OKANAGAN VALLEY GROUNDWATER STUDY
November 12, 1992

J. Forbes, Health & Welfare Canada
J. Hansen, Agriculture Canada
R. Bertrand, Ministry of Agriculture Fisheries & Food
R. Copes, Ministry of Health
A. Kohut, Ministry of Environment, Lands & Parks

Gentlemen:

Re: Okanagan Valley Groundwater Study

As I promised at our last meeting, enclosed are copies of a draft report

Development of a Detailed Pesticide Use Pattern and Groundwater Vulnerability Analysis for the Okanagan Valley of British Columbia - Phase I

and a proposal


The Eco-Health Branch in Ottawa have now abandoned the Phase II proposal because of lack of timely financial support. This region of Environment Canada has informed the local community that there is currently no funding available to pursue this project but advised them that it would be discussed with the proposed Federal/Provincial groundwater coordinating committee if and when it becomes established.

We might be prepared to provide some minor operating expenses and advice on this project.

I suggest we discuss this at our next meeting.

Regards,

L.N. Adamache, Head
Engineering & Groundwater Division

c.c. H. Liebscher
V. Bartnik
V. Niemela
Development of a Detailed Pesticide Use Pattern and Groundwater Vulnerability Analysis for the Okanagan Valley of British Columbia

Phase II:
Implementation of a Focused Groundwater Quality Monitoring Program for Agrochemicals

A Proposal Prepared by:

Eco-Health Branch
Ecosystem Science and Evaluation Directorate
Environment Canada
Ottawa

June, 1992
TECHNICAL PROPOSAL

Background

The Okanagan valley is one of the most important agricultural areas in British Columbia. When fruit, vegetable, and livestock production is considered, this region accounts for up to 20% of the total economic value of B.C.'s agriculture industry (Kerr et al. 1985). It is the largest producer of tree and vine fruit in the province. Maintenance of high rates of production necessitates an adequate water supply and the use of agricultural chemicals (including fertilizers, insecticides, fungicides, fumigants, and herbicides). However, some of these chemicals are toxic and, as such, may pose a hazard to mammalian, avian, and other receptors if uses result in significant losses to the environment. While many of these hazards have been investigated, the potential for impacts of agrochemical use on the quality of groundwater resources has received relatively little attention.

There are a number of factors that may influence the vulnerability of groundwater resources to contamination by pesticides. McRae (1989) suggested that soil texture, slope gradient, depth to water table, and surface formation were several of the most important factors that influence groundwater vulnerability. Using data on these characteristics, critical areas in Canada that were most vulnerable to groundwater contamination were identified. On this basis, several areas within the Okanagan valley were identified as having a high potential for groundwater contamination (McRae 1989). In addition to these physical features, the potential for groundwater contamination in the Okanagan valley is enhanced by the wide range and significant quantities of pesticide products utilized by growers and the high irrigation rates that are necessary to maintain productivity.

Groundwater quality is a significant concern in the south Okanagan Valley because this resource is used extensively for irrigation, livestock watering, and domestic water supplies. Evaluation of the hazards posed by agrochemical use to these water uses in this area necessarily requires the development of a detailed pesticide use and groundwater vulnerability analysis to identify the substances and areas that are most likely to be associated with groundwater contamination. In addition, evaluation of these hazards requires the implementation of a focused groundwater quality monitoring program to establish the presence, nature, severity, and extent of contamination.

Assessment of the hazards of agrochemical uses is not a novel concept in the Okanagan valley. In 1987, an investigation was conducted to determine the magnitude and extent of groundwater contamination by pesticides in the vicinity of the Town of Osoyoos (McNaughton 1991). The results of this study confirm the vulnerability of groundwater resources in the Okanagan valley. In addition, various site-specific regional programs, which have been implemented by the provincial and municipal government agencies, have been directed at the assessment of groundwater quality. While these data provide some evidence that groundwater resources in this area are vulnerable to pesticide contamination, the extent of the actual contamination has not been established. In addition, recently there have been major shifts in pesticide use patterns in this area that could dramatically alter the potential for groundwater contamination.
Phase I - Summary and Recommendations

In response to the need for more recent and more focused information on the quality of groundwater resources in the Okanagan valley, an ad hoc working group (see attached contact list in Appendix) was established by Environment Canada in 1991, comprised of representatives from federal, provincial, and municipal government agencies, academia, and industry. Specifically, the members of this working group include key representatives from the Town of Osoyoos, Town of Oliver, Okanagan College, Okanagan-Similkameen Cooperative Growers Association, Monashee Cooperative Growers Association, B.C. Ministry of the Environment (BCMOE), B.C. Ministry of Agriculture and Fisheries (BCMAF), B.C. Ministry of Health (BCMOH), Agriculture Canada, and Environment Canada (DOE).

Under the leadership of Environment Canada (Eco-Health Branch, Ottawa), this working group directed the first phase of a study on pesticide use patterns and groundwater vulnerability in the south Okanagan valley in 1991/92. The first draft of this report (MacDonald et al. 1992) has now been completed and is currently under review by the working group. The summary and recommendations of Phase I of the project are given below:

1. A detailed pesticide use pattern and groundwater vulnerability analysis was developed for the southern portion of the Okanagan valley (north Oliver to the international boundary). This analysis was based on detailed 1989-91 pesticide sales data, which were considered to be an accurate indication of actual pesticide use patterns within the study area. Using these data, overall use volumes within the study area, use volumes by area, and use volumes per month have been calculated. In addition, groundwater use patterns within the study area have been identified.

2. This analysis indicated that a number of specific areas within the south Okanagan valley may be at substantially higher risk with respect to contamination of groundwater resources than others. Therefore, a pilot groundwater quality monitoring program should be carried out to provide a preliminary evaluation of the nature and extent of groundwater contamination in this region (i.e. validate the high risk areas).

3. High risk (priority) pesticides, with respect to their potential for contaminating groundwater, were identified as azinphos-methyl and ziram. On the basis of pesticide sales data, sulphur, diazinon, glyphosate, copper, methidathion, paraquat, and captan were identified as moderate risk (priority) pesticides within the study area. The 1992-93 pest management recommendations provided to growers by BCMAF (1992) and 1992 pesticide sales records should be evaluated to determine if significant shifts in pesticide use patterns are likely to have occurred in 1992. The pesticides used in grape production were thought to be under-represented in the present analysis, and several of these should be considered for inclusion in the pilot monitoring program. Based on that evaluation, a final list of priority analytes for a groundwater quality monitoring program should be established.

4. Using the results of the pesticide use and groundwater vulnerability analysis together with the regions pedological and limited hydrogeological information, the highest risk (priority) areas with respect to the potential groundwater contamination, were considered to be Oliver Central - west, Osoyoos Central - west, and Osoyoos South - west. However, additional information, including input from stakeholder groups, is required to identify the precise locations for sampling groundwater quality.
5. The results of the pilot groundwater quality monitoring program should be used to evaluate the need for, and to design, a future, more intensive monitoring program. Such an intensive program should be focused on those areas in which significant groundwater contamination is identified from Phase II. In addition, the results of the pilot monitoring program should be provided to stakeholder groups so that informed decisions can be made about improving and maintaining the groundwater quality (e.g., pesticide use patterns may be shifted away from those active ingredients that are contaminating groundwater resources). Further, these results may be used to identify the need for pesticide products that are less prone to leaching into groundwater.

6. The results of the pilot monitoring program, in conjunction with the detailed pesticide use analysis, should be used to verify and calibrate the Express expert system that has been developed by Environment Canada (Crow et al. 1989; Crowe and Mutch 1990; Mutch and Crowe 1990) for evaluating the fate of agricultural chemicals in the subsurface.

The results from Phase I of this project have clearly shown that the principle objectives have successfully been met. Thus, in so doing, a detailed pesticide use and groundwater vulnerability analysis in the Okanagan valley have been provided. The solid basis provided by a multi-stakeholder working group in Phase I of this project can now be used for designing and implementing a focused groundwater quality monitoring program to allow for informed, sound decisions to be made by the inhabitants in the south Okanagan valley.

Phase II - Implementation

In the past, design and implementation of water quality monitoring programs in British Columbia have, largely, been the responsibility of the provincial government (BCMOE, BCMOH, etc.). Environment Canada and other federal agencies (e.g., Health and Welfare Canada) have also initiated and/or collaborated in such programs when issues of significant national interest have arisen (e.g., transboundary concerns, federal lands, groundwater quality, etc.). However, regional/local governments, industry representatives, and the public have had limited opportunities for involvement. While this approach has frequently provided the data required to support environmental management decisions, it has not always generated the kind of inter-agency, multi-stakeholder cooperation and effort that is necessary to achieve sound environmental management objectives.

The economy of the south Okanagan Valley is dependant, to a great extent, on agricultural activities (including wine-making and fruit processing) and tourism-based industries. Indeed, local interests have expended considerable effort to develop and integrate these sectors and, as such, establish the unique character of the region. This comprehensive understanding of regional interests and concerns provides local organizations with a unique perspective on environmental management. This perspective, in addition to their extensive knowledge of the area, makes these organizations essential partners in the design and implementation of effective environmental quality monitoring programs.

The working group recognizes that implementation of a responsive groundwater quality monitoring program in the south Okanagan valley will require the participation of the public, local organizations, and all levels of government. As such, the working group proposes to refine the design of, and to implement, a focused groundwater monitoring program to provide the information
that is required to assess the hazards associated with agrochemical use in this area. In addition, the working group will collate and evaluate the results of this investigation, and prepare a final report which summarizes these data.

**Monitoring Program Design**

The first stage in the implementation of a monitoring initiative in the south Okanagan Valley is to refine the design a cost-effective monitoring program. The pesticide use and groundwater vulnerability analysis conducted in Phase I provides a scientifically-defensible basis for designing such a program, detailing information on the types and volumes of pesticides used in the area. In addition, by considering the use volumes and physical-chemical properties of each substance, those pesticides which have the greatest potential for leaching through soils and contaminating groundwater were identified. Furthermore, the results of this study provide information on the location and timing of pesticide use in this area.

Refinement of the monitoring program will involve the final identification of sampling sites, sampling frequency, and list of priority analytes. It is anticipated that Phase II will primarily utilize the large network of abandoned and active wells in the study area (mapped and provided by municipalities). The working group will facilitate the refinement of the monitoring program design by consulting BCMAF to determine if any major changes in pest control strategies have been recommended to fruit growers (i.e., in fruit production guides). In addition, the pesticide distribution outlets (South Valley Sales, Okanagan-Similkameen Cooperative Growers Association, and Monashee Cooperative Growers Association) will be consulted to determine if any such changes have resulted in shifts in pesticide use patterns. Any significant changes in pesticide use will be reflected in the study design.

**Summary of Anticipated Analytical Requirements**

Information from the initial pesticide use and groundwater vulnerability analysis were used to develop an estimate of analytical requirements. This analysis indicated that six of the ten fruit growing areas in the south Okanagan valley should be investigated further to determine the presence, nature and extent of groundwater contamination. If one site from each of these areas was sampled on three separate dates, and two samples were collected on each date, then a total of 36 samples for pesticide analysis would be collected. In addition, roughly 12 additional samples would be included for the program’s QA/QC component (i.e., 4 samples per sampling date). It is anticipated that the following priority analytes would be measured in each sample.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hazard Ranking</th>
<th>Detection Limit</th>
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</thead>
<tbody>
<tr>
<td><strong>Pesticides:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azinphos-methyl</td>
<td>1</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Ziram</td>
<td>2</td>
<td>0.1 ug/L</td>
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<tr>
<td>Sulphur (as Sulphide)</td>
<td>3</td>
<td>1.0 ug/L</td>
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<td>Glyphosate</td>
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</tr>
<tr>
<td>Copper</td>
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<td>1.0 ug/L</td>
</tr>
<tr>
<td>Methidathion</td>
<td>7</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Paraquat</td>
<td>8</td>
<td>0.1 ug/L</td>
</tr>
</tbody>
</table>
**Variable** | **Hazard Ranking** | **Detection Limit**
--- | --- | ---
**Pesticides**:<br> Captan | 9 | 0.1 ug/L<br> Thiophanate-methyl | 10 | 0.1 ug/L<br> Carbaryl | 11 | 0.2 ug/L<br> Dodine | 12 | 0.1 ug/L<br> DNOC | 13 | 0.1 ug/L<br> Endosulfan | 14 | 0.05 ug/L<br> Mancozeb | 15 | 0.1 ug/L
**Other Variables:**<br> pH<br> Conductivity<br> Hardness<br> Alkalinity<br> Sulphate<br> Total Nitrogen<br> Nitrogen (NO₃)<br> Chloride<br> Temperature

*other pesticides could be including depending on the results of Phase II*

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**Report Preparation**

Report preparation and information dissemination to all stakeholders and public is an important aspect of this study. As such, Environment Canada with the continued help of the working group will facilitate the collection, collation, and summarization of the results of the groundwater quality monitoring program. These data will be interpreted in light of existing Canadian water quality guidelines (e.g., drinking water, agricultural water uses). This information will be presented in a detailed technical report, with an extended executive summary that provides all readers with easy access to the results of the study. Presentations of final results to interested stakeholders in the region are planned for Fall 1992.
PHASE II - COST ESTIMATES

Major Components:

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<td>Monitoring expenses</td>
<td>15 K</td>
</tr>
<tr>
<td>Chemical analysis</td>
<td>25 K</td>
</tr>
<tr>
<td>Report preparation</td>
<td>15 K</td>
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Total estimated cost: 55 K

Contributions (proposed) from working group members:

<table>
<thead>
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<th>Environment Canada:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco-Health Branch</td>
<td>25 K</td>
</tr>
<tr>
<td>National Hydrology Research Institute</td>
<td>10 K</td>
</tr>
<tr>
<td>Inland Waters - Pacific &amp; Yukon Region</td>
<td>10 K</td>
</tr>
</tbody>
</table>

Total contributions (to date): 45 K

Remaining shortfall: 10 K

\(^2\) Contributions still to be finalized
References


APPENDIX

Working Group Contacts

Robert Kent,  
Pierre-Yves Caux  
Eco-Health Branch  
Environment Canada  
Ottawa, Ont.  
K1A OH3  
(819) 953 1554  
(819) 953 0602  
Fax: 953 0461

Eugene Hogue  
Agriculture Canada  
Summerland, B.C.  
V1Y 1Z0  
(604) 494 7711  
Fax: 494 0755

Tony Laranjo,  
Joe Cardosa  
Monashee CO-OP Assoc.  
P.O. Box 3010  
Osoyoos, BC  
V0H 1V0  
(604) 495 6515 or 6518  
(604) 495 3366  
Fax: 495 2400 or 3202

Fred Mehl,  
Hugh Leibscher  
Inland Waters  
Environment Canada  
224 West Esplanade  
North Vancouver, B.C.  
V7M 3H7  
(604) 666 8000  
Fax: 666 6713

Jim Hendry,  
Wally Nicholaichuk  
National Hydrology Research Institute (NRHI)  
Environment Canada  
11 Innovation Blvd.  
Saskatoon, Sask.  
(306) 975 5953

Stuart Craig,  
Ron Johnston,  
Jim Bryan,  
Vic Jensen,  
L. Pauloski,  
Dan Nickel  
B.C. Ministry of the Environment  
3547 Skaha Lake Rd.  
Penticton, B.C.  
V2A 7K2  
(604) 493 8261  
Mobile: H433563

Peter Waterman  
B.C. Ministry of Agriculture and Fisheries  
Suite 101, 3547 Skaha Lake Rd., Kelowna, B.C.  
V1Y 7K2  
(604) 492 1320

Don Berthea  
Agriculture Canada  
1921 Kent Rd.  
Kelowna, B.C.  
V1Y 7S6  
(604) 782 2458

Tim Watson  
B.C. Ministry of Agriculture and Fisheries  
Box 340, West 7th St.  
Oliver, B.C.  
V0H 1TO

John Price  
B. C. Ministry of Agriculture and Fisheries  
4607 - 23rd St.  
Vernon, B.C.  
V1T 4K7  
(604) 549 5580

Bruce Woodbury  
Town of Osoyoos  
P.O. Box 3010  
Osoyoos, B.C.  
V0H 1V0  
(604) 495 6515

Bill McPhee  
Okanagan Similkameen Co-op Growers Association  
P.O. Box 39  
Oliver, B.C.  
V0H 110  
(604) 498 3491

John Price  
B. C. Ministry of Agriculture and Fisheries  
4607 - 23rd St.  
Vernon, B.C.  
V1T 4K7  
(604) 549 5580

John Holland  
Environmental Standards Association  
1036 Richter St.  
Kelowna, B.C.  
(604) 861 4811

Gerald Geen  
British Columbia Fruit Growers Association  
1473 Water St.  
Kelowna, B.C.  
V1Y 1J6  
(604) 782 5226

Peter Watnnum  
B.C. Ministry of Agriculture  
Suite 101, 3547 Skaha Lake Rd.  
Kelowna, B.C.  
V1Y 7K2  
(604) 492 1320

Tony Laranjo,  
Joe Cardosa  
Monashee CO-OP Assoc.  
P.O. Box 3010  
Osoyoos, BC  
V0H 1V0  
(604) 495 6515 or 6518  
(604) 495 3366  
Fax: 495 2400 or 3202

Fred Mehl,  
Hugh Leibscher  
Inland Waters  
Environment Canada  
224 West Esplanade  
North Vancouver, B.C.  
V7M 3H7  
(604) 666 8000  
Fax: 666 6713

Jim Hendry,  
Wally Nicholaichuk  
National Hydrology Research Institute (NRHI)  
Environment Canada  
11 Innovation Blvd.  
Saskatoon, Sask.  
(306) 975 5953

Stuart Craig,  
Ron Johnston,  
Jim Bryan,  
Vic Jensen,  
L. Pauloski,  
Dan Nickel  
B.C. Ministry of the Environment  
3547 Skaha Lake Rd.  
Penticton, B.C.  
V2A 7K2  
(604) 493 8261  
Mobile: H433563

Eugene Hogue  
Agriculture Canada  
Summerland, B.C.  
V1Y 1Z0  
(604) 494 7711  
Fax: 494 0755

Tony Laranjo,  
Joe Cardosa  
Monashee CO-OP Assoc.  
P.O. Box 3010  
Osoyoos, BC  
V0H 1V0  
(604) 495 6515 or 6518  
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Fax: 495 2400 or 3202

Fred Mehl,  
Hugh Leibscher  
Inland Waters  
Environment Canada  
224 West Esplanade  
North Vancouver, B.C.  
V7M 3H7  
(604) 666 8000  
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Jim Hendry,  
Wally Nicholaichuk  
National Hydrology Research Institute (NRHI)  
Environment Canada  
11 Innovation Blvd.  
Saskatoon, Sask.  
(306) 975 5953

Stuart Craig,  
Ron Johnston,  
Jim Bryan,  
Vic Jensen,  
L. Pauloski,  
Dan Nickel  
B.C. Ministry of the Environment  
3547 Skaha Lake Rd.  
Penticton, B.C.  
V2A 7K2  
(604) 493 8261  
Mobile: H433563

Peter Waterman  
B.C. Ministry of Agriculture and Fisheries  
Suite 101, 3547 Skaha Lake Rd., Kelowna, B.C.  
V1Y 7K2  
(604) 492 1320

John Price  
B. C. Ministry of Agriculture and Fisheries  
4607 - 23rd St.  
Vernon, B.C.  
V1T 4K7  
(604) 549 5580

Bruce Woodbury  
Town of Osoyoos  
P.O. Box 3010  
Osoyoos, B.C.  
V0H 1V0  
(604) 495 6515

Bill McPhee  
Okanagan Similkameen Co-op Growers Association  
P.O. Box 39  
Oliver, B.C.  
V0H 110  
(604) 498 3491

John Price  
B. C. Ministry of Agriculture and Fisheries  
4607 - 23rd St.  
Vernon, B.C.  
V1T 4K7  
(604) 549 5580

John Holland  
Environmental Standards Association  
1036 Richter St.  
Kelowna, B.C.  
(604) 861 4811

Gerald Geen  
British Columbia Fruit Growers Association  
1473 Water St.  
Kelowna, B.C.  
V1Y 1J6  
(604) 782 5226
July 28, 1992

File: 56060-15GW

Pierre-Yves Caux, Ph.D
Pesticide Guideline Specialist
Environment Canada
Eco-Health Branch
Ecosystem Science and Evaluation Directorate

Dear Pierre:

Further to our telephone conversation this morning, I am pleased to advise you that our headquarters Pesticide Management Branch is prepared to commit up to $10,000.00 towards the completion of Phase II of a groundwater quality monitoring program for agrochemicals in the Okanagan Valley.

Please contact me at your convenience to discuss this project further. My telephone number is (604) 490-8259.

Yours truly,

Stuart M. Craig
Regional Manager
Pesticide Management Program
Southern Interior Region
TOWN OF OSOYOOS

Box 3010, 8707-76th Avenue, Osoyoos, British Columbia, Canada V0H 1V0 Telephone (604) 495-6515 Fax (604) 495-2400

August 6, 1992

Environment Canada
Eco-Health Branch
ESED
Place Vincent Massey, 7th
Ottawa, Ontario
K1A 0E3

ATTN: Pierre-Yves Caux, Ph.D
Pesticide Specialist

Fax (819) 953-0461

Dear Pierre:

RE: Groundwater Monitoring Program

I am pleased to advise that the Council of the Town of Osoyoos has authorized the expenditure of up to $10,000.00 for implementation of the groundwater monitoring program for agrochemicals in the southern Okanagan Valley. We do hope that other jurisdictions such as the Town of Oliver will participate as well and will be seeking their support. Council believes this program is extremely important and should not be abandoned and is therefore willing to provide the funding required to proceed with at least a portion of the program.

Please contact me at your convenience to discuss implementation of the program.

Yours Truly,

Bruce Woodbury
Administrator
Development of a Detailed Pesticide Use Pattern and Groundwater Vulnerability Analysis for the Okanagan Valley of British Columbia - Phase I

Draft Report

Prepared by:
D.D. MacDonald, M.L. Haines, and I.D. Cuthbert
MacDonald Environmental Sciences Ltd.
2376 Yellow Point Road, R.R. #3
Ladysmith, British Columbia
V0R 2E0

Prepared for:
Robert Kent
Eco-Health Branch
Environment Canada
351 Boulevard St. Joseph
Hull, Quebec
K1A 0H3

Funds for this project were provided by Environment Canada, using resources made available through the Pestfund Program.
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ACKNOWLEDGEMENTS

The authors would like to gratefully acknowledge those persons who made very substantial contributions to this report's preparation. Pesticide sales and other data proved to be invaluable and were kindly provided by B. McPhee, T. Laranjo, J. Cardosa and S. Craig throughout the course of the study. Advice on study area selection and other relevant information was provided by B. Andrews, V. Jensen, E. Hogue, R. Johnston, L. Pauloski, B. Baehr, T. Watson, J. Bryan, and D. Bertoia. In addition, background information on land uses, water uses, and sources, and other relevant topics was supplied by B. Woodbury, N. Martin, and T. Szalay. Many thanks to D. Nickel, H. Arndt, G. Brown, P. Waterman, J. Holland, G. Geen, D Cronin, F. Mah, J. Hendry and J. Price. The authors would also like to thank R. Kent and P.-Y. Caux for their support of this study and the implementation of the monitoring program.
Chapter 1

Introduction

The Okanagan valley is one of the most important agricultural areas in British Columbia. When fruit, vegetable, and livestock production is considered, this region accounts for up to 20% of the total economic value of B.C.'s agriculture industry (Kerr et al. 1985). It is the largest producer of tree and vine fruit in the province. Maintenance of high rates of production necessitates the use of agricultural chemicals (including fertilizers, insecticides, fungicides, fumigants, and herbicides) to control pest species. Some of these chemicals are toxic and, as such, may pose a hazard to mammalian, avian, and other receptors if use patterns result in significant losses to the environment.

A variety of studies have been conducted to assess the environmental impacts of pesticide use. The vast majority of these investigations have been focused on the evaluation of toxicity of specific pesticide formulations to non-target crop, livestock, and wildlife species. In addition, limited research has been conducted to determine which environmental fate processes (e.g., biodegradation, hydrolysis, photolysis, volatilization, mobility, etc.) are the most important with respect to the ultimate fate of these substances in the environment. The potential for impacts on groundwater resources has not been fully examined, primarily because these systems were considered to be relatively immune to contamination by agricultural pesticides (Cheng and Koskinen 1986).

Overall, groundwater monitoring data is rather limited. In spite of this limitation these data suggest that groundwater contamination by pesticides is relatively widespread. In the United States, for example, the USEPA has detected at least twenty different pesticides in groundwater throughout the country, with a total of twenty-four states affected (USEPA 1987). The results of the limited number of monitoring programs that have been conducted in Canada indicate that at least 25 different pesticides have been detected in groundwater (Hiebsch 1988; Pupp 1985; Frank et al. 1987; MacDonald and Fairfield 1990; McNaughton 1991). These data underline the significant potential for groundwater contamination in the vicinity of agricultural operations.

There are a number of factors that may influence the vulnerability of groundwater resources to contamination by pesticides. McRae (1989) identified the areas in Canada that were vulnerable to groundwater contamination using data on soil texture, slope gradient, depth to water table,
and surface formation. On this basis, several areas within the Okanagan valley were identified as having a high potential for groundwater contamination (McRae 1989). In addition to these physical features, the potential for groundwater contamination in the Okanagan valley is enhanced by the wide range and significant quantities of pesticide products utilized by growers and the high irrigation rates that are necessary to maintain productivity.

In 1987, an investigation was conducted to determine the magnitude and extent of groundwater contamination by pesticides in the vicinity of Osoyoos. The results of this study confirm the vulnerability of groundwater resources in the Okanagan valley, as a total of five substances (dimethoate, simazine, DDT, DDE, and DDD) were detected at 8 of the 26 locations tested (21 existing wells and 5 shallow piezometers; McNaughton 1991). While these data provide clear evidence that groundwater resources in this area are vulnerable to pesticide contamination, the actual extent of contamination has not been established. In addition, there have been major shifts in pesticide use patterns in this area that could dramatically alter the potential for groundwater contamination.

The present study was designed to support the development of a detailed pesticide use and groundwater vulnerability analysis in the Okanagan valley. This information will provide a direct means of developing a list of priority pesticides with respect to the potential for environmental contamination. As such, the results of this study may be used to support the development and implementation the development of focused environmental quality monitoring programs within the Okanagan valley. While such monitoring programs may be focused on various media types (i.e., surface water, soils, sediment, etc.), the detailed pesticide use and groundwater vulnerability analysis is particularly relevant to the design of groundwater quality monitoring programs.

This cooperative federal/provincial study is also designed to provide a working level validation of the Express Database (the NHRI expert system model for assessing the migration and transformation of pesticides in the subsurface; Crowe et al. 1989) in an economically important region in British Columbia. In this respect, the data collected in the present study may be integrated with the results of a pilot groundwater quality monitoring program to determine if the expert system model applies directly to the Okanagan valley. In addition, the GIS compatible database that has been developed with support regional DOE activities that are directed at mapping pesticide use and related data in major agricultural regions in B.C.
Chapter 2
Study Design and Methodology

2.0 Introduction

The Okanagan valley is one of the most important fruit growing areas in Canada. Intensive fruit production necessitates the use of a diverse array of agrochemicals to control pests and to enhance crop yields. Recently, concerns have been raised relative to the potential for contamination of groundwater by agricultural chemicals used in the production of tree fruit. The present study is designed to provide the information that is required to identify the locations that are most at risk of groundwater contamination and to identify the chemicals that are most likely to occur in groundwater.

Three distinct phases of the study were conducted to obtain the information required to develop a groundwater quality monitoring program in the Okanagan valley. The first phase of the study involved the selection of a study area which appeared to be vulnerable to groundwater contamination. The second phase of the study involved the development of a detailed pesticide use pattern analysis within the study area. The third phase of the study was focused on the identification of the locations within the study areas that were most at risk of having groundwater contaminated by pesticides. Integration of the information collected during each phase of the study provides detailed information that is highly relevant to the development of a defensible groundwater quality monitoring program for this region.

2.1 Selection of the Study Area

The first goal of the present study was to identify an area within British Columbia that had a significant risk of groundwater contamination by agricultural pesticides. McRae (1989) identified a number of areas in the province which were considered to be vulnerable to groundwater contamination. Of the areas mapped, the most intensive agricultural activities (i.e., crop production) occurred in the Fraser valley and the Okanagan valley. Since the Fraser valley was already the subject of an investigation into pesticide use patterns (Moody 1989) and groundwater contamination (Environment Canada Unpublished data), the Okanagan region appeared to be the most logical choice for the present study.
The study areas selection process was initiated with a site visit to the Okanagan valley. This preliminary reconnaissance was designed to obtain a first hand perspective on agricultural activities in the area and to solicit input from local experts on the study design. To this end, meetings were scheduled with representatives from federal, provincial, and regional government agencies and various associations and cooperative fruit growers associations. Specifically, meetings were held with personnel from Agriculture Canada, B.C. Ministry of Agriculture and Fisheries, B.C. Ministry of the Environment, Town of Osoyoos, Monashee Cooperative Growers Association (MCGA), Okanagan-Similkameen Cooperative Growers Association (SCGA), and Okanagan Tree Fruit Authority. These local experts provided a significant amount of background data that will be useful for selecting specific sampling locations within the study area.

A number of criteria that could, potentially, influence the potential for groundwater contamination were considered during the study area selection process. These were the nature and extent of pesticide use, the groundwater use patterns and the soil characteristics. Thus, initially, the nature and extent pesticide use within various areas throughout the valley was considered to be one of the most important criteria with respect to site selection. Regional experts, however, have indicated that pesticide use patterns are similar in each of the portions of the valley dominated by tree fruit agriculture (B. McPhee. OSCGA. Oliver, British Columbia; T. Laranjo. MCGA. Osoyoos, British Columbia; P. Watson. BCMAF. Oliver, British Columbia). In this region, pesticide use patterns are, primarily, established by the provincial government publication, 'Tree Fruit Production Guide for Interior Districts' and by the information provided by the District Horticulturists (BCMAF). Therefore, these initial concerns that the types of pesticides used in various parts of the Okanagan valley could be grossly different proved to be unwarranted.

Groundwater use patterns were also considered in the site selection process. While residents in the Okanagan valley, as a whole, rely on surface waters to support domestic and agricultural water uses, there are a number of areas that are dependent on groundwater resources to satisfy water demand during portions of the year. On this basis, both the Oliver-Osoyoos area (which is located immediately north of the international boundary) and the Rutland area (which is located approximately 10 km NE of Kelowna; Figure 1) were identified as potential study sites.

In the Osoyoos area, groundwater is the principal source of domestic water supplies and provides much of the water used for irrigation. In the Oliver area, an irrigation canal from Okanagan Lake supplies much of the water for irrigation and domestic use throughout the open water season. Further,
groundwater is utilized extensively throughout the winter. In the Rutland area, groundwater is used for domestic supplies and to a lesser extent for irrigation. Therefore, based on the importance of groundwater to local areas residents, both of the areas investigated were considered to be appropriate for conducting the pesticide use analysis.

The final selection of the study area was based on soil characteristics. McNaughton (1991) compiled well log data for a total of 73 locations in the Osoyoos area. The vast majority of these locations were dominated by gravel and sandy soils, frequently to depths of 30 feet or more. As such, many of the aquifers in the area are unconfined and highly susceptible to contaminants from various land use activities (McNaughton 1991). In contrast, the soils in the Rutland area are composed of a greater percentage of silts and clays and, as such, are much less prone to leaching than soils in the Oliver-Osoyoos area. Therefore, the preliminary groundwater vulnerability analysis suggested that the Oliver-Osoyoos area would be the most appropriate study site for the present study. The rationale was that if groundwater contamination was not a problem in this area, then other areas in the Okanagan valley were not likely to be affected by pesticide use.

2.2 Development of a Detailed Pesticide Use Pattern in the Okanagan Valley

Historically, information on pesticide use patterns has been collected by conducting a series of interviews with individual pesticide applicators. This approach generally involved direct interviews with growers or distribution of detailed questionnaires to obtain the required data. In either case, the quality and quantity of data collected was dependent on the responses provided by the growers. Since individual growers do not always keep comprehensive records of pesticide applications, there was no assurance that data collected in these studies were complete and accurate. Implementation of this type of survey in the Okanagan valley would have been complicated by the diverse ethnic backgrounds of the growers in the area (i.e., English was a second language for a large proportion of the growers).

Due to the potential difficulties associated with the implementation of a conventional pesticide use survey, an alternate approach was developed and implemented. This alternate approach was suggested by Pesticide Control Program personnel (S. Craig. B.C. Ministry of the Environment. Penticton, British Columbia. Personal communication) and was based on the pesticide sales records that are maintained by the pesticide distribution outlets in the valley (Monashee Cooperative Growers Association, Okanagan-Similkameen
Cooperative Growers Association, and South Valley Sales). These records provide detailed data on the pesticide purchases by individual growers, including date of purchase, the pesticide product purchased, and quantity of product sold.

The overall pesticide use pattern analysis (i.e., types and quantities used in the Oliver-Osoyoos area) was developed from the information provided by the retail sales and packing house outlets located in the valley. Since individual growers rarely stockpile pesticide products or purchase these products elsewhere, data on sales were considered to provide suitable surrogates for actual pesticide use data (Bill McPhee. Okanagan-Similkameen Cooperative Growers Association. Oliver, British Columbia. Personal communication). Therefore, all of the available pesticide sales data were entered into a computerized database (which was termed PESTUSE; in Paradox™ format). This data includes all of the 1990 pesticide sales data from OSCGA and MCGA and the December 1990 - April 1991 pesticide sales data from South Valley Sales.

The PESTUSE database currently includes comprehensive information on pesticide sales within the south Okanagan valley. However, sales of certain pesticides may be under-represented in the database since data were not available from South Valley Sales over the late spring and autumn period. As grape growers utilize this retail outlet extensively for pesticide purchases, the formulations utilized by these growers may not be fully represented in the database. Specifically, the substances that are used by grape growers between the bud burst stage and harvest include paraquat (Gramoxone), glyphosate (Roundup), dichlobenil (Casoron), carbaryl (Sevin), endosulfan (Thiodan), malathion, azinphos-methyl (guthion), diazinon (Basudin), sulphur, and captan (Orthocide).

Using the PESTUSE database, the total quantity of each active ingredient that was purchased in 1990 and early 1991 was calculated. Each active ingredient was subsequently classified as a high, moderate, or low use pesticide, based on its total sales volume. High use pesticides were identified as those with sales volumes in excess of 1000 kg active ingredient (ai). Sales of 100 to 999.9 kg ai were considered to be indicative of moderate pesticide use. Those substances with total sales of less than 100 kg ai were considered to be low use pesticides. High and moderate use pesticides were considered to be of greatest concern with respect to groundwater contamination.
2.3 Groundwater Vulnerability Analysis

The overall pesticide use pattern analysis provided highly relevant data for identifying priority contaminants, however, it provided little guidance with respect to the identification of priority sites with respect to groundwater contamination. Identification of priority sites required further information on pesticide use patterns within the study area. The first step in this process was to identify a number of functional units within the study area.

A total of 10 functional units were identified within the study area (Figure 2). These units were based on local topographic (which are likely to influence hydrology) and climatic (such as number of frost free days) characteristics (B. McPhee, Okanagan-Similkameen Cooperative Growers Association, Oliver, British Columbia. Personal communication). Within each of these units, the location of individual growers had to be established to determine localized pesticide use patterns. To this end, legal descriptions of the lots owned by individual growers were obtained directly from the packing houses or from the South Okanagan Lake Irrigation District. The location of each grower was then plotted on 1:5000 scale maps of the study area. This information was cross referenced using the telephone numbers and mailing addresses of the growers to ensure that the holdings of individual growers were correctly identified. In this manner, the holdings of roughly 60% of the growers that purchased pesticide products in 1990 were located. These maps were then used as a basis for determining which growers were located in each unit of the study area. The information contained in PESTUSE was then used to calculate total pesticide use for each unit. In turn, this information was used to identify the units that had the greatest pesticide use and, hence, enhanced risk of groundwater contamination.

Data of groundwater use and the location of groundwater wells were obtained from the Town of Osoyoos, the Town of Oliver, and the B.C. Ministry of the Environment. The Town of Osoyoos was particularly helpful in this respect because it currently maintains information on the location and capacity of a significant number of the domestic and irrigation wells (active and inactive) that are located within the area.

2.4 Identification of Priority Pesticides

Identification of priority pesticides with respect to their potential for groundwater contamination is fundamental for developing a focused groundwater quality monitoring program. With respect to their potential for contaminating groundwater, the pesticides used in the south Okanagan valley
were evaluated in terms of their total use volume and their physical/chemical properties. McRae (1989) developed a procedure for ranking the relative potential of agricultural pesticides for contaminating groundwater. This procedure was based on the leaching potential (which considered solubility, volatility, and soil persistence) and use volume for each chemical. The procedure developed by McRae (1989) was modified for use in the present study to identify the chemicals that posed the greatest hazard with respect to groundwater contamination.

The relative hazard ranking for individual pesticides (Table 8), with respect to their potential to contaminate groundwater resources, was determined using the following procedure. For each of the high and moderate use pesticides identified in the study area, leaching potential values were calculated (using the scoring system developed by McRae 1989). Data on solubility, volatility, and persistence in soils was obtained from Worthing and Hance (1991) and used to determine the leaching potential value for each substance. When insufficient data was available to determine the solubility, volatility, or soil persistence score, an intermediate value of 10 was assigned. A total hazard score was the calculated for each active ingredient by multiplying the total quantity sold in 1990 by the leaching potential value. In turn, the total hazard score was used to determine the relative hazard ranking for each pesticide product.
Chapter 3

Description of Study Area

3.0 Introduction

The Okanagan valley (which also includes the Similkameen valley) is British Columbia’s premier fruit growing area. That this area contains roughly 90% and 95% of the province’s commercial orchards and vineyards, respectively, and produces over 40% of Canada’s tree fruits illustrates the importance of the Okanagan region (Kerr et al. 1985). In 1986, the most commonly grown fruit produced in this region was apples, with 7061 ha in production (Statistics Canada 1987). Significantly less acreage was devoted to grape (858 ha), cherry (841 ha), peach (829 ha), and pear (631 ha) production in that year (Statistics Canada 1987).

The Oliver-Osoyoos area represents less than 15% of the land area in the Okanagan valley. However, roughly 30% of the total fruit production of the region occurs within this area. While apple is the most extensively grown fruit, this area is the most important producer of cherries, plums, peaches, apricots, and grapes in the entire valley (Statistics Canada 1987). Due to its intensive agricultural production (Statistics Canada 1987), significant pesticide use (Burdock 1990), and the importance of groundwater resources, the Oliver-Osoyoos area was selected for the development of a detailed pesticide use pattern analysis. In addition, a preliminary groundwater vulnerability analysis was conducted in the area.

3.1 Climate

The Okanagan Valley is one of the warmest, driest areas in Canada, boasting a relatively long growing season (late March to late October), and a climate extremely well-suited for fruit production (Kerr et al. 1985). The Valley is characterized by cool, humid air (80% average relative humidity) and cloudy skies in winter and by warm, dry air (50% average relative humidity) and clear skies in summer.

In general, the temperature regime of the Okanagan is characteristic of a mild, continental climate, although occasional periods of extreme cold, resulting in extensive fruit crop damage, occur periodically (Kerr et al. 1985). In the valley, the summers are usually warm with hot days, and the
winters are cold, but temperatures are not as extreme as areas to the north and east. Average annual temperatures range from about 2.8 °C at McCulloch to approximately 10 °C at Oliver and Osoyoos (among the warmest in Canada). In the south Okanagan Valley (at Oliver), mean monthly temperatures vary from -3.3 °C in January to 21.7 °C in July. The lowest temperatures recorded at Oliver and Osoyoos (1941 to 1970) are -30.6 °C and -25.6 °C, respectively, the highest recorded temperatures being 42.8 °C and 37.8 °C, respectively (Leach et al. 1974).

With respect to agriculture, the valley floor is usually clear of snow by mid-March, and the growing season (mean daily temperature = 5.6 °C) in the southern portion of the basin usually lasts over 225 days. The average frost free period at Oliver is 152 days, the first frost occurring around October 1, and the last spring frost occurring around May 3. The mean number of degree days (5.6 °C) at Oliver is 4021, the highest in the Okanagan Valley (Leach et al. 1974).

The Okanagan Valley lies in the rain shadow of the Coast and Cascade mountain ranges. Moisture carried by air masses travelling inland from the Pacific is deposited as orographic precipitation within these ranges, leaving relatively warm, dry air moving into the Okanagan. As such, near desert conditions (i.e., precipitation < 254 mm a⁻¹) exist in some areas of the Okanagan Valley. Average annual precipitation in the valley ranges from approximately 296 mm at Penticton to 689 mm at McCulloch (Leach et al. 1974). Annual precipitation is greatest at higher elevations, while the valley bottom and major croplands are relatively dry.

In general, there are 60 to 70 days of measurable rainfall in the south Okanagan Valley. At Osoyoos, the average annual precipitation and total rainfall are 342 mm and 273 mm, respectively; at Oliver, the corresponding values are 305 mm and 238 mm, respectively. Due to influences from both coastal and continental circulations, there exists both winter and summer peaks in annual precipitation, occurring in June and January or December, each of approximately equal magnitude. In the south end of the basin, September is generally the driest month, the next driest being either March or April (Leach et al. 1974).

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3.2 Soils

The Okanagan Valley contains a variety of soil types, from silty loams to sandy soils and gravel. However, fruit trees require well aerated, coarse, dry soils, and the distribution of orchards within the region is largely dependent upon soil type. The well-drained, sandy soils commonly associated with alluvial deposits in the valley bottom are ideal for fruit production and vineyards (Kerr et al. 1985).

The character of surficial soils and geology in the Okanagan Valley is largely a product of the most recent glaciation. Bedrock materials in this region, consisting mostly of metamorphic igneous and sedimentary materials are overlain by deposits of glacial till, the parent material of the valley soils. These till moraine deposits vary in thickness from < 1 to > 12 m, and are generally deepest in the southernmost valley bottom areas. Many of these low-elevation areas consist of alluvial deposits, and the soils are typically composed of sand and gravel (Leach et al. 1974). This is especially true of the Oliver-Osoyoos area, where most surficial soils are very sandy and porous, with relatively low water retention and cation exchange capacities.

3.3 Agricultural Activities

In terms of land area, livestock grazing is the primary agricultural land use in the Okanagan Valley. Tree fruit production, however, is the most important agricultural activity in the region in terms of economic benefits (Kerr et al. 1985). In addition to fruit trees, the valley also supports several other significant crop types and land use activities. Grape production has always been of considerable importance in this area, however, in recent years
this sector has shifted its emphasis towards the production of specialty grapes (i.e., to support the estate and other wine industries) and, as such, has increased its economic value. In addition, a variety of market vegetable crops, (e.g., potatoes, sweet corn, tomatoes, cabbage, carrots, peppers, cucumbers, squashes, etc.) are grown in the region, as are berries and grapes, greenhouse vegetables, and forage crops (including rye, corn, oats, barley, and tame hay). Further, there is considerable livestock production (including beef, poultry, sheep, horses, and swine) in the area.

According to a 1986 census, approximately 40% of the total cropland in the Okanagan-Similkameen Region is used for tree fruit production. Another 52% of the cropland is used for tame hay and cereal production. The remainder of the land is used for vegetable and greenhouse operations (5%) and grapes and berries (3%). By contrast, more than 80% of the total farmland in the Okanagan-Similkameen Region is range land and pasture, which used largely for cattle production. Of the more than 77,000 farms surveyed in the region, approximately 31% reported beef cattle production, 32% reported poultry production, 2% reported horse production, 1% reported sheep production, and <1% reported swine production (Statistics Canada 1987).
4.0 Introduction

In British Columbia, the Ministry of Agriculture and Fisheries (BCMAF) provides general guidance to fruit growers in the form of production guides, such as the *Tree Fruit Production Guide for Interior Districts* (BCMAF 1991). The fruit production guides provide specific spray schedules for each of the growth stages of tree, vine, and berry fruit and each pest/disease organisms that attack these plants. In addition, BCMAF provides some outreach services (as provided by District Horticulturists) to growers on specific production concerns. In the South Okanagan valley region, growers are further supported by the outreach services that are provided by the Cooperative Growers Associations. As such, growers are well prepared to combat any production difficulties that arise throughout the growing season.

Effective use of the recommendations provided by BCMAF necessitates accurate identification of pest or disease organisms. Once the pest species has been identified, growers are provided with a choice of products that will effectively control the pest. In addition, recommended pesticide application rates for that product are also provided. The products that are actually used by individual growers are dependent on the nature and severity of pest outbreaks, the applicators past experience with specific products, cost/application, the occurrence of broader pest management strategies, and a variety of other factors. In addition to this directed pest management strategy, there are still a large number of growers that utilize a calendar spray strategy (i.e., they apply specific chemicals on pre-established dates each year). While it is possible to develop a generalized pesticide use analysis from this information, it is not possible to determine the relative importance of specific products. Therefore, the present pesticide use pattern analysis was conducted to provide a basis for the identification of high use pesticides in the south Okanagan valley.

Pesticides may be grouped into a number of broad categories, based on their specific uses. For the purpose of this pesticide use analysis five major groups of agricultural chemicals have been identified; insecticides, herbicides, fungicides, rodenticides, and plant growth regulators. When specific chemicals have more than one use, they have been categorized on the basis of their predominant use in the Okanagan valley. The following discussion
provides detailed information on the use of each pesticide product purchased in the Oliver-Osoyoos area in 1990/91.

4.1 Insecticide Use

A diverse array of insecticides have been used in the study area (Table 1). However, the most popular insecticide used in the Oliver-Osoyoos area in 1990/91 was mineral oil (which is also known as dormant oil; Okanagan Dormant Oil and Premium Emulsible Dormant Spray Oil). In total, over 350 000 L of mineral oil (97 - 98.5 % ai) were sold by the three pesticide outlets. When combined with lime sulphur, dormant oil provides effective control of a broad range of insects and diseases in fruit trees.

Two other high use insecticides (i.e., > 1000 kg ai sold) were identified; azinphos-methyl (Guthion 50% WP and Guthion Solupak 50%) and diazinon (Ciba-Geigy Basudin 500 E.C.). A total of 3991 kg ai of azinphos-methyl were purchased in 1990/91, mainly between April and August. While this product is used in a number of applications, it is primarily used to control leaf rollers, green fruitworms, budmoth, and coddling moth in virtually all fruit trees. In addition, it is used to control peach twig borer in apricots and peaches, and apple mealy buds in cherries. The implementation on a comprehensive coddling moth eradication program could lead to relative higher use of the substance in 1992. Presumably, use rates would decrease after that program is completed. Azinphos-methyl is also used to control climbing cutworms (0.55 kg ai ha\(^{-1}\)), thrips (0.55 kg ai ha\(^{-1}\)), and Virginia creeper leafhoppers (0.25 - .63 kg ai ha\(^{-1}\)) in grapes.

A total of 1233 kg ai of diazinon was sold in this region in 1990/91, with the vast majority of this total sold in April. Diazinon is a broad spectrum contact insecticide that is used to control a range of insect pests (including aphids, mites, fruitworms, leafrollers, budmoths, thrips, campylomma, scales, fruit flies, apple mealybuds, and peach twig borers) in all fruit trees and most berry crops. Recommended application rates range from 2.25 L ha\(^{-1}\) (1.13 kg ai ha\(^{-1}\)) for controlling campylomma in apples to 5.5 L ha\(^{-1}\) (2.75 kg ai ha\(^{-1}\)) for controlling San Jose scale in apples, apricots, cherries, peaches, pears, and plums.

Six moderate use insecticides (i.e., 100 - 999 kg ai sold) have also been identified; carbaryl (Sevin XLR Plus Carbaryl, Sevin Brand 50W Carbaryl, and Clean Crop Sevin), DNOC (4,6-dinitro-o-cresol; Elgetol), dimethoate (Laters Lagon 480E), endosulfan (Thiodan 50 WP), methidathion (Supracide 240 E.C.), and pirimicarb (Primor 50 W). The volume of sales of each of these pesticide products is presented in Table 2.
Carbaryl is used to control three other insect pests in cherries (including cherry fruit fly, pear sawfly and leafrollers) and leafhoppers in grapes. Recommended application rates range from 0.275 kg ha\(^{-1}\) (0.14 kg ai ha\(^{-1}\)) in grapes to 10 L ha\(^{-1}\) (4.8 kg ai ha\(^{-1}\)) in cherries. Dinitro-o-cresol (DNOC) plays only a very limited role in the control of insect pests within the study area. Its only known use is for the control of black cherry aphid in cherries. The recommended application rate for this use of DNOC is 12.75 L ha\(^{-1}\) (2.5 kg ai ha\(^{-1}\)).

Dimethoate was used only sparingly within the study area in 1990/91, with a total of 132.5 kg ai purchased by fruit growers. In apples, dimethoate is applied at a rate of 4.25 L ha\(^{-1}\) (2.0 kg ai ha\(^{-1}\)) to control rosy, woolly, and apple aphids. In addition, dimethoate has also been recommended for use in cherries and pears (BCMAF 1991). The recommended application rate for controlling cherry fruit flies in cherries is 2.25 L ha\(^{-1}\) (1.1 kg ai ha\(^{-1}\)).

Endosulfan is a broad spectrum insecticide that has a wide range of uses in the study area. It is used to control a range of insect pests in fruit trees, including green fruit worms, leafhoppers, aphids, mites, lygus bugs, stink bugs, pear psylla, peach tree borers, and peach twig borers. In addition, it is effective against click beetles and leafhoppers in grapes. Recommended application rates range from 1 to 3.4 kg ha\(^{-1}\) (0.5 to 1.7 kg ai ha\(^{-1}\)). Methidathion has a limited number of recommended uses in the Oliver-Osoyoos area, which includes the control San Jose and European fruit scale and resistant strain leafrollers in apples. In these applications, methidathion is applied at a rate of 5.8 L ha\(^{-1}\) (1.4 kg ai ha\(^{-1}\)).

Pirimicarb is recommended only for use in apples, however, it may not be used on apples that are to be sold in the United States (BCMAF 1991). It is likely import restrictions on pirimicarb residues significantly reduce the use of this substance within the study area. A total of 179.5 kg ai was purchased by growers in 1990/91. In apples, this insecticide is applied at a rate 1.1 kg ha\(^{-1}\) (0.55 kg ai ha\(^{-1}\)) to control rosy, woolly, and apple aphids.

In addition to chemically-based insecticides, there are a number of integrated pest management (IPM) systems and biologically-based pesticide products that are routinely used within the study area. In 1990/91, 450 billion i.u. of the bacterial-based insecticide DIPEL WP Biological (*Bacillus thuringiensis* is the active ingredient) was purchased by fruit growers in Oliver-Osoyoos area. This insecticide, which is also known as BT, is applied at rates of 2.25 - 3.35 kg ha\(^{-1}\) (36 - 53.6 billion i.u. ai ha\(^{-1}\)) to control leafrollers and fruitworms in apples, apricots, cherries, peaches, pears, and plums.
4.2 Herbicide Use

In the Okanagan valley, herbicides are used primarily to control the growth of vegetation at the base of newly planted fruit trees. This vegetation control is essential to promote satisfactory initial growth of trees, as recently-planted fruit trees compete poorly for moisture and nutrients. As such, heavy vegetative cover in orchards may cause severe stress and stunting (BCMAF 1991). In addition, removal of vegetation at the base of trees reduces the activity of rodents and, therefore, helps to prevent girdling damage. While manual vegetation control (e.g., hand weeding and mulching) may be practical in smaller orchards, chemical vegetation control is required in larger orchards.

A wide variety of herbicides were used within the study area (Table 3). However, the BCMAF (1991) has recommended only 8 of these herbicides for weed control in fruit trees. Of the herbicides recommended for use in fruit production, only three of these (paraquat, dichlobenil, and glyphosate) are recommended for use in all types of trees. The other five herbicides (napropramide, simazine, propyramide, terbacil, and amitole/amitrole T) are recommended, primarily, for use in apples and pears; however, napropramide is also recommended in the production of peaches. The monthly sales of glyphosate, paraquat, and simazine are presented in Table 4.

Of the recommended herbicides, glyphosate (Roundup, Laredo, Wrangler) was used most extensively. In 1990/91, a total of 1069 kg ai of glyphosate was purchased in the Oliver-Osoyoos area. Recommended application rates of glyphosate range from 2.25 -3.5 L ha⁻¹ (0.8 - 1.2 kg ai ha⁻¹) for the control of annual weeds to 10 - 12 L ha⁻¹ (3.6 - 4.3 kg ai ha⁻¹) for the control of perennials. Paraquat (Gramoxome) was also commonly used in fruit production within the study area. In 1990/91, a total of 532.2 kg ai of paraquat was sold by the three pesticide outlets in the study area. The recommended application rate of this herbicide is 5.5 L ha⁻¹ or 1.1 kg ai ha⁻¹ for controlling annual broadleaf species and grasses (BCMAF 1991). Both of these products are also recommended for use in grape production (BCMAF 1989).

4.3 Fungicide Use

Fruit trees are susceptible to a diverse array of diseases that have the potential to compromise production and/or reduce the value of the final product. The majority of these diseases are associated with outbreaks of specific fungi, with the most common being fireblight, crown rot, bull's-eye
rot, rhizopus rot, brown rot, apple scab, powdery mildew, coryneum blight, and peach leaf-curl. While physical control of some of these diseases is feasible and preferable (e.g., fireblight, crown rot, bullseye rot), chemical fungicides are required to prevent losses in the productivity and value of the crop.

The BCMAF (1991) has provided specific recommendations regarding the control of fungal diseases in fruit trees. A total of 18 fungicides (benomyl, captan, copper, dichlone, dicloran, dodine, dinocap, dithane, ferbam, iprodione, mancozeb, mane, metiram, streptomycin, sulphur, thiophanate-methyl, triforine, and ziram) have been recommended for use on fruit trees, while 5 of these (benomyl, captan, dinocap, iprodione, and sulphur) are recommended for use in grapes.

Five high use fungicides (i.e., > 1000 kg ai sold) have been identified in the study area; captan, copper, sulphur, thiophanate-methyl and ziram (Table 5). In 1990/91, a total of 1418 kg ai of captan was purchased in the study area (679 kg ai of Orthocide-50 and 739 kg of Captan 50-WP). Captan is registered for use in all types of fruit trees and grapes, with recommended applications rates ranging from 5.5 kg·ha⁻¹ (2.75 kg ai·ha⁻¹) to 6.0 kg·ha⁻¹ (3.0 kg ai·ha⁻¹). Captan is used to control bunch rot in grapes, apple scab and powdery mildew in apples, and brow rot in apricots, cherries, peaches, and plums. The monthly sales of captan (and other high and moderate use fungicides) are presented in Table 6.

Within the Oliver-Osoyoos area, copper is used primarily in pears to control fire blight, however, it is possible that this substance has a number of minor fungicidal uses as well. For this use, the recommended application rate of fixed copper is 1.75 kg·ha⁻¹ (0.88 kg ai·ha⁻¹). In 1990/91, a total of 1007.5 kg ai was purchased by growers within the study area.

Sulphur is probably the most commonly used fungicide in the study area. Sulphur is sold as a wettable powder (Holysul Micro-Sulphur) or as a liquid (Orchard Lime Sulphur). In 1990/91, a total of 3352 kg ai of sulphur was purchased by growers in the Oliver-Osoyoos area. Lime sulphur is applied at 175 L·ha⁻¹ (38.5 kg ai·ha⁻¹) to control peach leaf curl in peaches and at 90 L·ha⁻¹ (19.8 kg ai·ha⁻¹) to control powdery mildew in pears. The wettable powder formulation is used to control powdery mildew in apples, cherries, peaches (at 7.0 kg·ha⁻¹; 6.4 kg ai·ha⁻¹), and grapes (2.25 - 6.0 kg·ha⁻¹; 2.1 - 5.5 kg ai·ha⁻¹).

A total of 1119 kg ai of thiophanate-methyl (Green Cross Easout) was purchased by horticulturists in the Oliver-Osoyoos area 1990/91. The recommended application rate of this fungicide is 2.25 kg·ha⁻¹ or 1.6 kg ai·ha⁻¹.
I. Thiophanate-methyl is used to control powdery mildew in apples and brown rot in cherries, peaches, and plums. Ziram, the third high use fungicide, is registered for use in the control apple pin-point scab in apples, and coryneum blight in apricots and peaches. A total of 1878 kg ai of this fungicide was sold in the study area in 1990/91. The recommended application rates of ziram are 5.0 kg ha⁻¹ (4.25 kg ai ha⁻¹) in apples and 8.0 kg ha⁻¹ (6.9 kg ai ha⁻¹) in peaches and apricots.

A total of 5 fungicides were used only moderately (i.e., 100 to 999 kg ai purchased) within the study area in 1990/91. The moderate use fungicides included benomyl (Benlate 50 WP), dodine (Equal 65 WP and Cyprex 65-W), formaldehyde (Stanchem Formaldehyde SN), mancozeb (Dithane M-45, Tuberseed Potato Seed Piece Dust, and Manzate 200), and metiram (BASF Polyram 7 Dust, Polyram DF, and BASF Polyram 80 W), with a total of 263, 750.1, 338.9, 308.8, and 308.8 kg ai of these products, respectively, purchased in 1990/91. These fungicides are used in a variety of applications, however, the major uses are for the control of powdery mildew in apples (benomyl and mancozeb), apple scab in apples (mancozeb and metiram), pear psylla in pears (mancozeb), and brown rot in apricots, cherries, peaches, and plums (benomyl). Dodine is used in apple and pear production, however, the pest controlled has not been specified (BCMAF 1991). In agricultural applications, formaldehyde is primarily used as a soil fumigant, particularly in greenhouses after cropping (Worthing and Hance 1991).

4.4 Other Agrochemical Use

In addition to the insecticides, herbicides, and fungicides discussed in the previous sections, there were a variety of other agrochemicals used within the study area in 1990/91. Of these, nitrogen- and phosphorus- based fertilizers are probably the most significant in terms of use volume, however, the sales of these products have not been quantified. The volume of fertilizers used in this area is important because nitrogen represents a significant groundwater contaminant in many areas (e.g., Abbotsford aquifer; H. Liebscher. National Hydrology Research Institute, Environment Canada. Personal communication). Significant use of these products in the Okanagan valley also has the potential to result in groundwater contamination. Therefore, nitrate, nitrite, and ammonia should be included in any groundwater quality monitoring program that is implemented within this region.

The other agrochemicals that were used with the study area in 1990/91 fall into three general classes of compounds; rodenticides, plant growth regulators, and adjuvants. Only minor quantities of rodenticides and plant growth
regulators were purchased by growers in the Oliver-Osoyoos area in 1990/91 (Table 7). Zinc phosphide and strychnine were the most commonly used rodenticides, while ethephon was the most commonly used plant growth regulator.

Adjuvants or surfactants are used to facilitate the mixing of strongly hydrophobic pesticide products with water. The use of these substances provides a more uniform mixture of the chemical in the spray tank and, therefore, better coverage in the orchard. Paraffin-based mineral oil and octylphenoxyethoxethanol were the only adjuvants sold within the study area in 1990/91 (Table 7).

4.5 Priority Pesticides in the South Okanagan Valley

Priority pesticides, with respect to their potential for contaminating groundwater resources, were identified using a slightly modified version of the procedure used by Agriculture Canada to identify potentially leachable pesticides (McRae 1989; see Chapter 2). In this way, total hazard scores were calculated for each of the high and moderate use insecticides, herbicides, and fungicides. Relative hazard rankings were then assigned based on the total hazard scores. Using this procedure, azinphos-methyl and ziram were identified as the pesticides that had the greatest potential for contaminating groundwater. The relative hazard rankings for each pesticide are listed in Table 8.

This analysis indicates that the insecticide, azinphos-methyl, and the fungicide, ziram, are of greatest concern with respect to groundwater contamination (i.e., total hazard scores of > 30 000). Concerns relative to the use of azinphos-methyl are likely to be even greater in 1992, as the coddling moth eradication program that is currently scheduled for implementation could result in even higher use volumes than in 1990/91.

In addition to these high risk pesticides, a total of seven moderate risk pesticides, with respect to their potential for groundwater contamination, have been identified (i.e. total hazard scores of 10 000 to 29 999). The moderate risk pesticides include two insecticides (diazinon and methidathion), two herbicides (glyphosate and paraquat), and three fungicides (sulphur, copper, and captan).

Several of the high and moderate risk pesticide products identified above are also in grape production (azinphos-methyl, diazinon, glyphosate, and paraquat). Therefore, the relative importance of these pesticides are likely
to be somewhat greater than the present pesticide uses analysis would suggest. In addition, the relative importance of other active ingredients, such as endosulfan and carbaryl, which currently have a lower hazard ranking is likely to increase due to their use in grape production. Therefore, if monitoring efforts are directed at grape producing areas then these substances should be included in the suite of analytes.
Chapter 5

Vulnerability of Groundwater to Contamination by Pesticides in the Okanagan Valley

5.0 Introduction

Modern agriculture relies extensively on the use of pesticides to enhance and maintain current levels of productivity. The use of insecticides and fungicides has resulted, for the most part, in the control of traditional agricultural pests and thereby in large increases in yields. The widespread use of herbicides has facilitated the development of new agricultural strategies, such as minimum and conservation tillage, which greatly reduce soil erosion and provide cost savings to the farmer (Donigian and Carsel 1987). However, co-location of groundwater and pesticide use presents potential hazards to water users that must be addressed by management agencies responsible for groundwater quality and pesticide regulation.

Contamination of groundwater by pesticides used in agriculture, silviculture, and other applications may occur due to a variety of activities associated with the production, transport, storage, use, and disposal of pesticides. Direct applications of pesticides may result in the movement of the chemicals through soils in treated areas and into subsurface aquifers. In addition, contamination of groundwater resources may occur due to spills, leaks, and improper disposal of pesticides (Pierce and Wong 1988). Other sources of contamination of groundwater may include back flow into wells during pesticide mixing operations and infiltration of water used to wash spraying equipment after use (Frank et al. 1987). While the full extent of the problem is not known, the available data (Hiebsch 1988) suggest that groundwater contamination by pesticides is an emerging national issue in Canada. Additional monitoring effort is required to further define the scope of the problem, both in terms of the areal distribution of contamination, and number and types of chemicals which pose hazards to water users.

Contamination of sub-surface water supplies may have serious implications for water users that rely on groundwater resources to supply all or a portion of their water requirements. While the long-term effects of groundwater contamination by pesticides on human health and the environment remains relatively poorly understood (Clark et al. 1986), the social and economic implications of this contamination are not difficult to surmise. Once widespread contamination of groundwater resources by pesticides has occurred, it is often not technically or economically feasible to restore the
resource (USEPA 1987). In addition, the costs associated with the provision of alternate drinking water sources or treatment to remove contamination from drinking water prior to use may be prohibitive if the contamination has a wide distribution. For these reasons, prevention of groundwater contamination, rather than remedial action, should be the focus of groundwater management efforts.

5.1 Groundwater Uses in the South Okanagan Valley

In the South Okanagan valley, groundwater represents an essential component of the overall water supply. The Town of Osoyoos and the Town of Oliver rely heavily on groundwater to provide raw water for drinking water supplies. Residents in the Oliver area utilize surface water (which is taken from the irrigation canal) throughout the open water period, however groundwater is used in the winter. In addition, many residents still rely on private wells for their domestic water supply. The majority of residents in the Osoyoos area obtain their domestic water supply via the South Okanagan Lake Irrigation District (SOLID) distribution system. This system utilizes 50% groundwater through the spring and summer, and 100% groundwater through the autumn and winter. In addition, some residents still utilize private wells for their domestic water supply. Therefore, groundwater resources are heavily utilized as domestic water supplies.

The south Okanagan valley is classified as a desert (i.e., < 10 inches of precipitation per year). As such, fruit growers and other agriculturists utilize both groundwater and surface water to irrigate the crops produced in this area. Irrigation rates as high as $10^7$ L ha$^{-1}$ a$^{-1}$ are used in the south Okanagan valley (Kent et al. 1991). In the Oliver area, irrigation water is largely supplied by an irrigation canal that draw water from the Okanagan River system. However, roughly half of the water distributed by SOLID (which is administered by the Town of Osoyoos) during the spring and summer originates in a shallow aquifer located within the town limits. These water sources would also be used for livestock watering.

In addition to its other uses, groundwater is likely to be important to aquatic life. In an area that receives so little precipitation, it is likely that groundwater represents an important recharge source for surface water bodies in the area, particularly small streams and lakes. Therefore, contaminated groundwater has the potential to adversely affect aquatic organisms, if pesticide levels exceed the recommended Canadian Water Quality Guidelines (CCREM 1987).
Together, these data suggest the groundwater resources are essential for maintaining and enhancing the designated water uses in the south Okanagan valley. Degradation of groundwater quality has the potential to compromise those water uses that are associate with domestic water supplies, agricultural activities, and fish and aquatic life. Therefore, protection of groundwater resources should be identified as a high priority, long-term goal in the south Okanagan valley.

5.2 Identification of High Risk Areas with Respect to Groundwater Contamination

The overall pesticide use analysis provides important information which may be used to identify priority pesticides with respect to groundwater contamination in the study area. This analysis provides little guidance on identifying specific sampling locations within the south Okanagan valley. Therefore, additional information was required to focus monitoring efforts on the locations that have the greatest risk of groundwater contamination by pesticides.

Identification of high risk areas with respect to groundwater contamination by agricultural pesticides necessarily requires information on localized pesticide use patterns. To obtain this information, the south Okanagan valley was divided into 10 functional units (Figure 2) and the locations of individual growers within these units were mapped. Subsequently, the total quantity of each active ingredient purchased by individual growers located within each unit was calculated. These pesticide use estimates were then normalized to the land area contained each unit to obtain relative application rates (expressed in kg ai·ha⁻¹·a⁻¹) for each active ingredient.

In the south Okanagan valley, high risk areas with respect to groundwater contamination were identified on the basis of pesticide use. More specifically, those units which had relatively high usage rates of a number of pesticides were considered to have the greatest risk of groundwater contamination. For the purpose of this analysis, active ingredients were considered to be high use pesticides if 0.05 kg·ha⁻¹·a⁻¹ or more was purchased by growers in a single unit. The areas with the greatest number of high use pesticides were considered to have the greatest risk of groundwater contamination (Table 12).

Using the criteria outlined above, Oliver Central-west, Osoyoos Central-west, and Osoyoos South-west were considered to have the greatest risk of groundwater resources contaminated by pesticides, with high use pesticide
scores of 10, 9 and 9, respectively. Osoyoos North - west, Oliver South - east, and Oliver South - west were considered to have relatively lower risks of groundwater contamination due to pesticide use. The other 4 units were considered to have relatively low risks of groundwater contamination.

While pesticide use patterns provide a defensible means of identifying priority areas for groundwater quality monitoring, the actual design of a pilot monitoring program should also consider other factors, such as groundwater use patterns, local topography, and soil structure. In addition, data on specific pesticide application rates within very localized areas (i.e., within specific orchards) may be used to further focus the design of the monitoring program.
Chapter 6

Summary and Recommendations

1. A detailed pesticide use pattern and groundwater vulnerability analysis was developed for the southern portion of the Okanagan valley (north Oliver to the international boundary). This analysis was based on pesticide sales data, which were considered to provide an excellent indication of actual pesticide use patterns within the study area. Using these data, overall use volumes within the study area, use volumes by area, and use volumes per month have been calculated. In addition, important groundwater use patterns have been identified.

2. This analysis indicated that a number of areas within the south Okanagan valley may be at substantial risk with respect to contamination of groundwater resources. Therefore, a pilot groundwater quality monitoring program should be designed and implemented to provide a preliminary evaluation of the nature and extent of groundwater contamination in this region.

3. The highest priority pesticides, with respect to their potential for contaminating groundwater, were identified as azinphos-methyl and ziram. On the basis of pesticide sales data, sulphur, diazinon, glyphosate, copper, methidathion, paraquat, and captan were identified as moderate priority pesticides within the study area. The 1992-93 pest management recommendations provided to growers by BCMAF (1992) and 1992 pesticide sales records should be evaluated to determine if significant shifts in pesticide use patterns are likely to have occurred in 1992. The pesticide products used in grape production were thought to be under-represented in the present analysis, and several of these should be considered for inclusion in the pilot monitoring program. Based on that evaluation, a final list of priority analytes for a groundwater quality monitoring program should be established.

4. Using information on pesticide use rates, the highest priority areas with respect to the potential groundwater contamination, were considered to be Oliver Central - west, Osoyoos Central - west, and Osoyoos South - west. Additional information, including input from stakeholder groups, is required to identify the precise locations for sampling groundwater quality.

5. The results of the pilot groundwater quality monitoring program should be used to evaluate the need for, and to design, a more
intensive monitoring program. Such an intensive program should be focused on those areas in which significant groundwater contamination is identified. In addition, the results of the pilot monitoring program should be provided to stakeholder groups so that pesticide use patterns may be shifted away from those active ingredients that are contaminating groundwater resources. Further, these results may be used to identify the need for pesticide products that are less prone to leaching into groundwater.

6. The results of the pilot monitoring program, in conjunction with the detailed pesticide use analysis, should be used to verify and calibrate the expert system that has been developed by Environment Canada (Crowe et al. 1989; Crowe and Mutch 1990; Mutch and Crowe 1990) for evaluating the fate of agricultural chemicals in the subsurface.
7.0 References


Figure 1. Okanagan Fruitlands Study Area.
Figure 2. Locations of the 10 functional study units for pesticide use in the south Okanagan valley (scale 1:300 000).
Table 1. A summary of insecticide and acaricide sales data for the south Okanagan valley, B.C. in 1990/91.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>PCP #</th>
<th>Product Name</th>
<th>Pesticide Type</th>
<th>Form.</th>
<th>Concentration of AI in Product</th>
<th>Quantity (kg)</th>
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<tr>
<td>Azinphos-methyl</td>
<td>21374</td>
<td>Guthion Solupak 50%</td>
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Table 1. A summary of insecticide and acaricide sales data for the south Okanagan valley, B.C. in 1990/91.

<table>
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<tr>
<th>Active Ingredient</th>
<th>PCP #</th>
<th>Product Name</th>
<th>Pesticide Type</th>
<th>Form.</th>
<th>Concentration of AI in Product</th>
<th>Quantity of AI (kg)</th>
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<td>Kem Kill-B</td>
<td>Carbamate insecticide</td>
<td>EC</td>
<td>5 g/L</td>
<td>1.29</td>
</tr>
<tr>
<td>Soap</td>
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<td>Safer's Natural Insecticide Concentrate</td>
<td>Natural insecticide</td>
<td>WP</td>
<td>505 g/kg</td>
<td>5.05</td>
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</tbody>
</table>

Total Fungicide Use: 380518.7

Form. = Formulation; AR = aerosol; EC = emulsifiable concentrate; GR = granules; OL = oil miscible liquid; SC = flowable concentrate; SL = sol
WP = wettable powder; WG = water dispersible granules.

Quantity: AI = active ingredient; b.i.u. = billion international units.
Table 2. A summary of insecticide sales data for the south Okanagan valley, B.C. in 1990/91, by month.

<table>
<thead>
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<td>Pirimicarb</td>
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<td><strong>Total Insecticide Sales</strong></td>
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Table 3. A summary of herbicide sales data for the south Okanagan valley, B.C. in 1990/91.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>PCP #</th>
<th>Product Name</th>
<th>Pesticide Type</th>
<th>Form.</th>
<th>Concentration of AI in Product of AI (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkyl(benzyl)dimethyl ammonium chloride</td>
<td>20523</td>
<td>Bioguard Back-up</td>
<td>Alcide</td>
<td>SL</td>
<td>500 g/L</td>
</tr>
<tr>
<td>Alkyl(benzyl)dimethyl ammonium chloride</td>
<td>16447</td>
<td>Formula 500 Atrazine</td>
<td>Triazine herbicide</td>
<td>SC</td>
<td>500 g/L</td>
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<tr>
<td>Atrazine</td>
<td>12221</td>
<td>Basagran</td>
<td>Benzothiadiazinone herbicide</td>
<td>SC</td>
<td>500 g/L</td>
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<tr>
<td>Bentazone</td>
<td>14517</td>
<td>Granular Ureabor</td>
<td>Uracil herbicide</td>
<td>SL</td>
<td>480 g/L</td>
</tr>
<tr>
<td>Benpromised</td>
<td>9509</td>
<td>Tenoran 50 WP</td>
<td>Urea herbicide</td>
<td>GR</td>
<td>15 g/kg</td>
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<tr>
<td>Chloroxuron</td>
<td>8963</td>
<td>Dacthal W-75</td>
<td>Benzoic acid herbicide</td>
<td>WP</td>
<td>750 g/kg</td>
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<tr>
<td>Chlorothal</td>
<td>8491</td>
<td>2-4-D Amine-Broadleaf</td>
<td>Aryloxyalkanoic acid herbicide</td>
<td>EC</td>
<td>250 g/L</td>
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<tr>
<td>Dichlofenil</td>
<td>12533</td>
<td>Cleanup Crop Casoron G-4</td>
<td>Benzonitrile herbicide</td>
<td>EC</td>
<td>250 g/L</td>
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<td>Fluazifop-butyl</td>
<td>18013</td>
<td>Fusilade</td>
<td>(Aryloxyphenoxy)alkanoic acid herbicide</td>
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<td>356 g/L</td>
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<td>Glyphosate</td>
<td>13644</td>
<td>Roundup</td>
<td>Phosphonic acid herbicide</td>
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<td>480 g/L</td>
</tr>
<tr>
<td>Linuron</td>
<td>16279</td>
<td>Lorox L</td>
<td>Triazineone herbicide</td>
<td>WG</td>
<td>750 g/kg</td>
</tr>
<tr>
<td>Metribuzin</td>
<td>17242</td>
<td>Sencor 75 DF</td>
<td>Triazineone herbicide</td>
<td>WP</td>
<td>500 g/kg</td>
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<tr>
<td>Napropamide</td>
<td>20123</td>
<td>Devrinol 50 WP</td>
<td>Aryloxyalkanoic acid herbicide</td>
<td>WP</td>
<td>500 g/kg</td>
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<tr>
<td>Oxyfluorfen</td>
<td>18777</td>
<td>Goal Emulsifiable Concentrate</td>
<td>Bipyrilid ether herbicide</td>
<td>SC</td>
<td>100 g/L</td>
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<td>Paraquat</td>
<td>14179</td>
<td>Terrkleke</td>
<td>Bipyrilid herbicide</td>
<td>SC</td>
<td>200 g/L</td>
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<td>Paraquat</td>
<td>8661</td>
<td>Gramoxone</td>
<td>Bipyrilid herbicide</td>
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<td>400 g/L</td>
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<tr>
<td>Parafinene</td>
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<td>Terrkleke</td>
<td>Triazine herbicide</td>
<td>WP</td>
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<tr>
<td>Simazine</td>
<td>16370</td>
<td>Princep Nine T</td>
<td>Triazine herbicide</td>
<td>WP</td>
<td>900 g/kg</td>
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<td>Simazine</td>
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<td>Simadex Simazine</td>
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<td>Trifluralin</td>
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<td>Elanco Trelfin 545 E.C.</td>
<td>Dinitroanaline herbicide</td>
<td>EC</td>
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<td>Total Fungicide Use</td>
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</table>

Form. = Formulation; EC = emulsifiable concentrate; GR = granules; SC = flowable concentrate; SL = soluble liquid; WP = wettable powder; WG = water dispersible granules.
Table 4. A summary of herbicide sales data for the south Okanagan valley, B.C. in 1990/91, by month.

<table>
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<tbody>
<tr>
<td></td>
<td></td>
<td>13644</td>
<td></td>
<td></td>
<td>61.23</td>
<td>92.56</td>
<td>46.28</td>
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<td></td>
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<td>15902, 16370</td>
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<td>16.35</td>
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<td>Total Herbicide Sales</td>
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<td>35.8</td>
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</table>
Table 5. A summary of fungicide sales data for the south Okanagan valley, B.C. in 1990/91.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>PCP #</th>
<th>Product Name</th>
<th>Pesticide Type</th>
<th>Form.</th>
<th>Concentration of AI in Product</th>
<th>Quantity of AI (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benomyl</td>
<td>11062</td>
<td>Benlate 50 WP</td>
<td>Benzimidazole</td>
<td>WP</td>
<td>500 g/kg</td>
<td>263</td>
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<tr>
<td>Captan</td>
<td>4559</td>
<td>Captan 50-WP</td>
<td>Phthalimide</td>
<td>WP</td>
<td>500 g/kg</td>
<td>739.2</td>
</tr>
<tr>
<td>Captan</td>
<td>3780</td>
<td>Orthocide-50</td>
<td>Phthalimide</td>
<td>WP</td>
<td>500 g/kg</td>
<td>679</td>
</tr>
<tr>
<td>Chinomethionat</td>
<td>8588</td>
<td>Morestan 25%</td>
<td>Quinoxaline</td>
<td>WP</td>
<td>250 g/kg</td>
<td>29.75</td>
</tr>
<tr>
<td>Chlorothalonil</td>
<td>15723</td>
<td>Bravo 500</td>
<td>Chlorophenyl</td>
<td>SC</td>
<td>500 g/L</td>
<td>5</td>
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<tr>
<td>Copper</td>
<td>14741</td>
<td>Fixed Copper</td>
<td>Copper</td>
<td>WP</td>
<td>500 g/kg</td>
<td>816.5</td>
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<tr>
<td>Copper</td>
<td>13245</td>
<td>Guardsman</td>
<td>Copper</td>
<td>WP</td>
<td>500 g/kg</td>
<td>191</td>
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<td>Dichlone</td>
<td>14907</td>
<td>Phygon-XL</td>
<td>Chloroquinone</td>
<td>WP</td>
<td>500 g/kg</td>
<td>25</td>
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<tr>
<td>Dicloran</td>
<td>8772</td>
<td>Botran</td>
<td>Chloronitroben</td>
<td>WP</td>
<td>750 g/kg</td>
<td>18</td>
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<td>Dinocap</td>
<td>5475</td>
<td>Karathane</td>
<td>Dinitrophenyl</td>
<td>WP</td>
<td>250 g/kg</td>
<td>1.5</td>
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<tr>
<td>Dodine</td>
<td>15608</td>
<td>Equal 65 WP</td>
<td>Guanidine</td>
<td>WP</td>
<td>650 g/kg</td>
<td>39</td>
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<tr>
<td>Dodine</td>
<td>7315</td>
<td>Cyprex 65-W</td>
<td>Guanidine</td>
<td>WP</td>
<td>650 g/kg</td>
<td>711.1</td>
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<td>Ferbam</td>
<td>20138</td>
<td>Ferbam 76 WDG</td>
<td>Dimethyldithiocarbamate</td>
<td>WP</td>
<td>760 g/kg</td>
<td>22.29</td>
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<td>Ferbam</td>
<td>NR</td>
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<td>Dimethyldithiocarbamate</td>
<td>WP</td>
<td>760 g/kg</td>
<td>44.2</td>
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<td>Formaldehyde</td>
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<td>Stanchem</td>
<td>Fumigant</td>
<td>SL</td>
<td>370 g/kg</td>
<td>338.92</td>
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<td>Iprodione</td>
<td>15213</td>
<td>Rovral</td>
<td>Dichloroanilide</td>
<td>WP</td>
<td>500 g/kg</td>
<td>84.5</td>
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<td>Mancozeb</td>
<td>8556</td>
<td>Dithane M-45</td>
<td>Ethylenebis(dithiocarbamate)</td>
<td>WP</td>
<td>800 g/kg</td>
<td>12.8</td>
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<tr>
<td>Mancozeb</td>
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<td>Tuberseal</td>
<td>Ethylenebis(dithiocarbamate)</td>
<td>WP</td>
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<td>Potato Seed</td>
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<td>BASF Polyram</td>
<td>Ethylenebis(dithiocarbamate)</td>
<td>WG</td>
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<td>800 g/kg</td>
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<td>Metiram</td>
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<td>BASF Polyram</td>
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<td>WG</td>
<td>70 g/kg</td>
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<td>Sulphur</td>
<td>16249</td>
<td>Hollysul</td>
<td>Inorganic</td>
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<td>Micro-Sulphur</td>
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<td>Orchard Lime</td>
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<td>Phenylthiophenol</td>
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<td>Ziram 85W</td>
<td>Dimethyldithiocarbamate</td>
<td>WP</td>
<td>850 g/kg</td>
<td>1878.5</td>
</tr>
</tbody>
</table>

Form. = Formulation; EC = emulsifiable concentrate; SC = flowable concentrate; WP = wettable powder, WG = water dispersible granules;
Table 6. A summary of fungicide sales data for the south Okanagan valley, B.C. in 1990/91, by month.

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<td>40</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiophanate-methyl</td>
<td>12279</td>
<td>6.3</td>
<td>47.6</td>
<td>67.9</td>
<td>73.85</td>
<td>50.1</td>
<td>7.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ziram</td>
<td>15473</td>
<td>282.2</td>
<td>81.6</td>
<td>6.8</td>
<td>1.7</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Total Fungicide Sales</strong></td>
<td></td>
<td>0</td>
<td>0</td>
<td>288.5</td>
<td>557.8</td>
<td>283.9</td>
<td>431.55</td>
<td>209.5</td>
<td>253.4</td>
<td>76</td>
<td></td>
<td>17</td>
<td>30.6</td>
</tr>
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</table>
Table 7. A summary of data on the sales of other agrochemicals for the south Okanagan valley, B.C. in 1990/91.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>PCP #</th>
<th>Product Name</th>
<th>Pesticide Type</th>
<th>Form.</th>
<th>Concentration of AI in Product (g/L)</th>
<th>Quantity of AI (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rodenticides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>16926</td>
<td>Hinder Deer and Rabbit Repellent</td>
<td>Repellent</td>
<td>NR</td>
<td>150 g/L</td>
<td>0.9</td>
</tr>
<tr>
<td>Diphacinone</td>
<td>11670</td>
<td>Ramik Brown</td>
<td>Anticoagulant rodenticide</td>
<td>RB</td>
<td>0.1 g/kg</td>
<td>0.03</td>
</tr>
<tr>
<td>Strychnine</td>
<td>12408</td>
<td>Elston Gopher Getter</td>
<td>Botanical Poison</td>
<td>RB</td>
<td>3.9 g/kg</td>
<td>0.54</td>
</tr>
<tr>
<td>Zinc phosphide</td>
<td>14801</td>
<td>M&amp;B Waxed Mousebait 2 Agricultural</td>
<td>Rodenticide</td>
<td>PA</td>
<td>20 g/kg</td>
<td>6</td>
</tr>
<tr>
<td>Plant Growth Regulators</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzylamino purine</td>
<td>16636</td>
<td>Promalin</td>
<td>Plant growth regulator</td>
<td>SL</td>
<td>18 g/L</td>
<td>1.11</td>
</tr>
<tr>
<td>Ethephon</td>
<td>11580</td>
<td>Ethrel</td>
<td>Plant growth regulator</td>
<td>SL</td>
<td>240 g/L</td>
<td>22.22</td>
</tr>
<tr>
<td>Gibberellic acid</td>
<td>11904</td>
<td>Activol</td>
<td>Plant growth regulator</td>
<td>TB</td>
<td>92 g/kg</td>
<td>1.02</td>
</tr>
<tr>
<td>Naphthalene acetic acid</td>
<td>16027</td>
<td>Fruit Fix Concentrate</td>
<td>Plant growth regulator</td>
<td>SL</td>
<td>57 g/L</td>
<td>0.23</td>
</tr>
<tr>
<td>Naphthalene acetic acid</td>
<td>14756</td>
<td>Niagara Stik</td>
<td>Plant growth regulator</td>
<td>WP</td>
<td>63 g/kg</td>
<td>3.94</td>
</tr>
<tr>
<td>Naphthanene-acetamide</td>
<td>13167</td>
<td>Amid-thin</td>
<td>Plant growth regulator</td>
<td>WP</td>
<td>84 g/kg</td>
<td>2.26</td>
</tr>
<tr>
<td>Adjuvants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral oil (paraffin base)</td>
<td>16937</td>
<td>BASF Assist Oil Concentrate</td>
<td>Adjuvant</td>
<td>SL</td>
<td>830 g/L</td>
<td>33.2</td>
</tr>
<tr>
<td>Octylphenoxy polyethoxy ethanol</td>
<td>18822</td>
<td>Super Spread Non-Ionic Surfactant</td>
<td>Adjuvant</td>
<td>SL</td>
<td>480 g/L</td>
<td>84.48</td>
</tr>
</tbody>
</table>

Form. = Formulation; NR = no reported; OL = oil miscible liquid; PA = paste; RB = bait; SL = soluble liquid; TB = tablet; WP = wettable powder.
Table 8. Identification of Priority Pesticides with Respect to their Potential to Contaminate Groundwater within the Study Area.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Quantity of AI Sold (in kg)</th>
<th>Solubility Score (R1)</th>
<th>Volatility Score (R2)</th>
<th>Soil Persistence Score (R3)</th>
<th>Leaching Potential Value (R1+R2+R3/3)</th>
<th>Total Hazard Score</th>
<th>Hazard Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insecticides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azinphos-methyl</td>
<td>3991.5</td>
<td>5</td>
<td>8</td>
<td>20</td>
<td>11.00</td>
<td>43907</td>
<td>1</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>837</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>10.67</td>
<td>8928</td>
<td>11</td>
</tr>
<tr>
<td>Diazinon</td>
<td>1369</td>
<td>10</td>
<td>16</td>
<td>10</td>
<td>12.00</td>
<td>16428</td>
<td>4</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>132.48</td>
<td>5</td>
<td>14</td>
<td>10</td>
<td>9.67</td>
<td>1281</td>
<td>21</td>
</tr>
<tr>
<td>DNOC</td>
<td>742.75</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>10.67</td>
<td>7923</td>
<td>13</td>
</tr>
<tr>
<td>Endosulfan</td>
<td>969</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>5.33</td>
<td>5168</td>
<td>14</td>
</tr>
<tr>
<td>Methidathion</td>
<td>993.84</td>
<td>15</td>
<td>14</td>
<td>10</td>
<td>13.00</td>
<td>12920</td>
<td>7</td>
</tr>
<tr>
<td>Pirimicarb</td>
<td>179.5</td>
<td>20</td>
<td>14</td>
<td>5</td>
<td>13.00</td>
<td>2334</td>
<td>20</td>
</tr>
<tr>
<td><strong>Herbicides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyphosate</td>
<td>1069.42</td>
<td>20</td>
<td>16</td>
<td>10</td>
<td>15.33</td>
<td>16398</td>
<td>5</td>
</tr>
<tr>
<td>Parauquat</td>
<td>537.7</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20.00</td>
<td>10754</td>
<td>8</td>
</tr>
<tr>
<td>Simazine</td>
<td>198.9</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td>15.00</td>
<td>2984</td>
<td>18</td>
</tr>
<tr>
<td><strong>Fungicides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benomyl</td>
<td>263</td>
<td>5</td>
<td>20</td>
<td>10</td>
<td>11.67</td>
<td>3068</td>
<td>17</td>
</tr>
<tr>
<td>Captan</td>
<td>1418.2</td>
<td>5</td>
<td>12</td>
<td>5</td>
<td>7.33</td>
<td>10400</td>
<td>9</td>
</tr>
<tr>
<td>Copper</td>
<td>1007.5</td>
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<td>20</td>
<td>20</td>
<td>15.00</td>
<td>15113</td>
<td>6</td>
</tr>
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<td>Dodine</td>
<td>750.1</td>
<td>20</td>
<td>4</td>
<td>10</td>
<td>11.33</td>
<td>8501</td>
<td>12</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>338.9</td>
<td>20</td>
<td>6</td>
<td>5</td>
<td>10.33</td>
<td>3502</td>
<td>16</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>308.8</td>
<td>5</td>
<td>20</td>
<td>10</td>
<td>11.67</td>
<td>3603</td>
<td>15</td>
</tr>
<tr>
<td>Metiram</td>
<td>308.8</td>
<td>0</td>
<td>18</td>
<td>10</td>
<td>9.33</td>
<td>2882</td>
<td>19</td>
</tr>
<tr>
<td>Sulphur</td>
<td>3426.9</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>5.33</td>
<td>18277</td>
<td>3</td>
</tr>
<tr>
<td>Thiophanate-methyl</td>
<td>1119.3</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>8.33</td>
<td>9328</td>
<td>10</td>
</tr>
<tr>
<td>Ziram</td>
<td>1879</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>16.67</td>
<td>31317</td>
<td>2</td>
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</tbody>
</table>

Leaching Potential Value: Scoring system was developed by McRae (1989).
Table 9. Pesticide Application Rates with the South Okanagan Valley, 1990/91.

<table>
<thead>
<tr>
<th>Study Area Sub-Unit</th>
<th>Land Area (ha)</th>
<th>AZ-M</th>
<th>CAR</th>
<th>DIAZ</th>
<th>DIM</th>
<th>DNOC</th>
<th>END</th>
<th>METH</th>
<th>PIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oliver North - east</td>
<td>800</td>
<td>0.03</td>
<td>0.01</td>
<td>0.019</td>
<td>0</td>
<td>0</td>
<td>0.039</td>
<td>0.012</td>
<td>0.002</td>
</tr>
<tr>
<td>Oliver North - west</td>
<td>1400</td>
<td>0.099</td>
<td>0.014</td>
<td>0.012</td>
<td>0.003</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
<td>0.005</td>
</tr>
<tr>
<td>Oliver Central - west</td>
<td>2200</td>
<td>0.192</td>
<td>0.059</td>
<td>0.094</td>
<td>0.011</td>
<td>0.036</td>
<td>0.042</td>
<td>0.046</td>
<td>0.007</td>
</tr>
<tr>
<td>Oliver South - east</td>
<td>1300</td>
<td>0.117</td>
<td>0.057</td>
<td>0.068</td>
<td>0.006</td>
<td>0.022</td>
<td>0.028</td>
<td>0.024</td>
<td>0.003</td>
</tr>
<tr>
<td>Oliver South - west</td>
<td>3000</td>
<td>0.135</td>
<td>0.025</td>
<td>0.046</td>
<td>0.002</td>
<td>0.033</td>
<td>0.035</td>
<td>0.034</td>
<td>0.006</td>
</tr>
<tr>
<td>Golden Mile - west</td>
<td>850</td>
<td>0.118</td>
<td>0.011</td>
<td>0.033</td>
<td>0.003</td>
<td>0.021</td>
<td>0.014</td>
<td>0.014</td>
<td>0.01</td>
</tr>
<tr>
<td>Osoyoos North - west</td>
<td>1100</td>
<td>0.31</td>
<td>0.038</td>
<td>0.04</td>
<td>0.005</td>
<td>0.041</td>
<td>0.118</td>
<td>0.044</td>
<td>0.008</td>
</tr>
<tr>
<td>Osoyoos Central - east</td>
<td>2100</td>
<td>0.136</td>
<td>0.037</td>
<td>0.044</td>
<td>0.004</td>
<td>0.038</td>
<td>0.033</td>
<td>0.039</td>
<td>0.004</td>
</tr>
<tr>
<td>Osoyoos Central - west</td>
<td>1500</td>
<td>0.276</td>
<td>0.024</td>
<td>0.073</td>
<td>0.004</td>
<td>0.017</td>
<td>0.107</td>
<td>0.059</td>
<td>0.02</td>
</tr>
<tr>
<td>Osoyoos South - west</td>
<td>1100</td>
<td>0.324</td>
<td>0.06</td>
<td>0.066</td>
<td>0.003</td>
<td>0.027</td>
<td>0.071</td>
<td>0.059</td>
<td>0.016</td>
</tr>
</tbody>
</table>

AZ-M = azinphos-methyl; CAR = carbaryl; DIAZ = diazinon; DIM = dimethoate; DNOC = dinitro-o-cresol; END = endosulfan; METH = methidathion; PIR = pirimicarb.

<table>
<thead>
<tr>
<th>Study Area Sub-Unit</th>
<th>Land Area (ha)</th>
<th>Herbicide Application Rate (kg/ha/yr)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Glyphosate</td>
<td>Paraquat</td>
<td>Simazine</td>
<td></td>
</tr>
<tr>
<td>Oliver North - east</td>
<td>800</td>
<td>0.013</td>
<td>0.002</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Oliver North - west</td>
<td>1400</td>
<td>0.038</td>
<td>0.006</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Oliver Central - west</td>
<td>2200</td>
<td>0.056</td>
<td>0.027</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Oliver South - east</td>
<td>1300</td>
<td>0.05</td>
<td>0.019</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>Oliver South - west</td>
<td>3000</td>
<td>0.027</td>
<td>0.026</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Golden Mile - west</td>
<td>850</td>
<td>0.049</td>
<td>0.009</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Osoyoos North - west</td>
<td>1100</td>
<td>0.056</td>
<td>0.047</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Osoyoos Central - east</td>
<td>2100</td>
<td>0.022</td>
<td>0.022</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Osoyoos Central - west</td>
<td>1500</td>
<td>0.061</td>
<td>0.031</td>
<td>0.005</td>
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</tr>
<tr>
<td>Osoyoos South - west</td>
<td>1100</td>
<td>0.098</td>
<td>0.04</td>
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<td></td>
</tr>
</tbody>
</table>
Table 11. Fungicide application rates in the South Okanagan Valley, 1990/91.

<table>
<thead>
<tr>
<th>Study Area Sub-Unit</th>
<th>Land Area (ha)</th>
<th>BEN</th>
<th>CAP</th>
<th>CU</th>
<th>DOD</th>
<th>FOR</th>
<th>MAN</th>
<th>MET</th>
<th>SUL</th>
<th>TH-M</th>
<th>ZIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oliver North - east</td>
<td>800</td>
<td>0.001</td>
<td>0.01</td>
<td>0.002</td>
<td>0.005</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.056</td>
<td>0.007</td>
<td>0.004</td>
</tr>
<tr>
<td>Oliver North - west</td>
<td>1400</td>
<td>0.004</td>
<td>0.024</td>
<td>0.032</td>
<td>0.042</td>
<td>0</td>
<td>0.014</td>
<td>0</td>
<td>0.057</td>
<td>0.019</td>
<td>0.045</td>
</tr>
<tr>
<td>Oliver Central - west</td>
<td>2200</td>
<td>0.012</td>
<td>0.056</td>
<td>0.071</td>
<td>0.061</td>
<td>0.038</td>
<td>0.013</td>
<td>0.033</td>
<td>0.158</td>
<td>0.076</td>
<td>0.068</td>
</tr>
<tr>
<td>Oliver South - east</td>
<td>1300</td>
<td>0.011</td>
<td>0.032</td>
<td>0.014</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
<td>0.065</td>
<td>0.036</td>
<td>0.016</td>
</tr>
<tr>
<td>Oliver South - west</td>
<td>3000</td>
<td>0.013</td>
<td>0.051</td>
<td>0.059</td>
<td>0.046</td>
<td>0</td>
<td>0.004</td>
<td>0.019</td>
<td>0.204</td>
<td>0.037</td>
<td>0.068</td>
</tr>
<tr>
<td>Golden Mile - west</td>
<td>850</td>
<td>0.008</td>
<td>0.084</td>
<td>0.011</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.004</td>
<td>0.071</td>
<td>0.036</td>
<td>0.01</td>
</tr>
<tr>
<td>Osoyoos North - west</td>
<td>1100</td>
<td>0.009</td>
<td>0.123</td>
<td>0.106</td>
<td>0.024</td>
<td>0</td>
<td>0.001</td>
<td>0</td>
<td>0.127</td>
<td>0.051</td>
<td>0.048</td>
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<tr>
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<td>2100</td>
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<td>0.054</td>
<td>0.015</td>
<td>0.046</td>
<td>0</td>
<td>0.002</td>
<td>0</td>
<td>0.038</td>
<td>0.028</td>
<td>0.082</td>
</tr>
<tr>
<td>Osoyoos Central - west</td>
<td>1500</td>
<td>0.007</td>
<td>0.061</td>
<td>0.049</td>
<td>0.004</td>
<td>0</td>
<td>0.002</td>
<td>0.032</td>
<td>0.093</td>
<td>0.058</td>
<td>0.158</td>
</tr>
<tr>
<td>Osoyoos South - west</td>
<td>1100</td>
<td>0.01</td>
<td>0.14</td>
<td>0.103</td>
<td>0.046</td>
<td>0</td>
<td>0</td>
<td>0.029</td>
<td>0.091</td>
<td>0.08</td>
<td>0.116</td>
</tr>
</tbody>
</table>

BEN = benomyl; CAP = captan; Cu = copper; DOD = dodine; FOR = formaldehyde; MAN = mancozeb; MET = metiram; SUL = sulphur; TH-M = thiophanate-methyl; ZIR = ziram.
Table 12. Identification of priority areas for groundwater monitoring in the South Okanagan Valley.

<table>
<thead>
<tr>
<th>Study Area Sub-Unit</th>
<th>Land Area (ha)</th>
<th>Number of Priority Insecticides</th>
<th>Number of Priority Herbicides</th>
<th>Number of Priority Fungicides</th>
<th>Number of Priority Pesticides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oliver North - east</td>
<td>800</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Oliver North - west</td>
<td>1400</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Oliver Central - west</td>
<td>2200</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Oliver South - east</td>
<td>1300</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Oliver South - west</td>
<td>3000</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Golden Mile - west</td>
<td>850</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Osoyoos North - west</td>
<td>1100</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Osoyoos Central - east</td>
<td>2100</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Osoyoos Central - west</td>
<td>1500</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Osoyoos South - west</td>
<td>1100</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>

Priority substances, in this context, are defined as active ingredients with application rates of 0.05 kg/AI/ha.
Development of a Detailed Pesticide Use Pattern and Groundwater Vulnerability Analysis for the Okanagan Valley of B.C.—Draft Report Phase II

- to NTS.
- No well logs
- No P.T. data
- No WQ data—good background.
June 3, 1992

Ron Johnston
Ministry of the Environment
47 Skaha Lake Rd.
Penticton, B.C.
A 7K2

Dear Ron,

Enclosed please find a draft report of the study titled: "Development of a Detailed Pesticide Use Pattern and Groundwater Vulnerability Analysis for the Okanagan Valley of British Columbia Phase I." The study was an excellent example of collaborative effort between federal, provincial and municipal governments and regional cultural and industry groups. The resulting draft report identified current pesticide use patterns in the southern Okanagan, and the high risk areas with respect to pesticide contamination of groundwater. It concluded by emphasizing the need for the design and implementation of a focused groundwater quality monitoring program to verify the vulnerability analysis.

It is felt that the successful outcome of Phase I of the project, now enables us to proceed to Phase II. We welcome your comments on the draft report as well as any involvement where your group might contribute towards Phase II. As you will note in the attached proposal, an estimated shortfall of $10 K remains for Phase II. Like Phase I, the success of the monitoring program planned for this summer is dependent upon continued tri-jurisdiction/stakeholder support. The completion of this study will contribute towards responsible, informed decision making about groundwater quality in the Okanagan region.

I am looking forward to your reply.

Sincerely,

Fre-Yves Caux, Ph.D
Pesticide Guideline Specialist
(819) 953-0602
Fax: (819) 953-0461

Attachment
R.A. Kent
Development of a Detailed Pesticide Use Pattern and Groundwater Vulnerability Analysis for the Okanagan Valley of British Columbia

Phase II: Implementation of a Focused Groundwater Quality Monitoring Program for Agrochemicals

A Proposal Prepared by:

Eco-Health Branch
Ecosystem Science and Evaluation Directorate
Environment Canada
Ottawa

June, 1992
Background

The Okanagan valley is one of the most important agricultural areas in British Columbia. When fruit, vegetable, and livestock production is considered, this region accounts for up to 20% of the total economic value of B.C.'s agriculture industry (Kerr et al. 1985). It is the largest producer of tree and vine fruit in the province. Maintenance of high rates of production necessitates an adequate water supply and the use agricultural chemicals (including fertilizers, insecticides, fungicides, fumigants, and herbicides). However, some of these chemicals are toxic and, as such, may pose a hazard to mammalian, avian, and other receptors if uses result in significant losses to the environment. While many of these hazards have been investigated, the potential for impacts of agrochemical use on the quality of groundwater resources has received relatively little attention.

There are a number of factors that may influence the vulnerability of groundwater resources to contamination by pesticides. McRae (1989) suggested that soil texture, slope gradient, depth to water table, and surface formation were several of the most important factors that influence groundwater vulnerability. Using data on these characteristics, critical areas in Canada that were most vulnerable to groundwater contamination were identified. On this basis, several areas within the Okanagan valley were identified as having a high potential for groundwater contamination (McRae 1989). In addition to these physical features, the potential for groundwater contamination in the Okanagan valley is enhanced by the wide range and significant quantities of pesticide products utilized by growers and the high irrigation rates that are necessary to maintain productivity.

Groundwater quality is a significant concern in the south Okanagan Valley because this resource is used extensively for irrigation, livestock watering, and domestic water supplies. Valuation of the hazards posed by agrochemical use to these water uses in this area necessarily requires the development of a detailed pesticide use and groundwater vulnerability analysis to identify the substances and areas that are most likely to be associated with groundwater contamination. In addition, evaluation of these hazards requires the implementation of a focused groundwater quality monitoring program to establish the presence, nature, severity, and extent of contamination.

Assessment of the hazards of agrochemical uses is not a novel concept in the Okanagan Valley. In 1987, an investigation was conducted to determine the magnitude and extent of groundwater contamination by pesticides in the vicinity of the Town of Osoyoos (McNaughton 1991). The results of this study confirm the vulnerability of groundwater resources in the Okanagan valley. In addition, various site-specific regional programs, which have been implemented by the provincial and municipal government agencies, have been directed at the assessment of groundwater quality. While these data provide some evidence that groundwater sources in this area are vulnerable to pesticide contamination, the extent of the actual contamination has not been established. In addition, recently there have been major shifts in pesticide use patterns in this area that could dramatically alter the potential for groundwater contamination.
Phase I - Summary and Recommendations

In response to the need for more recent and more focused information on the quality of groundwater resources in the Okanagan valley, an ad hoc working group (see attached contact list in Appendix) was established by Environment Canada in 1991, comprised of representatives from federal, provincial, and municipal government agencies, academia, and industry. Specifically, the members of this working group include key representatives from the Town of Osoyoos, Town of Oliver, Okanagan College, Okanagan-Similkameen Cooperative Growers Association, Monashee Cooperative Growers Association, B.C. Ministry of the Environment (BCMOE), B.C. Ministry of Agriculture and Fisheries (BCMAF), B.C. Ministry of Health (BCMOH), Agriculture Canada, and Environment Canada (DOE).

Under the leadership of Environment Canada (Eco-Health Branch, Ottawa), this working group directed the first phase of a study on pesticide use patterns and groundwater vulnerability in the south Okanagan valley in 1991/92. The first draft of this report (MacDonald et al. 1992) has now been completed and is currently under review by the working group. The summary and recommendations of Phase I of the project are given below:

1. A detailed pesticide use pattern and groundwater vulnerability analysis was developed for the southern portion of the Okanagan valley (north Oliver to the international boundary). This analysis was based on detailed 1989-91 pesticide sales data, which were considered to be an accurate indication of actual pesticide use patterns within the study area. Using these data, overall use volumes within the study area, use volumes by area, and use volumes per month have been calculated. In addition, groundwater use patterns within the study area have been identified.

2. This analysis indicated that a number of specific areas within the south Okanagan valley may be at substantially higher risk with respect to contamination of groundwater resources than others. Therefore, a pilot groundwater quality monitoring program should be carried out to provide a preliminary evaluation of the nature and extent of groundwater contamination in this region (i.e. validate the high risk areas).

3. High risk (priority) pesticides, with respect to their potential for contaminating groundwater, were identified as azinphos-methyl and ziram. On the basis of pesticide sales data, sulphur, diazinon, glyphosate, copper, methidathion, paraquat, and captan were identified as moderate risk (priority) pesticides within the study area. The 1992-93 pest management recommendations provided to growers by BCMAF (1992) and 1992 pesticide sales records should be evaluated to determine if significant shifts in pesticide use patterns are likely to have occurred in 1992. The pesticides used in grape production were thought to be under-represented in the present analysis, and several of these should be considered for inclusion in the pilot monitoring program. Based on that evaluation, a final list of priority analytes for a groundwater quality monitoring program should be established.

4. Using the results of the pesticide use and groundwater vulnerability analysis together with the regions pedological and limited hydrogeological information, the highest risk (priority) areas with respect to the potential groundwater contamination, were considered to be Oliver Central - west, Osoyoos Central - west, and Osoyoos South - west. However, additional information, including input from stakeholder groups, is required to identify the precise locations for sampling groundwater quality.
5. The results of the pilot groundwater quality monitoring program should be used to evaluate the need for, and to design, a future, more intensive monitoring program. Such an intensive program should be focused on those areas in which significant groundwater contamination is identified from Phase II. In addition, the results of the pilot monitoring program should be provided to stakeholder groups so that informed decisions can be made about improving and maintaining the groundwater quality (e.g. pesticide use patterns may be shifted away from those active ingredients that are contaminating groundwater resources). Further, these results may be used to identify the need for pesticide products that are less prone to leaching into groundwater.

6. The results of the pilot monitoring program, in conjunction with the detailed pesticide use analysis, should be used to verify and calibrate the Expres expert system that has been developed by Environment Canada (Crowe et al. 1989; Crowe and Mutch 1990; Mutch and Crowe 1990) for evaluating the fate of agricultural chemicals in the subsurface.

The results from Phase I of this project have clearly shown that the principle objectives have successfully been met. Thus, in so doing, a detailed pesticide use and groundwater vulnerability analysis in the Okanagan valley have been provided. The solid basis provided by a multi-stakeholder working group in Phase I of this project can now be used for designing and implementing a focused groundwater quality monitoring program to allow for informed, sound decisions to be made by the inhabitants in the south Okanagan valley.

Phase II - Implementation

In the past, design and implementation of water quality monitoring programs in British Columbia have, largely, been the responsibility of the provincial government (BCMOE, BCMOH, etc.). Environment Canada and other federal agencies (e.g., Health and Welfare Canada) have also initiated and/or collaborated in such programs when issues of significant national interest have arisen (e.g., transboundary concerns, federal lands, groundwater quality, etc.). However, regional/local governments, industry representatives, and the public have had limited opportunities for involvement. While this approach has frequently provided the data required to support environmental management decisions, it has not always generated the kind of inter-agency, multi-stakeholder cooperation and effort that is necessary to achieve sound environmental management objectives.

The economy of the south Okanagan Valley is dependant, to a great extent, on agricultural activities (including wine-making and fruit processing) and tourism-based industries. Indeed, local interests have expended considerable effort to develop and integrate these sectors and, as such, establish the unique character of the region. This comprehensive understanding of regional interests and concerns provides local organizations with a unique perspective on environmental management. This perspective, in addition to their extensive knowledge of the area, makes these organizations essential partners in the design and implementation of effective environmental quality monitoring programs.

The working group recognizes that implementation of a responsive groundwater quality monitoring program in the south Okanagan valley will require the participation of the public, local organizations, and all levels of government. As such, the working group proposes to refine the design of, and to implement, a focused groundwater monitoring program to provide the information
that is required to assess the hazards associated with agrochemical use in this area. In addition, the working group will collate and evaluate the results of this investigation, and prepare a final report which summarizes these data.

**Monitoring Program Design**

The first stage in the implementation of a monitoring initiative in the south Okanagan Valley is to refine the design of a cost-effective monitoring program. The pesticide use and groundwater vulnerability analysis conducted in Phase I provides a scientifically-defensible basis for designing such a program, detailing information on the types and volumes of pesticides used in the area. In addition, by considering the use volumes and physical-chemical properties of each substance, those pesticides which have the greatest potential for leaching through soils and contaminating groundwater were identified. Furthermore, the results of this study provide information on the location and timing of pesticide use in this area.

Refinement of the monitoring program will involve the final identification of sampling sites, sampling frequency, and list of priority analytes. It is anticipated that Phase II will primarily utilize the large network of abandoned and active wells in the study area (mapped and provided by municipalities). The working group will facilitate the refinement of the monitoring program design by consulting BCMAF to determine if any major changes in pest control strategies have been recommended to fruit growers (i.e., in fruit production guides). In addition, the pesticide distribution outlets (South Valley Sales, Okanagan-Similkameen Cooperative Growers Association, and Monashee Cooperative Growers Association) will be consulted to determine if any such changes have resulted in shifts in pesticide use patterns. Any significant changes in pesticide use will be reflected in the study design.

**Summary of Anticipated Analytical Requirements**

Information from the initial pesticide use and groundwater vulnerability analysis were used to develop an estimate of analytical requirements. This analysis indicated that six of the ten fruit growing areas in the south Okanagan valley should be investigated further to determine the presence, nature and extent of groundwater contamination. If one site from each of these areas was sampled on three separate dates, and two samples were collected on each date, then a total of 36 samples for pesticide analysis would be collected. In addition, roughly 12 additional samples would be included for the program’s QA/QC component (i.e., 4 samples per sampling date). It is anticipated that the following priority analytes would be measured in each sample.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hazard Ranking</th>
<th>Detection Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pesticides:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azinphos-methyl</td>
<td>1</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Ziram</td>
<td>2</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Sulphur (as Sulphide)</td>
<td>3</td>
<td>1.0 ug/L</td>
</tr>
<tr>
<td>Diazinon</td>
<td>4</td>
<td>1.0 ug/L</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>5</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Copper</td>
<td>6</td>
<td>1.0 ug/L</td>
</tr>
<tr>
<td>Methidathion</td>
<td>7</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Paraquat</td>
<td>8</td>
<td>0.1 ug/L</td>
</tr>
</tbody>
</table>
Variable & Hazard Ranking & Detection Limit

<table>
<thead>
<tr>
<th>Pesticides:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Captan</td>
<td>9</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Thiophanate-methyl</td>
<td>10</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>11</td>
<td>0.2 ug/L</td>
</tr>
<tr>
<td>Dodine</td>
<td>12</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>DNOC</td>
<td>13</td>
<td>0.1 ug/L</td>
</tr>
<tr>
<td>Endosulfan</td>
<td>14</td>
<td>0.05 ug/L</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>15</td>
<td>0.1 ug/L</td>
</tr>
</tbody>
</table>

Other Variables:
- pH
- Conductivity
- Hardness
- Alkalinity
- Sulphate
- Total Nitrogen
- Nitrogen (NO₃)
- Chloride
- Temperature

*other pesticides could be including depending on the results of Phase II*

**Report Preparation**

Report preparation and information dissemination to all stakeholders and public is an important aspect of this study. As such, Environment Canada with the continued help of the working group will facilitate the collection, collation, and summarization of the results of the groundwater quality monitoring program. These data will be interpreted in light of existing Canadian water quality guidelines (e.g., drinking water, agricultural water uses). This information will be presented in a detailed technical report, with an extended executive summary that provides all readers with easy access to the results of the study. Presentations of final results to interested stakeholders in the region are planned for Fall 1992.