Environment Canada

Environmental Protection

Environnement Canada

Protection de l'environnement

9

ASSESSMENT OF PRINCE EDWARD ISLAND GROUNDWATERS FOR THE PESTICIDE ALDICARB

A JOINT FEDERAL/PROVINCIAL REPORT

Surveillance Report EPS-5-AR-87-4

Atlantic Region

Canada

ENVIRONMENTAL PROTECTION REPORT SERIES

Surveillance reports present the results of monitoring programs carried out by Environmental Protection. These reports will usually be published on a regular basis.

Other categories in the EP series include such groups as Regulations, Codes and Protocols; Policy and Planning, Economic and Technical Appraisal; Technology Development; Briefs and Submissions to Public Inquiries; and Environmental Impact and Assessment.

Inquiries pertaining to Environmental Protection Reports should be directed to Environmental Protection, Environment Canada, Dartmouth, Nova Scotia. B2Y 2N6.

ASSESSMENT OF PRINCE EDWARD ISLAND GROUNDWATERS FOR THE PESTICIDE ALDICARB

by

R.A.F. Matheson[1], R.M. Francis[2], W.R. Ernst[1],
D.E. Jardine[2], M.N. Gill[1] and P.A. Hennigar[1]

[1] Environmental Protection
Conservation and Protection
Environment Canada
Atlantic Region

[2] Water Resources Section
Department of Community and
Cultural Affairs
Prince Edward Island

June, 1987

EPS-5-AR-87-4

ACKNOWLEDGEMENTS

The authors wish to thank Dr. F.C. Duerden and Dr. T. Pollock of Conservation and Protection, Atlantic Region (Environment Canada) and Dr. H. Lerer of the Commercial Chemicals Branch (Environment Canada) for their helpful review of this manuscript.

Special thanks are due to Joan Keating and Barb Pellerin for their patience in typing this report.

The assessment survey was a joint study by Conservation and Protection, Atlantic Region (Environment Canada) and the Prince Edward Island Department of Community and Cultural Affairs. The Toxic Chemicals Fund (Environment Canada) and Union Carbide Agricultural Products Company, Inc. assisted with the financing of this study.

ABSTRACT

In a 1982 survey, aldicarb was identified as one of the most intensively used pesticides in Prince Edward Island. In addition, Prince Edward Island soils exhibit characteristics similar to areas in the United States where aldicarb residues have been detected in groundwaters. As a consequence of these two factors, an eighteen month sampling program was initiated to determine the distribution and concentration of aldicarb in Prince Edward Island groundwaters.

Depending on sampling time, aldicarb residues of 1 ppb or greater were detected in 5-27% of tested wells. For the most part, detectable levels ranged from 1.0 - 3.0 ppb, with 5.4 ppb the maximum reported value. The incidence of detection was directly related to the distance of a sampled well from a treated field, the time between pesticide application and sampling, the history of aldicarb use in the treatment area and well construction.

RÉSUMÉ

Une étude effectuée en 1982 a démontré que l'aldicarbe était l'un des pesticides les plus utilisés à l'Ile-du-Prince-Edouard. De plus, les sols de l'Ile-du-Prince-Edouard présentent les mêmes charactéristiques que les régions des Etats-Unis où des traces d'aldicarbe ont été décelées dans les eaux souterraines. Fort de ces deux facteurs, un programme d'échantillonage de dix-huit mois fut effectué afin d'établir la distribution et la concentration d'aldicarbe dans les eaux souterraines à l'Ile-du-Prince-Edouard.

Suivant le moment de l'échantillonage, des traces d'aldicarbe de l'ordre de 1 ppb ou plus furent décelées dans 5-27% des puits testés. Pour la plupart, les niveaux détectes variaient entre 1.0 et 3.0 ppb, avec 5.4 ppb comme valeur maximale. La fréquence de détection dépendait.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Project Background

A number of reports (Zaki et al., 1982; Rothschild et al., 1982) have documented the presence of aldicarb residues in groundwater in several American States. A pesticide use survey conducted on Prince Edward Island (P.E.I.) in 1982 by the Environmental Protection Service (EPS), indicated that aldicarb was one of the most intensively used pesticides in the province (Environmental Protection Service, 1984).

P.E.I. soils exhibit characteristics similar to those areas in the United States where aldicarb was detected. In particular, Island soils are generally porous and low in organic content, leaving groundwater susceptible to contamination from highly soluble materials. Based on the extent of use and solubility, aldicarb was considered a potential contaminant of the province's aquifers.

In 1983 EPS, in conjunction with the P.E.I. Department of Community and Cultural Affairs, initiated a preliminary study to determine if aldicarb residues were leaching to groundwater. Approximately one month after crop planting, 51 water samples were collected and sent to the EPS lab for analysis. The results of these tests indicated that 27% of the samples had detectable levels of aldicarb. As a result of these findings, a more extensive eighteen month survey was implemented to establish the environmental fate of aldicarb in P.E.I. groundwater.

1.2 Physical and Chemical Properties of Aldicarb

Aldicarb is an oxime carbamate insecticide manufactured by Union Carbide Agricultural Products Company, Inc. and sold under the brand name Temik. It is one of the most acutely toxic pesticides registered for agricultural use in Canada with an oral LD50 (rat) value of 0.9 mg/kg (Union

Carbide Agricultural Products Company Inc., 1983). The insecticidal properties of this material are due to its ability to inhibit the functioning of the cholinesterase enzymes necessary for proper nervous system response (Harkin et al., 1986).

As a consequence of its high acute mammalian toxicity compared with other agricultural pesticides, aldicarb is marketed in a granular formulation for the protection of the applicator. Technical aldicarb, and a bonding agent to reduce friability, are incorporated onto an inert carrier material made of corn cob or gypsum (Union Carbide Agricultural Products Company Inc., 1983).

The aldicarb granules are mechanically incorporated into the soil, in bands, at planting time. Moisture in the soil releases the pesticide from the granule. It is absorbed by the plant root system and translocated throughout the plant where it functions as a systemic insecticide for the duration of the growing season.

Aldicarb is highly soluble in water (6 000 000 ppb*) and not readily adsorbed onto soil particles, thus facilitating both absorption by plant roots and leaching through soil to groundwater (Harkin et al., 1986).

Following incorporation into soil, parent aldicarb is rapidly oxidized by microorganisms to aldicarb sulfoxide and aldicarb sulfone. Within a month after application, most of the parent compound is reported to be converted to these two metabolites which eventually hydrolyze to purportedly non-toxic compounds as a result of chemical and microbial action (Union Carbide Agricultural Products Company Inc., 1983).

* In this manuscript ppb = micrograms/litre.

1.3 Groundwater Contamination

Aldicarb residues have been reported in groundwaters of thirteen U.S. States (Cohen et al., 1984) and several Canadian provinces (Canadian Association of Pesticide Control Officials, 1984). The two most intensively studied situations are those in New York and Wisconsin.

In Suffolk County, Long Island, New York, residues were first detected in groundwater in 1979. Aldicarb had been heavily used in this area as a potato insecticide from 1974 to 1979. It was initially registered for application at 3.3 kg active ingredient (a.i.) per hectare, but by 1978 New York State had approved the use of 5.5 kg a.i. per hectare at planting and an additional 2.2 kg a.i. per hectare as a post-emergence side-dressing (Guerrera, 1981).

An acceptable level of 7 ppb aldicarb in drinking water was recommended for New York State by the National Academy of Sciences. A survey of over 8 000 wells indicated that 13.5% were above this action level (Zaki et al., 1982). As a result of these studies, Union Carbide removed aldicarb from the Long Island market in 1980.

The entry of aldicarb into Long Island groundwater was attributed to a combination of factors, including: sandy soil conditions, low soil organic matter, low soil microbial activity, low soil pH and temperature, shallow water table, high pesticide application rates and heavy rainfall during planting (Union Carbide Agricultural Products Company Inc., 1983).

In Wisconsin, aldicarb residues were first detected in groundwater in 1980. Over 500 wells were sampled and 28 of these were above the 10 ppb drinking water criterium established by the U.S. Environmental Protection Agency (Harkin et al., 1986). In addition to excessive irrigation, most of the factors contributing to the Suffolk County problem were also cited as potential causes of groundwater contamination in Wisconsin (Wyman et al., 1985).

A number of measures were initiated to control further contamination. These included reducing the application rate from 3.3 to 2.2 kg a.i. per hectare, applying aldicarb at emergence instead of at planting and restricting application to once every two years (Harkin et al., 1986).

Many of the conditions contributing to groundwater contamination in New York and Wisconsin are applicable to the P.E.I situation. Island soils tend to be low in soil temperature, pH and organic material; and rainfall is usually heavy during the early part of planting.

1.4 Aldicarb Use History

Aldicarb was first registered in Canada in 1974 for use on potatoes and since that time has been widely used in the potato industry. On P.E.I., aldicarb in the form of Temik 10G has been in use since 1978 for the control of Colorado Potato Beetles, flea beetles and aphids. During the 1983 season 5 000 to 10 000 kg a.i. were applied at a rate of 1.8-2.3 kg a.i. per hectare on approximately 3 000 hectares (P.E.I. Department of Agriculture).

1.5 Geology of Prince Edward Island

The surficial geology of P.E.I consists of generally sandy overburden ranging in depth from 0-20 m. This overlies fractured porous red beds composed mainly of sandstone, siltstone and claystone. Sandstone constitutes approximately 60-85% of the bedrock. Individual beds of rock are often very lenticular in nature resulting in rapid lateral and vertical variation in geology (Van de Poll, 1975).

Groundwater supplies are obtained from the fractured sandstone formations. The overburden is generally of lower permeability than the bedrock resulting in a semiconfined aquifer system. Groundwater movement in bedrock is mainly through fracture flow.

1.6 Aldicarb Study Sponsors

The first phase of the aldicarb study, from June 1983 to February 1984, was jointly funded by the Environmental Protection Service of Environment Canada and the P.E.I. Department of Community and Cultural Affairs. During the second phase of the study, from May 1984 to November 1984, Union Carbide Agricultural Products Co. Inc. provided additional financial support.

2. SAMPLING PROGRAM

2.1 Site Selection

The P.E.I. Department of Agriculture and local pesticide dealers assisted in identifying areas of aldicarb use. Potato growers in these areas were contacted to obtain information regarding aldicarb application rates, years of aldicarb use and possible sampling sites.

The actual sites were chosen on the basis of their proximity to an aldicarb treated field and their assumed position in the local groundwater flow system. Wells located downslope were considered the most vulnerable to contamination.

The study was initially designed to sample aldicarb in groundwater throughout the province; however, after some investigation it became evident that very little aldicarb was used in eastern P.E.I. Consequently, the bulk of the sampling sites was located west of Charlottetown. Figures 1 - 3 show sampling locations.

2.2 Survey Structure

The aldicarb study was initiated in June 1983, approximately one month after potato planting, to determine whether detectable concentrations of aldicarb were present in P.E.I. groundwaters. Based on the results of this survey of 51 wells, the study was expanded to include 20 additional sites and an additional three samplings, prior to the next growing season, in order to assess the behaviour of aldicarb residue levels over an eight month period. These surveys took place in September - October 1983, December 1983- January 1984 and February 1984.

A review of the results from this phase of the study indicated aldicarb residue concentrations were greater during the first five months after planting. Consequently, following a pre-planting sampling in May

ALDICARB SAMPLING SITES

Western
Prince Edward Island

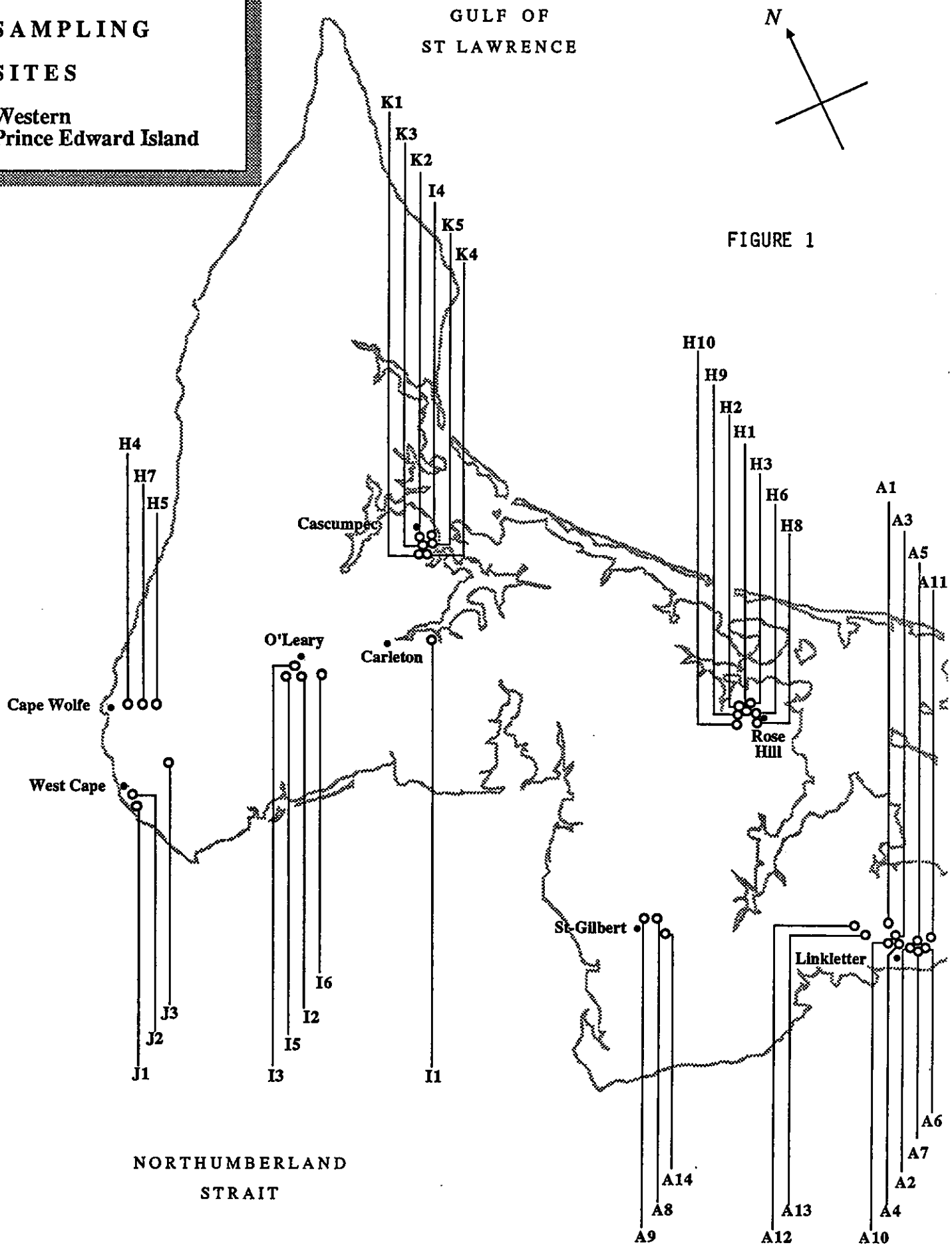


FIGURE 1

ALDICARB SAMPLING SITES

Central Prince Edward Island

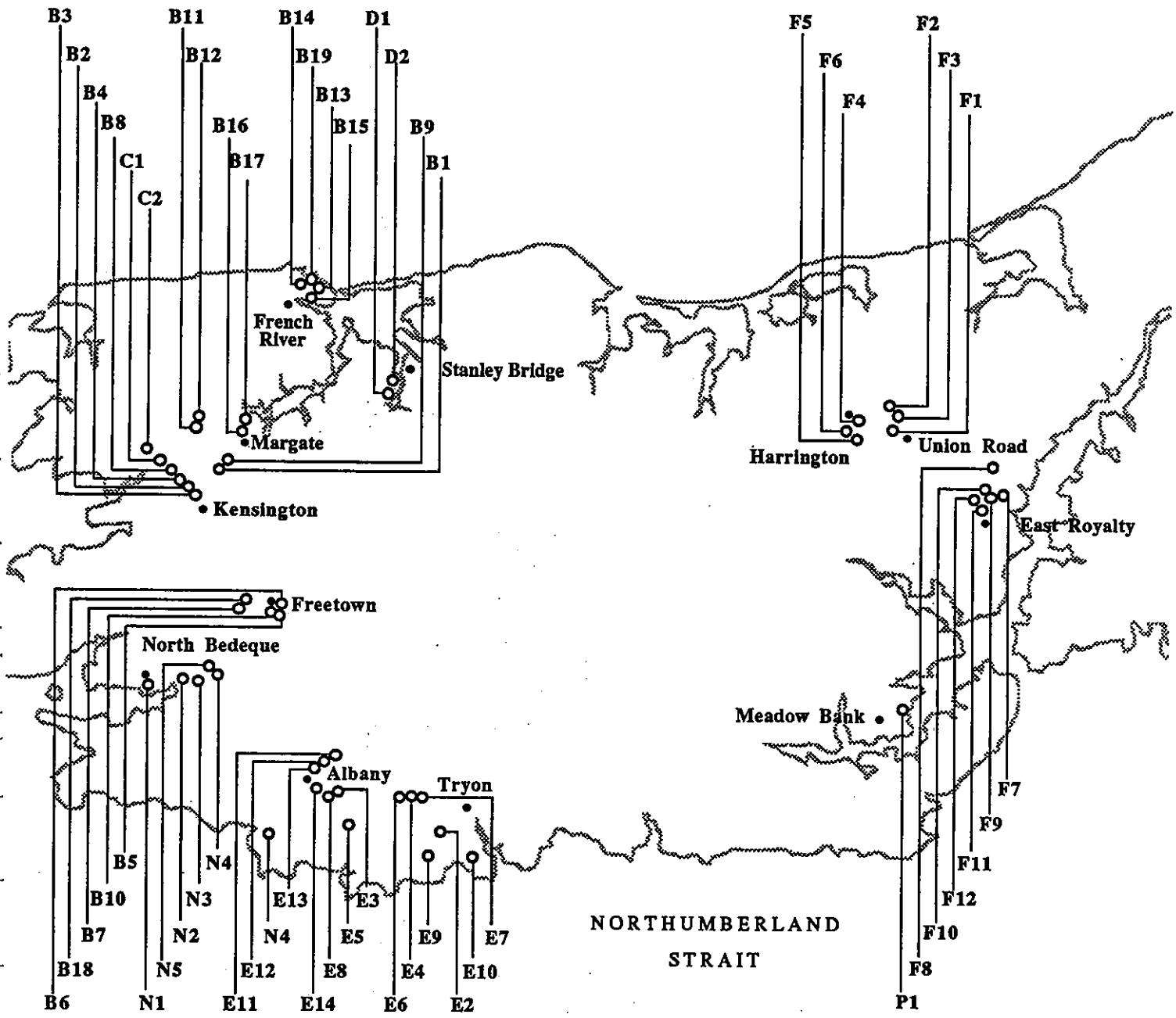


FIGURE 2

ALDICARB SAMPLING SITES

Eastern Prince Edward Island

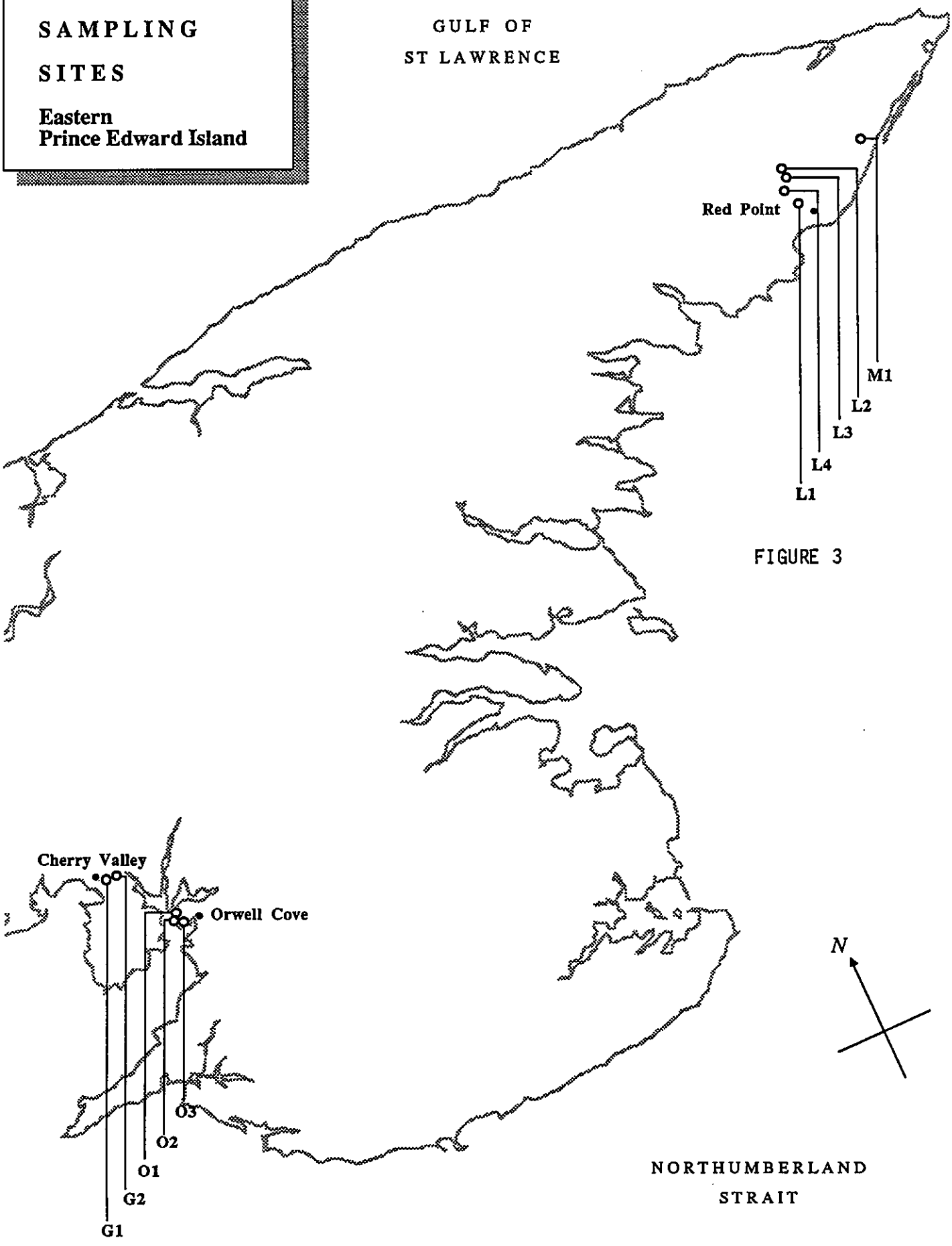


FIGURE 3

1984, to establish reference levels, samples were collected in June-July 1984 (after planting), August 1984 (approximately mid-season) and November 1984 (after fall groundwater recharge had commenced). Sampling sites included wells from the 1983/1984 survey with detectable quantities of aldicarb, wells from the 1983/1984 survey with no detectable concentrations but adjacent to fields where aldicarb would be used for the second consecutive year, and 32 new wells selected using the criteria established in 1983/1984 (Section 2.1). A total of 60 sites was included in the second phase of the study. For various reasons, it was not always possible to obtain a sample from each site during every sampling.

2.3 Sample Collection

Groundwater samples were obtained solely from domestic wells which, unfortunately, placed some restrictions on sampling location and posed problems in ensuring sample consistency. In particular, there was a lack of control over such important factors as the position of the well with respect to the field, the depth of the well in the aquifer, the amount of casing used in construction and sampling methodology. However, due to the number of sites and the large geographical area encompassed by the survey, domestic wells proved to be the most convenient and economic means of obtaining groundwater samples.

Water samples were collected in 1.4 L amber glass bottles with aluminum foil cap liners. The bottles were prepared by first washing with a biodegradable soap and then rinsing with distilled water, acetone and hexane. Aluminum foil cap liners were also rinsed with hexane. Samples were acidified to pH 3-4 with concentrated sulfuric acid, stored at 4°C and extracted within 6-12 days after collection.

3. ANALYTICAL METHODOLOGY

3.1 Introduction

Analysis of groundwater samples for aldicarb was conducted according to the methodology developed by Union Carbide. The detection limit was 1 ppb.

Aldicarb residues in water consist, for the most part, of aldicarb, aldicarb sulfoxide and aldicarb sulfone. For purposes of analysis, aldicarb and aldicarb sulfoxide are oxidized by peracetic acid to aldicarb sulfone which is then extracted from the water sample with methylene chloride. Identification and quantitation are by gas chromatography utilizing a flame photometric detector with a sulfur filter.

3.2 Reagents

- Peracetic acid
- Sodium bicarbonate, 10% aqueous solution
- Methylene chloride
- Sodium sulfate, anhydrous, granular
- Acetone
- Aldicarb (Agriculture Canada)
- Aldicarb sulfoxide (Agriculture Canada)
- Aldicarb sulfone (Agriculture Canada)

All reagents were analytical grade and blank samples were run to verify the integrity of the materials.

3.3 Apparatus

Aldicarb sulfone residues were quantified using a Tracor 222 Gas Chromatograph equipped with an SPD-100-AT Flame Photometer operating in the sulfur mode.

Instrument conditions were:

Column Temperature	- 155°C
Column Length	- 100 cm (glass)
Column diameter (internal)	- 4 mm
Column Packing	- 3% SP 1000 on Supelco 100/120 mesh
Detector Temperature	- 183°C
Injection Temperature	- 200°C
Injection Volume	- 0.005 mL

3.4 Extraction and Quantitation

A water sample (200 mL) and peracetic acid (2 mL) were placed in a separatory funnel, shaken and allowed to stand for 15 minutes. A 10% sodium bicarbonate solution (50 mL) was added to the separatory funnel, the contents shaken and allowed to stand for 15 minutes with occasional swirling. Methylene chloride (100 mL) was added and the mixture shaken for thirty seconds with frequent venting to release the evolved carbon dioxide gas.

The mixture was left standing to allow the layers to separate and the methylene chloride (lower) layer was then drained through a bed of anhydrous granular sodium sulfate (100 g) into a 250 mL Erlenmeyer flask. The aqueous solution was partitioned with a second 100 mL portion of methylene chloride and the organic extract was then drained through the sodium sulfate bed. An additional 25 ml of fresh methylene chloride was used to wash down the sodium sulfate bed.

The methylene chloride extract was reduced to 5 mL under reduced pressure. The concentrate was transferred with washings to a 15 mL centrifuge tube and evaporated to 0.5 mL under a stream of dry nitrogen. The concentrate was diluted to 10 mL with acetone and a 0.005 mL portion injected into the gas chromatograph. Aldicarb sulfone concentrations were determined on the basis of integrated peak areas and reported on the basis of equivalent aldicarb values.

3.5 Quality Control

Recovery experiments with aldicarb sulfoxide and aldicarb sulfone indicated 65% recovery for aldicarb sulfoxide and a 100% recovery for aldicarb sulfone.

3.6 Nitrates

Nitrate analyses were conducted by the P.E.I. Department of Community and Cultural Affairs using the method for nitrate determination described in Deep Sea Research (Brewer and Riley, 1965).

4. RESULTS AND DISCUSSION

4.1 Aldicarb Residues

Detailed analytical results for the eight aldicarb surveys are listed in Appendix A and the data are summarized in Tables 1 and 2. Average aldicarb concentrations in this and other tables included in the report have been calculated using only positive results; non-detected values (i.e. L 1.0 ppb) have been excluded in the calculation.

Aldicarb residues were detected at 20 of 103 sites. All measured concentrations were below the Interim Maximum Acceptable Level (9 ppb) established by Health and Welfare Canada (1983), as well as action levels established by the USEPA (10 ppb) and the State of New York (7 ppb). The maximum concentration detected was 5.4 ppb; however, most levels ranged between 1-3 ppb. As measured residues were, for the most part, only slightly in excess of the detection limit, frequency of detection rather than concentration fluctuation was considered a more usable indicator for developing an overview of rates of entry and persistence in the aquifers.

In the first phase of the study, June 1983 to February 1984, the highest percentage of wells with measurable aldicarb and the highest individual concentrations were reported in the June-July and September-October surveys. Average aldicarb concentrations, however, remained relatively unchanged from June to January with a slight decline noted in February. In general, both the percentage of wells with detectable concentrations of aldicarb and the average concentration declined over the eight month period.

During the second phase of the study, May 1984 to November 1984, average aldicarb concentrations were slightly lower than values recorded for similar periods in the first phase. High concentratons in 1983 may be attributable to the extremely heavy precipitation experienced during the early part of planting. Other factors, however, such as frequency of use and dosage rates, may also be important.

TABLE 1 - SUMMARIZED SURVEY DATA FOR GROUNDWATER SAMPLES COLLECTED BETWEEN JUNE 1983 AND FEBRUARY 1984

Sampling Period	Aldicarb Conc. (ppb)* Mean ± Standard Deviation	Number of Wells Sampled	Number of Wells with Detectable Aldicarb Conc.	Percent of Wells with Detectable Aldicarb Conc.	Range of Aldicarb Conc. (ppb)*
June 1983 to July 1983	2.0 ± 1.1	48	13	27	1.0-4.6
September 1983 to October 1983	2.2 ± 1.4	68	11	16	1.0-5.4
December 1983 to January 1984	2.1 ± 0.2	59	3	5	1.9-2.3
February 1984	1.3 ± 0.4	57	6	11	1.0-1.9

* ppb = micrograms/litre.

TABLE 2 - SUMMARIZED SURVEY DATA FOR GROUNDWATER SAMPLES COLLECTED BETWEEN MAY 1984 AND NOVEMBER 1984

Sampling Period	Aldicarb Conc. (ppb)* Mean ± Standard Deviation	Number of Wells Sampled	Number of Wells with Detectable Aldicarb Conc.	Percent of Wells with Detectable Aldicarb Conc.	Range of Aldicarb Conc. (ppb)*
May 1984	1.7 ± 0.9	58	13	22	1.0-4.2
June 1984 to July 1984	1.6 ± 1.0	58	9	16	1.0-4.2
August 1984	2.0 ± 1.0	57	9	16	1.0-3.6
November 1984	1.2 ± 0.1	55	3	5	1.1-1.3

* ppb = micrograms/litre.

Based on the fact that residues were detected in some of the samples from the preplanting survey in May 1984, low concentrations of aldicarb persist in some groundwaters for at least eleven months. The high percentage of wells with detectable levels in May may be the result of spring recharge leaching residues from the soil and into groundwater. Although there was no preplanting survey to establish background levels in 1983, residues from previous years most likely contributed to the detection frequency and overall concentration of aldicarb reported in the 1983 postplanting survey.

Results from two wells (B3 and B4 in Appendices A and B) indicate that aldicarb may enter some aquifers as early as one month after initial application while values for two other wells (A2 and A7 in Appendices A and B) suggest persistence may be as long as three years after the last application.

4.2 Aldicarb Use Patterns

The historical application pattern for aldicarb at each site is documented in Appendix B. Tables 3, 4, 5 and 6 contain summary overview information abstracted from this data and the results reported in Tables 1 and 2.

The occurrence of aldicarb in groundwater appears to be related to the number of years of aldicarb use. Review of the summaries indicates that the frequency of detection and average concentrations are substantially higher after two or more years application of aldicarb than after only one year.

The approximate distance from each well to the nearest field is documented in Appendix B. Most residues were detected in groundwater close to the treated field. Of the 20 wells in which aldicarb was detected, 17 were within 60 m of a treated field and 10 of these were within 30 m. The remaining three wells were 120 m, 600 m and 800 m from the boundary of the field. These three exceptions are significant in that they indicate aldicarb migration can be substantial under certain conditions.

TABLE 3 - SUMMARIZED SURVEY DATA FROM AREAS WHERE ALDICARB WAS APPLIED IN 1983 AND PREVIOUS YEAR(S)*

Sampling Period	Aldicarb Conc. (ppb)** Mean ± Standard Deviation	Number of Wells Sampled	Number of Wells with Detectable Aldicarb Conc.	Percent of Wells with Detectable Aldicarb Conc.	Range of Aldicarb Conc. (ppb)**
June 1983 to July 1983	2.1 ± 1.2	14	9	64	1.0-4.6
September 1983 to October 1983	2.6 ± 1.4	21	8	38	1.2-5.4
December 1983 to January 1984	2.3 ± 0.1	17	2	12	2.2-2.3
February 1984	1.2 ± 0.4	16	5	31	1.0-1.9

* Not necessarily consecutive years.

** ppb = micrograms/litre.

TABLE 4 - SUMMARIZED SURVEY DATA FROM AREAS WHERE ALDICARB WAS APPLIED IN 1984 AND PREVIOUS YEAR(S)*

Sampling Period	Aldicarb Conc. (ppb)** Mean ± Standard Deviation	Number of Wells Sampled	Number of Wells with Detectable Aldicarb Conc.	Percent of Wells with Detectable Aldicarb Conc.	Range of Aldicarb Conc. (ppb)**
May 1984	2.1 ± 1.2	31	6	20	1.1-4.2
June 1984 to July 1984	2.1 ± 1.4	31	4	13	1.3-4.2
August 1984	2.6 ± 1.0	30	5	17	1.4-3.6
November 1984	1.3	30	1	3	1.3

* Not necessarily consecutive years.

** ppb = micrograms/litre.

TABLE 5 - SUMMARIZED SURVEY DATA FROM AREAS WHERE ALDICARB WAS APPLIED IN 1983 ONLY

Sampling Period	Aldicarb Conc. (ppb)* Mean + Standard Deviation	Number of Wells Sampled	Number of Wells with Detectable Aldicarb Conc.	Percent of Wells with Detectable Aldicarb Conc.	Range of Aldicarb Conc. (ppb)*
June 1983 to July 1983	1.2 ± 0.2	13	2	15	1.0-1.3
September 1983 to October 1983	1.4	21	1	5	1.4
December 1983 to January 1984	-	21	0	0	-
February 1984	-	19	0	0	-

* ppb = micrograms/litre.

TABLE 6 - SUMMARIZED SURVEY DATA FROM AREAS WHERE ALDICARB WAS APPLIED IN 1984 ONLY

Sampling Period	Aldicarb Conc. (ppb)* Mean + Standard Deviation	Number of Wells Sampled	Number of Wells with Detectable Aldicarb Conc.	Percent of Wells with Detectable Aldicarb Conc.	Range of Aldicarb Conc. (ppb)*
May 1984	1.0	15	1	7	1.0
June 1984 to July 1984	-	15	0	0	-
August 1984	1.0	15	1	7	1.0
November 1984	-	16	0	0	-

* ppb = micrograms/litre.

This may be due to local soil or groundwater conditions, heavier application rates or several consecutive years of aldicarb use.

4.3 Nitrates

Nutrient movement through soil has been cited as an indicator of the potential for similar migration of pesticides into groundwaters (Cohen et al., 1984). Water samples were collected at each site and nitrate concentrations determined. No correlation, however, could be developed between these values and aldicarb levels.

4.4 Well Data

Information on relevant well construction factors is summarized in Table 7. Well depth, casing length and water level were, on the average, less for wells having detectable aldicarb residues compared to those where the pesticide was not detected.

In a similar study in Wisconsin, aldicarb was more frequently detected in shallow wells where the well screen was placed less than 3 m below the ground surface. Very little aldicarb was detected in the middle depth wells where the well screen was placed at approximately 11 m and no aldicarb was detected in deep wells where the well screen was placed about 24 m below ground surface (Rothschild et al., 1982). As in the P.E.I. study, aldicarb residues were detected in the shallower region of the aquifer.

4.5 Soil and Groundwater pH

Soil samples were collected for pH analysis from all potato fields included in the second phase of the study. Soil pH values ranged from 5.0 to 6.6, with an overall average of 5.8. In fields near wells where aldicarb was detected, the average soil pH was 6.0; while in instances where aldicarb was not detected, the average pH was 5.7.

TABLE 7 - SUMMARIZED DATA ON WELL CONSTRUCTION

	Well Depth (m)	Casing Length (m)	Water Level (m below ground surface)
All Wells	21.1 ± 10.2	9.0 ± 3.7	8.9 ± 4.9
Aldicarb Detected	18.7 ± 8.4	7.5 ± 2.8	6.8 ± 3.1
Aldicarb Not Detected	21.7 ± 10.5	9.3 ± 3.8	9.5 ± 5.1

Well Depth: Distance from ground level to the bottom of the drilled hole.

Casing Length: The length of metal pipe used to seal the borehole of a well.

Water Level: The depth to standing water in a well.

Groundwater pH analysis was conducted in the first phase of the study. Levels ranged from 6.1 to 8.5, with an overall average of 7.4. Wells with detectable levels of aldicarb had an average pH of 7.3, while those with no detectable levels had an average pH of 7.5.

No significant correlation was noted between aldicarb occurrence and either soil or groundwater pH.

At a pH of 7.5 or lower and a temperature of 15°C or lower (typical values from P.E.I. groundwater), aldicarb is stable to hydrolysis (Cohen et al., 1984). Under the same conditions, aldicarb sulfoxide has a half-life of 1-2.2 years and aldicarb sulfone has a half-life of 0.3-2.5 years (Cohen et al., 1984). This suggests that successive years' inputs will be, to some extent, additive.

4.6 Surficial Geology

The three major classes of surficial deposits present in the survey areas are sand phase till, clay sand phase till and clay and clay silt phase till (Prest, 1973). Over half the areas in which aldicarb was detected were sand phase till while the remaining areas were either clay sand phase till or a combination of sand/clay sand till. No significant correlation was noted between surficial geology and aldicarb occurrence.

4.7 Precipitation

Precipitation was generally below normal for the first three months of 1983. Twice the normal precipitation fell in May followed by a drop to below normal in June. Precipitation levels reported at the Summerside meteorological station for the month of August were almost double that of the Charlottetown station. Both reported lower than normal precipitation through October increasing slightly to above normal towards year's end.

Precipitation remained close to normal during the first two months of 1984. This was followed by above normal precipitation levels from May to September; one exception to this trend was reported at the Charlottetown station in July where levels fell below normal. The final months of 1984 were quite dry. Figure 4 is a graphic representation of precipitation data.

Figure 5 contains mean monthly water level hydrographs for 1983 from the Federal-Provincial groundwater observation wells at Kensington and Mount Pleasant. At Kensington, a recharge began in March lasting until April. This was followed by a decline in water level until early August when a summer recharge began, lasting until late August. The water level then declined until November when a last fall recharge began, lasting to year's end. The Mount Pleasant hydrograph shows recharge beginning in March and continuing to May. This was followed by a decline in water level until the end of October. Another recharge began in November and continued to year's end.

Overall the Mount Pleasant hydrograph exhibits a normal, or near normal, response for the year. The Kensington hydrograph shows water table elevations above normal in June, August and September.

Precipitation appears to affect the occurrence of aldicarb in groundwater. During periods of heavy precipitation, not only are residues more mobile as a consequence of downward flushing through the soil but the water table is slightly more elevated than normal, decreasing the distance the aldicarb must travel to groundwater. In the spring prior to planting, heavy rainfall leaches residues from the soil and into groundwater. After planting, the rate of detection remains relatively constant as long as precipitation is able to penetrate into the ground. This rate generally decreases, however, during the months when the ground is frozen and no recharge is reaching the water table.

FIGURE 4 PRECIPITATION DATA FOR SUMMERSIDE AND CHARLOTTETOWN P. E. I.

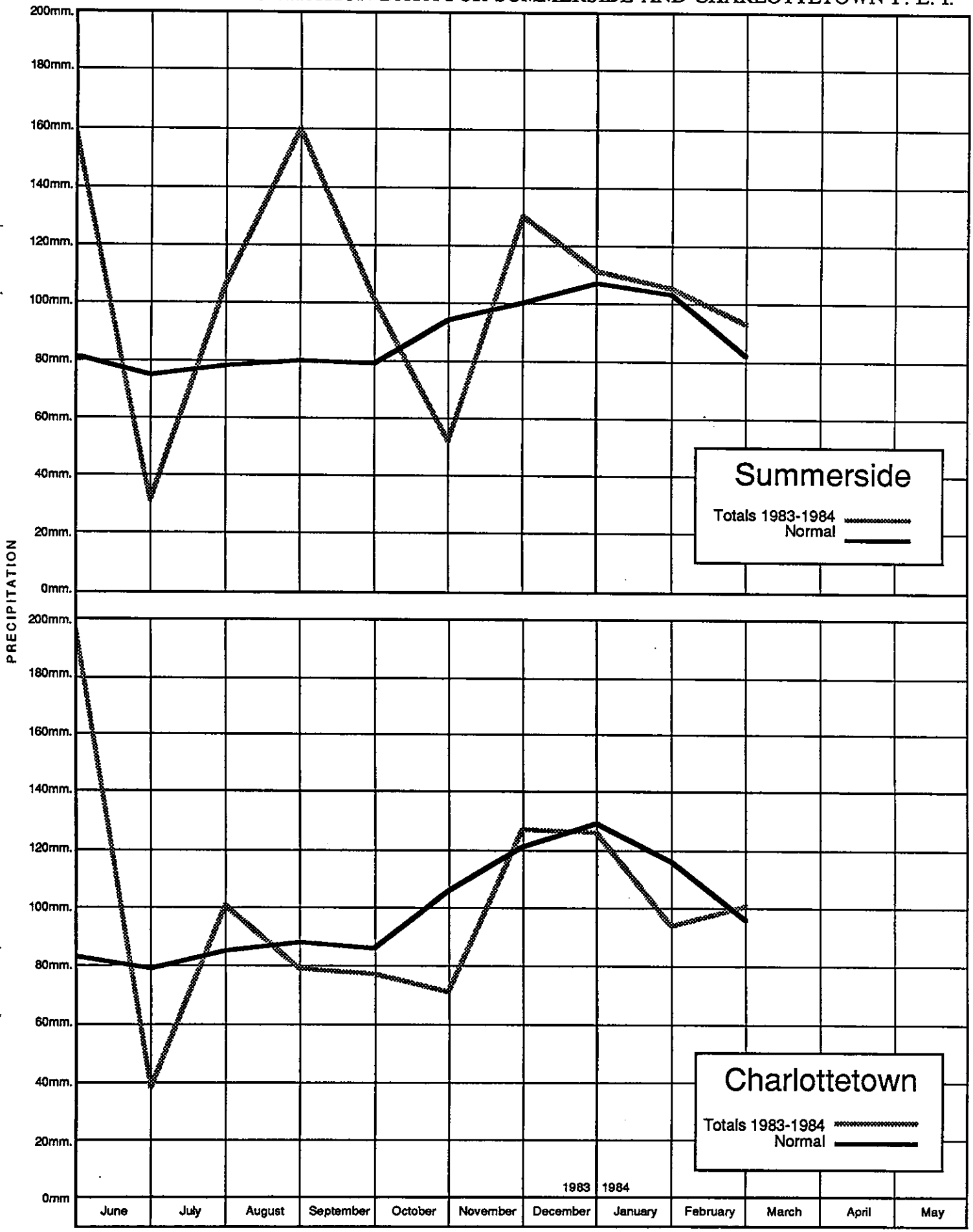
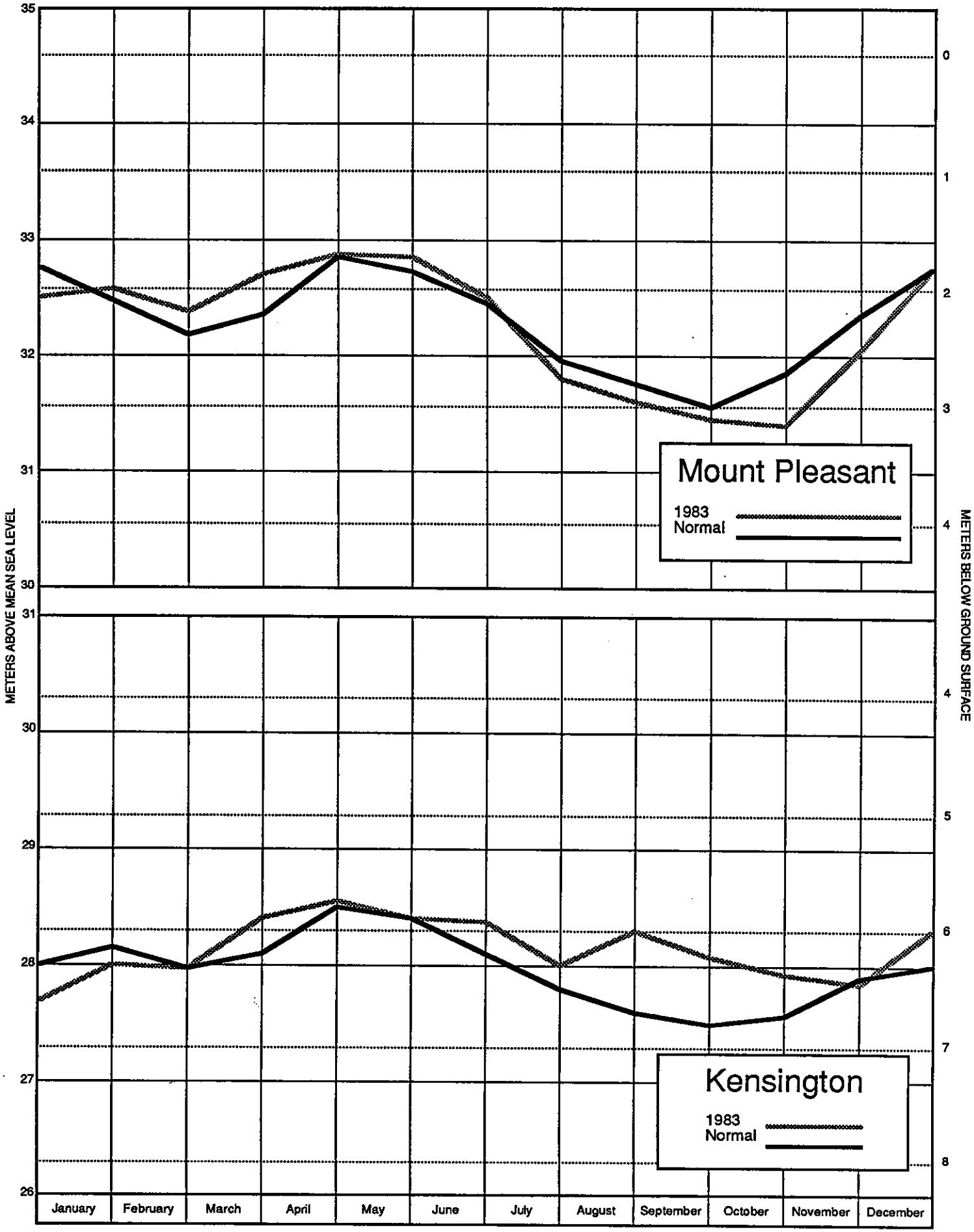


FIGURE 5 GROUNDWATER DATA FOR MOUNT PLEASANT AND KENSINGTON



5. SUMMARY AND RECOMMENDATIONS

Aldicarb has been detected in P.E.I. groundwater, however, there appears to be no significant buildup of residues.

Average aldicarb concentrations measured during the study ranged from 1.3 to 2.2 ppb. All detectable residues were below the Interim Maximum Acceptable Level of 9 ppb established by Health and Welfare Canada.

There was a direct correlation between the rate of detection and the distance of the sampling well from a treated field.

Residues were detected as early as one month after the first application and as late as three years after the last application.

The chance of detecting aldicarb in groundwater is greater if the pesticide has been applied for several years.

Aldicarb residues tend to concentrate in the upper region of the aquifer.

It would appear that further detailed surveys to assess the extent of aldicarb entry to P.E.I. groundwater are not necessary at this time. While residues were detected at some survey sites, current information indicates that no significant environmental hazard exists. A resurvey program should be initiated in two to three years to determine whether the situation has substantially changed.

6. REFERENCES

Brewer, P.G. and J.P. Riley. 1965. "Automatic determination of nitrate in sea water." Deep Sea Research, 12: 765-772.

Canadian Association of Pesticide Control Officials. 1984. Report of the Twenty-First Meeting, Nov. 6-8, 1984, Quebec City, Quebec, pp. 7-8.

Cohen, S.Z., S.M. Creeger, R.F. Carzel, and C.G. Enfield. 1984. Potential pesticide contamination of groundwater from agricultural uses. Treatment and Disposal of Pesticide Wastes: based on a symposium sponsored by the Division of Pesticide Chemistry of the 186th meeting of the American Chemical Society, Washington, D.C., August 28 - September 2, 1983. ACS Symposium Series; 259, Washington, D.C.: The Society 1984. pp. 297-325.

Environmental Protection Service, Prince Edward Island Department of Community and Cultural Affairs, Prince Edward Island Department of Health and Social Services and Prince Edward Island Department of Agriculture. 1984. An inventory of agricultural pesticide usage in Prince Edward Island in 1982. Environmental Protection Surveillance Rpt. EPS-5-AR-84-10. pp. 9.

Guerrora, A.A. 1981. "Chemical contamination of aquifers on Long Island, New York." J. Am. Water Works Assoc., 73: 190-199.

Harkin, J.M., G. Chesters, F.A. Jones, R.N. Fathulla and E.K. Dzantor. 1986. Fate of aldicarb in Wisconsin groundwater. Wisconsin Water Resources Center Rpt. WIS-WRC-86-01 (U.S. Geological Survey Rpt. USGS/G-942-02). 55 pp.

Health and Welfare Canada. 1986. Interim guideline values for aldicarb in drinking water. In a memorandum from Dr. P. Toft of Health and Welfare Canada to the Prince Edward Island Department of Community and Cultural Affairs, Oct. 9, 1986.

Prest, V.K. 1973. Surficial deposits of Prince Edward Island. Geologic Survey of Canada, Energy Mines and Resources Canada. Map 1366 A.

Prince Edward Island Department of Agriculture. 1984. Pers. comm.

Rothschild, E.R., R.J. Manser, and M.P. Anderson. 1982. "Investigation of aldicarb in groundwater in selected areas of the central sand plain of Wisconsin." Ground. Wat. 20 (4): 437-445.

Union Carbide Agricultural Products Company Inc. 1983. Temik aldicarb pesticide - a scientific assessment. Research Triangle Park, North Carolina, U.S.A. pp. 59.

Van de Poll, W. 1975. Geology of Prince Edward Island. The Prince Edward Island Environeer. 3 (3): 12-14.

Wyman, J.A., J.O. Jensen, D. Curren, R.L. Jones and T.E. Marquart. 1985. Effects of application procedures and irrigation on degradation and movement of aldicarb residues in soil. Environ. Toxicol. Chem. 4 (5): 641-651.

Zaki, M.H., D. Moran, and D. Harris. 1982. "Pesticides in groundwater: The aldicarb story in Suffolk County, New York." Am. J. Pub. Health, 72 (12): 1391-1395.

APPENDIX A

ANALYTICAL DATA

APPENDIX A

WELL CODE	ALDICARB (ppb)							
	JUNE '83-JULY '83	SEPT '83-OCT '83	DEC '83-JAN '84	FEB '84	MAY '84	JUNE '84-JULY '84	AUG '84	NOV '84
A1	2.2	2.8	L 1.0	1.0	1.8	1.7	L 1.0	L 1.0
A2	2.8	1.1	L 1.0	L 1.0	1.1	L 1.0	L 1.0	L 1.0
A3	1.0	1.4	L 1.0	-	L 1.0	L 1.0	L 1.0	1.1
A4	1.3	1.6	-	-	L 1.0	1.0	L 1.0	L 1.0
A5	L 1.0	L 1.0	-	-				
A6	L 1.0	L 1.0	-	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0
A7		1.0	L 1.0	L 1.0	L 1.0	L 1.0	1.6	L 1.0
A8		L 1.0	L 1.0	L 1.0				
A9			L 1.0	L 1.0				
A10					L 1.0	L 1.0	L 1.0	L 1.0
A11					L 1.0	L 1.0	L 1.0	L 1.0
A12					L 1.0	L 1.0	L 1.0	L 1.0
A13					L 1.0	L 1.0	L 1.0	L 1.0
A14					L 1.0	L 1.0	L 1.0	L 1.0
B1	L 1.0	L 1.0	L 1.0	L 1.0				
B2	L 1.0	L 1.0	L 1.0	L 1.0	1.1	L 1.0	L 1.0	L 1.0
B3	1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0
B4	1.3	1.4	L 1.0	L 1.0	2.0	1.5	1.4	L 1.0
B5	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	-	-	L 1.0
B6	L 1.0	L 1.0	L 1.0	-	L 1.0	L 1.0	L 1.0	L 1.0
B7	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0

Cont'd

APPENDIX A (Cont'd)

WELL CODE	ALDICARB (ppb)							
	JUNE '83-JULY '83	SEPT '83-OCT '83	DEC '83-JAN '84	FEB '84	MAY '84	JUNE '84-JULY '84	AUG '84	NOV '84
B8		L 1.0	L 1.0	L 1.0	1.2	L 1.0	1.6	L 1.0
B9		L 1.0	L 1.0	L 1.0				
B10		L 1.0	L 1.0	L 1.0				
B11					L 1.0	L 1.0	L 1.0	L 1.0
B12					L 1.0	L 1.0	L 1.0	L 1.0
B13					L 1.0	L 1.0	L 1.0	-
B14					L 1.0	L 1.0	L 1.0	L 1.0
B15					L 1.0	L 1.0	L 1.0	-
B16					L 1.0	L 1.0	L 1.0	L 1.0
B17					L 1.0	-	-	L 1.0
B18					L 1.0	L 1.0	L 1.0	L 1.0
B19						L 1.0	L 1.0	L 1.0
C1	-	L 1.0	L 1.0	L 1.0				
C2	L 1.0	L 1.0	L 1.0	-				
D1	L 1.0	L 1.0	L 1.0	L 1.0				
D2	L 1.0	L 1.0	L 1.0	L 1.0				
E1	L 1.0	L 1.0	L 1.0	L 1.0				
E2	1.3	L 1.0	L 1.0	1.0	1.5	1.0	1.3	L 1.0
E3	L 1.0	L 1.0	L 1.0	-				
E4	L 1.0	L 1.0	L 1.0	L 1.0				
E5	L 1.0	L 1.0	L 1.0	L 1.0				

Cont'd

APPENDIX A (Cont'd)

WELL CODE	ALDICARB (ppb)							
	JUNE '83-JULY '83	SEPT '83-OCT '83	DEC '83-JAN '84	FEB '84	MAY '84	JUNE '84-JULY '84	AUG '84	NOV '84
E6	L 1.0	L 1.0	L 1.0	L 1.0				
E7		L 1.0	L 1.0	L 1.0				
E8		L 1.0	L 1.0	L 1.0				
E9		L 1.0	-	-				
E10					2.5	4.2	3.1	-
E11					L 1.0	L 1.0	L 1.0	L 1.0
E12					L 1.0	L 1.0	L 1.0	-
E13					L 1.0	L 1.0	L 1.0	L 1.0
E14					L 1.0	L 1.0	L 1.0	L 1.0
F1	L 1.0	L 1.0	L 1.0	L 1.0				
F2	L 1.0	L 1.0	-	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0
F3	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0
F4	1.0	L 1.0	L 1.0	L 1.0	1.0	L 1.0	L 1.0	L 1.0
F5	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0			
F6	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0			
F7		L 1.0	-	-	L 1.0	L 1.0	L 1.0	L 1.0
F8					L 1.0	L 1.0	L 1.0	L 1.0
F9					L 1.0	L 1.0	L 1.0	L 1.0
F10					L 1.0	L 1.0	L 1.0	L 1.0
F11					L 1.0	L 1.0	L 1.0	L 1.0
F12					L 1.0	L 1.0	L 1.0	L 1.0

Cont'd

APPENDIX A (Cont'd)

WELL CODE	ALDICARB (ppb)							
	JUNE '83-JULY '83	SEPT '83-OCT '83	DEC '83-JAN '84	FEB '84	MAY '84	JUNE '84-JULY '84	AUG '84	NOV '84
G 1	L 1.0	L 1.0	L 1.0	L 1.0				
G 2	L 1.0	L 1.0	L 1.0	L 1.0				
H1	3.4	3.6	2.2	1.9	4.2	1.3	3.2	1.3
H2	2.5	2.9	2.3	1.3	1.7	L 1.0	1.5	1.1
H3	4.6	5.4	-	-	-	1.5	3.6	-
H4	L 1.0	L 1.0	L 1.0	L 1.0				
H5	1.8	L 1.0	L 1.0	L 1.0	L 1.0	1.0	L 1.0	L 1.0
H6		L 1.0	-	L 1.0				
H7		L 1.0	L 1.0	L 1.0				
H8		L 1.0	L 1.0	L 1.0				
H9		1.5	L 1.0	L 1.0	1.6	L 1.0	L 1.0	L 1.0
H10					L 1.0	L 1.0	L 1.0	L 1.0
I1	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0
I2	L 1.0	-	-	-				
I3	L 1.0	L 1.0	L 1.0	L 1.0				
I4	1.3	L 1.0	1.9	1.8	1.7	1.6	L 1.0	L 1.0
I5		L 1.0	L 1.0	L 1.0				
I6					L 1.0	L 1.0	L 1.0	L 1.0
J1	L 1.0	L 1.0	L 1.0	L 1.0				
J2	L 1.0	L 1.0	L 1.0	L 1.0				
J3	-	L 1.0	L 1.0	L 1.0				

Cont'd

APPENDIX A (Cont'd)

WELL CODE	ALDICARB (ppb)							
	JUNE '83-JULY '83	SEPT '83-OCT '83	DEC '83-JAN '84	FEB '84	MAY '84	JUNE '84-JULY '84	AUG '84	NOV '84
K1	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0
K2	L 1.0	-	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0	L 1.0
K3	-	L 1.0	-	-				
K4					L 1.0	L 1.0	L 1.0	L 1.0
K5					1.0	L 1.0	1.0	L 1.0
L1	L 1.0	L 1.0	L 1.0	L 1.0				
L2	L 1.0	L 1.0	L 1.0	L 1.0				
L3	L 1.0	L 1.0	L 1.0	L 1.0				
L4	L 1.0	L 1.0	-	L 1.0				
M1	L 1.0	L 1.0	L 1.0	-				
N1		1.2	L 1.0	1.0	L 1.0	L 1.0	L 1.0	L 1.0
N2		L 1.0	L 1.0	-				
N3					L 1.0	L 1.0	L 1.0	L 1.0
N4					L 1.0	L 1.0	-	L 1.0
N5					L 1.0	L 1.0	L 1.0	L 1.0
01		L 1.0	L 1.0	L 1.0				
02		L 1.0	-	-				
03		L 1.0	L 1.0	L 1.0				
P1					L 1.0	L 1.0	L 1.0	L 1.0

APPENDIX B

WELL DATA AND ALDICARB USE HISTORY

APPENDIX B

WELL CODE	WELL DEPTH (m)	CASING LENGTH (m)	WATER LEVEL (m)	APPROXIMATE WELL DISTANCE FROM FIELD (m)	YEARS ALDICARB APPLIED
A1	8.2	Min	4.1	60	1983, 1981
A2	25.9	10.7	10.7	30	1981, 1979
A3	6±	Min	4.8	600	1983, 1981
A4	16.8	8.5	3.0	800	1983, 1981
A5	N/A	N/A	N/A	30	1981, 1979
A6	18.3	N/A	9.8	20	1981, 1978
A7	31±	N/A	N/A	20	1981, 1979
A8	9.1	N/A	N/A	30	1983
A9	N/A	N/A	N/A	30	1983
A10	6.8	N/A	4.7	20	1984
A11	8.5	6.1	8.3	60	1984,
A12	8.5	N/A	7.3	30	1984, 1982
A13	25.9	14±	6.7	30	1984
A14	25±	9±	6±	30	1984, 1982
B1	9±	N/A	N/A	30	1983
B2	11±	N/A	N/A	30	1984, 1983
B3	18.3	6.1	N/A	30	1984, 1983
B4	8.8	Min	7.2	25	1984, 1983
B5	Handpump	Min		30	1984, 1983, 1980, 1979
B6	19.8	8.5	8.5	30	1984, 1983, 1980, 1979
B7	4.6	2±	4.0	600	1984, 1983, 1980, 1979

Cont'd

APPENDIX B

WELL CODE	WELL DEPTH (m)	CASING LENGTH (m)	WATER LEVEL (m)	APPROXIMATE WELL DISTANCE FROM FIELD (m)	YEARS ALDICARB APPLIED
B8	18±	6±	N/A	60	1984, 1983
B9	16.8	9.1	4.6	90	1983
B10	17±	N/A	8.2	30	1983, 1980, 1979
B11	25.9	9.1	13.7	50	1984, 1979, 1978
B12	18.3	N/A	N/A	50	1984, 1979, 1978
B13	Handpump	Min		120	1984, 1983
B14	27.4	N/A	N/A	30	1984
B15	27±	18.3	17.7	50	1984, 1983
B16	15.2	6.4	2.4	30	1984
B17	18.3	7.6	4.6	20	1984
B18	24±	N/A	5±	400	1984, 1983, 1980, 1979
B19	Handpump	Min		5	1984
C1	25.9	6.1	N/A	30	1982
C2	11±	Min	N/A	60	1982
D1	31.7	7.0	6.4	30	1983
D2	45.7	N/A	N/A	30	1983
E1	27.4	8.2	11.6	45	1980
E2	24.4	None	12.2	20	1983, 1980
E3	36.0	5.8	22.9	30	1983
E4	22.9	8.8	9.8	30	1983
E5	N/A	N/A	5±	30	1980

Cont'd

APPENDIX B

WELL CODE	WELL DEPTH (m)	CASING LENGTH (m)	WATER LEVEL (m)	APPROXIMATE WELL DISTANCE FROM FIELD (m)	YEARS ALDICARB APPLIED
E6	25.9	Min	11.4	30	1983
E7	36.6	17.4	16.2	30	1983
E8	30.5	N/A	10.7	60	1983
E9	27.4	13±	N/A	800	1983, 1980
E10	11.6	N/A	8.5	50	1984, 1983
E11	11.3	6±	6±	90	1984, 1981
E12	Handpump	Min		120	1984, 1981
E13	18.3	9.4	3.4	120	1984
E14	9.1	N/A	N/A	40	1984
F1	26±	6.1	N/A	90	1983, 1981
F2	29.6	9.1	13.7	30	1984, 1982, 1981
F3	24.1	12.8	11.0	30	1984, 1982, 1981
F4	N/A	N/A	N/A	120	1983, 1982, 1980
F5	18.3	10.4	5.8	90	1983, 1982
F6	27.0	12.8	7.6	90	1983, 1982
F7	28±	13.1	10±	60	1984, 1981
F8	27.4	18.3	N/A	50	1984, 1981, 1978
F9	33.5	4.6	19.8	60	1984
F10	38.1	12.2	15.2	50	1984
F11	37.5	9.1	13.7	120	1984
F12	45.7	15.8	22.9	90	1984

Cont'd

APPENDIX B

WELL CODE	WELL DEPTH (m)	CASING LENGTH (m)	WATER LEVEL (m)	APPROXIMATE WELL DISTANCE FROM FIELD (m)	YEARS ALDICARB APPLIED
G1	25.9	12.2	16.8	60	1983
G2	19.8	11±	13.7	90	1983
H1	36.3	9.4	5.2	20	1984, 1983, 1982
H2	18.3	Min	8.3	30	1983, 1982
H3	12±	5±	4.1	20	1984, 1983, 1982
H4	9±	N/A	N/A	400	1983, 1980
H5	24.4	12.2	11±	30	1983, 1980
H6	N/A	N/A	N/A	60	1983, 1982
H7	19.8	9.1	7.6	150	1983, 1980
H8	15.2	N/A	7.1	30	1981
H9	27±	6±	N/A	60	1984, 1983, 1982
H10	9.1	5.5	7.6	100	1984, 1982
I1	12±	N/A	N/A	40	1984, 1982
I2	18.3	9.1	3.0	60	1982
I3	9±	N/A	6.3	30	1982
I4	15±	N/A	4.8	45	1982, 1981
I5	23.2	N/A	N/A	30	1982
I6	Handpump	Min		400	1984, 1980
J1	29.6	10.7	N/A	60	1981
J2	26.5	8.5	10.7	60	1981
J3	N/A	Min	N/A	30	1981

Cont'd

APPENDIX B

WELL CODE	WELL DEPTH (m)	CASING LENGTH (m)	WATER LEVEL (m)	APPROXIMATE WELL DISTANCE FROM FIELD (m)	YEARS ALDICARB APPLIED
K1	7.6	Min	5.2	45	1984, 1981
K2	Handpump	Min		60	1984, 1983
K3	9±	1±	2±	30	1983
K4	9.8	8.1	7.7	60	1984
K5	Handpump	Min		60	1984
L1	24.4	7.9	10.7	60	1981
L2	28.3	Min	Handpump	30	1981
L3	12.2	10.4	4.6	30	1981
L4	29.3	6.1	6.1	30	1981
M1	34.3	12.2	15.2	200	1983
N1	22.9	4.0	4.6	60	1983, 1980, 1978
N2	N/A	N/A	N/A	30	1983, 1981
N3	24±	4.3	11.3	20	1984, 1981
N4	26±	9±	18±	20	1984, 1981
N5	24.4	5.5	7.3	20	1984, 1981
01	56±	N/A	N/A	60	1983
02	12.2	N/A	N/A	30	1983
03	9±	N/A	6.0	30	1983
P1	8±	Min	Handpump	100	1984

N/A - Not available.

Min - Minimum (probably less than 3 metres).

5.5	7.3	[illegible]	1984, 1981