be explained by consideration of the physical flow system and transport processes; however, the observed decline in nitrate concentration was observed to correspond with a decline in dissolved oxygen (D.O.) values and Eh.

Denitrification is the only geochemical process with the potential to remove significant amounts of nitrate from groundwater.Under reducingconditions, and in the presence of denitrifying bacteria and a sufficient supply of labile organic carbon, denitrification results in the transformation of nitrate to nitrogen gas.Thus the geochemical profiles indicated thatnitrate was being lost through denitrification, a conclusion that was further supported by a nitrogen balance performed on the basin. Further details of this particular study are given in Hendry et al. (1983). In a subsequentstudy in a similar hydrogeologic environment, an injection-withdrawal tracer test confirmed the occurrence of denitrification (Trudell *et al.* 1986). Substantial denitrification rates, ranging from 7.8×10^{-3} to 1.3×10^{-1} mg/L.hr NO_3-N were observed.

Recognizing the potential importance of denitrification in the management of agricultural watersheds, several vertical profiles of nitrate and D.O. have been determined in eight additional sandy agricultural areas of southern Ontario. A portion of the data is summarized in Gillham and Cherry (1978). In all cases, elevated levels of nitrate, frequently above the 10 mg/L NO_3-N drinking water limit were detected. Comparing these values with those typical of uncultivated sandy watersheds in Ontario (less than 1 mg/L NO_3-N), there seems to be little question that agricultural activity is a major contributor to nitrate contamination of groundwater. Furthermore, based on the apparent ubiquity of nitrate contamination, it is reasonable to suggest that nitrate contamination will occur in all surficial sandy aquifers in areas of intensive agricultural activity. Further evidence to this effect can be found in Hill (1982), who showed significant nitrate contamination in a shallow aquifer near Alliston, Ontario, to be limited primarily to those areas that were under intensive agricultural production.

In examining data from the detailed vertical profiles, two important trends were observed. Of the several hundred samples that were analyzed, almost all of those that showed D.O. values of less than 1.5 mg/L had nitrate concentrations of less than 2.0 mg/L NO_3-N. Furthermore, most high nitrate values were accompanied by D.O. values in excess of 1.0 mg/L. Though far from conclusive, the evidence suggests that denitrification is a common process in groundwaters, and that provided the dissolved oxygen concentration is low, denitrification is likely to occur. This implies that the presence of bacteria in the subsurface and the availability of organic carbon are generally not limitations to denitrification. It was further observed that in areas where the water table was less than about 2 m below ground surface, both nitrate and D.O. declined to near zero values at depths of about 1 to 2 m below the water table, indicating the occurrence of denitrification. On the other hand, if the water table was at greater depth (greater than 3 or 4 m below ground surface) both nitrate and D.O. persisted to considerable depths below the water table, indicating that in these situations denitrification was not a significant process. This characteristic behaviour is demonstrated in the examples of Figure 1. The persistence of this pattern was considered to hold important clues concerning the factors that control the occurrence of denitrification.

NATURAL CONTROLS ON THE OCCURRENCE OF DENITRIFICATION IN GROUNDWATER

It was postulated that under shallow water-table conditions, significant amounts of labile organic carbon are leached from the soil zone to the water table. Once below the water table and removed from a source of oxygen, continued degradation of the organic carbon causes the D.O. to be depleted. In the absence of dissolved oxygen, denitrification can proceed. Under deep water table conditions, it is suggested that most of the labile organic carbon is oxidized (biodegraded) within the unsaturated zone before the infiltrating water reaches the water table. Thus, upon reaching the water table, there is little biological activity and the dissolved oxygen concentrations remain high, preventing denitrification.

To test this hypothesis, a column device was developed for measuring denitrification rates in situ (Starr, 1988 and Gillham *et al.*,1989).Watercould be withdrawn from the device, ammendments added before reinjection and samples collected in order to observe chemical changes over time. In addition to nitrate, and in some cases glucose, acetylene was added to the injection water to inhibit the conversion of nitrous oxide (N_2O), an intermediate produced in the denitrification process, to nitrogen gas.Thus the rate ofaccumulation of N_2O was used as a measure of the rate of denitrification.

Two field sites were selected, one where denitrification was believed to be an active process (Rodney), and one with a deep water table where denitrification was not believed to occur (Alliston). Detailed geochemical profiles, including dissolved and solid-phase organic carbon, were determined at both sites. Figure 2 shows results of the in situ denitrification tests. From Figure 2(a) it is evident that denitrification occurs under natural conditions at the shallow water table site, while the absence of N_2O in the deep water table test (Figure 2b) indicates that denitrification does not occur at this site. In subsequent tests, the addition of glucose to the deep tester caused denitrification to proceed, indicating that the occurrence of denitrification under natural conditions was not limited by the absence of suitable bacteria, but rather by the absence of an adequate carbon source for the bacteria.

The results were consistent with higher concentrations of dissolved organic carbon below the water table at the shallow site than at the deep site. Supplementary microcosm tests were conducted in the laboratory to determine the potential of the soil material at both sites to support denitrification. At both sites the upper soil zone had the potential to support high rates of denitrification. This potential declined with depth however. At the deepwater table site, little or no denitrification could be detected in samples collected from depths greater than about 2.0 m below ground surface. This agrees with the results of the *in situ* tests, and gives further support to the initial hypothesis. Further details of this study are given in Starr (1988) and Starr and Gillham (1989).

CONCLUSIONS AND IMPLICATIONS

It is clear that many surficial aquifers in southern Ontario are contaminated by nitrate to concentrations above the current drinking water limit. However, because of uncertainty in the health effects of nitrate, the severity of the problem remains in question. It is equally clear that agriculture is asignificant contributor to nitrate contamination of groundwater.

The studies presented have shown that once within the groundwater system, nitrate does not necessarily behave as a non-reactive solute. Indeed, under some circumstances, denitrification can result in substantial losses of nitrate, with the major control on the occurrence of denitrification appearing to be the presence of labile organic carbon in the aquifer. In areas where denitrification is an active process, increased use of fertilizers is likely have little effect on the degree of nitrate contamination. Furthermore, it is quite likely that the quality of domestic water supplies in these areas could be improved by installing well screens at depths considerably below the upper zone of contamination. Recognizing organic carbon as the limiting factor in denitrification, consideration should be given to the development of management practices that promote the leaching of organic carbon. Before this can be addressed effectively, more must be learned regarding the leaching and transport characteristics of organic carbon in the unsaturated zone.

To reduce levels of nitrate contamination, particularly in areas where denitrification is not likely to proceed, revised and improved land management practices may be required. Timing of fertilizer application or the use of slow-release nitrogen fertilizers should be considered.

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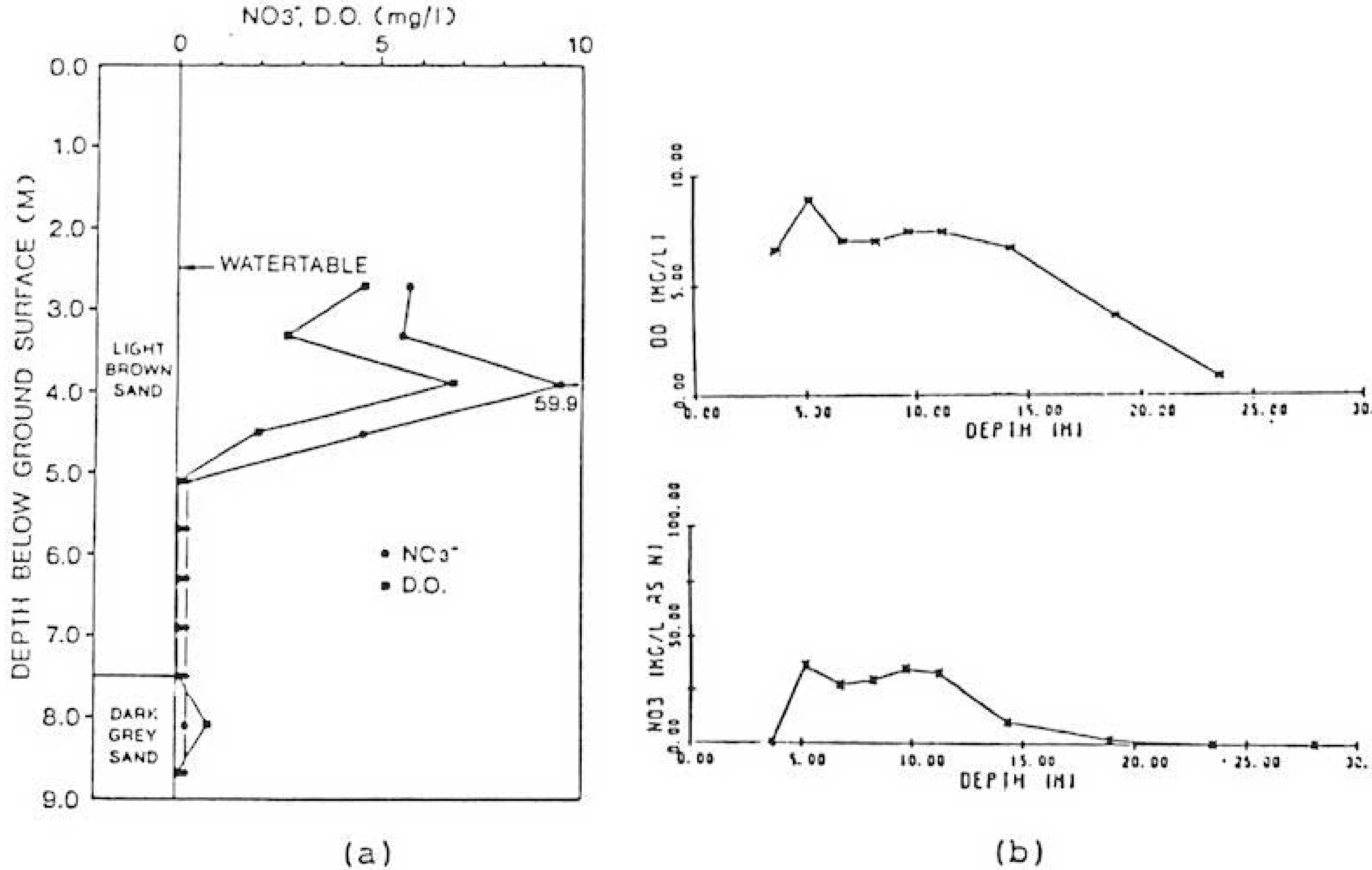

Figure 1: Vertical profiles of nitrate and dissolved oxygen concentration (a) shallow water table (Hillman Creek), (b) deep water table (Alliston).

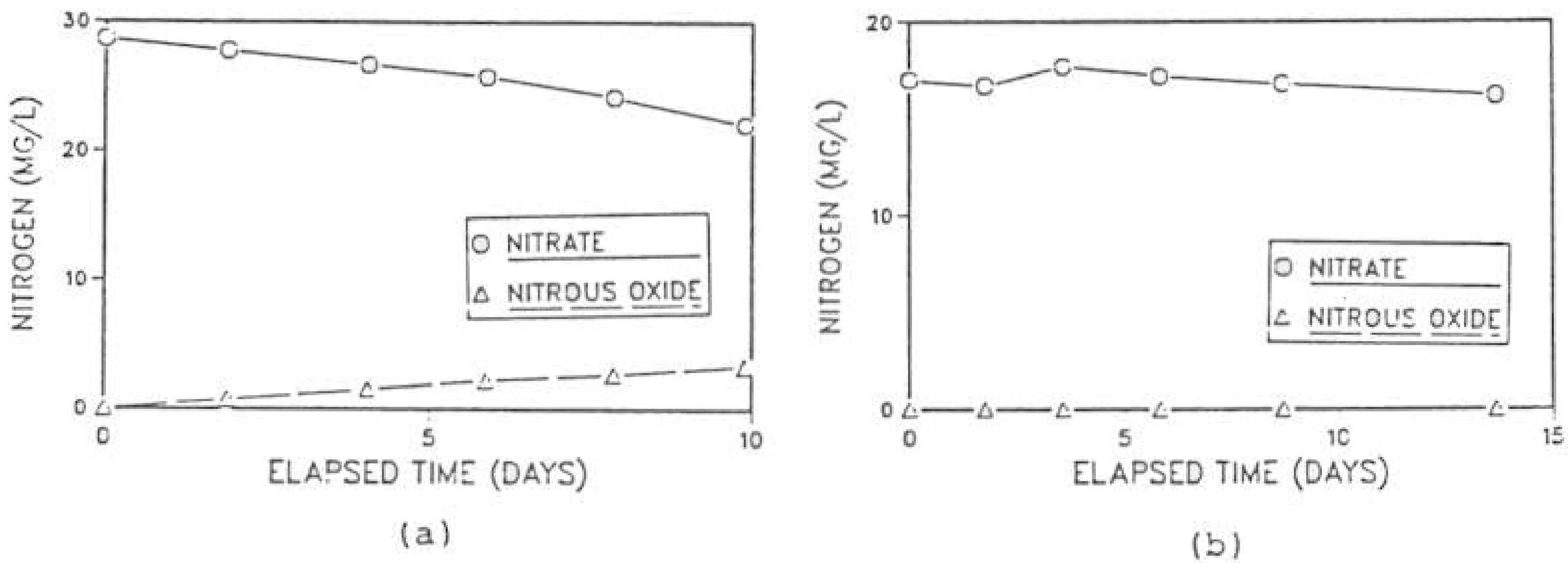

Figure 2: *In situ* measurement of denitrification (a) shallow water table (Rodney), (b) deep water table (Alliston).

IMPACT OF AGRICULTURAL PRACTICES ON SUBSURFACE WATER QUALITY

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ABSTRACT

Faculty members from a number of departments have been involved for several years in studies on the impact of the use of agricultural chemicals in crop production on water quality. Major emphasis has been on the contribution of nutrients, particularly nitrate nitrogen and phosphorus, to ground and surface waters. Studies have ranged from development of theoretical models for transport in unsaturated soils to measurement of nutrients in water supplies under field conditions. Current studies are focused on NO_3-N in groundwater from fertilizer application on sandy soils and from application of livestock manure. Past and present studies will be briefly summarized, and an overview of the issues as we view them will be presented.

INTRODUCTION

The impact of agricultural practices on surface and subsurface water quality has been a major concern of faculty at the University of Guelph for many years. Several faculty from the University were involved in the IJC PLUARG program (Pollution from Land Use Activities Reference Group) particularly in relation to sediment and phosphorus in runoff from agricultural land and in the impact of livestock operations on surface water quality. Following PLUARG, studies have continued with particular emphasis on modelling sediment and phosphorus in runoff. These Studies, conducted primarily by W.T. Dickinson and R. Rudra in the School of Engineering have resulted in the development of GAMES (Guelph Agricultural Model for Erosion and Sediment) and GAMES-P. PLUARG and more recent studies related to surface water quality have received full consideration in discussions of the SWEEP program so will not be discussed further here. Several faculty, R.G. Kachanoski particularly, have major involvement in the SWEEP program.

The purpose of this paper is to present issues relating to agricultural practices and the quality of subsurface water.The term subsurface water rather than groundwater is used because of the intensive tile drainage systems in Ontario which intercept the water as it moves toward the groundwater. Chemicals in this water thus appear in surface water rather than moving to the groundwater.

ISSUES

The major concerns for subsurface water quality are phosphorus, pesticides and nitrate-nitrogen (NO_3-N).

PHOSPHORUS

Phosphorus enters water supplies primarily through surface runoff. This issue is being addressed by the SWEEP program.Except in unusual situations (exorganic soils or soils with severe crack development) movement of phosphorus into tile drains or groundwater is slight. Under very intensive and continued application of manure it is possible for the P content of the soil profile to become so great that P leaching into tile drains or shallow groundwater will occur. This is a concern in Western Europe, but I don't believe this will be a significant concern in Ontario in the foreseeable future.

PESTICIDES

The issues of pesticides in the environment have gained a great deal of public attention and will continue to do so. Clearly there are many questions that must be addressed. The complexity in terms of the continuing introduction of new chemicals, their properties, their reactions in the soil and the degree to which they pose a threat to health of humans or animals makes it difficult to define the research needs. As a result, research programs tend to bereactive, responding to specific questions as they arise, rather than anticipatory.

NITRATE-NITROGEN

Nitrate-nitrogen in subsurface water will, in my opinion, become one of our most serious concerns within a very few years. Laws are currently in place in a number of U.S. states to control the use of nitrogen fertilizer and to control rural real estate development based on NO_3-N concentration in water. There are suggestions that the currently accepted safe limit of 10 mg NO_3-N/L should be lowered to 1 mg/L. Some subsurface water supplies in rural Ontario now exceed the 10 mg/L limit; many exceed the 1 mg/L level. The remainder of this paper will deal with this issue.

NITRATE-NITROGEN INPUTS TO SUBSURFACE WATER

The two major sources of excess NO_3-N are animal manure and fertilizer use, either separately or in combination.

ANIMAL MANURE STORAGE

Storage of animal manure does not pose a direct threat to NO_3-N in water supplies. Manure, either fluid or solid, contains little NO_3-N. Aerobic microbial processes are required to convert the ammonium (NH_4) or organic N to the nitrate form. The supply of readily usable carbon in manure inconjunction with the slow movement of oxygen into the material normally precludes significant nitrification. When NO_3-N is formed it will usually be converted to gaseous N through denitrification in anaerobic microsites.

A study conducted on a manure storage pond at a large beef feedlot near Kitchener demonstrated clearly that fluid manure storage is unlikely to contribute NO_3-N to subsurface water (Miller *et. al.* 1985). The storage pond was located on a coarse sand material but the bottom of the pond sealed within two months of the addition of manure. Although NO_3-N concentrations in groundwater over 12 m below the surface in areas surrounding the pond were high (over 30 mg NO_3-N/L), NO_3-N concentrations in the groundwater directly below the pond were reduced to essentially zero during a brief period after addition of manure to the pond. This is thought to be due to denitrification in the groundwater as a result of input of carbon from the manure during the short period before the pond became sealed.

LAND APPLICATION OF MANURE AND FERTILIZER NITROGEN

Nitrogen is the nutrient most often limiting crop production in Ontario. This is due in part to the high requirement of most crops, but primarily to the dynamic nature of nitrogen in the soil system. All nitrogen added to the soil as manure or as fertilizer will eventually be converted to the nitrate form. Because NO_3-N is not adsorbed to the soil, it moves freely with the soil water. In Ontario where precipitation exceeds evaporation during much of the year, any NO_3-N not absorbed by the crop will be either denitrified or leached and thus lost to succeeding crops. Hence there is little buildup of N in the soil as occurs with P and K, and the nitrogen requirements of the crop must be supplied on an annual basis.Except where a legume crop is included, thisnitrogen will be added as manure and/or fertilizer. Nitrogen recommendations, based on the requirements of the crop to be grown and the past history of the field, are designed to provide the most economic return.

One major question that we need to answer is: If nitrogen is applied according to recommendations is there likely to be significant contributions to drainage water? Some evidence related to this question was obtained in a study of tile drainage water in Kent Co. The NO_3-N concentration was monitored on a continuous basis for two years on six sites. The average concentration ranged from 4 to 16 mg NO_3-N/L. The total annual output ranged from 4 to 57 kg N/ha. On four of the 6 sites where N applications were equal to or less than recommended, the maximum average concentration was 8 mg/L and the maximum annual contribution was 16 kg/ha. On the remaining two sites where the application exceeded the recommendation by as much as 50 kg/ha, the average concentration was 16 mg/L and the average annual contribution was 56 kg/ha. These data suggest that current recommendations, in addition to being most economic, also provide reasonable protection of the environment. Further data are required to confirm this suggestion.

Even if the current recommendations are found to provide adequate protection of the environment, several problems exist with manure management. A partial list is as follows:

1) The N content of manure is usually not known
2) Manure can not always be applied at a time that makes most effective use of the nutrients
3) Many livestock operations do not have sufficient land available to allow application at rates below those recommended.

As a result of these and other problems, applications of manure in combination with fertilizer often exceed recommendations. Research is urgently required to allow the development of recommendations in which farmers have greater confidence and which will ensure protection of water quality.

ONGOING RESEARCH PROJECTS

BACKGROUND PAPER ON IMPACT OF ANIMAL MANURE ON WATER QUALITY

A 3-month contract funded by Ontario Ministry of the Environment. To be completed in early 1989. This background paper will review current literature applicable to Ontario, present information on past and present Ontario studies, assess our current understanding and establish research priorities. Participants: M.H. Miller, E.G. Beauchamp, R.G. Kachanoski and H.R. Whiteley.

FATE OF MANURE N AT ARKELL, ELORA AND PONSOMBY RESEARCH STATIONS

A 3-year study funded by OMAF beginning in 1988. The study will monitor N concentration in groundwater in relation to manure use as well as determine the availability of manure N more precisely. Participants: E.G. Beauchamp and H.R. Whiteley.

NITRATE CONTAMINATION OF GROUNDWATER WITH SANDY SOILS USED FOR TOBACCO

A 3-year study beginning in 1988 at Delhi research station funded by Agriculture Canada as part of the tobacco replacement research program. The study will determine the extent of leaching of NO_3-N when corn replaces tobacco on the sandy soils in the region. The fate of fertilizer N with different tillage and irrigation management systems will also be studied. Participants: E.G. Beauchamp, R.G. Kachanoski, D.E. Elrick and D.M. Brown.

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NATIONAL WATER RESEARCH INSTITUTE PESTICIDES RESEARCH PROGRAM

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ABSTRACT

Research on pesticides at the National Water Research Institute is carried out to generate information on the nature, extent and effects of contamination of the aquatic environment resulting from pesticide use. This information will be used for the establishment of water quality guidelines and criteria, and in the evaluation of pesticide registration data.

There are approximately 500 pesticides registered for use in Canada. Part of the pesticide registration and re-evaluation process overseen by the Department of Agriculture is the identification and evaluation of concerns regarding human safety and adverse environmental effects.The aim ofpesticides research at NWRI is to provide information which will be used to assess the hazard posed by pesticides to acquatic environments.The hazardposed by a toxic substance to an organism in any medium such as water or sediment is a function of its toxicity and its concentration, and its persistence in water or sediment.Pesticide research at NWRI encompassesanalytical method development, determinations of persistence and fate, biomonitoring and determinations of effects on aquatic organisms, communities and ecosystems. Examples from each of these areas will be given below. The choice of a particular pesticide to be investigated may he dictated by (i) Pest Control Products Act or Canadian Environmental Protection Act priority lists, (ii) regional considerations, and/or (iii) perceived gaps in the scientific literature. Alternatively, a pesticide may be simply chosen to demonstrate a phenomenon such as partitioning between dissolved and particulate phases, volatilization, or formation of bound residues in sediment.

ANALYTICAL METHODS DEVELOPMENT

A study on atrazine and neutral herbicides in sediment is in progress. Methods recently developed and submitted to the National Water Quality Laboratory for inclusion in the IWD Analytical Methods Manual are:

- dinoseb in water by *in situ* acetylation
- nitrophenols in water
- nitrophenols in sediment
- acid and neutral herbicides in water
- acid and neutral herbicides in sediment
- chlorophenols in sediment

Current work in analytical methods development includes immunoassay screening techniques. Conventional methods for the analysis of trace organic contaminants in environmental samples are generally time-consuming and expensive. Often, many samples that are contaminant-free must be extracted and cleaned up before being analyzed by GC or GC-MS techniques. The inclusion of a pre-screening step in the analytical protocol for such contaminants would, by the elimination of those samples that are contaminant-free from subsequent analysis, greatly reduce analytical costs. Samples which test positive using the screening assay can be analyzed using conventional methods. Of the pre-screening tests that have been suggested for this purpose, immunoassays appear to offer the most promise. Based on the classical antigen-antibody reaction, immunoassays are relatively simple, powerful and adaptable techniques for the rapid determination of trace levels of organic compounds. Originally developed for the micro-determination of proteinaceous substances, they are also extensively used in the determination of steroidal hormones and other low molecular weight organic molecules. An immunoassay technique is currently being developed for atrazine in fresh water.

PERSISTENCE AND FATE

TRIBUTYLTIN

Tributyltin, the active ingredient in some antifouling paint formulations, is perhaps the most acutely toxic chemical to aquatic organisms ever deliberately introduced to water.It was demonstrated to have an adverse effect onshellfish in France and England, and as a consequence, the use of tributyltin-containing antifouling paint has been restricted in these countries. Tributyltin has been found in Canada mainly in harbours, marinas and shipping channels. In some locations, concentrations were high enough to affect sensitive organisms.Biological degradation of tributyltin in waterand sediment appears to be the most important factor limiting the persistence of tributyltin in aquatic environments. To some degree, then, the persistence of tributyltin in aquatic environments depends upon the nature of the ecosystem. Half-lives for the disappearance of tributyltin are in the range 1-10 weeks for water, and 16 weeks for sediment. In October 1987, theDepartment of Agriculture proposed a limited ban on antifouling uses of tributyltin (restricted to vessels longer than 19.5 m, with limits on short and long term release rates from larger vessels). This ban will help Canada avoid the unfortunate experience of other countries that have large numbers of tributyltin-painted boats close to vulnerable fisheries.

ALDICARB

The persistence of aldicarb and its toxic transformation products aldicarb sulfoxide and aldicarb sulfone has been observed in PEI groundwaters of low pH and high nitrate concentration.High aldicarb concentrations rarely appearwithout elevated nitrate concentrations. The high permeability of PEI soils offers a physical explanation for this phenomenon; however, the low pH values suggest that there may be a chemical reason as well.We have shown bygeochemical simulation that the oxidation of ammonium nitrate fertilizer produces nitrate and a low pH groundwater. Under the low pH - low temperature regime in PEI soils, aldicarb degradation to less toxic species is reduced. Consequently, the degradation of fertilizer residues in PEI appears to inhibit the degradation of aldicarb. This phenomenon could be avoided by application of aldicarb following plant emergence in late June rather than at seeding in May. This would allow the soil temperature to rise considerably, and for the bulk of the ammonium ion oxidation to take place in the absence of aldicarb. A further reason for applying aldicarb, at plant emergence rather than at seeding is that aldicarb is a systemic insecticide which is taken up by plant roots. Since no roots exist at the time of seeding, uptake is minimal and leaching is promoted.

DELAMETHRIN

Deltamethrin sprayed on a pond and stream in PEI disappeared quickly from subsurface water, with a half-life of about 1 hour. Major routes of degradation or dissipation were (i) chemical and photochemical conversion to inactive (2+2')-deltamethrin stereoisomers, and (ii) hydrolysis with subsequent oxidation of products. No residues of deltamethrin stereoisomers or any of the four major products sought were found in water or sediment 11 days post-spray. Laboratory experiments on the volatilization of deltamethrin formulations from sprayed water as opposed to subsurface-injected water indicated that volatilization from the surface microlayer was a very fast process which could be <u>the major route</u> of dissipation of deltamethrin, or any lipophilic pesticide, sprayed on the surface of water. We have previouslymade this observation with fenitrothion sprayed on a pond during forest spraying against the spruce budworm in New Brunswick.

BIOMONITORING

PESTICIDES IN FISH BILE

We are examining the bile and major organs and tissues of 100 fish from different reaches of the Yamaska River in Quebec to determine the organ distribution of a variety of pesticides. The Yamaska River is an excellent site for this work since more than one-quarter of all pesticides used for agricultural purposes in Quebec are used in this relatively small basin.

Chlorinated pesticides will be determined, as well as those classes which are heavily used in the Yamaska basin, triazines and triazoles, amide derivatives, carbamates and organophosphates.

MUSSELS

Unionid mussels (*Elliptio complanata* and *Lampsilis radiata*) were collected from several sites in the St. Lawrence and Ottawa rivers. Bioconcentration patterns for pesticides in mussel tissues implicated Lake Ontario as the source of Mirex, DDT derivatives and lindane, while chlordane concentrations were highest in mussels from Lac St. Pierre. Hexachlorobenzene appeared to have multiple sources, but concentrations were highest in mussels from the mouth of the Grasse River.

LEECHES

In earlier work, we found that leeches from an industrially polluted creek bioaccumulated chlorophenols to much higher concentrations than other resident benthic invertebrates and fish. We suggested that leeches may have significant potential as biomonitors for these and other organic contaminants in the environment. Recently, we compared the bioaccumulation and depuration of 16 organic compounds, including eight chlorophenols (CPs), lindane, DDT and four derivatives, benzothiazole (BT) and 2-(Methylthio)benzothiazole (MMBT) for three species of leeches. *Dina dubia* had the highest bioaccumulation capacity for most contaminants, but residues persisted longest in *Erpobdella punctata. Helobdella stagnalis* appeared capable of degrading some compounds. Half lives of CPs, DDT and DDT derivatives were generally longer than one month. In contrast, half lives were only 1 day for lindane, 1-2.5 days for MMBT and 7 days for BT despite very high initial tissue concentrations of the latter two compounds. Bioconcentration factors for contaminants in leeches were higher than those reported for other aquatic organisms. Half lives for lindane, DDT and DDT derivatives were consistent with the literature for other organisms, but half lives for CPs were much longer. The results suggest that leeches would be excellent biomonitors of both continuous and intermittent contamination of a waterway with CPs and DDT, as they retain these compounds for long periods after exposure. Their usefulness as a screening tool for lindane and benzothiazoles would be limited to chronically contaminated environments.

EFFECTS

BENTHIC MACROINVERTEBRATE COMMUNITY STRUCTURE

Benthic macroinvertebrate community structure has long been recognized as an accurate assessment technique for evaluating ecological degradation as a result of organic and toxic pollution. Work is presently being carried out in the Yamaska River, Quebec, in areas contaminated by pesticides and industrial chemicals (largely from textile mills). Work is also being carried out at Kintore, near London, in a paired watershed study which is examining effects of pesticides from tilled and untilled areas. Biomass measurements will allow the calculation of secondary productivity using the growth increment summation method, and a comparison of production in the two watersheds will be made.

EFFECTS ON PERIPHYTON

This past summer, unglazed ceramic tiles were placed in open areas in the two creeks of the Kintore Creek paired watershed study. At intervals, all attached periphyton was removed from the tiles and are being analyzed for chlorophyll "a" and pesticides. Results will allow a comparison of periphyton colonization as well as growth and survival under different conditions.

BIOCHEMICAL INDICATORS OF STRESS IN STREAM INVERTEBRATES

Caged mussels (*E. complanata*) were placed at several sites in the Yamaska River in 1987 close to sources of agricultural run-off. After 30 and 50 days of exposure, mussels were collected, dissected and analyzed for free amino acids.

Preliminary results indicate that total concentrations of free amino acids increased at contaminated sites compared to control sites after 30 days' exposure. Glycine and alanine consistently accounted for a significant portion of the total increase in free amino acids. The tissues are presently being analyzed for pesticides.

Transcript of Guest Speaker Presentation
Workshop Dinner
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"WHAT'S COMING DOWN THE ROAD"

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Before I begin, I would like first to thank the Ontario Water Management Research and Services committee and the chairman, Dr. Stone for your kind invitation. Though at times our various co-ordination systems must seem quite cumbersome, there are few places in the world where such a mix of various disciplines, from academic to agri-business, from representatives of various government agencies to farmers, can sit down together to determine the problems, needs and priorities facing water management, or any other area, and then act on them. Your work is unique and very important. I urge you not to surrender to what can at times be a bureaucratic maze. Continue on and help us in Ontario and Canada enjoy our resources...and keep them.

For a long time we took water for granted. It's plentiful...just look at a map of Ontario...thousands and thousands of lakes and rivers. Recently though, water has become a topic of discussion by everyone, not just experts such as yourselves. There's been a summer drought; front page controversies over the possibility of water exports; acid rain. These events have made the general public aware just how precious this commodity is. I can safely say that the quantity and quality of water will be one of the priority issues facing all our governments within the next five years.

The Ontario government is committed to good water management. We want the efficient and effective use of water to be an everyday occurrence. We want to have systems that will assure us of long-term adequate water supply of a quality that is safe for man and animal. We are dedicated to developing systems of food production that will ensure that after water is used it does not pollute. We recognize that our soil and water are precious and we must protect them. And at times, I guess we may sound a bit evangelical.

The Ontario Ministry of Agriculture and Food has two major programs underway that confront the problems facing our land and water resources...the Land Stewardship program and Food Systems 2002.The first, the Land Stewardship Program, addresses the improvement of our soil and water resources, and the maintenance of food production. We do this through education and by financially encouraging conservation farming methods. The second, Food Systems 2002, is designed to cut the use of agricultural pesticides in Ontario by 50% over the next 15 years. While doing this, we aim to maintain efficient and internationally competitive crop production with an emphasis on developing new, environmentally-sound pest control methods. Since the use of agricultural chemicals and their effect on water quality is the purpose of this workshop, I'll be directing my remarks to the Food Systems 2002 program.

Before I go on, I would like to stress one thing. Although we are committed to reducing the use of agricultural chemicals by 50% within 15 years, we do not want to go to the extreme and say that all chemicals are bad and therefore should not be used. We do not want to do away with pesticides, we want to place emphasis on the responsible and wise use of pesticides. Without agricultural chemicals we would not be enjoying the quantity and quality of food that we do now. Not to mention our competitiveness in world markets. Chemicals are necessary, but they must be carefully used.

For centuries, farmers relied on scarecrows, rodent traps, removing insects by hand and continuous hoeing to fight pests. But, as the demand for increased food production grew, newer more effective methods were sought. The use of chemicals to fight pests dates back to the mid-1800's, when it was found that arsenic was toxic to the Colorado potato beetle. Yes, that's right, arsenic, the poison of choice of the Borgias, was soon used for insect control on a wide variety of crops. Other chemicals such as rotenone, derived from the roots of a South American plant, pyrethrum from the flowers of the chrysanthemum and even sulfur became widely used as pesticides. However, compared to other technologies, the development of crop protection chemicals was slow. By 1939, there were only about 30 chemicals registered for use as pesticides in the United States.

The biggest breakthrough came during World War II. A German scientist discovered the efficiency of DDT as an insecticide. DDT became a hero. It eliminated or reduced the outbreak of various diseases by controlling insect carriers. It was credited with saving thousands upon thousands of lives. It became so popular that by the mid-1950's, the production of DDT in the United States was over 100 million pounds annually. With amounts like that being sprayed on crops and eventually ending up in the food supply, something had to give. Scientists and others began to notice that the widespread use of DDT and other chemicals was beginning to have a profound effect on the environment and on public health.

In 1962, Rachel Carson wrote her book Silent Spring. She depicted a land ravished by pesticides. The general public took notice, and the modern environmental movement was born. It's now 26 years since the publication of Silent Spring, we are now extremely aware of the dangers posed by pesticide mis-use and over-use. Having learned from the past, we are moving on a surer, more environmentally-responsible path.

To make a program such as Food Systems 2002 work, the government first needs the cooperation and help of three inter-related groups...the farmers, the consumers and the agro-chemical industry.

First, the farmers. At one time, conservation methods were popularly thought to be the province of hippies and alternate lifestyle, "back-to-the-earth" types. This has changed. Today, even the most conservative-thinking farmers are keenly aware of the dangers to themselves and to the environment posed by the constant handling and use of chemicals.

In addition, there are increasingly strict government regulations over the disposal of chemical containers and unused chemicals. These regulations are hammering home the idea that although chemicals are necessary, they must also be treated with respect. On the other hand, the constant competition between the farmer and nature is taking on a new look as more and more pesticide resistant species are developing. What will it take to combat them?

There is also the financial aspect. The price of maintaining fields and crops increases, while profits decrease. Farmers are more and more aware of the costs to their soil, their water and, just as important, their pocketbooks, that come from the use of chemicals. They must be educated and made aware of the benefits of using other methods.

The consumer is another cog in the machinery. More and more people in Canada are becoming aware of various environmental problems. And they're willing to pay to have a safer system.

A recent Angus Reid poll (thankfully not an election one), taken a few weeks ago for Eco Corporation of Toronto, stated that 77% of Canadians...81% of Ontarians...are willing to pay more for plastic containers that are biodegradable. Now, Eco makes a resin that speeds up the degradation process of plastic when added to the mix, and of course, they're publicizing the results of their poll. But, there is one inescapable conclusion...81% of the people in Ontario are willing to pay a bit more for a safer environment. We're past the lip-service stage! People are willing to put their money where their mouth is.

No longer is environmental safety the jurisdiction of activists...it is now an issue and a concern held by everyone. This increased awareness of environmental problems by the general public means that the consumer will more and more demand food that's grown using environmentally safe and responsible methods. In addition, people are also concerned over what they're eating. They want to know what's in and on their food. They won't buy what they feel is unsafe. We, on the other hand, must keep the consumer informed about the consequences of pesticide use, and of the consequences of pesticide non-use. As I have mentioned before, not all chemicals are bad, and some are necessary to maintain the high quality of food we are accustomed to.

The third group is the agricultural chemical industry. The industry has over the years, shown that it does listen to its clients. For instance, in light of increased awareness by farmers over the safe handling and use of chemicals, some pesticides are now being marketed in water soluble packaging. This not only permits safe handling; the farmer is left with a clean, easily disposed container after using the chemical. Chemical companies are now moving their research over to biological and other, non-chemical methods of pest control. New strategies are being developed. The expertise and resources of the crop protection industry are being channeled in new directions that can only help preserve our environment.

So far, I've spoken about three necessary participants in Food Systems 2002. Now, it's time to address two others...the researchers and the government.

Food Systems 2002 has an allocation of $800,000 per year to spend over the first 5 years of the program soliciting research. We first find the gaps in pest control procedures, then contract out the research to fill them. We are willing to buy and fund the required research. This is a strong commitment to find alternate methods of pest control, methods that will not harm our ecological system. I would now like to zero in on the major facet of that research, the area I believe is the most important. Biotechnology. I like to refer to this as "What's coming down the road".

Biotechnology is the most significant alternative to chemical pest control available. The development of biological control products is the wave of the future. One warning...it's not a panacea or a cure-all. Other methods will still be necessary.

Biotechnology in crop protection has two distinct parts. The development of tougher, pest resistant strains of crops, and the development of biological pest control agents. The development of drought resistant and hardier strains of crops will have the effect of lengthening the growing season, something that is very important in our northern climate. Greater yields can be obtained, increasing the food supply available to us here and for export.

Biotechnology is also developing pest resistant strains of crops. For instance, we are now using genetic organisms to develop corn that is toxic to the corn root worm. At Bradford we have witnessed the first successful effort to control onion white rot using a combination of fungicides, flooding and crop rotation. Another program under way is trying to combat the Colorado potato beetle again through genetic engineering. The native wild potato has a chemical in its make-up called letosine, that repels the Colorado potato beetle. Researchers are now genetically splicing this chemical into the domestic potato. Eventually they hope to create a potato that we humans like to eat, but bugs don't. Again, this lessens the need for chemical protection. These are naturally occurring agents we are adding to existing strains. Agents that do not pollute our water and soil systems.

Biotechnology is also being used for active pest control. For instance entomologists are using one of the most effective weapons to try to control insects...sex. Yes, the world's oldest profession is now being adapted to provide us with better crops. Now that's food for thought! Scientists have found that using sex pheromones is an effective method of pest monitoring and control. The method is devilishly simple. Artificial female insect pheromones are placed in a cardboard tent in a field. The smell drives the males into a frenzy. They swarm to the area. Unfortunately, when they get there, there are no females...sort of like a Friday night at a singles' bar. Once they get there, they can either be eliminated or controlled. The benefit of using methods such as pheromones has great benefits. These chemicals are effective, they don't get absorbed by the crop, the soil or the water. They do not harm either our food or our land.

Another biological control technique is the introduction of so-called good insects to control other pests. A good guy versus bad guy technique. A good example of this method is the biological control of the green house white fly with the *Encarsia formosa*, a parasitic wasp that eats the white fly, but doesn't harm anything else.

Research is also being carried on to develop selective pesticides -pesticides that kill target pests without disrupting beneficials. Pesticides that will do their job, then degrade rapidly in the soil and water leaving no residue. Up to now, pesticides have been broad spectrum. With the development of species-specific pesticides, less chemical is needed, and is used only when the pest species is around. And, these new pesticides are designed to break down quickly and not disrupt anything else.

All of these examples of biotechnology sound good on paper and perform well in controlled tests. They are fantastic developments in pest control. However, there are potential problems that must be addressed. These days, the public is much more aware of technological developments and possible pitfalls, than ever before in history. The public does not only want to know what is going on, it demands to know.

A whole new approval system will have to be put into place. We cannot introduce what are essentially new organisms or methods without arousing concern from all sides. We will be questioned, questioned and questioned. And we must be ready for it. Testing and regulation will have to increase to prevent situations such as happened with DDT. Remember, in 1944, Winston Churchill called DDT "that miraculous DDT powder". Twenty years later Rachel Carson in her book Silent Spring, called it "the elixir of death". We cannot and must not let a predicament like this happen again. Our ecology is just too fragile. We must examine what we're doing and creating under the most powerful microscopes.

I have spent most of my time this evening on the plant side of agriculture...probably because we are a little further ahead than on the animal side. What we need, and what we are working on now, is a Food Systems 2002 for animals. In other words, how to reduce the use of drugs and antibiotics in livestock and poultry production. How to do it is the question. Is it a 50 per cent reduction? Or 25 per cent or 90 per cent? That has to be established. But we know that consumers are demanding reduction or elimination. We also know we will need drugs and antibiotics to some extent, for efficient and competitive animal production. We have yet to work out the details -- and of course a name, like Food Systems 2002, Phase II, or something. We will have to monitor what impact our use of drugs and antibiotics has on our environment. We really don't know.

So, before concluding, I want to make a few comments on what we might call "water stewardship". What I have talked about so far relates to, and has mostly an indirect impact on, water quality. What I want to see "come down the pipe" (pardon the pun) is a "water stewardship" program which parallels and complements land stewardship.

What do I want to see in such a program? To start with, what does it mean? We have to look at ways and means of improving the level of water management on the farm and in the agricultural industry, and to reduce the impact of agricultural activity on water quality. More specifically, we need to:

- get a better reading or survey of water quantity and quality as they exist today.
- emphasize improved, or proper, well management.
- develop reliable climatological information based on agricultural needs.
- develop agricultural management practices close to wetlands.
- use available supplies efficiently and effectively.
- devise ways and means of reducing contamination of ground and surface water.

Not that long ago we only thought of the short term solutions to agricultural problems. Those days are over, we must think of the long term. Fortunately for us in Ontario, the long term is now government agricultural policy. Generations down the line will thank us for it.

I would like to end my talk by making the point that agriculture has been having a tough time recently, and will continue to have many challenges in the foreseeable future. It's not only natural occurrences such as this past summer's drought that are affecting us. The world market is becoming more and more competitive and we must not let it overtake us. We must build our agricultural industry on high technology to maintain our position. We must ensure that our food products are of the highest possible quality and safe. We must look at the world as our market place, and we must not let it overtake us. We must do all these things while ensuring that our land, our soil and water, does not suffer. We can and we will, with the dedication and help of such people as yourselves.

Once again, you're doing a unique and valuable job. Keep it up, everybody needs you.

WORKSHOP GROUP COMMENTS AND RECOMMENDATIONS

Workshop participants split into four discussion groups and addressed 5 topics formulated by the O.W.M.R.S.C. The following is a list of comments and recommendations compiled by the discussion groups. Comments and recommendations are not listed in order of priority.

Topic No. 1: Are ongoing management (or service) programs adequately addressing water quality problems related to agriculture in Ontario?

Workshop Group Comments and Recommendations:

I. Education

A. Practical demonstrations should be used more as a means of continued education.

B. Transfer of information to the public needs to be increased.

C. Available information needs to be presented clearly and cautiously extrapolated.

D. Pesticide handling educational programs should be expanded.

II. Programs are not adequately addressing groundwater quality problems. More studies which integrate surface water and groundwater are needed.

III. Monitoring Programs

A. Small watershed monitoring programs need to be expanded.

B. Past and present programs, which have emphasized monitoring of phosphates, should be expanded to include additional chemicals of concern.

C. Monitoring programs appear adequate and problem areas are being defined. However, programs do not appear to be investigating innovative solutions for the problems identified. For example, nutrient enrichment of streams has been identified and remedial measures to solve the problem have been implemented using existing technology, but no new initiatives are being funded or developed.

IV. Remedial Measures

A. Present remedial action programs do not adequately address agricultural impacts on water quality.
B. Funds for farmer assistance need to be focused on target areas where problems exist rather than applying remedial measures to all areas, including areas where they may not be needed.
C. Feedback from farmers who have tried remedial measures needs to be evaluated.

V. Existing programs do not address the impact of airborne contamination from agricultural practices on water quality, i.e. Annex 15 - IJC.

<u>Topic No. 2:</u> What additional management (or service) programs are needed to minimize the impacts of agricultural chemicals on water quality in Ontario?

Workshop Group Comments and Recommendations:

I. Education and Technology Transfer

A. mandatory education program and subsequent licensing should be required for those using and purchasing agricultural chemicals.
B. There is need for an increased level of public education and awareness regarding pesticide use guidelines.
C. There should be a balance between pesticide use enforcement and educational programs.
D. Technology and information transfer between agencies and farmers needs to be improved.
E. Farmer educational programs must: 1) stress the importance of following pesticide use guidelines, 2) provide current research results, and 3) provide one clearing house agency for information.

II. Pesticide and fertilizer use recommendations

A. More emphasis should be put on in-situ chemical analysis of soils to determine application rates for agricultural fertilizers.
B. Pesticides recommendations should consider pesticide use history. Records

of past pesticide use should be a mandate of a pesticide use licencing agency.

C. Soil testing program recommendations should be designed to minimize potential impacts on water quality in addition to maximizing productivity.

III. Manure Handling

A. There is need for a lead agency to address the problem of manure storage, spreading rate applications, etc.

B. Manure handling and disposal recommendations should consider tillage systems of the land to which they apply.

C. There should be a re-release and updating of the code of practice for manure spreading.

D. A model bylaw on manure disposal is needed.

IV. Domestic waste system guidelines (private, on-site) should be enforced and/or new designs should be investigated in agricultural areas.

V. There is a growing demand for the application of municipal sludges on agricultural lands and, therefore, a need for a testing/certification program so that the sludges meet acceptable criteria.

VI. There is a need for improved methods for handling miscellaneous agricultural wastes such as pesticide containers and tank tailings from pesticide application.

VII. Soil Conservation Programs

A. Existing soil conservation programs (SWEEP, T2000, LSP, etc.) are short-term solutions to long-term problems and should therefore be expanded and integrated with future programs.

B. There is a need for a built-in review process of the objectives of each agency's programs.

C. Data collection from existing soil conservation programs needs to be coordinated so that projects result in relevant and realistic recommendations.

VIII. Analytical Support

A. Analytical lab capabilities need review in terms of the volume of samples they can process and coordination of lab techniques.
B. The feasibility of on-site screening tests for water quality should be studied.

Topic No. 3: What is the degree of cooperation and integration of services and programs identified in Topics 1 and 2 within each Ministry and among agencies?

Workshop Group Comments and Recommendations:

I. Integration

A. There are four agencies involved in water quality problems: OMAF, MOE, MNR and MOH. It should be made clear to the public which agency should be approached when a problem occurs. A lead agency should be identified, with the other agencies acting in a supportive role.
B. The lead agency responsible for quality analysis of private water supplies, especially health related aspects, needs to be identified.

II. Coordination

A. Is there a coordinated approach to studies between government agencies and between government agencies and educational agencies?
B. There is concern about coordination between Provincial pesticide management (FS 2002) and soil conservation (LSP) programs.

III. Cooperation

A. Programs are generally complimentary and do not appear to overlap.
B. The internal structure of some agencies does not encourage cooperation within the agency, therefore, cooperation between agencies is inhibited.

Topic No. 4: What additional research programs are needed to adequately address the water quality problems related to agriculture in Ontario?

Workshop Group Comments and Recommendations:

I. Extent of the problem

A. much broader data base resulting from groundwater monitoring in different hydrogeologic environments is needed.
B. The extent and magnitude of groundwater pollution is not well defined.

II. Technology which will minimize fertilizer nitrogen losses (due to leaching, volatilization, runoff etc.) needs to be developed.

III. The effect of conservation tillage on the amount and rate of leaching of organic carbon (which increases denitrification) needs to he studied.

IV. There is a need for a cost analysis study which addresses the environmental cost of point source manure application vs. transportation costs associated with distribution over larger areas at acceptable levels.

V. More information on toxicity of metabolites is needed.

VI. Guidelines for animal waste and fertilizer W application should be reviewed and research on the interaction of rates, health, and economics studied.

VII. Research on the epidemiology of organisms in drainageways and their affect on human and animal health is needed.

VIII. Computer models should be used as a means of identifying research areas and not as predictive tools.

IX. A better understanding of the transport processes of nutrients and pesticides is needed.

X. Improved methods for estimating the nutrient value of manures and organic wastes for determination of application rates consistent with soil test recommendations need to be developed.

XI. Technology (models) to determine the fate and pathway of pesticides through the environment which can be used as approval criteria for the sale of pesticides is needed.

Topic No. 5: What safety precaution, human health hazard, or risk procedures should be addressed in order to enhance protection?

Workshop Group Comments and Recommendations:

I. Standards and Guidelines

A. Establishment of uniform water quality standards based on actual or realistic threshold concentrations for health protection rather than on analytical detection capability.

B. There is a need for increased public awareness of water quality guidelines and for educational programs which emphasize interpretation of available information and health risks.

II. A universal symbol system for agrichemical use should be developed.

III. New technology should be developed or existing technology be made more available for pesticide container disposal or recycling.

IV. Improve chemical emergency response to chemical spills by better publicizing the MOE emergency response telephone number.

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WORKSHOP AGENDA
AGRICULTURAL CHEMICALS AND WATER QUALITY IN ONTARIO

Sponsored by the
Ontario Water Management Research and Services Committee

Best Western Conestoga Inn
Kitchener, Ontario
November 17-18, 1988

November 17, 1988

8:00 - 9:00 Registration, Refreshments
9:00 - 9:15 Welcome and Introduction
>> Jim Stone, Chairman, OWMRSC
>> Lloyd Logan, Chairman-elect OWMRSC

General Programs: Session Chairman - Jim Stone

9:15 - 9:40 Water Quality Perspectives in Ontario
I Sam Singer, Soil and Water Management Branch, O.M.A.F., Guelph
II Dennis Draper, Water Resources Branch, O.M.E., Toronto

9:40 - 10:05 Research Implications of the Revised Great Lakes Water Quality Agreement, 1987
>> Greg Wall, Agriculture Canada, Guelph

10:05 - 10:30 Break, Refreshments
10:30 - 10:55 Technology Evaluation and Development Sub-program of SWEEP
>> Wally Findlay, Agriculture Canada, Harrow

10:55 - 11:20 Tillage 2000
>> Galen Driver, Soil and Water Management Branch O.M.A.F., Guelph

11:20 - 11:45 Food Systems 2002 - An Update
>> Wayne Roberts, Plant Industry Branch, O.M.A.F., Guelph

12:00 - 1:00 Lunch

Monitoring Programs: Session Chairman - Stewart Saul

1:00 - 1:25 Pesticide Monitoring of Groundwater
>> Paul Beck, Groundwater Quality, Water Resources Branch, M.O.E., Toronto

1:25 - 1:50 M.O.E. Surface Water Quality Monitoring Program
>> Lloyd Logan, Hydrology and Networks, Water Resources Branch, M.O.E.

1:50 - 2:15 Pesticide Analysis and Water Quality Studies
>> Brian Ripley, Pesticide Residue Testing Laboratory, O.M.A.F., Guelph

Workshop Session 1: Chairman - Tim Lotimer

2:15 - 4:30 Workshop Group Discussions

4:30 - 5:00 Presentation of Workshop Group Recommendations (Flip Charts)

EVENING

6:00 - 7:00 Social Hour (Cash bar)
7:00 Dinner - Stewart Saul, Chairman
Introduction of Guests

Guest Speaker:
Dr. J. C. Rennie, Assistant Deputy Minister, O.M.A.F.
"What's Coming Down the Road"

November 18, 1988

Research Programs: Session Chairman - Lloyd Logan

8:30 - 9:00 Nitrate Contamination of Groundwater in Southern Ontario: A Hydrogeologic Perspective
>> Bob Gillham, Water Quality Center of Excellence, University of Waterloo

9:00 - 9:30 Impact of Agricultural Practices on Subsurface Water Quality
>> Murray Miller, Centre for Soil and Water Conservation, University of Guelph

9:30 - 10:00 National Water Research Institute Pesticides Research Program
>> Jim Maguire, National Waters Research Institute, C.C.I.W., Burlington, Ontario

10:00 - 10:30 Break, Refreshments

Workshop Session 2: Chairman - Greg Wall

10:30 - 11:30 Workshop Group Discussions

11:30 - 11:45 Presentation of Workshop Group Recommendations

11:45 - 12:00 Concluding Remarks - Jim Stone, Chairman, OWMRSC

12:00 - 1:00 Lunch

O.W.M.R.S.C.

The Ontario Water Management Research and Services Committee (OWMRSC) is a subcommittee which reports annually to the Ontario Soil, Water, and Air Research and Services Committee (OSWARSC). OWMRSC membership (15) includes representation from the federal, provincial, university, and private sector. For information about the OWMRSC or copies of these proceedings, contact:

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