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Proceedings of the Workshop on Assessing the Potential for Great Lakes Contamination via Groundwater, October 24 and 26, 1989, Waterloo Centre for Groundwater Research, University of Waterloo

Great Lakes Science Advisory Board. Technological Committee

University of Waterloo. Waterloo Centre for Groundwater Research

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Proceedings of the Workshop on Assessing the Potential for Great Lakes Contamination via Groundwater

October 24 and 25, 1989

Waterloo Centre for Groundwater Research
University of Waterloo
Waterloo, Ontario
DISCLAIMER

The report to the Science Advisory Board was carried out as part of the activities of the Technological Committee. Although the Board supported this work, the specific conclusions and/or recommendations do not necessarily represent the views of the International Joint Commission, the Science Advisory Board or its other committees.
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PREAMBLE AND ACKNOWLEDGEMENTS
I notice in the program, my share is listed as giving the opening address but I prefer to think of it as "welcoming comments," so I would like to welcome you all to the University of Waterloo on behalf of the University and the Centre. I might say a couple of words about the centre. We are part of an Ontario experiment. We are one of seven Centres of Excellence funded through the Premier's Psychology Plan and through that fund, the Centre receives about 1.8 million dollars a year. For five years and we are approaching the end of our second year in the program. In particular with the money is going primarily into research infrastructure and through that we are able to pay some of our full-time technicians. We require three full-time, 20 part-time faculty members, various junior faculty, and research equipment. So a very small amount of money is actually going into research itself but it certainly underlines the "capacity" for research with such additional faculty member required. We now have approximately twenty faculty members that are making a significant for all the research in the groundwater area and particularly in a time of university restrictions the growth. We now have more than one-third of the faculty in the groundwater area under the age of forty which really is quite an achievement I think compared to the centres of excellence programs because it gives us an opportunity to make these kinds of advances.

Our total research budget at the moment, including the Centre funding, is in the order of 4.5 million dollars a year and from some figures that I heard about a year ago, that's a million dollars more than the federal government has committed to groundwater research. So in the groundwater area we feel that we do have a significant role to play in Canada.
I notice in the program, my chore is listed as giving the opening address but I prefer to think of it as "welcoming comments," so I would like to welcome you all to the University of Waterloo on behalf of the University and the Centre. I might say a couple of words about the centre. We are part of an Ontario experiment, we are one of seven Centres of Excellence funded through the Premier's Psychology Fund and through that fund, the Centre receives about 1.8 million dollars a year for five years and we are approaching the end of our second year in the program. In our particular case, the money is going primarily into research infrastructure and through that we are able to pay some of our full-time technicians. We require three full-time, 20 part-time faculty members, various post-doctorates and some other types of infra-structures such as research equipment. This has put us in a position or "capacity" to do more research. So a very small amount of money is actually going into research itself but it certainly increases our "capacity" for research with each additional faculty member required. We now have approximately twenty faculty members that are making a significance for all the research in the groundwater area and particularly in a time of university restraints for growth. We now have more than one-third of the faculty in the groundwater area under the age of forty which really is quite an achievement I think compared to the centres of excellence programs because it gives us an opportunity to make these sorts of advances.

Our total research budget at the moment, including the Centre funding, is in the order of 4.3 million dollars a year and from some figures that I heard about a year ago, that's a million dollars more than the federal government has committed to groundwater research. So in the groundwater area we feel that we do have a significant role to play in Canada.
1.2 INTRODUCTION AND BACKGROUND
Kurt Bauer, Workshop Moderator

In 1983, the Science Advisory Board of the International Joint Commission examined, in a preliminary way, the potential for the contamination of the Great Lakes by groundwater-transported substances. That preliminary examination found known cases where toxic substances had indeed contaminated groundwater, which contaminated groundwater had, in turn, reached the waters of the Great Lakes. The preliminary examination indicated that major deficiencies existed in the knowledge about this potentially serious problem. Knowledge was found to be lacking about: the nature and extent of groundwater contamination in the Great Lakes basin; the quantities and directions of groundwater flows; and the hydrogeologic regimens of the basin that have the greatest potential for contamination of the Great Lakes. Groundwater hydrology is a relatively new and imprecise science; and the means of preventing, as well as mitigating, contamination of groundwater are among the least understood aspects of this science. Accordingly, the preliminary examination concluded that without further study the potential for contamination of the Great Lakes by groundwater-transported substances could not be properly assessed; and needed preventive, as well as corrective, measures could not be properly identified.

Based upon the findings of that preliminary examination, the Science Advisory Board created a task force of knowledgeable United States and Canadian members and charged that task force with the responsibility of reviewing the results of the preliminary examination and with recommending to the Board a future course of action. The task force in October 1985 published a report to the Science Advisory Board entitled "A Study Proposal for Assessing Potential for Great Lakes Contamination via Groundwater." The study proposed in the report was subsequently specifically endorsed by two prestigious scientific organizations: the National Academy of Sciences of the United States; and the Royal Society of Canada, in a joint report issued in 1985 entitled "The Great Lakes Water Quality Agreement, an Evolving Instrument for Ecosystem Management." The study, as proposed, would have made a substantial contribution to meeting the requirements of Annex 16 of the Great Lakes Water Quality Agreement of 1978 as amended by the Protocol of November 18, 1987.

The study proposal was approved by the International Joint Commission and partially funded by the United States Government. Work was undertaken on some of the study elements by the U.S. Geological Survey utilizing the funding provided through the
International Joint Commission and some U.S. Geological Survey funding reprogrammed for this purpose. The work was, of course, confined to the United States portion of the Great Lakes basin.

In 1989, the Science Advisory Board of the International Joint Commission became concerned about the partial implementation of the study proposal and by the apparent lack of any coordination in that implementation in the American portion of the Great Lakes basin with activities in the Canadian portion of the Great Lakes basin. Accordingly, the Science Advisory Board through its Technological Committee, convened a workshop on assessing the status of the study proposal. The workshop was held at the University of Waterloo, Centre for Groundwater Research, Waterloo, on October 24 and 25, 1989.

Charge to the Workshop

The workshop is charged by the Science Advisory Board with the following four tasks:

1. to review the study proposal for assessing the potential for Great Lakes contamination via groundwater as prepared by the Groundwater Contamination Task Force of the Science Advisory Board of the International Joint Commission and published in October 1985, reexamining the findings and recommendations made in that study proposal in light of developments since its publication;
2. to review the recommendations of the study proposal to identify needed work elements which may have been adequately addressed by subsequent actions of the two federal governments and the states and provinces concerned;
3. to review the recommendations of the study proposal to identify those needed work elements which have not been adequately addressed; and
4. to reach a consensus on needed future actions with respect to assessing the potential for Great Lakes contamination via groundwater.

Workshop Procedure

All participants were provided with a copy of the Science Advisory Board study proposal as published in October 1985 for review prior to the workshop. Two discussion papers were prepared for the workshop and provided to all participants for review prior to the workshop. One discussion paper, describing the activities of the U.S. Geological Survey undertaken in partial implementation of the study proposal, was prepared by Mr. Lindsay A. Swain of the U.S. Geological Survey. The other discussion paper, describing
the activities of the Canada-Ontario Agreement Groundwater Committee and of the Ontario Ministry of the Environment (OMOE), was prepared by Mr. Paul Beck of OMOE. It should be noted in this respect, that the discussion paper prepared by Mr. Swain was not reviewed and approved by the U.S. Geological Survey and therefore, under the policies of that agency, is not "quotable" as a reference.

The two discussion papers are to be presented in the plenary session of the workshop. The presentation of the discussion papers will be followed by presentations on state and university activities in the American portion of the Great Lakes basin by Mr. Steve Hindall of the U.S. Geological Survey, and Dr. David Baker of Heidelberg College. Presentations on federal and university activities in the Canadian portion of the basin will be from Mr. Kent Novakowski of the Canada Centre for Inland Waters and Dr. Donald Mackay of the University of Toronto.

Following the presentations at the plenary session, the participants will meet in two workgroups: one for the U.S. participants, chaired by Mr. Lindsay Swain, with Ms. Kelly Norton-Warner as rapporteur, both with the U.S. Geological Survey; and one for the Canadian participants, chaired by Mr. Paul Beck of the Ontario Ministry of the Environment, and Dr. Robert Gillham of the University of Waterloo, as rapporteur. The discussion groups are asked to specifically address the charge to the workshop and to reach a consensus within the workgroups with respect to findings and a course of action which could be recommended to the International Joint Commission. The workgroup reports will then be presented for discussion at a second plenary session of the workshop to reach consensus on the findings and recommendations which will be reported to the International Joint Commission through its Science Advisory Board.
2.0 UNITED STATES GROUNDWATER ACTIVITIES

The objective of the study proposed by the Groundwater Contamination Task Force (International Joint Commission 1985) was to define the major hydrogeologic regimes of the Great Lakes basin and to assess the potential for groundwater to these regimes to carry contaminants into the Great Lakes. Specifically, the study was supposed to:

1. Define regionally the hydrogeologic units within the Great Lakes basin

2. Evaluate the potential for and significance of contaminants to move through the hydrogeologic units and into the Great Lakes

The proposed study plan was divided into three phases and were to be carried out over a period of two years.

Phase I was to conclude within the first four months of the study's execution and was to include the examination and subsequent selection of a contamination potential mapping methodology. The contractor, as a consultant, was to use the four methods and procedures identified in the proposal and to develop a legend to be used in the interpretation stage. The methods would include a discussion of where and how the data generated could be used within the context of the proposed legend; provide specific guidance using actual Great Lakes basin data for differing hydrogeologic regimes; and provide recommendations on the various methods to select a selection of the appropriate method could be used for the Groundwater Contamination Study.
Following the presentations, the participants were divided into two workgroups: one for the United States and one for Canada. The Canadian participants focused on the domestic issues of the federal government and the provinces. The United States groups discussed the national and international aspects of the conference. The discussion groups were tasked with preparing a report on the outcomes and a draft of action which would be sent to all participants. The two workgroups then met to discuss and finalize the report to be presented at the conference.
What Was the Original Plan?

The objective of the study proposed by the Groundwater Contamination Task Force (International Joint Commission 1985) was to define the major hydrogeologic regimens of the Great Lakes basin and to assess the potential for groundwater in those regimens to carry contaminants into the Great Lakes. Specifically, the study was supposed to:

1. define regionally the hydrogeologic units within the Great Lakes basin
2. locate the areas with potentially major sources of groundwater contamination, and
3. evaluate the potential for and significance of accompanying contaminants to move through the hydrogeologic units and into the Great Lakes

The foremost objective of the work was to identify areas to the IJC where contamination potential is the greatest such that the IJC can recommend to the various governments those areas of major concern which should be further investigated or where mitigation of the contamination should be carried out.

The proposed study plan was divided into three phases and were to be carried out over a period of two years.

Phase I was to conclude within the first four months of the study's inception and was to include the examination and subsequent selection of a contamination potential mapping methodology. The contractor, as a minimum, was to review the four methods and procedures identified in the proposal and based on that review, develop a legend to be used in the interpretative maps. The analysis would include a discussion of where and how the data gathered would be used within the context of the proposed legend; provide specific examples using actual Great Lakes basin data for differing hydrogeologic regimens; and provide conclusions and recommendations on the various methods so that a selection of the preferred method could be made by the Groundwater Contamination Task Force.
Phase II was to involve the collection of existing information and maps available in public files, to define the natural hydrogeologic regimens of the Great Lakes basin. The level of mapping detail was to be as good as the data allow. The information was to be collated and interpretations made on base maps covering the entire basin at a scale of 1:1,000,000, which represents a "best" compromise since many of the existing study maps are at some fraction of the 1:1,000,000 scale. In the mapping efforts, whenever possible, the gathered data should be mapped according to the 15 major U.S. river basins as identified by Waller and Allen (1975) and the 11 major U.S. river basins identified by the International Reference Group on the Great Lakes Pollution from Land-Use Activities (PLUARG) report (1977). The prepared maps, which were to be similar in format to examples presented with the proposal, were to include but not necessarily be limited to the following:

1. Surficial materials and depth to bedrock
2. Bedrock geology
3. Permeability of surficial materials
4. Groundwater flow characteristics and directions
5. Aquifer utilization
6. Land-use
7. Points of contamination

Phase III was to involve the synthesis of the existing information and the preparation of an interpretive map describing the hydrogeologic regimes in the Great Lakes basin according to the methodology selected in Phase I of the study. This work was to involve the classification of hydrogeologic regimens as to their hydraulic properties, proximity to and severity of contamination sources and proximity to the Great Lakes.

The plan of study called for funding of $120,000 for the first year and $95,000 for the second. The following recommendations by the [Groundwater Contamination] Task Force were made to the Great Lakes Science Advisory Board:

1. commission a study to prepare a hydrogeology inventory of the Great Lakes basin as the basis for assessing the potential for Great Lakes contamination via groundwater
2. the commissioned study should be based upon the proposal outlined in this report and
3. the Water Resources Division, United States Geological Survey be contracted to perform this work
What Really Happened?

The IJC study plan was published in October 1985, yet it wasn't until early 1987 that any funds were made available to do any work. The funds allotted for this one-year study were much less than needed and the proposed study was greatly diluted before it even began. Despite the meager funding, Ms. Kelly Warner has attempted a beginning on the work proposed by the Groundwater Contamination Task Force.

Recent advances in the area of computer-aided mapping and data compilation, has made this method of developing the maps required for this study far more feasible than was possible when the original plan of study was developed. With the advent of Geographic Information Systems and the specific one acquired by the U.S. GS, called ARC/INFO, it has become much easier to develop the maps by using the computer. Since the plan of study was written, the Geologic Division of the U.S. GS had remapped the surficial glacial deposits of the entire Great Lakes basin based upon thickness and texture. Most of this mapped information has been digitized on ARC/INFO at a scale of 1:1,000,000. In addition, many of the states in the basin have established ARC/INFO as their chosen software for displaying and managing information they enter in their state databases. Many of the maps listed in the approach section of the IJC plan of study have recently been digitized by various government agencies.

In an effort to illustrate the ability to do the projects via ARC/INFO, the Illinois district proposed developing one computer-generated map showing both the hazardous waste sites and the public supply wells on the same base map such that their areal relationships could be easily seen in proximity to each other. Additional work of this project was to develop a bibliography of work within the Great Lakes groundwater basin with keywords chosen so that a rapid search and indexing could be made through the INFO database format. Also, the report would describe what information was known about the geohydrology within the basin for each of the eight states. This work was completed by Warner in 1988 but nothing was published as funding was insufficient.

With additional funds from the Office of Water Data Coordination, the report with a map showing the 4,236 public supply wells in the eight states, 2,856 hazardous waste sites (98 Superfund) and 1,135 bibliographic entries plus the hydrogeologic description for each state is presently in the colleague review stage and should be approved for publication in a few months. Currently, additional work by Warner is attempting to delineate the areas of pesticide application by hydrogeologic units for the IJC. A newly proposed study by the Illinois U.S. GS for the U.S. EPA is planned to develop a means of estimating the flow rates of shallow groundwater (<550 feet) to Lake Michigan in an area from Milwaukee, Wisconsin to Muskegon, Michigan.
As significant as this work by Warner is, it still does not answer the nagging questions which the original plan had hoped would be determined by the study. That study plan was seeking an overall evaluation of the entire basin to pinpoint where areas of greatest concern for potential contamination should be made and thus allowing the wisest use of funds by concentrating on those areas of greatest need. We still need therefore, to study the basin as a whole and define where we need to spend our funds instead of hopscotching around the basin doing numerous site-specific studies which may actually miss the areas of greatest concern.

What We Have Learned Anyhow

However, one benefit of these numerous site-specific studies of groundwater contamination which have been conducted over the past few years is that the flow systems and transport mechanisms for contaminated groundwater are being better understood at least for some sites and that information will be useful in future efforts. A very significant finding over the past years since the plan of study was written is the discovery that man's engineering structures are having substantial negative effects by providing more rapid transport pathways for contaminated groundwater to reach the lakes.

One such study which shows the effect of man's engineering took place in the Niagara Falls area. A study by Miller and Kappel (1987) found that groundwater seepage into the connecting channels directly along the shoreline is probably very small. However, because of limited funds, no test well was drilled into the 250 foot thick buried glacial channel which is directly below the Detroit area and connects with the Detroit River. These buried channels which should have more coarse material than the surrounding areas exist throughout the entire basin and may provide rapid transport pathways for contaminants to the lakes from the groundwater system.

A study which was described in the plan of study (Twenter, Cummings and Granneman, 1985) documented one site where contamination of Lake Michigan was occurring as the result of direct seepage of groundwater through a sand aquifer and into Traverse Bay. That study used skindivers to take samples along the bottom of the bay at measured distances from where the plume would be expected to be aligned to the bay. Concentration of benzene of 20 micrograms per liter at 300 feet offshore along the bottom of the bay was sufficient evidence to prove that these contaminants can directly infiltrate into the lakes.

In another study near Oswego, New York (Anderson and Miller, 1986), high concentration of organic chemicals in the groundwater system is being discharged into
White and Wine Creeks and then into Lake Ontario. Because the glacial till within which the contaminants exist is of such low permeability, it would not normally be expected for the contaminants to reach the lake if the water table were not intersected by these creeks which provide a short circuit and a rapid pathway to Lake Ontario.

Currently, a major study for the U.S. EPA by the New York District of U.S. GS is being conducted for the entire Niagara area. This study is to define the regional hydrogeology of the surficial and bedrock aquifers for that large region. Abundant drilling, coring, packer testing and water sampling are being done in order to obtain the needed data for this major study. It is hoped that this study will better define the potential flow paths, both vertically and horizontally for this area. One study of 156 hazardous waste sites in the area (Koszalka et al. 1985) concluded that 57 of those sites examined had a major potential for contaminant migration to the river.

For the small section of Pennsylvania that is within the basin, a study of groundwater resources of the Erie County has recently been published (Richards, McCoy and Gallagher, 1987). A study of groundwater quality in Erie County is in its last year and a report will be written by September 1990.

A study of the glacial aquifers near Lake Erie from Cleveland to Conneaut, Ohio (Coen 1989, in review) defined the flow system and general water quality of the shallow glacial aquifer system in that area based upon a mass water-level measurement of over 200 wells and specific conductance measurements from 59 wells.

What Do We Still Not Know?

Despite all these specific studies, we still know very little more about the "regional" contamination potential for groundwater within the Great Lakes basin than we did in 1983. No major effort has centered on defining which areas have the greatest potential for problems. We still don't know what areas have the worst groundwater quality at present because we simply don't sample the shallow groundwater for most of the area. We have not yet quantified how much of the stream flow is from groundwater and of that amount how much is from contaminated groundwater. We still don't know whether the numerous buried glacial channels are major conduits for contaminated groundwater, especially in the Detroit or Ashtebula areas where they are so prominent. We don't know whether pesticides are increasing in the groundwater system from no tillage-best management practices and then entering back into the streams and then to lakes.

To add to the unknowns, now we must also determine where abandoned or decaying infrastructures exist which would allow for contaminated groundwater to have a more rapid pathway to the lakes. If the theories of Sklash and Farvolden (1979) are correct,
and up to 60% of the initial peak of a stream hydrograph is from groundwater flushing as the capillary fringe achieves 100% saturation, what are the repercussions of this surge of contaminants along streams where hazardous waste sites exist?

So, it looks like we have more questions than answers and we still haven't even taken the first step to answer the major questions presented in the plan of study which was developed by the Groundwater Contamination Task Force of the IJC in 1985.

References


2.2 UNITED STATES UNIVERSITY ACTIVITIES

David Baker

I'm totally new to groundwater and I didn't know I was going to be giving a talk here until I walked in this morning. I made the mistake of volunteering; that's what I did -- just making an innocent inquiry to the IJC. I looked at the program before I came, they said the universities would be talking about what they're doing so I called up IJC and Andrew [Watson] wasn't there but talked to his secretary and then the next thing I knew I came here and my name was scribbled in on the program and so I was asked to comment on behalf of what U.S. universities were doing. Heidelberg College is not a groundwater research institute by any means and so I opened up my ear and before I came in, I learned that in the University of Wisconsin, they're working on the problems of transport of toxic substances in the Green Bay Mass-Balance Studies for toxics going into that system and they're looking at chloride, nitrate, lead and dieldrin loading and then I heard some very interesting work at the University of Syracuse that's underway, thanks to the comments already before me. I think I also heard the problem is that not many people in universities are doing any work in this area. I think that the problem there is that this group has really focussed only the question of loadings of toxics into the Great Lakes, per se and all they need to do is to listen to the political, the bandwagon of groundwater in the States and obviously the universities have responded in mass to the opportunities and so when we look in Ohio, practically every state university has a groundwater institute that are addressing the local problems which is appropriate and the local problems turned to be the municipal watersupply problems, especially where the municipal water supplies groundwater systems are coming from or possibly influenced by toxic waste dumps. In the agricultural sector, there's a lot of concern about non-point sources of pesticides and that being groundwater supplies -- municipal and private supplies, so when I look at what the universities are doing, a lot of them are under the bandwagon for groundwater education programs; Michigan State University, for example. Many of the universities in Michigan are getting grants from the Kellogg Foundation and so forth to really begin to address what people should be doing in their own back yard to prevent contamination of groundwater. Now, is that relevant to this group? I guess if we use the Great Lakes Ecosystem concept, then perhaps we should pay some attention to what is going on with the ecosystem as a whole and groundwater quality because after all it is a system that possibly some of these nonpoint sources contamination way inland could through groundwater systems be transporting some things into the Great Lakes. Maybe those efforts are relevant to our considerations here.
So, I know there a lot going in the universities and I am sure and in other States as well. Possibly I was invited here simply because we’re are basically involved in tributary loading studies into the Great Lakes -- Lake Erie in particular; very detailed storm events sampling programs looking at ... chemical sediments and nutrients and we know that although our sampling programs focus on storm events, we back off to daily samples the rest of the year. Now that daily samples the rest of the year turns to be a totally outrageously detailed sampling program as far as tributary loadings are concerned but it does give us a lot of low flow water quality data and relative to nitrates and relative to pesticides -- all I’ll say is that low-flow periods are not of much significance at all either in terms of ambient water quality in the streams let alone any loadings, because the loadings of nitrates and pesticides that go into Lake Erie are so fine, current generation pesticides that I can’t envision the streams contributing significant parts during low-flows. Now this isn’t to say that some of the other toxic substances might be going down at this point and we do not have the adequate data on tributary loadings of the toxics. And when I say pesticides, it turns out that in the Great Lakes, in the things we’re worrying in the Great Lakes, current generation pesticides take a very low priority, because most of them are not persistent, they don’t bioaccumulate and not much attention paid to them at all. So low-flow tributaries we have some information on that might be relevant. What we’ve also just completed a private-lump survey to get at the issues of general groundwater contamination associated again with the problems on nonpoint source contamination of groundwater. How significant is the ubiquitous spread of pesticides, nitrates and fertilizers around the landscapes in terms of groundwater quality. Every thing is moving toward policy and program and I don’t feel we have adequate problem assessment yet. We have notions from worse-case studies that things are bad and that’s driving a political agenda that’s thrusting many programs but I just looking at 16,000 private wells in Ohio for nitrates and pesticides mapping and what do I find? In Ohio, the models have told us that 60 out of 88 counties were potentially contaminated by pesticides and nitrates based on a drastic model, .... values and chemical use and Indiana and Illinois would be in similar situations with moderate drastic scores, moderate ..... with high chemical use.

What did we find? 2.9% of the wells succeeded the drinking water standard. Northwestern Ohio with the heavy agriculture had virtually the lowest levels of contamination, the forests in southeastern Ohio had the highest levels of contamination along the Southwestern Ohio. This was nitrate, I'm talking about nitrate and that probably one conclusion is the septic tanks was probably our biggest problem of elevated nitrate contamination. When it came to pesticides, we biased our pesticide sampling programs so that we were looking primarily at nitrate-contaminated wells and we have six systems that have exceeded MCLs for atrazine and Lasso. Three of them were dug wells, two were springs, and the other one was shallow drilled well used for geothermal
heating with surface water going right back to the cornfield beside the system and so it is an extension agent that had installed that system and he wasn’t all that surprised that there were six parts per billion Lasso in his well which he did not use for drinking. Otherwise, accuzin is the one that current generates pesticide certainly the one we find most often in Ohio, we would estimate that it is present in maybe 4.3% of the wells of the state, but the concentrations more than half of those detections were in the range of between 0.2 and 0.5 parts per billion. So very, very low. If we had come up to one part per billion detection limit for atrazine, detection in the state would be less than 0.5 percent based on extrapolations within our datasets. And I think that Michigan State was involved in a survey of private wells in that state for nitrogen, nitrates was a popular program with the farm bureau and the percentage of nitrates contamination that they found were much different from what we found. That’s surprising because I figured Michigan was nothing but a big sand pile and we have clay, but of course that’s kind of a over-generalization. In any case maybe some of the other folks here would like to comment on what ............ (end of tape).
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The

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3.0 CANADIAN GROUNDWATER ACTIVITIES

3.0 CANADIAN GROUNDWATER ACTIVITIES

Introduction

The Canada-Ontario Agreement (COA) Groundwater Committee was established in the Fall of 1988 in response to Annex 16 of the Great Lakes Water Quality Agreement of 1978. Annex 16 was added to the Agreement through an amendment by Protocols signed in November 1987 to address pollution from contaminated groundwater. Terms of the Annex are given in Figure 1.
3.1 CANADA-ONTARIO AGREEMENT AND
THE ONTARIO MINISTRY OF THE ENVIRONMENT ACTIVITIES

Paul Beck

Background

I have been asked to prepare this discussion paper to address a number of items under the auspices of both the Canada-Ontario Agreement (COA) Groundwater Committee and the Ontario Ministry of the Environment.

One of the items under discussion is a review by the COA Groundwater Committee of the recommendations of the Science Advisory Board Groundwater Task Force Report of 1985 which recommended hydrogeological mapping of the Great Lakes basin at a scale of 1:1,000,000.

Other initiatives of the COA Groundwater Committee will also be discussed including:

i. assessment of direct discharges of groundwater contamination to the Great Lakes and connecting channels; and

ii. the organization of working groups to address the development of standard protocols and techniques for groundwater sampling, analytical techniques and calculating contaminant loadings.

Groundwater activities of the Ontario Ministry of the Environment will also be discussed and some of the relevant legislation is included in an Appendix.

Canada-Ontario Agreement (COA) Groundwater Committee Activities

Introduction

The Canada-Ontario Agreement (COA) Groundwater Committee was established in the Fall of 1988 in response to Annex 16 of the Great Lakes Water Quality Agreement of 1978. Annex 16 was added to the Agreement through an amendment by Protocol signed in November 1987 to address pollution from contaminated groundwater. Terms of the Annex are given in Figure 1.
Membership of the COA Groundwater Committee is shown on Table 1 and includes seven hydrogeologists and hydrologists affiliated with various federal and provincial government agencies.

TABLE 1. Membership of the COA Groundwater Committee

<table>
<thead>
<tr>
<th>NAME</th>
<th>AFFILIATION &amp; LOCATION</th>
</tr>
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<tbody>
<tr>
<td>A. Lefeuvre</td>
<td>Environment Canada Burlington, ON</td>
</tr>
<tr>
<td>K. Novakowski</td>
<td>Environment Canada Burlington, ON</td>
</tr>
<tr>
<td>S. Singer</td>
<td>Ontario Ministry of Agriculture and Food Guelph, ON</td>
</tr>
<tr>
<td>B. Kaye</td>
<td>Ontario Ministry of the Environment Kingston, ON</td>
</tr>
<tr>
<td>M. Goodwin</td>
<td>Ontario Ministry of the Environment Toronto, ON</td>
</tr>
<tr>
<td>B. Novakovic</td>
<td>Ontario Ministry of the Environment London, ON</td>
</tr>
<tr>
<td>P. Beck</td>
<td>Ontario Ministry of the Environment Toronto, ON</td>
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The Parties, in cooperation with State and Provincial Governments, shall coordinate existing programs to control contaminated groundwater affecting the boundary waters of the Great Lakes System. For this purpose, the Parties shall:

(i) Identify existing and potential sources of contaminated groundwater affecting the Great Lakes;

(ii) Map hydrogeological conditions in the vicinity of existing and potential sources of contaminated groundwater;

(iii) Develop a standard approach and agreed procedures for sampling and analysis of contaminants in groundwater in order to: (1) assess and characterize the degree and extent of contamination; and (2) estimate the loadings of contaminants from groundwater to the Lakes to support the development of Remedial Action Plans and Lakewide Management Plans pursuant to Annex 2;

(iv) Control the sources of contamination of groundwater and the contaminated groundwater itself, when the problem has been identified; and


FIGURE 1. ANNEX 16: POLLUTION FROM CONTAMINATED GROUNDWATER
An academic advisory group has been established consisting of Professor R. Gillham, University of Waterloo and Professor K. Howard, University of Toronto. This group operates at arm's length from the committee and is free to comment on its activities.

The role of the Groundwater Committee is two-fold:

a. it serves to report on activities of federal and provincial agencies in relation to the terms of Annex 16 (specifically, items (i), (ii), (iv) and (v)).
b. it initiates the organization of working groups to address item (iii) of Annex 16.


In 1985, the Groundwater Contamination Task Force of the Science Advisory Board of the International Joint Commission prepared a report outlining a study proposal to assess the potential for Great Lakes contamination through groundwater discharge.

The objectives and recommendations of the report are given in Figures 2.

4. Objectives

The objectives of the study, as proposed herein, are to define the major hydrogeologic regimens of the Great Lakes basin and to assess the potential for groundwater in those regimens to carry contaminants into the Great Lakes. Specifically, the study will attempt to:

1. define regionally, the hydrogeologic units within the Great Lakes basin;
2. locate the areas with potentially major sources of groundwater contamination; and
3. evaluate the potential for and significance of accompanying contaminants to move through the hydrogeologic units and into the Great Lakes.

The foremost objective of this work is to identify areas to the UJC where contamination potential is the greatest such that UJC can, in turn, recommend to the various governments those areas of major concern which should be further investigated and where mitigation of the contamination should be carried out.

7. Recommendations

The Groundwater Contamination Task Force requests that the Great Lakes Science Advisory Board:

1. commission a study to prepare a hydrogeology inventory of the Great Lakes basin as the basis for assessing the potential for Great Lakes contamination via groundwater;
2. the commissioned study be based upon the proposal outline in this report; and
3. the Water Resources Division, United States Geological Survey be contracted to perform the work.

FIGURE 2. Objectives and Recommendations from the Groundwater Contamination Report.
Funding for the study was estimated in 1985 to be $215k (U.S.). Assuming an even split of the funding between Canada and the United States, annual inflation rates of between 4.1 and 5.1% since 1985 (Statistics Canada) and an $.80 Canadian dollar (U.S.), then the Canadian contribution in terms of current dollars would be $161k (Canadian).

The final product of the study would be a series of maps prepared at a scale of 1:1,000,000 consisting of surficial materials, bedrock geology, permeability, groundwater flow, aquifer utilization, landuse and location of point sources of contamination.

The COA Groundwater Committee reviewed and discussed the proposal. Some of the main concerns included:

i. The end user of the maps is not well defined. The scale of the maps (1:1,000,000) is too small to be of much use to practicing hydrogeologists, both in industry and government. They may perhaps be of some use to management policy-makers in government but because of the low priority that is given to groundwater at the present time within both the federal and provincial governments, it is unlikely that the maps will be utilized.

ii. Much of the information that would serve as a source for the final maps is available on larger scale maps (1:600,000 to 1:50,000) which are a more practical scale for practicing hydrogeologists.

iii. There is a considerable amount of information available on the hydrogeology of the Great Lakes basin in the form of government maps and reports, well logs, consultant’s reports and university research. The committee questioned whether all this information could be synthesized within the time-frame and budget suggested in the proposal.

iv. At a time when funding is becoming difficult to obtain, the committee thought that the allocation of $161k (Canadian) or more to undertake a mapping exercise of existing information was too extravagant and that the funds could be better spent toward a further understanding of groundwater flow and hydrogeologic processes in the basin. For example, the estimated cost of a second 300 m (1,000’) deep borehole to the waste disposal zone in the Sarnia area instrumented with Westbay casing is $168k (Canadian) or roughly the cost of the Canadian contribution to this proposal.
Initiatives Addressing Annex 16 of the Great Lakes Water Quality Agreement

The COA Groundwater Committee has met three times since its inception in the Fall of 1988. While the committee's main function is to report on hydrogeologic activities of government agencies, it has undertaken several initiatives relating to Annex 16. These include:

i. The committee has produced a report identifying generic sources of groundwater contamination within the basin including: the pertinent legislation addressing the source of pollution; what government programs have been initiated relating to those sources; and references to examples where available.

ii. The committee members are evaluating 11 of 17 RAP sites around the lakes in terms of the contribution of groundwater contamination via groundwater pathways to the lakes. Committee members will attempt to identify major contaminants at each RAP, estimate the contaminant loadings from groundwater at each site and compare with other known sources to evaluate the significance of the groundwater component.

iii. The committee has initiated the organization of several working groups to address:

a. standard methodology for groundwater sampling and analysis; and
b. standard methodology for instrumentation for the determination of contaminant loadings to surface water bodies.

Through the COA Groundwater Committee initiative, Canada has requested that individuals from United States environmental agencies be identified so that the COA committee, along with its U.S. counterparts, can establish bi-national workgroups to address the item (iii) concerns.

Groundwater Activities of the Ontario Ministry of the Environment

Background

While the activities of the COA Groundwater Committee are geared toward the direct discharge of contaminated groundwater to the Great Lakes and the connecting channels, the work of the Ontario Ministry of the Environment (OMOE) is carried out throughout the entire Great Lakes basin. A brief description of the work will be described along with major legislation that is relevant to groundwater contamination in Ontario.
Fighting Island

A literature study of previous field work was conducted to assess the environmental impacts of the disposal of industrial waste from the Wyandotte Chemical plant in Michigan on Fighting Island and the St. Clair River. A final report has just been received by the Ministry from the consultant.

Niagara River Improvement Project

Funding Support for Regional Groundwater Flow at Niagara

The OMOE has assisted with partial funding to Environment Canada to conduct an investigation of regional groundwater flow at Niagara. This work will be described more fully by Kent Novakowski who is carrying out the work.

Evaluation of Contaminant Flux to the Niagara River

A consultant was retained by OMOE to evaluate the methodology used by Geotrans and Gradient Corp. in calculating contaminant loadings to the Niagara River from waste disposal sites located within five kilometers of the river in New York State. The next step will involve similar calculations on the Canadian side to estimate contaminant flux to the river.

Regional Activities

The Ontario Ministry of Environment regional staff undertake a number of activities which range from direct complaints from the public concerning interference of groundwater quality and quantity, to the assessment of the impacts of contaminant spills and review of hydrogeological work done in compliance with legislation. The priority given to each activity varies among the six regional offices which reflects the variations in regional management philosophies, hydrogeological conditions and political pressures.

The following listing of major activities carried out by regional staff was obtained from the Regional Groundwater Unit's Activities Report dated February 6, 1989. The activities are listed in declining order of person-days spent on each activity. These figures were calculated from three-quarters of the 1988/89 fiscal year ending March 31, 1989. Statistics for Central Region were not available.

Water Well Program

The water well program was established to provide protection to the aquifer and for the public against substandard work by water well drilling contractors. Activities
include: (i) the investigation of complaints by homeowners of well drillers; (ii) inspections of wells to ensure compliance with regulations and contractor visits in the field; and (iii) office support and water well records management.

**Water Quality Complaints**

Dealing with complaints relating to the deterioration of water quality are a major component of regional activities. Major complaints, including taste, odor and colour, can be related to the use of road salt to leaking underground gasoline tanks and to bacteria.

**Contaminant Spills**

Regional groundwater units are involved in the assessment of the impact of chemical spills on groundwater, and clean up.

**Waste Disposal Sites**

Regional hydrogeologists review applications for new certificates of approval (C of A) as well as extensions of Cs of A. This may require participation in the public hearing process. Additional activities include the review of monitoring reports describing the operation and closure of waste disposal sites as well as the review of waste disposal master plans (including environmental assessments).

**Water Supply Interference**

Water supply interference is a concern for many parts of the province where development demands on water cause a lowering of water levels. Interference complaints result from subdivision development, farm irrigation, golf courses, industrial process requirements, municipal supply and dewatering associated with pipelines or sewer installation or other major construction projects.

**Review of Private Subdivisions**

Phenomenal growth in housing across Ontario and particularly southern Ontario has resulted in the development of subdivisions which are not serviced with sewers and watermains. Where water supplies are obtained from groundwater and regional staff are involved in the review of subdivision applications from a standpoint of groundwater yield and quality.
Permits to Take Water

Individuals withdrawing 50,000 L of water or more per day for other than domestic use or farm, are required to apply for a permit. Applications for permits are reviewed by the regional hydrogeologist.

Review of Subsurface Disposal

Regional hydrogeologists are responsible for the application of policy, 15-08, the Reasonable Use Policy, which is designed to set groundwater quality limits at the boundary of waste disposal sites such that water quality cannot be adversely affects on adjacent properties.

Private Services Funding

In cases where individual water supplies in a community become impaired, the community can apply for a program of well replacement or the development of a communal supply. Regional hydrogeologists are involved with the review of technical reports associated with the program.

Industrial Site Investigations

Investigations at industrial sites including assessment, monitoring and closure may be carried out by regional staff or by a consultant on behalf of the Region.

Financial Assistance for Waste Disposal

Regional hydrogeologists are involved with the technical review of consultants' reports in all stages of siting, extension and closure of waste disposal sites which are funded under this program.

Other Activities

A number of lower-priority activities rounds out the scope of work that is conducted by the regional hydrogeological staff and include:

i. review of septic systems under Part VI of Environmental Policies Act;
ii. assessment of septic sludge sites;
iii. monitoring of water levels in observation well network;
iv. review of official plans and amendments to official plans;
v. review of severance applications;
vi. assessment of gravel pits and quarry impact on groundwater; and
vii. review of waterworks and sewage works for project engineering.

Branch Activities

Three branches headquartered in Toronto: Approvals Branch, Waste Management Branch and Water Resources Branch have a contingent of hydrogeologists to undertake a variety of groundwater assessments.

Approvals Branch

Hydrogeologists at Approval Branch are responsible for the hydrogeological reviews relating directly to the licensing of waste management systems (e.g. landfills, landfarms, transfer facilities) as required by Part V of the Environmental Protections Act. As well, they are responsible for the coordination of all reviews on waste management environmental assessments as required by the Environmental Assessment Act or the Consolidated Hearings Act and may be required to provide testimony at public hearings related to the licensing of waste disposal facilities.

Waste Management Branch

Waste Management Branch groundwater expertise lies within the Landfill Disposal Technology Unit and the Waste Site Evaluation Unit. The Landfill Disposal Technology Unit provides technical expertise to other Ministry staff regarding landfill disposal technology. It provides technical review of consultants reports and expert witness testimony at public hearings relating to waste disposal matters. As well, the Unit oversees relevant research projects that are funded by the Research and Technology Branch of the Ministry.

The Waste Site Evaluation Unit has inventoried waste disposal sites across the Province and contracted an inventory as well as detailed investigations of coal gasification plants across the Province. Hydrogeologists with this unit also provide expert testimony at public hearings.

Water Resources Branch

Groundwater expertise within the branch resides in the Groundwater Management Unit of the Drinking Water Section. This Unit undertakes programs to assess the impact of nonpoint sources of contamination such as acid precipitation and agricultural chemicals on groundwater quality. The Unit coordinates well inspection and administers the licensing of well contractors, well technicians and pump installers. Technical advice on
water quality is provided by the unit to OMOE staff and the public and the unit is involved in the overseeing of research programs funded by the Research and Technology Branch.

Summary

i. The recommendations of the 1985 Report to the Great Lakes Science Advisory Board to map the hydrogeology of the Great Lakes basin at a scale of 1:1,000,000 were considered by the COA Groundwater Committee to be inappropriate as a means to assess the potential contamination of the Great Lakes via groundwater. The map scale was considered to be too small to be of any real use to hydrogeologists and the cost of the project could be used to finance other studies that would provide a better understanding of groundwater flow and contaminant flux to the Great Lakes.

ii. The COA Groundwater Committee acts primarily in a reporting role to report on groundwater activities which address Annex 16 of the Great Lakes Water Quality Agreement. The potential for groundwater contamination to the Great Lakes has not been quantified and while groundwater contamination may be an important issue locally, within the Great Lakes basin, it may not be a major pathway for contamination directly to the lakes relative to other sources such as direct outfalls from industry and municipalities, airborne deposition and ship ballast discharges. The COA Groundwater Committee is currently estimating the groundwater contaminant loadings at a number of RAP sites around the Great Lakes to attempt to put into perspective the groundwater contaminant contribution relative to other sources. As well, the committee has initiated the formation of working groups to address the need for a standard methodology for sampling and the analysis of groundwater.

iii. The Ministry of the Environment undertakes specific hydrogeological investigations along the connecting channels to better understand groundwater flow and contaminant flux to these waters. However, most of the work carried out by the Ministry hydrogeologists relates to groundwater quantity and quality problems within the basin and the investigations and remediation to contamination problems ranging from individual homeowner wells to industrial and municipal waste disposal sites.

Legislation and Policies Affecting Groundwater Management

Groundwater is protected through a number of pieces of legislation. The most important being the Water Resources Act and its associated regulations, the
Environmental Assessment Act and The Environmental Assessment Act.

**Legislation**

**Water Resources Act**

The Water Resources Act protects groundwater quality from direct discharge of contaminants through Section 16 of the Act. Groundwater quantity is protected under Section 20 which prohibits the withdrawal of greater than 50,000 L/day without a permit, with the exception of domestic or farm purposes or fire fighting. Section 21, 22 of the Act and O Reg. 0612/84 deals with permits to drill wells and the licensing of drillers and drilling technicians. The construction and maintenance of some sewage works require approval under Section 24 of the Act. Exceptions include private systems serving five or fewer residences and sewage works designed to drain agricultural land.

**Environmental Protection Act**

The Environmental Protection Act and its associated regulations provides the Minister of the Environment with the authority to investigate problems of environmental pollution and to carry out the necessary programs and research leading to the wise use of the natural environment including landspreading of municipal sewage. Waste management is addressed in Part V, Section 24-26 of the Act which specifies the need for a Certificate of Approval by the Ministry to operate or extend waste disposal sites. Public and private sewage systems are covered by Part VII of the Act under Regulation 374/81, while spill legislation is covered by Part IX under Regulation 618/85. Direct discharge of contaminants to the environment are control by control orders and stop orders described in Part V.

**Policies and Guidelines**


Ministry policies and guidelines outline the main directions of the Province's groundwater management. Policies and guidelines can be implemented where groundwater issues are resolved under the Water Resource Act or the Environmental
Protection Act, but where issues are resolved under the Consolidated Hearings Act or the Environmental Assessment Act, policies and guidelines can only be suggested or recommended.

**Ontario Drinking Water Objective. Policy 15-06.**

Currently, the Ontario Drinking Water Objectives publication lists 53 health and aesthetic related parameters and specifies concentrations that should not be exceeded or which are desirable to provide good quality drinking water. The Federal-Provincial Subcommittee on Drinking Water has established guidelines for health and aesthetic parameters under Health and Welfare Canada's Guidelines for Canadian Drinking Water Quality. These parameters are under review by Ontario for possible adoption in early 1990.

**Reasonable Use. Policy 15-08.**

The Reasonable Use Policy applies only to water quality management. It establishes the basis for determining the existing and future reasonable use of groundwater adjacent to regulated sources of contamination including landfills, ex-filtration lagoons and large sub-surface sewage systems. Generally, the reasonable use of groundwater is taken as its present use and in most cases this will be for domestic consumption. As a result, water quality criteria, in most cases, will be based on the Ontario Drinking Water Objectives. The policy quantifies what level of contaminant is acceptable at the waste facility boundary such that groundwater beneath the adjacent property is not impaired beyond its reasonable use.

**Resolution of Groundwater Interference Problems. Policy 15-10.**

Policy 15-10 provides guidelines on the extent of remediation of contaminated groundwater. Except where the contamination is: from a natural source; the fault of the complainant; or is considered insignificant. The Ministry will take action to resolve the groundwater quality interference. In cases where the owner of the contamination can be identified, that person will be ultimately responsible for the financial cost of cleanup.

**Resolution of Wellwater Quality Problems Resulting from Winter Road Maintenance. Policy 15-04**

Policy 15-04 summarizes cost-sharing arrangements for situations where restoration of groundwater supplies are required as a result of winter road maintenance by a road authority.
3.2 CANADIAN FEDERAL ACTIVITIES

Kent Novakowski

My name is Kent Novakowski. I work with the National Water Research Institute which is part of the Federal Department of the Environment. The main Water Research Institute within Environment Canada. What I'm going to talk to you about today will give you a brief idea of what our federal mandate is for working groundwork and describe one study, the study of the Niagara area that we have undertaken at the National Water Research Institute.

In Canada, groundwater resources are under the jurisdiction of the provincial governments. There is very little leeway for the federal government to get involved in groundwater studies. There are a number of exceptions, of course, I think there is a total of eight exceptions. The ones that play the largest role as far as you're concerned in Southern Ontario in the Great Lakes basin, are these four here. The federal lands and facilities in groundwater problems and those will have to be addressed by the federal government.

The Boundary Waters Act, the Pest Control Products Act and the Atomic Energy Control Act. In all cases, if we were to address an individual problem, that problem is addressed in consultation with the provincial government, so even if we have a mandate to address the problem, we don't have the jurisdiction to address it independently. At the moment, the Boundary Water Act and the Pest Control Products Act are the mandates of of highest priority with respect to groundwater issues in the Federal Governments -- that's across Canada.

These mandates that I have described are being carried out by the two research institutes within Environment Canada: the National Hydrology Institute in Saskatoon, Saskatchewan and the National Water Research Institute in Burlington. Obviously the Institute in Saskatoon handles western issues and we at NWRI, in Burlington handle eastern issues by and large. Now I like to point out that between these two institutes there is only a total of six hydrogeologists so within Environment Canada there are six trained hydrogeologists who can address these issues and out of the six hydrogeologists, the primary function of these individuals is to do research. So these operational mandates which I have just outlined are secondary issues and because of the importance of these, we often end up incorporating the issues that arise on these mandates into our research program and thus watering down our research funding.
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In the Great Lakes basin, the groundwater issues are generally managed by the offices of the Regional Director-General of Environment Canada and we provide the technical support at NWRI. Now in the Great Lakes basin, the primary concern of the federal government with respect to groundwater is the Boundary Waters Act: that is the second mandate. That may change over the next few years but at the moment that is the act of interest.

Therefore, we focus our attention in the areas of possible transboundary migration into connecting channels of the Great Lakes. In particular, the Niagara Falls area and Sarnia. Also, we talked about Sarnia so I won't mention that any further except perhaps in comparison to contaminant loadings. I'm going to discuss the balance of this talk some of the work that Environment Canada has done at Niagara Falls. Work that we have done was started on the Canadian and has since spread the U.S. side and that has been conducted by the U.S. GS.

Now this slide gives you an idea. If you recall the estimate of contaminant loadings from the freshwater aquifer at Sarnia in the St. Clair River; phenols was 5.2 grams a day. If you look at estimates that have been done for loading into the Niagara River, there's actually two ways to go about this. These two estimates that shown here are relatively recent estimates. But what I'd like to point out here is that you can get remarkably different estimates depending on how you might approach the determination or the calculation for loading. For example, the upper estimate was based on site-specific information at 33 site areas on three-mile strip along the Niagara River on the U.S. side. That calculation was done by the Geotrans and the Gradiant Corporation of 1988. They obtained an estimate now, I can't underline how rough this estimate is but they obtained an estimate of about 400,000 lbs. a day of organics and that's a lump number that includes all possible organics. Nonetheless the magnitude of that number is quite remarkable, it is very large. I think in terms of problems elsewhere in the basin, this must be considered the most severe.

The second estimate is based on concentration measurements that were obtained from a groundstream stationed in the river subtracted from the concentration measurements obtained in the upstream section of the river, so it's just a differential loading. You get a completely different number but I'm trying to illustrate how easy it is to come up with a calculation and how meaningless these calculations are. Nonetheless there are still significant amounts of contaminants entering the Lake Erie.
In the early 1980s, this problem along the Niagara area was recognized and Environment Canada decided to initiate the study of the regional groundwater flow in the Niagara Falls area and of course, we can only work on the Canadian and that's what we focussed on. The idea, first of all, was to assess possible transboundary migration of contaminants. Secondly, to determine the possible extensive contamination at depth, in other words, to get an idea of what potential long-term problems might be in the Niagara Falls area and thirdly, to provide some aid in estimating contaminant loading to the Niagara River. This third objective as I pointed out might be a little bit useless.

For those of you who haven't honeymooned lately, Niagara Falls is between Lakes Ontario and Erie. We've seen on several maps, so I don't need to show that. The method that we used to approach this study was essentially an integrated type of approach in which the ultimate product is the conceptional regional groundwater flow model and to develop that product, we used three general submodels: the geological model; the hydrostratic-graphic model; and the geo-chemical evolution model. The conceptional regional groundwater flow model can also be validated although this hasn't been done, it may be done by the U.S. GS, but I'm not sure what the status of that is. (Bill, is that still being done? Yes, it's still alive). The conceptional model could be validated using a numerical groundwater flow model of some sort. That would provide information on regional movement of contaminants and also provide boundary conditions for flood site-specific studies in the Niagara Falls area.

Now, I apologize for this slide. It's not very good. This gives you a rough idea of what the boundaries of the study area are. The Niagara Escarpment to the north, the Niagara River runs this way. There's Niagara Falls there and then the gorge leaning off to Lake Ontario. Grand Island over here. Baby Island over here. The geology of the area is fairly straight forward with a thin veneer overburden of mostly clay material underlaid by layer cake sequence of sola.... and sedimentary rocks. Primarily dull stones, shales and sandstones.

The input into each of these submodels: the geological model is generally developed from borehole information such as core, local geophysics and regional stratigraphic information. The hydrostratigraphic model is also developed from borehole information, primarily, hydraulic tests of several types and also from hydraulic tech measurements which I'll describe very briefly and the geochemical evolution model is developed from geochemical samples. We haven't done very much on this particular model having found what I think what we needed from the other two. Backwork may be ongoing as far as the U.S. GS study.
This slide shows you, those of you who are not hydrogeologists and geologists, this is a diamond core rig. The reason I show you, just to show that we drilled some of the holes, let me back up one more time. We drilled seven holes as far as our study, the holes ranged in depths about 75 -150 meters and distributed around the Niagara Falls area, one up there, one here, one here, three on the Navy Islands and one here at the south of Chippawa. Most of the holes were vertical.

This slide shows you some of the core that was taken from some of that particular regional site. About 75 feet of core. What I wanted to show here is that groundwater flow in this area is primarily through fracture plains, the fracture plains are for the most horizontal. This is actually looking from bottom to top off sequence in particular and you can see the breaks in the core. In this particular case a lot of those breaks do not conduct water but in most part as you get nearer towards the surface, they do. When we drove the incline holes, we were looking for vertical fractures, fractures that might conduct water from near surface to depth and does provide conduit for contaminant migration.

Once the boreholes were drilled and the permeability of the boreholes assessed using hydraulic testing methods, we installed a plastic casing. Paul briefly mentioned this in his talk. This particular casing is manufactured in Canada by Westbay Instruments. What it does is it essentially isolates sections of the borehole along each borehole length so that we can obtain individual measurements of hydraulic flow at that particular level and also obtain detailed geochemistry and also to do hydraulic testing through this particular casing, we have done that in this site. I also threw up this slide to show that we are cooperating with the U.S. GS in this study. In fact, this is Bill Kappel whose sitting right up at the back there. It was a very nice day, as you can see lots of mud but we still managed to talk these guys into coming down and install this casing.

Just to give you an idea of cost. This particular hole was about 500 feet deep and it cost about $12 - 13,000 and the casing itself cost about the same so roughly speaking, each individual hole of the seven is worth about $30,000.

This is a schematic. The reason why I don’t show anything more sophisticated than a simple cross-section is because of the complex nature of hydrogeology here. Basically, this is a three-zone system, free flow system with a flow regime in the Guelph formation, Lockport formation in the upper top, a very low permeability high hydraulic head in the Clinton group and a low hydraulic head and relatively high permeability zone near the bottom. But the basic finding is that this cross-section is looking across from Navy Island to the Horseshoe Falls and we’re actually seeing a distance of about five kilometers along there with about a hundred meters relief. With the upperground flow regime, the circulation is fairly rapid. Movement in there is quite considerable and therefore,
particularly at the very near surface of the highly weathered bedrock where the fractures are very good conduits for contaminant migration. Obviously, that's what we should focus on when looking at regional, or perhaps regional picture of contaminant migration in the Niagara Falls area. But in terms of vertical migration contaminants, we did find a fairly good connection through the lockwork flow regime. However, the Clinton group for the most part in that is area is such low permeability that any contaminants migrated vertically will not migrate pass that "bearing." This is perhaps not surprising. It is well established this group existed and that group probably provide a barrier of some sort. However, near the gorge, near the Falls as shown here and of course, all the way along the gorge, that is quite different. Vertical fracturing as a result of stress relief due to presence of the gorge and the presence of the falls, has created some vertical pathways and contaminant migration near those pathways is pretty substantial just to put that into perspective.

I should point out where, I can't reach it, where Hyde Park is in respect to the gorge. Hyde Park is just there, "S" area is here. These areas are the most famous dump sites in the Niagara Falls area, and Love Canal is just off the edge of the slide.

So to conclude, the federal government basically has a very limited mandate and limited resources for assessing site-specific groundwater problems and pollution problems in the Great Lakes basin. Those that we have identified as being serious problems, particularly in the interconnecting channels have studies undertaken or underway.
This is really a conundrum. I didn't realize that I was going to say anything today. So this is really impertinent of me to talk about groundwater in this part of the world.

A few basic facts about how universities are organized in Ontario. I think there are 15 universities in Ontario and don't ask me to name them because I can't. They are all publicly supported and they're rather homogeneous in nature. There are no private cornells of that type in Ontario. They are all supported entirely by the Provincial Government, not the Federal Government. There is a severe problem with resources and Kent Novakowski has been discussing one of his aspects of it. Universities are also suffering. You must remember that there are eight Great Lakes states. There is only one "state" on the Canadian side and that is Ontario. So it is quite a strain for Ontario to handle the equivalent of eight U.S. state programs and that eventually comes down to a shortage of money.

If you look at groundwater activities in Ontario universities, I think you'll see two types of activity. One is the group or centre and Waterloo is the only group of centres that is well run and Bob Gillham runs it and if you want to know what they're doing you can subscribe to their little newsletter which will tell you all about it. It's a big operation, bigger than the federal operation or the provincial operation as far as the expenditure on research. There are also a second group, mourners, that's individual faculty members adopted throughout Queen's, McMaster, Toronto and various other places who, in a rather disjointed ad hoc way, in bits and pieces of work relating to groundwater research.

They tend, in my perception, to deal often with the local issues; the local dump or the local well contamination problem or this sort of thing. The research funding situation for these people is basic research comes from NSERC (Natural Science and Engineering Research Council) which is kind of an analogue of the National Science Foundation but not quite. It is a federal operated program. It gives out operating grants and this is in a rather non-competitive way. Any self-respecting faculty member at a university in Ontario should be able to get between $20 to $40,000 a year by writing a proposal once every three years in the same time when they do good things in the next two years. Somewhat similar to what I did last year somewhat similar to what I did last year. But it's rather low-level funding but it's stable and continuing but also had some
equipment branch scholarships for some students. There is a bigger program, more focused and more critically reviewed, strategic grants program but they are also very small compared to the corresponding U.S. programs.

The Province of Ontario has a Research Advisory Committee through the Ontario Ministry of Environment which seems to have gone to sleep in the last year or so. It has not been very active in giving out money. It funds specific projects and if you want to find out what’s going on, you get the Proceedings from the Technology Transfer Conference which is held annually in November in Toronto where it is a show-and-tell network and everybody says their piece. There are also specific Centres of Excellence and this-that-and-the-other and Bob Gillham runs one of them. He has been fortunate in getting the Ontario funding for this specific activity and people like me are often jealous of them. There is I think virtually no funding flows from the Federal Government for research in universities except on an ad hoc basis, whereas U.S. EPA has a program of funding universities, the Environment of Canada has not and this is a big problem. However, there are possibilities of picking up money from industry and so-on-and-so-forth.

The present climate in universities is that universities are eager for people to bring money in so that they can "tax" it essentially on overhead systems to get money for themselves. There is no analogue at all, for example, to the EPA and State Funded Green Bay program of PCBs -- that would be unthinkable in Canada.

The resources problem is really at the heart of this issue and I think it is important to address because it is all pretty well to come out with a nice report saying we should do this or we should do that. The resources are not available on the Canadian side and this is our problem as you heard from Kent and Paul.

Canada as a country is actually smaller than California as a state so you can't really expect great things. The Department of Environment in Canada is about $800,000,000 a year operation which about half goes for weather forecasting which in the States is done by another agency. Another big chunk goes for parks, which in the States is done by another operation. Another big chunk goes for Canadian Wildlife Service and so you're left with something like I think is about $150,000 million a year for environmental protection conservation. Which means in Canada roughly there will be 30-40¢ spent by the Federal Government for every dollar that we spend on environmental things through EPA. EPA is about a four to five-billion dollar a year operation. So money is very thin on the Canadian side. That's why there are only six hydrogeologists in all Canada. This is an important problem too to address.

Just as a personal point, one aspect of this, we're talking about loadings. My interest in life is putting together mass balances for chemicals in the Great Lakes because I'm
convinced that if we can do that then we can really understand how the Great Lakes are contaminated and these come from point sources, sewage treatment plants, industrial operations and Ontario is doing a really good job trying to pinpoint through its MISA program. There are nonpoint sources. There are atmospheric sources. There are in-place sources. There are spills which our Committee has been working on a great deal in recent months. There is groundwater problems and we have no idea at all what the contribution of groundwater is. I suspect, like Paul says in his report, that it is not large but we don't have the kilograms per year numbers except for a few isolated cases. Let me give you an idea of the quantities; this a very, very rough calculation, but Lake Ontario contains about 10 to the power of 12 cubic meters of water and it contains about one nanogram per meter or one microgram cubic meter of PCB. So if that contains 10 to 12 micrograms of PCB, which ten to the power of six grams, which is ten to the power of three kilograms of PCB. The residence time of that is about a year to two years. So the loading of PCB to Lake Ontario must be roughly in the order of magnitude calculation of about 1,000 kilograms per year or three to four kilograms per day. So when Paul mentions something about a gram per day, that's really quite small. This causes a problem in Lake Ontario, it's been contaminated and there are fish advisories. My guess is that number has to come down to a number certainly less than 100, possibly round-about 10 kilograms per year in order to virtually eliminate PCBs. That is roughly where, I think, we're going for persistent organic emissions, about 10 or so kilograms per year and the question really is how does groundwater fluxes contaminants compare with this number? And if that could be answered, that would be a big step forwards.

I can not support the program that Kurt has been promoting as a result of this '83 workshop. If only because I think it has an enormous educational capacity. I teach electrical engineers, chemistry which is a terrible chore, because they hate chemistry. (end of tape)

* * *

(begining tape) to clean the electrical equipment and you ask them "What should you do with it once you have cleaned it?" and they say "Well we just put it in the ground; it goes away." They don't know once it's tenuated, nobody knows quite what that means. They don't know what groundwater is. They don't really know that it is flowing and they don't the type of chemicals that cause the problems, and they are not only educated. So there is a big educational problem out there, believe me. You're are all intimately into groundwater business and the vast majority of even engineers don't know what is going on. These are very intelligent, competent engineers that dumped all that stuff in Love Canal, not 300 yards from the Niagara River. So anything that can be done to enhance the awareness of groundwater contamination, I think is worth $100,000? It's just peanuts. I worry, Kurt, about the workshop that we're going to start this afternoon
on the Canadian side because of institutional memory. Paul, for example, is leaving the Ministry of Environment in Ontario. In fact this will probably be his last official duty. Where will Ontario’s institutional memory of what happens this afternoon? It will be gone and I think it’s going to be a real problem nailing down commitment on the Canadian side because the resources are so thin on the ground.

Looking back at the report, you look into Page 41, it says "We shall do this, we shall do this and item 3 says it should be done by the U.S. Geological Survey." I think that must have been the part of the kiss-of-death on the Canadian side and I think that you have got to find some way of involving the Canadian groundwater people in a program. We have got to get something out of them and I, like Walter, think there’d no point of going after the federal and provincial government to prize out more money. I am not quite as pessimistic as Kent but I don’t take such a beating as he does. But not to shape a feasible program financially and at least talk to them. Thanks.
4.0 WORKGROUP REPORTS
4.1 INTRODUCTION TO WORKGROUP REPORTS

Kurt Bauer, Workshop Moderator

Well, it's somewhat after 9 o'clock and I'll open the plenary session of the workshop. The workgroups did not produce written reports that is actual text but they did each produce summary outlines of the findings and conclusions of their deliberations which from everything that I was able to observe, was sincere and dedicated on everybody's part. I know that the IJC appreciates that. Interestingly enough, even though I had some misgivings at the end of yesterday's plenary session that we would be achieving agreement, it developed that both the American and Canadian workgroups were very much in the same essential agreement on recommendations to the IJC and for that reason, in the meeting of the Steering Committee group last evening, it was felt there was no need to present two reports for discussion here this morning much to my pleasant surprise. That is going to make the discussion here this morning much easier to carry on. It was agreed that Dr. Gillham and Dr. Gillham consented irrespective of his very busy schedule to present what really is common finding of the two workgroups, plus I am asking Lindsay Swain, as chairman of the U.S. workgroup to add Dr. Gillham's presentation and open the subject for discussion.
4.2 CANADIAN WORKGROUP REPORT

Robert W. Gillham

It sure is a sign of the inefficiency of the spoken word or the strength of the written
word to see four hours of discussion condensed to a page-and-a-half.

The Canadian group had three critical recommendations: one, as you might expect,
was that work done on the Canadian side be done by Canadian agencies or groups; the
second key recommendation was that the project involve some sort of database
development for mapping effort; and the third recommendation was that the Groundwater
Task Force of the IJC be reinstituted to take care of some of the details of the problems
that we have discussed on for sometime.

What you have before you was prepared this morning from some very rough notes so
some of these segments are not all that clearly expressed, but we'll work our way through
the Canadian report.

There was quite a bit of discussion on what form this project would take and I think
there is still quite a bit of uneasiness about whether a database mapping project is really
the best way to go about it. But I think, not being able to count on federal imperatives, I
think we agreed that probably the best alternative at this time that was arrived at, in
part, by recognizing the project was largely an educational project, a promotional-type
project to the governments and also to the public raising the awareness of groundwater in
general and potential problems to the Great Lakes as a result of groundwater and so if
you take that as the objective of the project, the prime objective, then that seems to make
the database mapping exercise relatively acceptable. I knew that would be the main
objective but the main purpose we saw for the project, we hoped that the database is of a
sufficient quality that could be used for other things. Perhaps as diagram material
providing material for guiding other research or other applications.

We went through the document that was circulated. Phase one, which is really
defining the product in a level of detail within the project. We made a decision whether to
map anymore or if a database project was acceptable. We went back through the previous
proposal and project description and we decided that Phase 1 needed to remain in the
project as it and really addresses details that would be considered in Phase 2. We felt
that it was essential that the Canadian and the American efforts be very carefully coordinated so that maps not procedures and databases would be completely compatible between the two groups. So, in fact, they would probably end up being one single report of the databases. The other conclusion that we came to was, that in this workshop, we probably wouldn’t be able to arrive at sufficient terms of reference to actually describe the project to the level of detail in the project and largely for that reason, there are other reasons, we recommended that the Task Force would be reinstated to draw details and guidelines to address the proposals or whatever route is taken.

In terms of the specifics of what was listed in the previous report as Phase 2. I think these need to be addressed in some detail by the revitalized or reinstated Task Force. Going through some of the detailed items that were listed, we felt that surficial maps were certainly required in such a report, bedrock geology maps would be required and permeability of surficial materials. Some discussion on what level of detail could be included and but then again, this is something a Task Force should need to address. Groundwater flow characteristics and directions and again there were some discussion at the level of detail. The top geologic unit would give flow directions in all the geologic units, no doubt would be resolved by the Task Force, probably in cooperation and discussion with whoever is going to execute the project. After realization of the project, a useful thing that could be included in the report would certainly be a land-use map, again some questions concerning the level of detail. Certainly agricultural versus urban and probably at some level, the urban land use, residential versus industrial and that we feel that many of the more important contaminants to the Great Lakes would come from industrialized parts of the urban areas. While probably all this could not be shown on one map, but then the database .....
probably will fall very closely to land use maps, agricultural versus forestry or whatever and the point sources may be broken down into two or three categories: perhaps petroleum products in that gasoline stations and wide distribution tend to have different source characteristics, perhaps than manufacturing companies using PCBs for example, I think distribution source will look very, very different or mining or whatever. So it seems a point source would be broken down into two or three or four types of sources. Discharge through lake bottoms and contaminants or parameters may be carried to discharges and other areas of natural contamination as well should be addressed in the report. Again I’m unsure if these should be addressed as natural but they should be addressed perhaps if the tests find it necessary.

Hesitating to recognize that this document is going to be used to a large extent, a lobbying document, we felt that it has to end up being a very persuasive document -- something that will cause regulators to read it, be impressed and be concerned. We didn’t feel that producing essentially an atlas of potential groundwater contamination in the Great Lakes basin would be a persuasive document. We felt that it has to be a well thought-out and persuasive text to go with the document and it should be state-of-the-art on specific topics and topics could deal with specific contaminants that we have identified as being of particular interest or concern in the Great Lakes, like state-of-the-art, state-of-knowledge report on petroleum, for example. Somehow those state-of-the-art reports are going to have to be consistently put together in a manner that people to be concerned about the future of Great Lakes. To add to the persuasiveness of the report, we would present two or three case histories of serious problems or significant discharges to the lakes. Again, to get people attention and focus.

Along the same lines, to add persuasiveness particularly on the Canadian side, considering Canadian mandate in place and presence of a mandate in some areas. The text that accompanies the mapping should consider transboundary movement of contaminants but maybe part of the case histories in a separate section from the text. I should also stress the understanding of current distribution and loadings of contaminants that provides the means for prevention in future and that could be persuasive in some people’s minds. Plus, you’re dealing with contaminants as indicated in CEPA (the Canadian Environmental Protection Act) and Kent may want to comment on this as I’m not sure of the details of it. But making the report somewhat consistent with that document would certainly help on the Canadian side in terms of selling the future work plan.

Those were our comments concerning specific documents. Again, I think a lot of these details could go to the revised Task Force, reinstituted Task Force as recommendations to decide what this document should include.
Some of the other discussion concerning how the project actually comes into being, I think perhaps our group had the coordinated effort between the U.S. and the Canadian side. There got to be some central management committee or body that might be this Task Force or might be through the IJC. Obviously the IJC folks must have much better ideas of what can be done and what can't be done but somehow we feel if the project is to be successful to have .......... worked out on both side and have the close coordination and consistency then there will have to be a quite active management committee or structure involved.

That was the nuts and bolts of our report and I certainly invite the other Canadians who were at our meeting to recall points I didn't recall being mentioned or if certainly there were things that were not in Canadian report that the other side felt should be in.
When we discussed and put this report together last night, a lot of what we talked went into a great deal of detail of what we thought the genetic would be addressed and what needed to be addressed and specifics that we would like to have included in the new directions. One of the things the U.S. Committee came up with that was different, was that we suggested that it be a political action tool to get the governments to recognize that groundwater problems exist prior to this project being started. This was essentially because of the fact that the last time the project was proposed to the Committee, it sat for two years and nothing has really happened. If for no other reason, it was because there was a stipulation in there that the United States, under the U.S. GS would be doing the project (tape ends).............

* * *

(new tape continues) ........... this to be done by the Canadian government and this part to be done by the United States government and maybe that was the problem with the original document. We may not need that. We have suggested that a political action tool of some sort which would show areas of concern with projects or some sort of data or illustrations showing where the tenants have moved and giving types of hydrogeologic environments which exist around the lake. We are talking essentially a one-page handout that could be given to water managers or people that are involved in the management of water resources in the two countries to try to get them aware that the problem does exist and it has shown that we have cases where contamination has happened.

In addition to the items that Dr. Gillham has already talked about we were very specific about which kind of maps we have that inadequately address and need to be done more thoroughly. We have listed six specific future needs at the end of our meeting and those were:

- a new standardized sampling equipment analysis procedures;

- that there needs to be a new the Great Lakes policy committee with correct agencies represented;
• the question of how to quantify base flow needs to be standardized in some way that it is uniform on both sides, especially for this project;

• there needs to be an evaluational master chemical inputs that needs to be added to the original project direction;

A very general comment that was made is that there needs to be more well trained hydrogeologist available that has nothing to do with the project. This is something we thought was a need and we asked for a directory of employers that were involved in water resources on both sides of the border. I think we are in much agreement in the comments we had on developing water policy, groundwater policy. To me, these would easily fit into a reconstituted groundwater task force. This would essentially serve the same purpose. We could talk to somebody with the same results.
I think I have written on this subject before. We must be ready to talk of war and I think that the U.S. government should be aware of this. We cannot afford to let this go on without an adequate response. The United States has a responsibility to the world to ensure peace.

The situation is complicated by the fact that the United States is an ally of both sides in the conflict. We must be careful not to take sides, but to act in the best interests of world peace. There is a need for international intervention to bring about a resolution to the conflict.

I would like to see the United States take a more active role in the negotiations. We have the resources and the influence to make a difference. We must not allow this conflict to continue without resolution.

As for the future, we must be prepared for the possibility of a long-term conflict. The United States must be ready to respond to any threats to our national security. We must not allow ourselves to be drawn into another unnecessary war.
5.0 CONCLUSIONS AND RECOMMENDATIONS
5.1 CONCLUSIONS AND RECOMMENDATIONS OF THE WORKSHOP

Kurt W. Bauer, Workshop Moderator

The workshop was unanimous in recommending that a basinwide database collation and related mapping operation was needed, similar to that recommended in the original International Joint Commission study proposal. The workshop further recommended that the required work should be undertaken to provide a basis for a better understanding by the various levels and agencies of government concerned and by the citizen body of the problem and thereby provide a basis for a basis for needed political action. The work should be done in sufficient depth and detail, however, to serve as a framework for use in more detailed hydrogeologic studies and as a guide for further research efforts. Importantly, the work should identify specific geographic areas of concern based upon the varying hydrogeologic regimens, sources of contamination and known problems.

The workshop found that the original study proposal, as published in October 1985, required updating and detailing and that the workshop could not, in the time available, produce a revised document adequate to serve as a "terms of reference" or "specifications" for the needed study. Accordingly, the workshop recommended that the International Joint Commission recreate the Commission task force on groundwater; that the recreated task force be comprised of appropriately knowledgeable and experienced persons with a balanced representation from the Canadian and American portions of the Great Lakes basin; and that the constituted task force be charged with preparing an updated and revised study proposal which could serve as a basis for cooperative action by the Canadian and American interests concerned. More specifically with respect to the work elements proposed in the original study design, the workshop made the following findings and recommendations:

- The data proposed to be collated and the maps proposed to be prepared showing surficial materials and depth to bedrock, bedrock geology and aquifer utilization were generally sound as originally proposed. Some workshop participants expressed concern about the relatively large scale at which these maps were original proposed to be published. It was, however, agreed that, if the data were assembled in a geographic information system, that is, in a computer manipulatable and reproducible form with proper documentation of data source and reliability, this concern could be overcome.

- The workshop further found that the maps concerning the permeability of surficial materials, groundwater flow characteristics and land use, while required as originally
proposed, would need further definition in a revised study design in order to clarify important details. These details include, with respect to the permeability of surficial materials and groundwater flow characteristics maps, the treatment of differential permeability and differential flow characteristics with depth. With respect to landuse, these details include the need to differentiate between industrial and other urban landuses.

- The workshop found that additional data and related maps not provided for in the original study proposal were needed and should be provided for in a revised study design. These included maps showing surface waterflow systems, differentiated by perennial and intermittent streams; topography at an adequate scale and contour interval; and pertinent manmade infrastructure systems -- such as abandoned sewers and wells that may provide ready pathways for the rapid movement of contaminated groundwater -- if the preparation of the latter is found to be practicable. A map identifying specifically the sources of contamination should also be provided. The sources of contamination should be categorized by distributed sources -- which would follow the rural landuses and point sources. The latter may require categorization on some basis, such as organic versus inorganic contaminants.

- The workshop also identified three additional issues which needed to be addressed in the required areawide study but which could probably not be carried through to a mapping operation. These included the discharge of contaminants through lake bottoms; the contribution of natural contaminants; and the issue of groundwater quality objectives.

- The workshop noted that some work had been done in the American portion of the Great Lakes basin in assembling needed data in a computerized format on drainage patterns, location of public groundwater supplies, contaminated sites, surficial deposits, pesticide applications and land use; and that this work could serve to somewhat reduce the cost of the required study. On the other hand, the workshop noted that the existing efforts in the American portion of the basin were deficient with respect to the definition of bedrock units by yield; the total thickness of unconsolidated deposits; groundwater flow systems with particular emphasis upon recharge and discharge areas; and with respect to manmade infrastructures which may provide conduits for the rapid movement of contaminated groundwater to the Great Lakes.

- The workshop also noted the need to develop a directory of experts that could provide a resource for both the formation of the recommended task force and for the conduct of the required study, particularly the collation of existing data under the study.
The workshop recommended that a single report should result from the required study. In this respect, it was considered particularly important that the work involving the classification of the hydrogeologic regimens with respect to hydraulic properties; proximity to, and severity of, contamination sources; and proximity to the Great Lakes be presented in a contamination potential map covering the entire Great Lakes basin in a uniform manner.

- The workshop assessed that the report resulting from the study needs to be a persuasive document which can serve to raise the awareness of governments and citizens of the potential for the contamination of the Great Lakes via groundwater. To this end, the workshop recommended that the final study report include a "state-of-the-knowledge" section in which topics such as specific contaminants -- for example, petroleum products and nitrates -- are discussed and in which the processes involved in the contamination of the Great Lakes via groundwater by these specific contaminants are described. The workshop also recommended that the final report present several good case histories of actual occurrences of significant pollution of the Great Lakes via groundwater, the case histories being selected to demonstrate different pathways for the movement of different contaminants and potential remedial actions. The case histories should include examples of the transboundary movement of contaminants.

- Finally, the workshop stressed the importance of a strong institutional arrangement for project management. Such an arrangement was considered to be particularly important because the workshop stressed that any work done to the Canadian portion of the basin should be done by Canadians and any work done in the American portion of the basin be done by Americans. A pressing need would, therefore, exist to coordinate the Canadian and American work efforts so that the final results of the study are fully compatible and can be integrated into a single report and single areawide maps of the entire Great Lakes drainage basin. It was the collective opinion of the workshop that such project management could probably best be provided through the office of the International Joint Commission.

- The workshop also stressed the need to assure that, if the needed study is funded, such funding would be over and above the levels routinely provided to the federal, state and provincial agencies concerned so that the conduct of the study does not jeopardize the conduct of the ongoing day-to-day work of the agencies concerned, all of which have very limited staff and financial resources at their disposal. The workshop
noted that the latter was a particularly critical problem in Canada where the small staff of experts in the public sector was being seriously depleted by loss to the private sector.

The workshop noted the existence of certain other needs with respect to groundwater studies, including the need for the establishment of standards for groundwater sampling equipment and analytical procedures, and for the quantification of the base flow of streams. It was felt, however, that these kinds of needs might best be addressed by the recreated task force. After that task force completed the revised design for the needed areawide study, obtains the funding for that study, and oversees the proper completion of the study.

**Conclusion**

In conclusion, it should be noted that the workshop was a productive one in that it brought the Canadian and American interests represented to a better understanding of the study originally proposed by the International Joint Commission in 1985 and into agreement on a course of action which should be recommended to the International Joint Commission in pursuit of Annex 16 of the Great Lakes Water Quality Agreement. Although the participants held rather widely divergent viewpoints at the beginning of the workshop, as reflected in the discussion papers, agreement on the findings and recommendations at the conclusion of the workshop was unanimous. It is accordingly, respectfully, recommended that the Science Advisory Board and the International Joint Commission adopt those findings and recommendations and proceed with necessary implementation actions.
APPENDICES

A. LIST OF PARTICIPANTS

B. TECHNOLOGICAL COMMITTEE MEMBERSHIP LIST

C. TERMS OF REFERENCE FOR THE TECHNOLOGICAL COMMITTEE
noted that the latter was a particularly critical problem in Canada where the small staff of experts in the public sector was being seriously depleted by loss to the private sector.

The workshop noted the existence of certain other needs with respect to groundwater studies, including the need for the establishment of standards for groundwater sampling equipment and analytical procedures, and for the quantification of the rate flow of contaminants. It was felt, however, that these kinds of needs might best be addressed by the concerted task force. After that task force completed the relevant design for the model research study, offers the funding for that study, and enters the unique contribution of the study.

Appendices

Conclusion

In conclusion, it should be noted that the workshop was of tremendous and overall benefit the Canadian and American scientific communities. The work of the workshop originally was anticipated to be of major benefit to the Canadian Scientific Committee, although the participants held rather varied, divergent viewpoints on the difficulty of the workshop's task within the framework. Nevertheless, representatives of the scientific and recommendations for the implementation of the workshop were encouraged. In the final analysis, the participants recommended that the National Advisory Board for the Groundwater Joint Commission adopt these findings and recommendations and provide the necessary implementation action.
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1Workshop Steering Committee (Dr. Dick Jackson, NWRI, Environment Canada absent)
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3Formerly with International Joint Commission

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APPENDIX B. TECHNOLOGICAL COMMITTEE MEMBERSHIP LIST

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Secretary  
Dr. Michael A. Zarull  
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The Science Advisory Board directs its Technological Committee, within the context of the Great Lakes Water Quality Agreement, to advise the Board with respect to technological issues and concerns, broadly interpreted, that bear upon the human use of and impact upon the Great Lakes.

The pursuit of this charge, the Committee will draw upon relevant theories and practical expertise from the technological and engineering sciences; in particular, it shall draw to the Board’s attention relevant new and ongoing research in the area along with other factors affecting the development of knowledge pertinent to human activities and decision-making throughout the Great Lakes Basin Ecosystem. The Committee will assist the Board in drawing on such knowledge in formulating its advice to the Commission.

The Committee will report, at least annually, to the Board and obtain Board approval for the undertaking of specific projects, workshops and other activities related to the discharge of the Committee’s responsibilities.