NOVA SCOTIA

FARM WELL WATER

QUALITY ASSURANCE STUDY

Final Report

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EXECUTIVE SUMMARY

As part of the ongoing environmental monitoring and research efforts of the Nova Scotia Government, the Departments of the Environment, Agriculture and Marketing, and Health have conducted a study of rural well water supplies in Kings County. Initiated in 1989, the four-year project was designed to assess the quality of drinking water supplies in one of the most intensively farmed areas of the province.

As one component of the study, 237 randomly selected wells were sampled in the summer of 1989 to obtain an overview of water quality in the study area. Of these, 102 wells were tested for a range of pest control products, inorganic parameters, and bacteria, and 135 wells were tested for inorganic parameters only. Sampling was weighted towards those areas determined to be most sensitive according to a groundwater pollution potential rating of sub-regions within the study area using a modified DRASTIC risk model.

The random survey found that none of the wells contained pesticide levels that exceeded safe drinking water limits established under the Canadian drinking water guidelines, however, very low levels of pest control products were detected in 41% of the wells. Almost all of the detections were less than 1 microgram per litre (1 part per billion) and in many cases approached the lower detection limits of the analysis. Atrazine, including its degradation products, was the most prevalent pest control product found accounting for 72% of the total number of detections and 79% of the wells in which pesticides were detected.

The results of this survey also found that nitrate-N levels and coliform bacteria exceeded the limits established under the Canadian drinking water guidelines in 13% and 9% of the wells respectively. Well type and well depth appear to play significant roles in determining which wells exceed the guidelines. Comparison to historic values indicates that nitrate-N levels have not changed in the Canning area since 1974.

The second component of the study focused on identifying the sources of contamination for wells in which pesticides and/or elevated nitrate-N and coliform bacteria were found. This was done through 17 detailed case studies. Point sources accounted for only 9% of the cases of contamination by pesticides but accounted for 83% of the cases of contamination by coliform bacteria. Cases of nitrate-N contamination were more evenly split between point, non-point and unknown sources of contamination. The principle factor causing point source contamination of the wells was poor well construction and/or maintenance. The case studies also indicated that the atrazine contamination detected may be the result of historic use rather than current agricultural practices.

ACKNOWLEDGEMENTS

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1 INTRODUCTION

As part of a coordinated effort to study the quality of well water supplies in agricultural areas of Nova Scotia, the Provincial Departments of Agriculture and Marketing, Environment, and Health, with funding support from the Canada/Nova Scotia Agri-Food Development Agreement, have conducted a random survey of 237 rural wells in the intensive agriculture area of Kings County. The study, entitled the *Nova Scotia Farm Well Water Quality Assurance Study*, examined these wells for a range of pest control products, nitrates, and bacteria as indicators of possible contamination from agricultural activities. As follow up to the survey, detailed case studies were carried out on 17 selected sites where well contamination was found.

The combined study program had three objectives:

1) To identify occurrences and estimate the degree of farm well contamination in an intensive agricultural region of Nova Scotia.

2) To identify the most likely sources of contaminants found and the possible mechanisms and pathways by which the contaminants entered the well.

3) To provide the results in useful form to agricultural policy makers, specialists and farmers to aid them in improving policies and practices that will maintain or improve the quality of groundwater in agricultural areas.

This report presents the results of the *Nova Scotia Farm Well Water Quality Assurance Study*, outlines possible future areas of study and suggests possible directions for avoiding well water contamination in the future.

This document by its nature requires the use of some technical terms. Appendix F provides a glossary defining most of the technical terms used in the report.

2 STUDY AREA

The study area for the project encompasses the watersheds of four river basins draining into the Minas Basin from the agricultural areas of Kings County, Nova Scotia (Figure 2.1). These are: the Cornwallis River; the Canard River; the Habitant River; and the Gaspereau River.

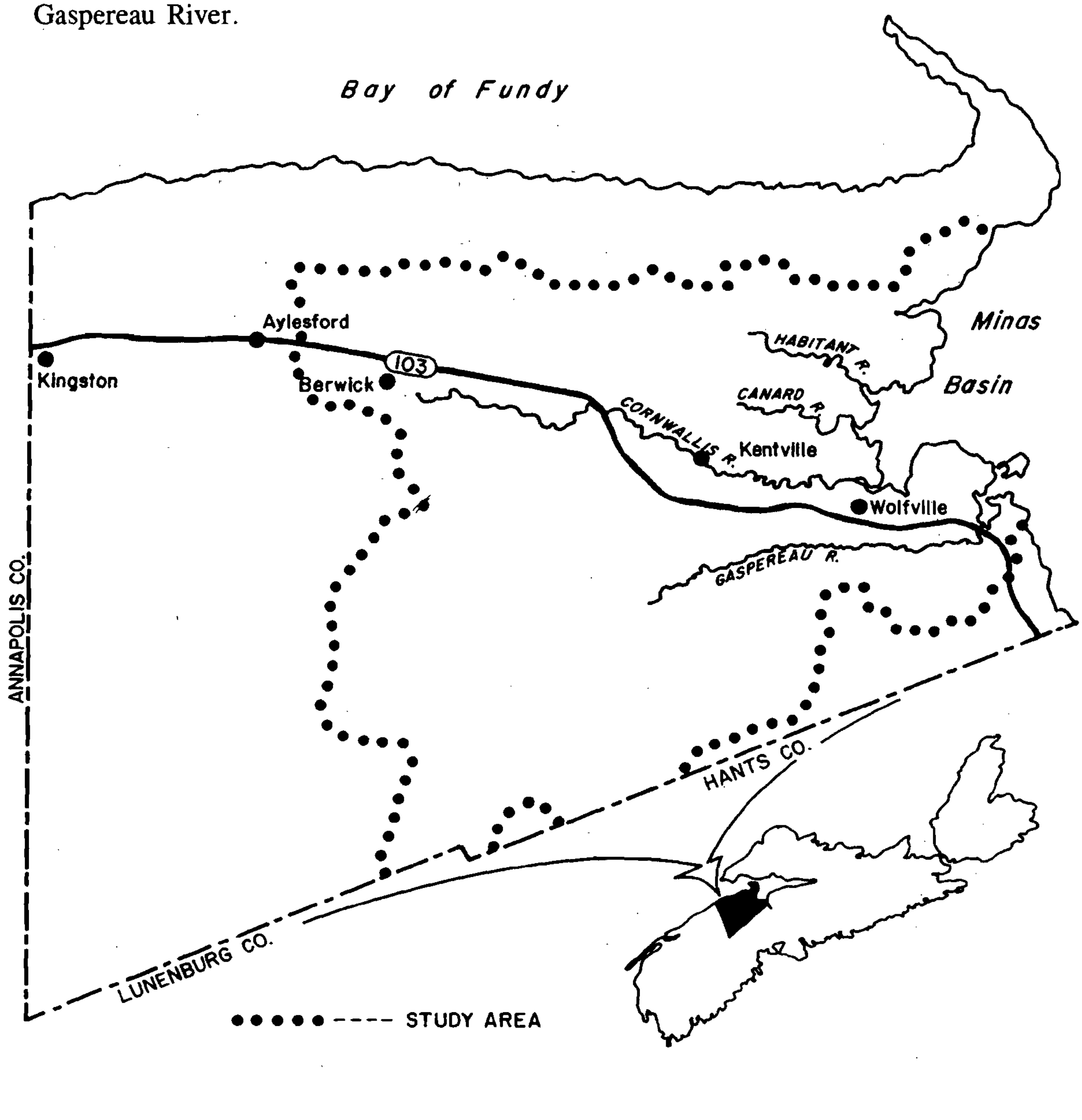


Figure 2.1 Study area - Nova Scotia Farm Well Water Quality Assurance Study.

2.1 Agricultural Land Use

Kings County has a land area of approximately 218,150 hectares (Cann et al.,1965). Of this total area, 22,633 hectares (10.4%) was classed as land in crops, 384 hectares as summer fallow, and 4,026 hectares and 5,707 hectares as improved and unimproved pasture, respectively (Statistics Canada, 1992). Figure 2.2 presents the breakdown of the cropped acreage in the study area.

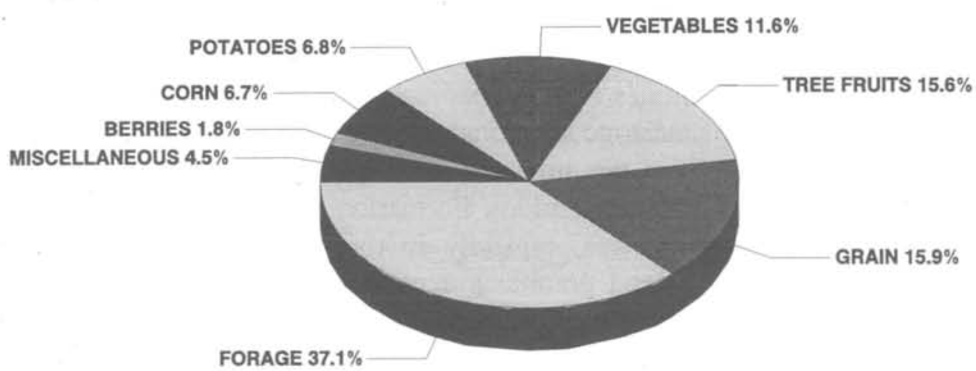


Figure 2.2 Breakdown of cropped land in the study area.

Livestock populations on farms in Kings County in 1986 were as follows (McLaughlin and Robinson, 1989);

- 20,479 cattle and calves
- 71,817 pigs
- 2,282 sheep
- 429 horses
- 196 goats
- 197 rabbits
- no published data is available on poultry numbers within Kings County

2.2 Geology and Hydrogeology

Data on the geology and hydrogeology of the study area have been derived from Nova Scotia Department of the Environment Water Well Records and various regional reports including Trescott (1968) and Hennigar et al. (1992).

2.2.1 Bedrock Units

Bedrock in the study area consists of Triassic basalt to the north, forming the North Mountain, and granite and Palaeozoic metasediments to the south, forming the South Mountain. The valley floor is underlain by sandstone, siltstone, shale and conglomerate belonging to the Wolfville and Blomidon Formations. The majority of the farmed land in the study area is underlain by these two formations. Figure 2.3 presents a simplified map showing the bedrock geology of the area.

The Wolfville Formation constitutes the best bedrock aquifer in the study area. Wells constructed in the permeable sandstone and conglomerate beds that predominate this unit may yield greater than 455 litres per minute (>100 gallons per minute). The finer grained siltstones and shales of the Blomidon Formation are less permeable and wells tend to have much lower flow rates, typically in the order of 23 l/min (5 gpm). Groundwater flow in the basalt and granite is dependant on joints and fractures (i.e. secondary permeability) and as such well yields can be quite variable. Well yields from these rock types range from less than 4.5 l/min (1 gpm) to 182 l/min (40 gpm) with an average of 18 l/min (4 gpm). The metamorphosed slates and quartzite comprising the remainder of the study area are also dependant on secondary permeability and produce well yields averaging 16 l/min (3 gpm) with a range of less than 4.5 l/min (1 gpm) to 55 l/min (12 gpm).

2.2.2 Surficial Units

The surficial geology consists primarily of glacial till on the top and flanks of the North and South Mountains, ranging from sandy to sandy clay loam in texture, and glaciofluvial deposits of sand and gravel on the valley floor (Figure 2.4). Most of the surficial material was deposited during the Pleistocene glaciation and while these deposits are generally thin or absent along bedrock highs, thicknesses greater than 61 meters (200 ft.) may be present in some bedrock depressions. Recent deposits, including stream alluvium, dykeland, salt marsh and tidal flats, are generally confined to streams and estuaries.

The glaciofluvial deposits of sand and gravel are the most productive aquifers in the study area, especially where the sand and gravel is well sorted and of significant saturated thickness. Well yields are typically between 114 - 455 l/min (25 - 100 gpm)

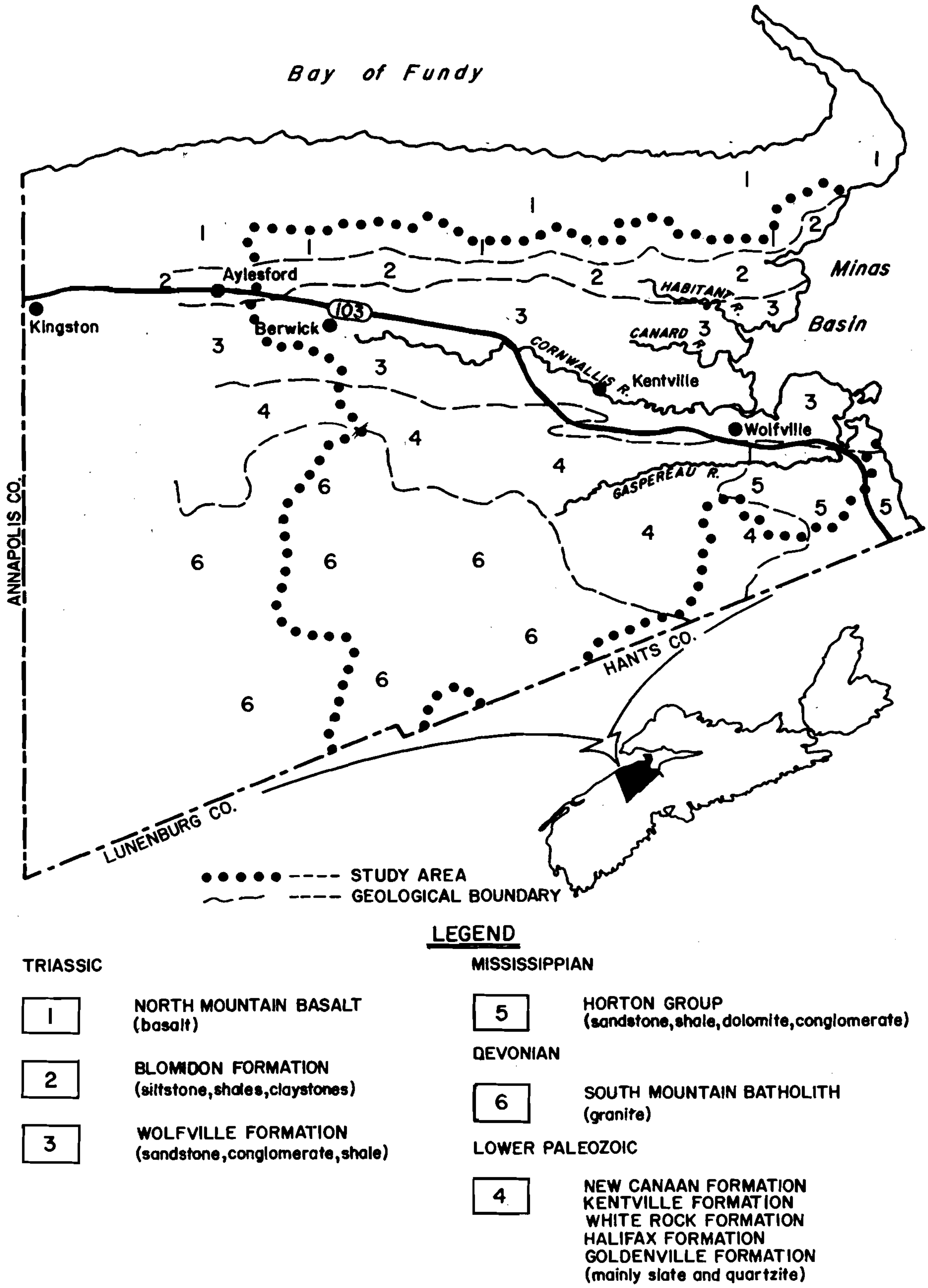


Figure 2.3 Simplified bedrock geology of the study area.

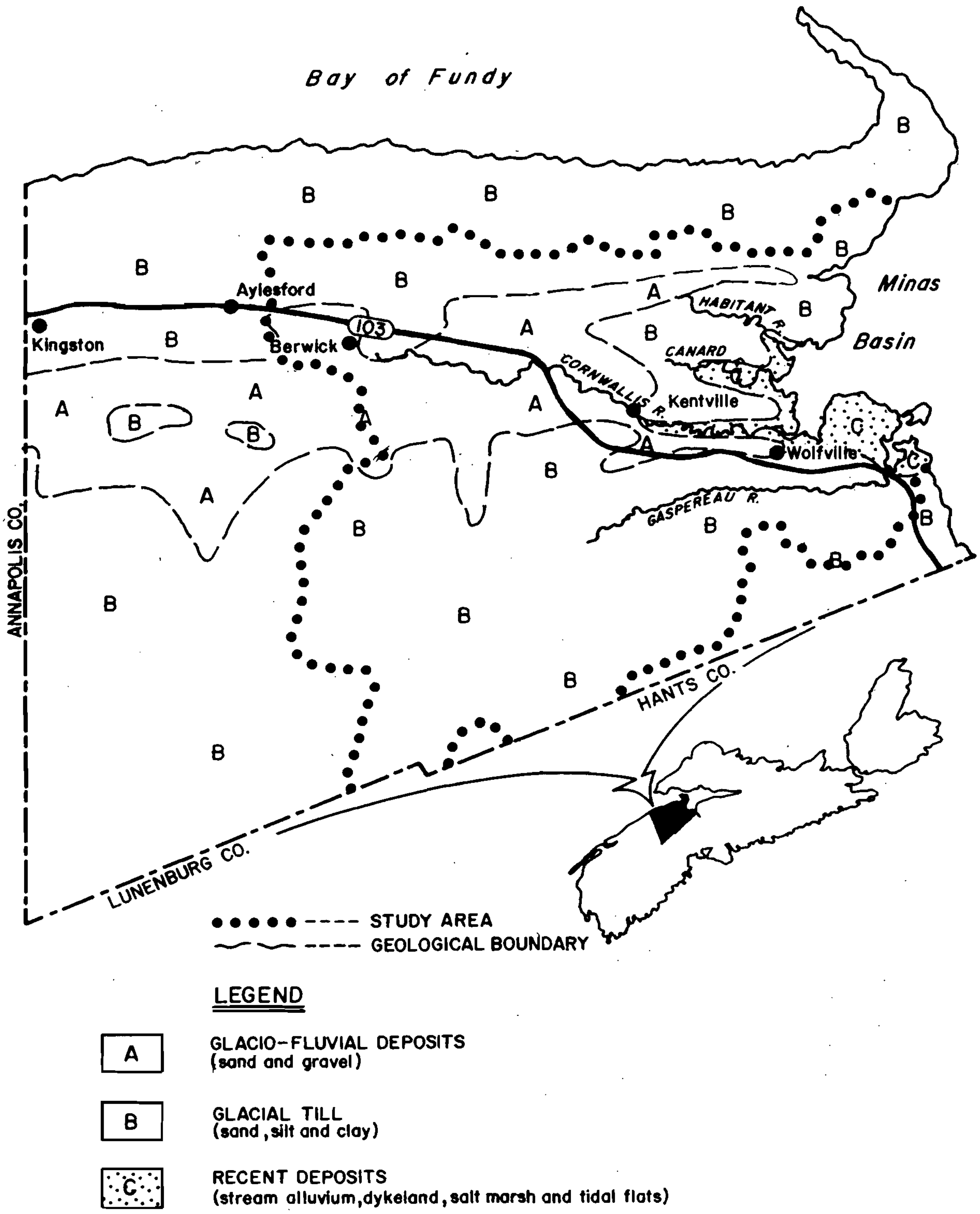


Figure 2.4 Simplified surficial geology of the study area.

with yields upward of 4500 l/min (1000 gpm) possible. Lesser yields, below 114 l/min (25 gpm), are found where the surficial deposits are poorly sorted, fine grained, thin or limited in areal extent. The glacial till deposits are more widespread but are relatively thin and, because of poor sorting and higher silt and clay content, are generally not very permeable. Wells constructed in glacial till typically have yields less than 23 l/min (5 gpm). Only small quantities of water may be obtained from the Recent deposits, with the exception of areas where streams have cut through glacial sand and gravel, and they are not considered to be a potential source of groundwater.

3 SURVEY PROCEDURES

3.1 Project Design

The four watersheds which comprise the study area were subdivided into 75 sub-basins on the basis of secondary streams. Each sub-basin was evaluated based on a modified United States Environmental Protection Agency (EPA) risk model called DRASTIC (Aller et al., 1987). DRASTIC is an acronym for a numerical ranking system to evaluate the vulnerability of aquifers to contamination based on the use of existing hydrogeological data. DRASTIC parameters used in the Nova Scotia classification scheme were:

- D - depth to water
- A - aquifer media
- S - soil media
- T - topography (slope)

Nova Scotia water well records for Kings County were used to assign a mean value for water table depth for each sub-basin. Depth to water values were then given a rating from 1 to 10 according to the DRASTIC rating system with the most shallow depths rating the highest and the greatest depths rating the lowest. Similarly, geological and soil maps for Kings County were used to assign representative aquifer media, soil types and slopes for each sub-basin and given a DRASTIC rating. The most permeable aquifer and soil types and the shallowest slopes were given the highest ratings and the least permeable aquifer and soil types and the steepest slopes were given the lowest ratings. The four ratings from each parameter were added together to obtain a cumulative rating for each sub-basin.

The DRASTIC model also includes ratings for net recharge (R), impact of the vadose zone (I) and hydraulic conductivity of the aquifer (C). These parameters have not yet been determined for the Kings County sub-basins. Figure 3.1 presents an overview of the modified DRASTIC classification for the study area. The cumulative DRASTIC ratings for each sub-basin have been divided into four groups and given a different shading as shown. The dark-shaded sub-basins scored the highest cumulative ratings and thus represent the areas most likely to be susceptible to groundwater contamination relative to one another.

Following modified DRASTIC classification of the sub-basins, 1:10,000 orthophoto base maps were used to identify the location of every farm within the study area. Each farm identified was assigned a number and a stratification weighting based on the DRASTIC classifications with a higher weighting given to those farms in the areas with the highest DRASTIC ratings. Using random probability list sampling (Mendenhall, 1979), a computer-assisted random selection process was utilized to select 100 target farms and

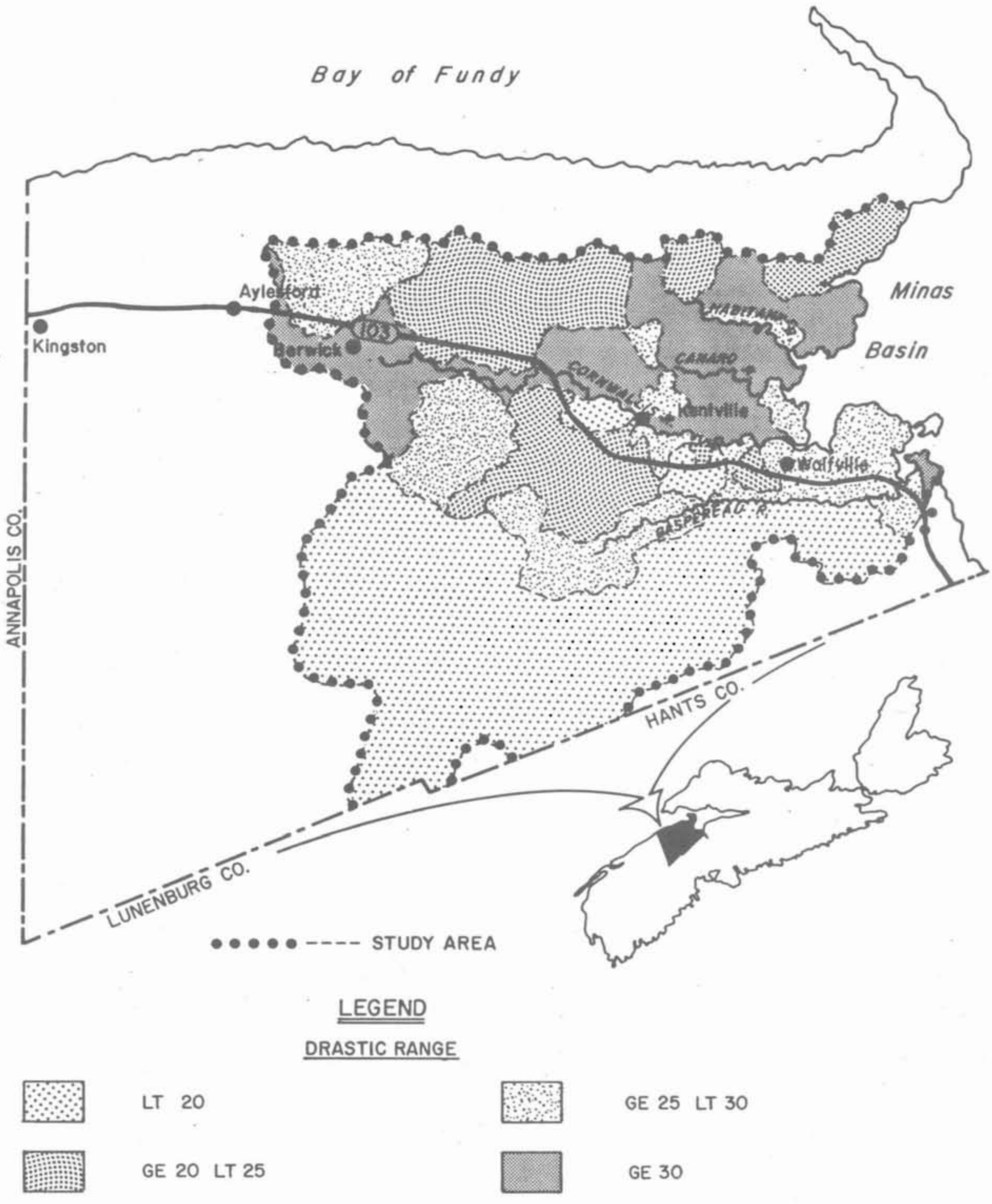


Figure 3.1 Simplified DRASTIC classification of the study area.

40 alternate farms for the sampling program. Well water samples were collected from 102 of these sites to be analyzed for a suite of pest control products, inorganic parameters and total coliform bacteria. An additional 135 random wells in the study area were hand-selected for inorganic analysis only. A listing of organic and inorganic parameters screened is presented in Table 3.1.

Table 3.1 Organic and inorganic parameters screened for.

PEST CONTROL PRODUCT*		INORGANIC PARAMETERS
CHEMICAL NAME	COMMON OR TRADE NAMES	
Atrazine	Aatrex, Primatol, Vectal, Blazine (with cyanazine), Laddok (with bentazon), Marksman (with dicamba), Ekko (with simazine), Primextra (with metolachlor)	Calcium
Des Ethyl Atrazine	atrazine degradation product	Magnesium
Dimethoate	Cygon, Lagon, Hopper Stopper, Sys-Tem	Sodium
Malthion	Malthion, Cythion	Chloride
Chlorfenvinphos	Burlane	Sulfate
Azinphosmethyl	Guthion	Iron
Chlorothalonil	Bravo	Manganese
Captan	Captan FL	Copper
Permethrin	Ambush, Pounce	Zinc
Deltamethrin	Decis	Nitrate-N
		Alkalinity
		pH
		Hardness
		Conductivity

* Additional parameters were added at specific sites (eg. methyl isothiocyanate (Vorlex) in strawberry operations and aldicarb (Temik) in potato operations).

Following the analysis of samples from the 237 randomly selected wells, case study sites were selected based on the following set of criteria:

1. Five or more pest control products detected
2. Two to five pest control products detected plus nitrate levels of 10 mg/l or higher
3. Nitrate-N levels of 20 mg/L or higher
4. Bacteria levels of 50 counts/100 ml or higher

At each selected site a series of incremental analysis were performed to identify possible sources of contamination. Not all steps were necessarily completed at each site as analysis ceased when either a source had been identified or the well was abandoned. The types of investigations conducted were:

1. Repeat sampling of the well
2. Interviews with the farmer/well owner (Appendix A)
3. Well inspections

3.2 Sampling Procedures

Beginning in June of 1989 and continuing to the end of August 1989, field crews visited ten to twenty of the selected sites per week. Selected sample sites that were unsuitable due to error in classification (i.e. not a farm) or no one was home, were replaced by the closest alternate site. A total of 102 well water samples were collected from these sites. In late August and early September 1989, an additional 135 wells in the study area were randomly selected and sampled for inorganic analysis only. All of these samples were collected in a two week period.

All samples were collected following a five to ten minute flushing period to clear the lines of stale water and allow the pump to draw fresh water from the well. Pesticide samples were collected in amber glass bottles with teflon sealed tops, prewashed with acetone and hexane rinsed. Mineral samples were collected in 100 ml polyethylene sample bottles pre-washed with distilled deionized water. Bacteria samples were collected in 100 ml polyethylene bottles treated with sodium thiosulphate ($Na_2S_2O_3$), a chlorine neutralizer. All samples were delivered to the appropriate labs on the day of survey or refrigerated if same day delivery was not possible. Quality assurance samples were submitted to the labs along with the regular pesticide and mineral samples. These blanks and duplicate samples were numbered in sequence with the "true" samples to ensure their anonymity.

Along with the collection of water samples, field crews met with the well owner for completion of a water supply questionnaire. This included basic information about the location and construction of the well and the history of any problems with the water supply. An example of the water supply questionnaire is presented in Appendix A. Also, using available soil survey data (Cann et al., 1965), the surficial material type and textural class was determined for each site.

3.3 Analytical Procedures

3.3.1 Pest Control Products

Water samples for analysis of pest control products were extracted on the day of arrival. The procedure for screening samples for atrazine, des ethyl atrazine, dimethoate, malathion, chlorfenvinphos, azinphosmethyl, chlorothalonil, captan, permethrin, and deltamethrin involved extraction of the entire sample by solvent/solvent partition with methylene chloride, drying of the extract by passing it through anhydrous sodium sulfate, and concentration of the sample extract to a small volume in ethyl acetate:hexane (1:1) by rotary vacuum evaporation. The laboratory was also given the discretion to identify other peaks found from the same extraction. These analytes are reported wherever they occur.

Analysis of the extract was performed on a gas chromatograph using the following detection systems:

- DB17 megabore capillary column with themionic specific detector (TSD)
- DB210 megabore capillary column with a TSD
- DB1701 megabore capillary column with an electron capture detector (ECD)
- DB5 megabore capillary column with a Hall electrolytic conductivity detector

Aldicarb was analyzed on a packed column containing Silar 10C with flame photometric (sulphur) detection. Dinoseb was analyzed on systems similar to those listed above after derivitization to its methyl ether with diazomethane.

Each group of ten samples was accompanied by a spike sample to check on the accuracy and effectiveness of the method. The spike was prepared by adding a known amount of a mixture of the pesticides of interest to a sample of distilled deionized water and then analyzing the spike sample along with the survey samples. A reagent blank was also done on each run to check on the possibility of contamination in the reagents or the laboratory environment.

The percent recoveries of the spike samples were used to correct the results for the survey samples for those pesticides not completely recovered by the method used.

In all analyses, concentrations of pesticides in the survey samples were determined by comparison to pesticide standards of similar concentration.

3.3.2 Inorganic Parameters

Water samples collected for inorganic analysis were submitted to the lab on the day following sampling. Concentrations of the parameters were determined as follows:

- pH was determined using a Fisher Accumet pH meter, model 750.
- Nitrate-N was determined using a Fisher Accumet pH meter, model 925 equipped with a nitrate module.
- Conductivity was determined using a YSI model 5L conductance meter.
- All other parameters were determined using a Gerril Ash 9000 ICAP (Inductively Coupled Argon Plasma) on samples acidified using 3 drops of nitric acid per 9 ml of sample.

3.3.3 Bacteria

Water samples for total coliform bacteria analysis were submitted to the lab on the day of sampling, or refrigerated and delivered the following day. Samples were analyzed using the "Membrane Filter Procedure" as outlined in American Public Health Association Standard Methods Manual (Clesceri et al., 1989).

4 RESULTS AND DISCUSSION

4.1 Well Construction

Data collected through interviews with the well owner indicated a general lack of knowledge about the construction of their well. While 93% of well owners reported their well type, only 24% of the well owners surveyed reported their well depth. Of the 221 wells for which data on well type was available the majority were drilled wells (Figure 4.1) with the bulk of the wells of known depth being shallow, i.e. less than 31 m (100 ft.) (Figure 4.2).

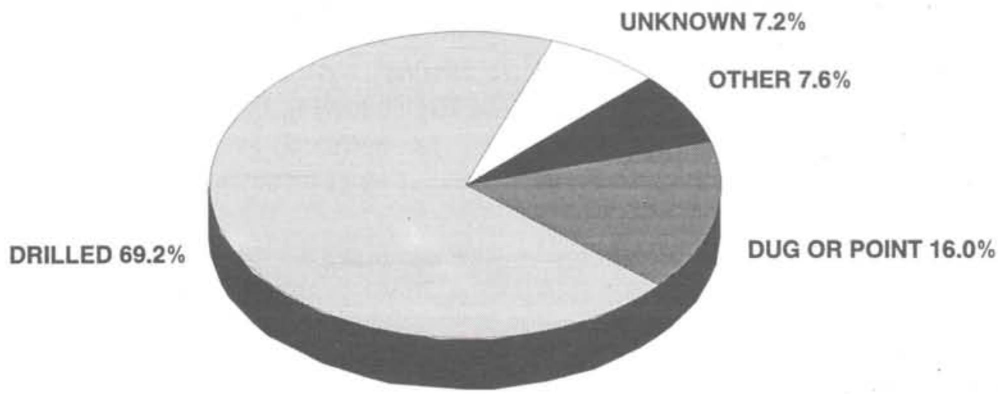
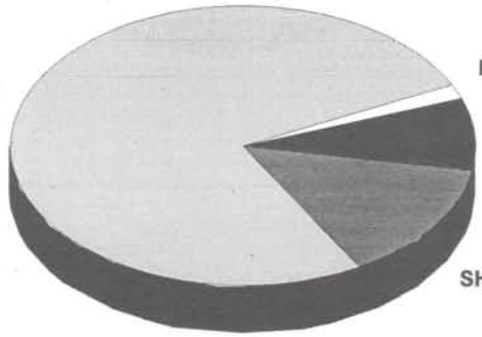


Figure 4.1 Types of wells sampled.



Note:
Shallow = < 31 m (100 ft.)
Moderately Deep = 31 - 61 m (100 - 200 ft.)
Deep = > 61 m (200 ft.)

Figure 4.2 Depth of wells sampled.

4.2 Surficial Material

Information on surficial material was available for 211 (89%) of the wells. Most of the sites for which data was available were located in either glacial till or glaciofluvial deposits (Figure 4.3). Textural classes of surficial material were more evenly divided between sandy, coarse loamy, and fine loamy deposits (Figure 4.4).

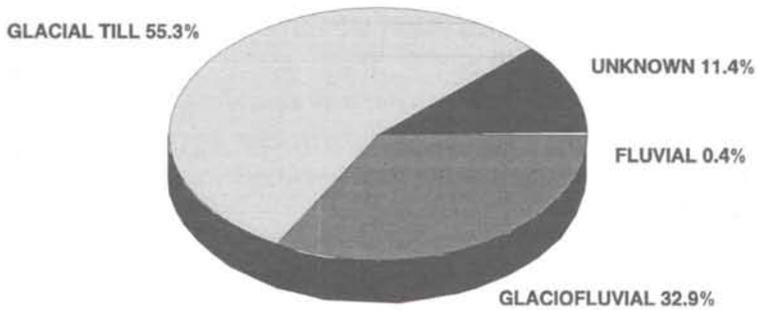


Figure 4.3 Type of surficial material.

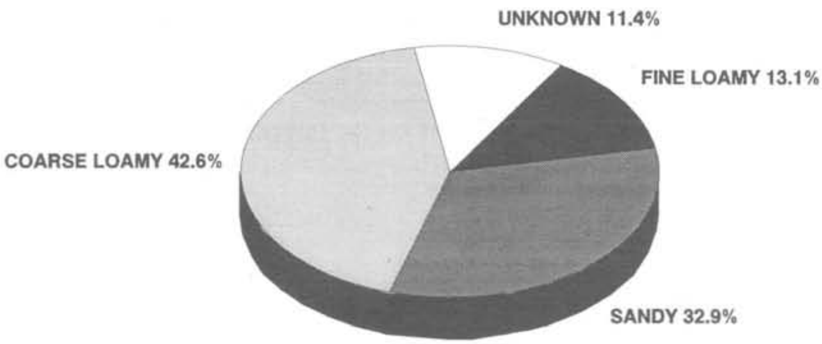


Figure 4.4 Texture of surficial material.

4.3 Pest Control Products

A total of 102 randomly selected wells were tested for pest control products. Test results (Figure 4.5) showed that all wells were within the maximum acceptable concentrations (MAC) established under the Guidelines for Canadian Drinking Water Quality (GCDWQ) (Health and Welfare Canada, 1993).

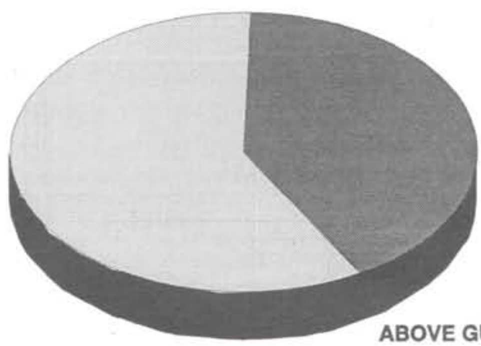


Figure 4.5 Pesticide detections versus GCDWQ levels.

Nine pest control products or their degradation products (eg. des ethyl atrazine) were found (81 occurrences) at very low levels in 42 (41%) of the wells (Figure 4.6). Ninety six percent of these detections were at concentrations less than 1 μg/L (1 ppb) and more than half (55%) occurred at or near the lower detection limit of the laboratory procedures used. The high frequency of wells with detections is a reflection of weighted sampling based on the modified DRASTIC ratings and would seem to indicate that the model was sucessful in predicting those areas most susceptible to groundwater contamination. See Appendix C for detailed pest control product results.

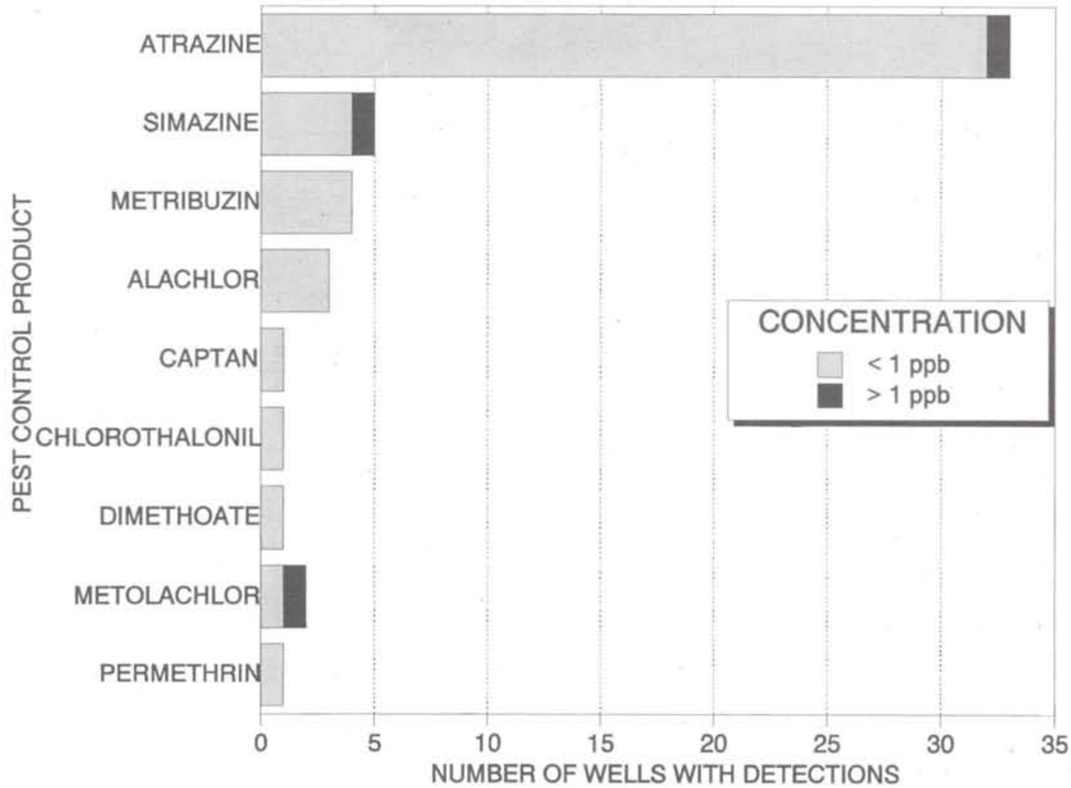


Figure 4.6 Number of detections by pest control product.

Atrazine (and its degradation products des ethyl atrazine and des isopropyl atrazine) was the most prevalent pest control product found. For this reason, it was used for statistical examination of the possible factors affecting the incidence and level of pest control products in wells. Atrazine is a herbicide which has been in general use since the early 1960's primarily for weed control in corn.

Well construction does not appear to play a role in determining the sensitivity of wells to atrazine contamination (Table 4.1). Atrazine contamination was independent of well construction (type and depth). A description of the statistical methods used to analyze the data is presented in Appendix B of this report. Atrazine contamination of dug wells and sand points was found to be related to surficial material (type and texture). This was not the case for drilled wells.

There was no significant difference in atrazine levels with different well types and depths or surficial material types and textures (Table 4.2).

Table 4.1 Statistical relationship of atrazine, nitrate and bacteria contamination to well construction and surficial material.

Parameter	Atrazine		Nitrate-N		Bacteria	
	Chi Sq.	V	Chi Sq.	V	Chi Sq.	V
Well Type	1.637	2	21.961*	4	9.605*	2
Well Depth	2.280	2	9.668*	4	0.631	2
Surficial Material Type					9.234*	2
Drilled Wells	0.110	1	1.449	4		
Dug Wells & Sand Points	3.615*	1	4.073	4		
Surficial Material Texture					8.613*	2
Drilled Wells	1.718	2	4.807	4		
Dug Wells & Sand Points	6.238*	2	7.288	4		

* Statistically significant at an alpha level of 0.10

Table 4.2 Effect of well construction and surficial material on atrazine levels (alpha = 0.05).

Parameter	Mean Atrazine Level (μg/L)**			
Group*	Well		Surficial Material	
	Type	Depth	Type	Texture
1	0.800a	0.181a	0.097a	0.091a
2	0.191a	0.094a	0.096a	0.124a
3	0.002a	I.D.	I.D.	0.022a

* Parameter group definitions:

Well Type: 1=drilled, 2=dug & sand points, 3=other
Well Depth: 1=1-100 feet, 2=101-200 feet, 3= >200 feet
Surficial Material Type: 1=Glacial till, 2=Glaciofluvial, 3=fluvial
Surficial Material Texture: 1=sandy-sandy skeletal,
2=coarse loamy - gravelly coarse loamy,
3=fine loamy - gravelly fine loamy.

** Letter codes, i.e. a, b or c, indicate groups of values that do not differ significantly from one another.

I.D. = Insufficient Data

4.4 Inorganic Parameters

Two hundred and thirty seven randomly selected wells were tested for inorganic parameters as given in Table 3.1. With the exception of nitrate-N, recommended limits for these parameters have been established under the GCDWQ on the basis of aesthetic considerations such as colour and taste. In general, the wells sampled met aesthetic objectives (Figure 4.7). The parameters which most commonly exceeded aesthetic criteria were manganese and pH. Details of the results of the inorganic analyses are presented in Appendix D.

The Guidelines for Canadian Drinking Water Quality have identified 10 mg/L as the maximum acceptable concentration (MAC) of nitrate-N in drinking water based on health considerations for infants under the age of 6 months. Thirty (13%) of the 237 wells sampled exceeded the MAC level for nitrate-N (Figure 4.8).

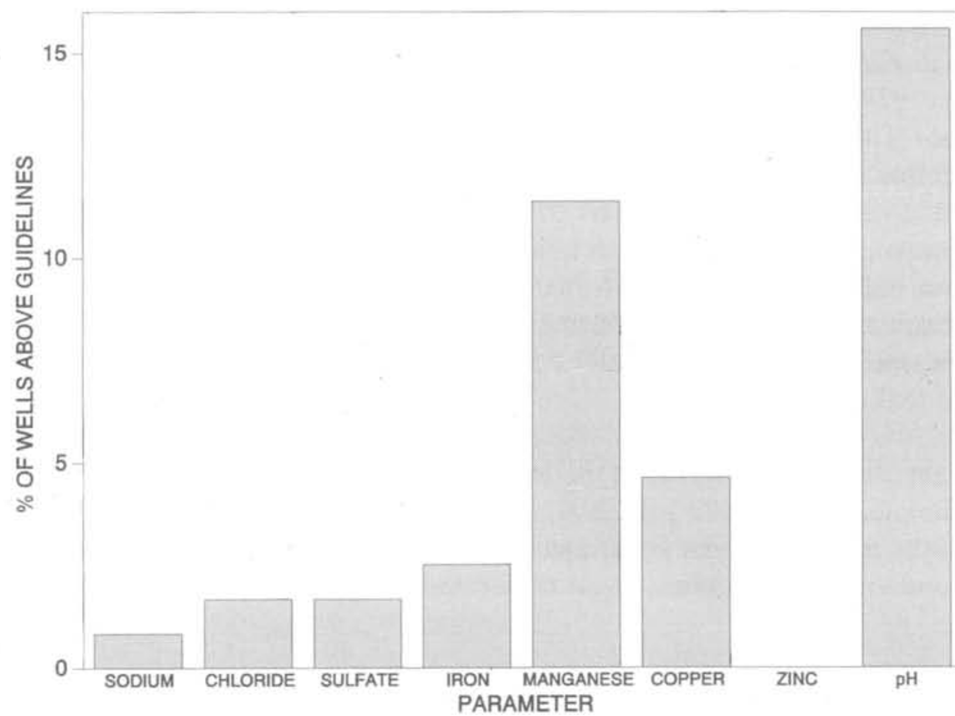


Figure 4.7 Percentage of wells exceeding aesthetic objectives.

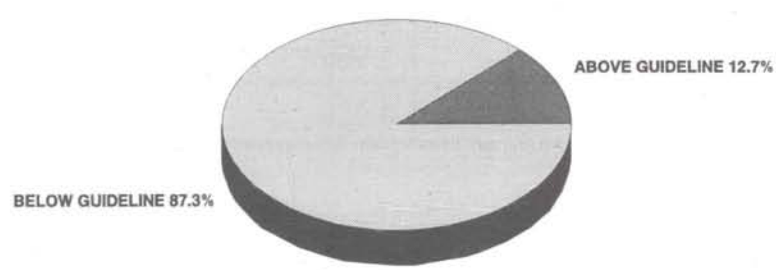


Figure 4.8 Nitrate-N detections versus GCDWQ levels.

In a summary of historic nitrate data for Nova Scotia, McLeod and Fulton (1985) reported that 7% of wells province-wide and 29% of wells in the intensive agricultural regions in Kings County exceeded the nitrate-N drinking water guideline of 10 mg/L. Thomas (1974) reported that 25% of the wells in the Canning area exceeded the nitrate-N guideline. This study found that 29% of the wells sampled in the Canning area exceeded the guideline which indicates that there has been no significant change in the incidence of nitrate contamination in this part of the study area.

Based on statistical analysis of the data (Table 4.1), the incidence of nitrate-N contamination was found to be related to the type of well construction and well depth. However, the incidence of nitrate-N contamination was independent of surficial material type and texture.

Significant differences in nitrate-N levels between the various well construction or surficial material parameter groups were found (Table 4.3). Dug wells, shallow drilled wells, wells in glaciofluvial soils, and those in soils of sandy to sandy skeletal textures were found to have the highest levels of nitrate-N. These results are comparable to other

Table 4.3 Effect of well construction and surficial material on Nitrate-N levels (alpha = 0.05).

Parameter	Mean Nitrate-N Level (mg/L)**			
Group*	Well		Surficial Material	
	Type	Depth	Type	Texture
1	3.35a	5.99a	4.76a	5.54a
2	8.36b	2.98b	4.72a	4.42ab
3	1.48c	0.91b	0.51b	2.49b

* Parameter group definitions:

Well Type: 1=drilled, 2=dug & sand points, 3=other
Well Depth: 1=1-100 feet, 2=101-200 feet, 3= >200 feet
Surficial Material Type: 1=Glacial till, 2=Glaciofluvial, 3=fluvial
Surficial Material Texture: 1=sandy-sandy skeletal,
2=coarse loamy - gravelly coarse loamy,
3=fine loamy - gravelly fine loamy.

** Letter codes, i.e. a, b or c, indicate groups of values that do not differ significantly from one another.

recent studies (Goss and Fleming, 1993; Spalding and Exner, 1993) which have also found nitrate contamination to be more common in poorly constructed and shallow dug wells or wells constructed in sandy, more permeable soils.

4.5 Bacteria

Of the 102 bacteria samples analyzed, 9% exceeded the action limit of 10 counts/100 ml established under the GCDWQ (Figure 4.9), with the highest count being 260 counts/100 ml. The incidence of bacterial contamination was found to be related to well type, surficial material type and surficial material texture but independent of well depth (Table 4.1).

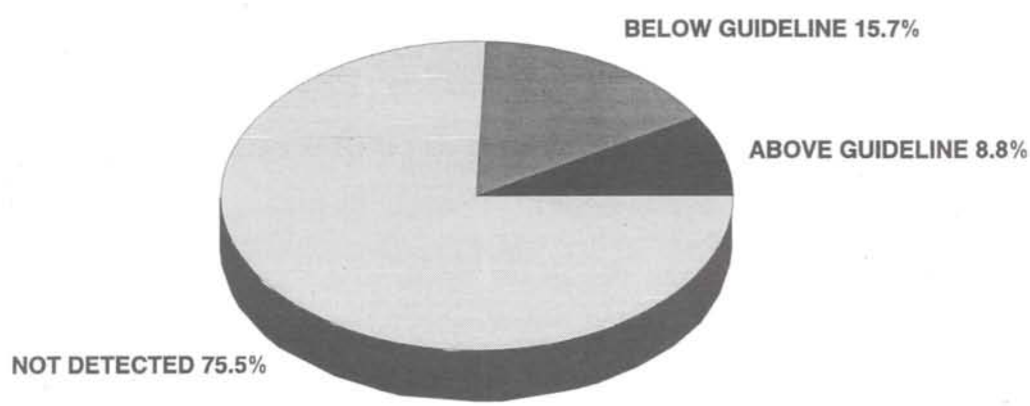


Figure 4.9 Bacteria detections versus GCDWQ levels.

A significant difference in bacteria levels between well type and surficial material parameters was found (Table 4.4). "Other" well types, including spring-fed wells, along with till soil types and coarse loamy - gravelly coarse loamy textures were found to have the highest bacteria levels. As all "other" well types were located in till soils of coarse loamy to gravelly coarse loamy texture, it is likely that well type rather than surficial material type is the overriding factor. No significant difference in bacteria levels with well depth was found.

Table 4.4 Effect of well construction and surficial material on bacteria levels (alpha = 0.05).

Parameter	Mean Bacteria Level (counts/100 ml)**			
Group*	Well		Surficial Material	
	Type	Depth	Type	Texture
1	1a	1a	13a	5a
2	2a	2a	0b	11b
3	46b	I.D.	I.D.	3a

* Parameter group definitions:

Well Type: 1=drilled, 2=dug & sand points, 3=other
Well Depth: 1=1-100 feet, 2=101-200 feet, 3= >200 feet
Surficial Material Type: 1=Glacial till, 2=Glaciofluvial, 3=fluvial
Surficial Material Texture: 1=sandy-sandy skeletal,
2=coarse loamy - gravelly coarse loamy,
3=fine loamy - gravelly fine loamy.

** Letter codes, i.e. a, b or c, indicate groups of values that do not differ significantly from one another.

I.D. = Insufficient Data

4.6 Case Studies

A total of 17 case studies were performed as part of this study. Conclusions as to source of contamination are summarized in Figure 4.10. As with the preliminary water supply questionnaires, the case studies further emphasized the general lack of knowledge among well owners concerning their water supplies. The results of the case study interview process (11 of 17 returned) showed that many farmers lack records on pesticide and fertilizer use, and do not know the location of well heads, septic systems, etc. (Table 4.5). Detailed summaries of case study information are contained in Appendix E.

Eleven of the 17 case study wells contained detectable levels of pest control products. It was determined that the majority of detections of pest control products resulted from non-point sources although the source was unknown in some cases (Figure 4.10). Point source pesticide contamination was identified in only one case, the result of spray drift into a shallow, spring-fed well.

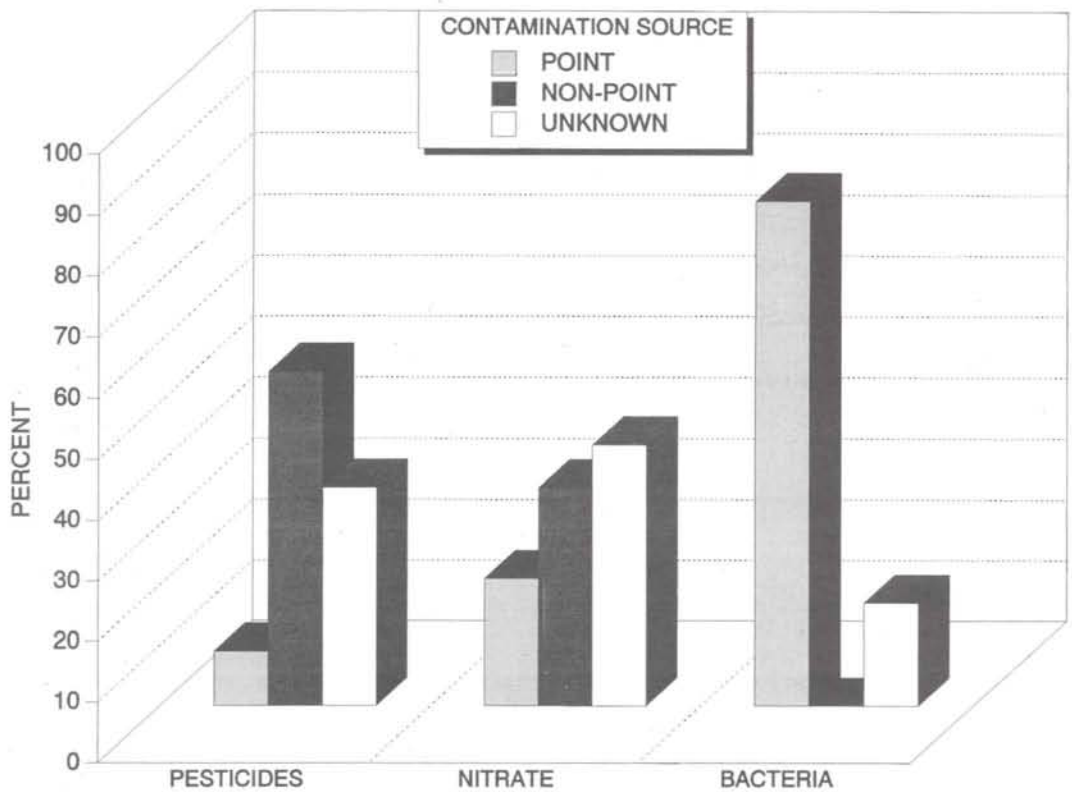


Figure 4.10 Source of well contamination by contaminant type.

Six of the 10 case studies in which atrazine was found reported no atrazine use in the three years prior to sampling. Two of these six reported no atrazine use in at least ten years. This indicates that the atrazine contamination detected may be the result of historic use rather than current agricultural practices.

Of the other pest control products screened for, alachlor was detected at two sites but not used at either site, metribuzin and metolachlor were detected and used at one site and chlorothalonil was detected at one site and used at three.

Table 4.5 Summary of case study questionnaire results.

Information	Reported	Not Reported	Not Applicable
Proximity to Facilities			
Septic	4	7	0
Pesticide	2	4	5
Manure	1	3	7
Pesticide Use[1]	8	1	2
Written Records	2		
Verbal Records	6		
Manure Use	5	4	2
Fertilizer Use[2]	8	3	0

[1] Of the 8 reporting pesticide use, 3 reported having taken a sprayer certification course, 3 had not, and 2 did not report.

[2] Of the 8 reporting fertilizer use, 6 reported using soil testing and accounting for manure in planning fertilizer rates, 2 reported they did not.

Fourteen of the 17 case studies contained nitrates in excess of the 10 mg/L recommended limit. Of the 3 wells with point source contamination by nitrate-N (Figure 4.10), poor well construction allowing infiltration of surface water was the sole mechanism identified for contamination to take place.

Six of the 17 wells in the case studies contained bacteria in excess of the 10 counts/100 ml action limit, with five of these identified as point sources (Figure 4.10). Poor well construction allowing infiltration of surface water was the dominant mechanism of point source contamination found in four of these wells. The exception to this was found in a properly constructed, drilled well fitted with a pitless adaptor. Contamination in this case was caused by earwigs getting into the well through the well cap.

5 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from the results of this study:

1. Contamination by pest control products is not a serious problem in the study area.

2. There is widespread occurrence of very low level pesticide detections, especially atrazine, in the study area. The atrazine occurrences are largely from non-point sources and may be from historic use rather than current agricultural practices.

3. Occurrences of nitrate-N and bacteria in excess of the Guidelines for Canadian Drinking Water Quality continue. There is no significant change in the Canning area since the 1974 Thomas study.

4. Well construction parameters such as type and depth play a role in determining the sensitivity of a well to nitrate and bacterial contamination.

5. There is a general lack of knowledge among well owners about their water supply, both source and quality.

6. Many farmers kept insufficient records on the use of pest control products, manure and fertilizers.

The following recommendations result from this study:

1. Well owners must become more aware of their water supplies.

2. New wells should be constructed using the best possible construction techniques and located away from possible sources of contamination.

3. Routine maintenance of existing wells should be encouraged and well improvements made where necessary.

4. Well owners should be encouraged to have their well water quality checked on a regular basis.

5. Farming practices should be identified and implemented that will improve the management of nutrients and pesticides and minimize their impact on groundwater.

6. Farmers and well owners should be encouraged to keep accurate records of product use on their properties.

7. Government agencies should continue to produce educational materials for provision to well owners and farm operators.

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APPENDIX A: QUESTIONNAIRES

Water Supply Inventory
Check List

____

Index # ______________
Date ______________
Interviewed by ______________
Telephone ______________

Name ______________

Signature of homeowner or representative
(Interviewee ______________)

Address ______________

Telephone ______________

Interviewer's Signature
______________)

1. Present Water Source

a) Dug Well

b) Well Point

c) Drilled Well

d) Other (specify)

2. General

a) When was well constructed?

b) By whom was well constructed?

c) For whom was well constructed?

d) Has water ever been tested for bacteria? Yes ______ No ______
If yes, by whom? (own, health inspector, etc.) ______________
Approximate date tested ______________

e) Has water every been tested for chemical quality? Yes ______ No ______
If yes, by whom? ______________
Approximate date of testing ______________

f) Have any water shortages been experienced recently? If so, describe ______________

g) Any other problems with the water supply? ______________

h) Shallow or deep well pump?

i) Size of storage tank ______________

3. If Dug Well:

a) Depth of well ___________

b) Diameter of well ________

c) Construction of well: Well crocks on top of rock ____________________
Well crocks only ____________________
Rocked well only ____________________
Other (specify) ____________________

d) Are joints between crocks sealed? ____________________

e) Does well have cover? ____________________
If so, specify type (e.g. wooden, concrete) ____________________

f) How far above ground surface is top of well? ____________________

g) Is ground mounded around well? ____________________

h) Does well have a concrete apron? ____________________

i) Approximate depth from top of well to water surface ______________

j) How much water used so far today? ____________________

4. If Well Point:

a) Diameter ____________________

b) Depth ____________________

5. If Drilled Well:

a) Well depth ____________________

b) Well Diameter ____________________

c) Depth of casing ____________________

d) Does well have a sanitary seal? ____________________

e) Does well have a vent? ____________________

f) Where is vent located ____________________

g) Is top of well in a well pit, separate building, underground or in home?

____

h) Depth of intake in well ____________________

i) Any problems in last 5 years which required repair by the well contractor?
If yes, please specify problem ____________________

____

Any other related comments ______________________________

Nova Scotia Farm Well Water Quality Assurance Study
Case Study Questionnaire

Case Number: ______ Date: ______________

Cleared Hectareage Farmed:______________

1 Location of farm facilities

On a rough sketch (paces etc.) please indicate the location of the following:

1. well head(s)
2. manure storage
3. pesticide storage area
4. sprayer loading/cleaning area
5. septic tank
6. main buildings

2 Pesticides

2.1 Handling and Storage

Please answer the following questions as completetly as possible. Use the bacck of the sheet if required.

1. Where are Pesticides normally stored on the farm? (eg. barn, shed etc.)

2. Is this facility equiped with spill control structures or devices? If so what type? (eg. berm, concrete lip, etc.)

3. Where and how is the sprayer normally loaded? (eg. from a tap at the storage, by tanker in the field, etc.)

4. If the sprayer is loaded from a tap is the tap equiped with a backflow prevention device.? ______

5. Have there been any spills or backsiphoning of pesticides on the farm in the ppast five (5) years? ______

6. If the answer to question 5 was YES please describe the incident as fully as possible. Include an estimate of the time (year, month, day), pest control product spilled, amount and cleanup procedures used (if any).

7. Have you taken a Sprayer Certification Course? ______

2.2 Use History

On the attached Pesticides Use Form please indicate (using X) the pesticides used in each of the last 5 years.

For each pesticide used please complete as fully as possible a copy of the 'Pesticide Application Rate Form'. The following is a key to the items in the table:

- Formulation: indicate liquid, wettable powder, etc.
- Rate Applied: active ingredient per hectare, please indicate units (ie. g/ha, l/ha etc.)
- Total Amount Applied: please indicate total amount of chemical used and indicate units (ie. litres, grams etc.)

Pesticide Use Form

CHEMICAL NAME	COMMON OR TRADE NAMES	1992	1991	1990	1989	1988
ATRAZINE	AATREX					
	PRIMATOL					
	VECTAL					
ATRAZINE WITH CYANAZINE	BLAZINE					
ATRAZINE WITH BENTAZON	LADDOK					
ATRAZINE WITH DICAMBA	MARKSMAN					
ATRAZINE WITH SIMAZINE	EKKO					
	ERAMOX					
ATRAZINE WITH METALOCHLOR	PRIMEXTRA					
DIMETHOATE	CYGON					
	LAGON					
	HOPPER STOPPER					
	SYS-TEM					
MALTHION	MALTHION					
	CYTHION					
CHLORFENVINPHOS	BURLANE					
AZINPHOSMETHYL	GUTHION					
CHLOROTHALONIL	BRAVO					
CAPTAN	CAPTAN FL					
PERMETHRIN	AMBUSH					
	POUNCE					
DELTAMETHRIN	DECIS					
METRIBUZIN	SENCOR					
	SENCOR 500					
	SENCOR 75 DF					
	LEXONE					
	LEXONE L					
	LEXONE DF					
SIMAZINE	PRINCEP-NINE-T					
	SIMMAPRIM NINE T					
	SIMADEX					
SIMAZINE WITH AMITROLE	AMIZINE					

Pesticide Application Rate Form

Active Ingredient: ____________________

YEAR APPLIED	FORMULATION	RATE APPLIED	TOTAL AMOUNT USED
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________

3 Manure

3.1 Handling and Storage

1. What type(s) of manure are stored on the farm? (eg. solid or liquid cow, poultry, etc.)

2. How many months of storage does the existing storage facilities allow?

3. What type(s) of storage is used? (eg. slab, earth pit, concrete pit)

4. Is the storage sealed from the environment? (roofed etc.)

5. Estimate the percentage of manure that is normally applied using the following methods and times.

a. Spring surface applied. ____________

b. Spring incorporated. ____________

c. Summer surface applied. ____________

d. Fall surface applied. ____________

e. Fall incorporated. ____________

f. Winter surface applied. ____________

6. Do you have a copy of the revised "Guidelines for the Management of Animal Manures in Nova Scotia"? ____________

3.2 Use History

On the Manure Use Form please indicate which types of manure have been used (applied to fields) on the farm in the last 5 years.

Manure Use Form

MANURE TYPE	AMOUNT APPLIED (Tonnes)				
	1992	1991	1990	1989	1988
Solid or Semi Solid Cow Manure	____________	____________	____________	____________	____________
Liquid Cow Manure	____________	____________	____________	____________	____________
Swine Effluent	____________	____________	____________	____________	____________
Poultry Litter	____________	____________	____________	____________	____________

4 Chemical Fertilizers

4.1 Handling and Storage

1. Do you currently soil test? ____________

2. Do you account for manure applications and green plowdowns when planning fertilizer application rates? ____________

3. Do you practice a pH management program? (eg. liming) ____________

4.2 Use History

On the Fertilizer Use Form please indicate the aproximate amount of nitrogen containing fertilizers used (applied to fields) on the farm in each of the last 5 years.

Fertilizer Use Form

FORMULATION	AMOUNT APPLIED (Tonnes)				
	1992	1991	1990	1989	1988
17-17-17					
12-24-24					
6-12-12					

Fertilizer Use Form

FORMULATION	AMOUNT APPLIED (Tonnes) 1992	1991	1990	1989	1988

APPENDIX B: SUMMARY OF STATISTICAL ANALYSIS

Three data sets were the core of this study: atrazine, nitrate-N and bacteria levels. The characteristics of these data sets are presented in Table B.1 below.

Table B.1 Characteristics of the data sets analyzed.

Descriptor	Atrazine	Nitrate-N	Bacteria
Number of Observations	102	237	102
Minimum	0.000 μg/L	0.30 mg/L	0 counts/100 ml
Maximum	1.970 μg/L	46.10 mg/L	200 counts/100 ml
Mean	0.061 μg/L	4.61 mg/L	7 counts/100 ml
Median	0.000 μg/L	2.68 mg/L	0 counts/100 ml
Standard Deviation	0.226	5.78	34

In order to use "standard" statistical methods for comparing the data (i.e. T-test, analysis of variance, regression, etc.), the data must meet two conditions: (1) it must be normally distributed and (2) the two populations being compared must have equal variance (Zar, 1974). If the populations being studied vary widely from these assumptions, non-parametric statistical methods must be used to compare the data.

The following analyses were performed on the random survey sample results to determine if the data met the criteria for use with "standard" statistical methods:

- Three plotting methods (histogram, boxplot and dotplot) were used to make a visual estimate of the distribution.

- The normal probability scores (nscore) for the data were determined and a plot made of the data versus its nscore. A straight line indicates normal distribution.

- A series of "standard" data transformation methods were used if the data versus nscore plot indicated non-normal data. The purpose of these transformations was to attempt to convert non-normal data into normal data for analysis purposes. The transformations tried were:

  - log base ten transformation on the data points + 10.
  - log base e transformation on the data points + 10.
  - inverse transformation (i.e. 1/(data + 10)).

- The nscore for each set of transformed data was determined and a plot of the transformed data versus its nscore made.

- The data was regressed against other measured parameters and a plot of the residuals made. While this method does not specifically identify non-normal data, the shape of the residual curve can indicate possible additional transformations (i.e. curvilinear, etc.). As well, the plot can indicate data for which there was likely an error in the regression calculation. This error is generally an invalid assumption in the distribution of the data (i.e. the data is not normal).

As atrazine was the most frequently encountered pesticide analyte, the data on atrazine levels from the random survey was used to determine which statistical methods should be used for analysis of the pest control product data.

Visual assessment of the data sets indicated that they were not normally distributed. This was verified by the data versus nscore plots (Figures B.1, B.2 and B.3). These plots are clearly curved, indicating a non-normal population. Transformed plots showed similar curvature.

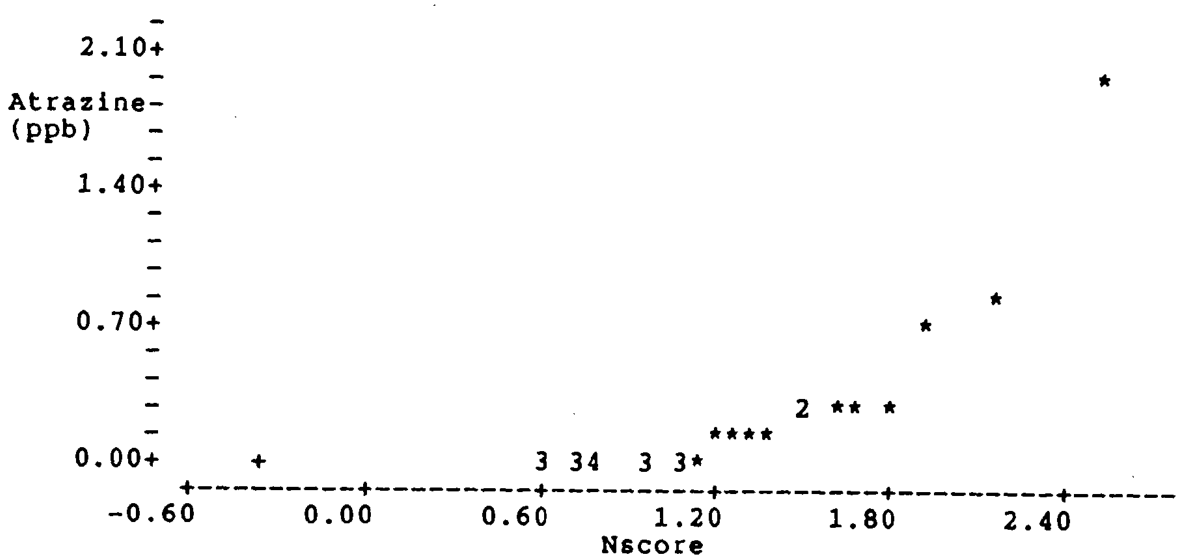

Figure B.1 Random survey atrazine levels versus nscore.

Figure B.2 Random survey nitrate levels versus nscore.

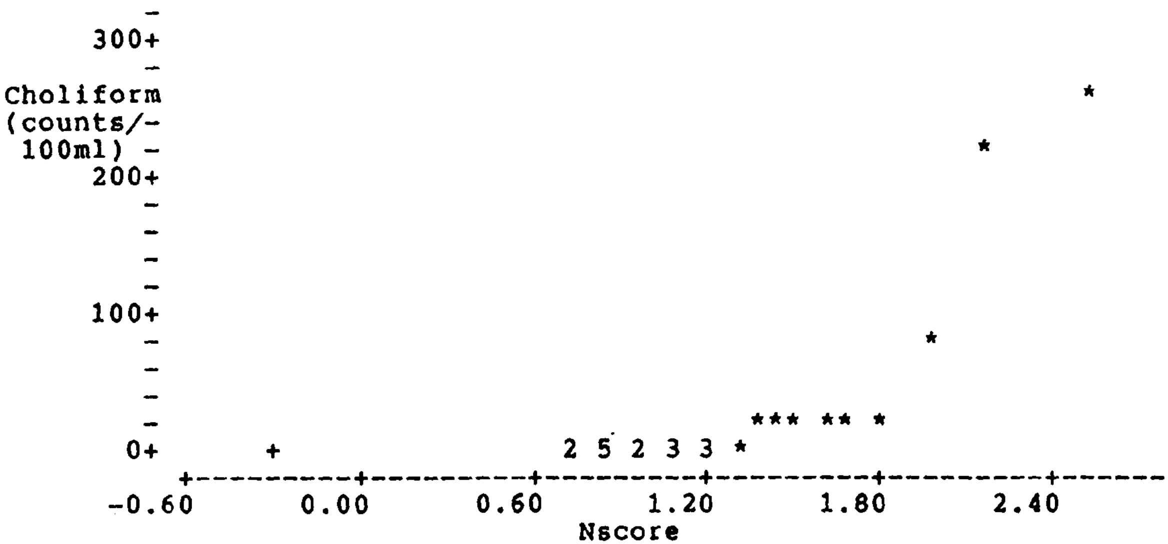

Figure B.3 Random survey bacteria levels versus nscore.

As required by the non-normal distribution of all the data sets, non-parametric statistics were used to check for differences between samples from different sources (i.e. shallow vs. deep wells, sandy vs. fine loamy materials, etc.). A series of Mann-Whitney tests (Zar, 1974) to compare specific parameters (i.e. well construction) to the level of contaminants found were conducted.

Also, a series of contingency table (chi square) tests were used determine the dependence/independence of the variables studied. All tests used the procedures as outlined in Zar, 1974. These are:

1) Null and alternative hypothesis set up as follows:

Ho: Variable 1 is independent of Variable 2.
Ha: Variable 1 is not independent of Variable 2.

2) A contingency table is set up as per the following example:

	Variable 2			
Variable 1	Class 1	Class 2	Class 3	Total obs.
Class 1 obs.	fij	fij	fij	Sum fij
exp.	(Fij)	(Fij)	(Fij)	
Class 2 obs.	fij	fij	fij	Sum fij
exp.	(Fij)	(Fij)	(Fij)	
Total obs.	Sum fij	Sum fij	Sum fij	n

where: fij = the observed frequency
Fij = [(Sum Row)(Sum Column)]/n

3) The test statistic, Chi Sq. obs., is determined as follows:

Chi sq. obs = Sum[(fij - Fij)2/Fij]

4) This is compared to the table statistic determined as follows for an alpha level of 0.1:

Chi sq. 0.1,v = table value

where: v = (r - 1)(c - 1)

5) If Chi sq. obs. is greater than Chi sq. 0.1,v then Ho is rejected or else Ho is not rejected. Rejection of Ho implies that the two variables being tested are not independent of one another; not rejecting Ho implies that the two variables being tested are independent of one another.

APPENDIX C: PEST CONTROL PRODUCT RESULTS

Table C.1 Results of pest control product scans.

Pest Control Product	Wells With Detec -tions	Range ($\mu g/L$)	Average ($\mu g/L$)	Guideline ($\mu g/L$) *1	Wells Above Guideline	Detection Limit *2	Wells Near Detec-tion Limit*3
Alachlor	3	0.02-0.06	0.05	N.G.	N.A.	0.01	3
Atrazine	29	0.02-1.97	0.21	60.0	0	0.02	17
Des Ethyl Atrazine	27	0.02-0.53	0.13	N.A.	N.A.	0.02	15
Des Isopropyl Atrazine	2	0.01 & 0.09	N.A.	N.A.	N.A.	0.01	2
Sum Atrazine	33	0.02-2.19	0.29	60.0	0	N.A.	N.A.
Captan	2	0.01 & 0.08	0.05	N.G.	N.A.	0.01	2
Chlorothalonil	1	0.065	N.A.	N.G	N.A.	0.004	0
Dimethoate	1	0.40	N.A.	20.0	0	0.06	0
Metolachlor	2	0.52 & 1.20	N.A.	50.0	0	0.02	0
Metribuzin	4	0.003-0.04	0.02	80.0	0	0.003	2
Permethrin	1	0.05	N.A.	N.G.	N.A.	0.02	1
Simazine	5	0.21-1.05	0.47	10.0	0	0.02	0
Des Ethyl Simazine	4	0.03-0.16	0.07	N.A.	N.A.	0.02	3
Sum Simazine	5	0.25-1.21	0.52	10.0	0	N.A.	N.A.

*1 Guidelines for Canadian Drinking Water Quality (Health and Welfare Canada, 1993).

*2 The average detection limit; this value varies slightly depending on operating conditions at the time of analysis.

*3 Within one order of magnitude of the average detection limit, i.e. if the detection limit was 0.02 $\mu g/L$, all those <0.1 $\mu g/L$.

N.A. = Not Applicable
N.G. = No Guideline

APPENDIX D: INORGANIC ANALYSIS RESULTS

Table D.1 Results of inorganic screens.

Parameter	Wells with Detections	Range	Guideline *1	Wells Above Guideline
Calcium (mg/L)	232	N.D.- 535	N.G.	N.A.
Magnesium (mg/L)	228	N.D.- 27.4	N.G.	N.A.
Sodium (mg/L)	237	0.8 - 429.0	200.0	2
Chloride (mg/L)	173	N.D.- 455.7	250.0	4
Sulfate (mg/L)	232	N.D. - 1,231.0	500	4
Iron (mg/L)	119	N.D.- 1.97	0.30	6
Manganese (mg/L)	57	N.D.- 1.15	0.05	27
Copper (mg/L)	150	N.D.- 5.10	1.0	11
Zinc (mg/L)	197	N.D.- 1.86	5.0	0
Nitrate-N (mg/L)	237	0.30 - 46.10	10.0	30
Alkalinity	213	N.D.- 225	N.G.	N.A.
pH	237	4.4 - 8.3	6.5 - 8.5	37 < 6.5
Conductivity (μmhos)	237	45.0 - 2,570.0	N.G.	N.A.
Hardness (as $CaCO_3$)	237	1.4 - 1,376.4	N.G.*2	N.A.

*1 Guidelines for Canadian Drinking Water Quality (Health and Welfare Canada, 1993).

*2 Public acceptance of hardness varies considerably. Generally, hardness levels between 80 and 100 mg/L (as $CaCO_3$) are considered acceptable; levels greater than 200 mg/L are considered poor but can be tolerated; those in excess of 500 mg/L are normally considered unacceptable. Only 3 wells sampled had hardness levels greater than 500 mg/L.

N.D. = Not Detected
N.G. = No Guideline
N.A. = Not Applicable

APPENDIX E: CASE STUDY RESULTS

E.1 Case A

This well was sampled twice, on August 10, 1989 and March 25, 1992. Four pest control products (alachlor, atrazine, metolachlor, metribuzin) and one degradation product (des ethyl atrazine) were detected in the well in at least one of the samples (Table E.1). Nitrate-N exceeded the MAC of 10 mg/L in both samples. Bacteria were not detected at the site.

Table E.1 Detection history - case study A.

Analyte	Date Sampled (and Sample Number)	
	August 10, 1989	March 25, 1992
	(1)	(2)
Alachlor (µg/L)	0.060	N.D.
Atrazine (µg/L)	0.120	0.080
Des Ethyl Atrazine (µg/L)	0.020	0.030
Metolachlor (µg/L)	0.520	0.300
Metribuzin (µg/L)	0.030	0.060
Nitrate-N (mg/L)	13.60	14.00
Bacteria (count/100 ml)	N.D.	N.S.

N.D. = Not Detected N.S. = Not Sampled

The well is reported to be a drilled well, 175 feet deep, 5 inches in diameter with 75 feet of casing. The well is buried and was not uncovered for detailed inspection. It is located approximately 75 feet from the septic system and 180 feet from the pesticide storage area. Sprayer loading and cleaning is performed in the field, not at the well site. No reported spills of chemicals have occurred at the well site.

Records on pest control product use do not exists prior to 1989. Atrazine and alachlor were not used by the farmer in 1989 through 1992 though they were detected in the well. Metribuzin was used in 1989, and metolachlor in 1989 through 1992. Both products were found in the well during both sampling periods. The farmer also reported using chlorothalonil in 1989 through 1992, and azinphosmethyl during 1989. Neither product was detected.

Due to the inability to perform a complete well inspection, no conclusion could be drawn as to the source of the nitrate contamination. Given the pesticide handling practices on the farm, the presence of a sound storage area, and the history of use, it is most likely that pesticide contamination of this well stemmed from non-point sources.

E.2 Case B

This site was sampled three times between July 20, 1989 and March 25, 1992. Atrazine and its degradation product, des ethyl atrazine, were detected in the well in samples from two different wells (Table E.2). Nitrate-N exceeded the MAC of 10 mg/L in all samples. Bacteria were not detected at the site.

Table E.2 Detection history - case study B.

Analyte	Date Sampled (and Sample Number)		
	July 20, 1989	Sept. 26, 1990	Mar. 25, 1992
	(A1)	(B1)	(B2)
Atrazine (μg/L)	0.210	N.S.	0.300
Des Ethyl Atrazine (μg/L)	0.480	N.S.	0.790
Nitrate-N (mg/L)	14.00	16.00	19.00
Bacteria (counts/100 ml)	N.D.	N.S.	N.S.

N.D. = Not Detected N.S. = Not Sampled

Well records indicate that Well A was a drilled well 48 feet deep, 3 inches in diameter with 16 feet of casing and that well B is a drilled well 95 feet deep, 6 inches in diameter with 22 feet of casing. Well A was replaced by the homeowner with well B on September 7, 1989 as the result of well A having ran dry during the summer of 1989. Both wells were buried and neither were uncovered for detailed inspection.

No information was provided on the proximity of the well to the septic system. The well owner is not a farmer, so information on proximity to agricultural facilities is inapplicable.

The farmer cropping the fields adjacent to the home was interviewed and indicated that atrazine had been used on the fields during the study period but that no records of specific use existed.

No point sources of contamination were identified therefore, it appears that the sources of atrazine and nitrate contamination at this site were non-point.

E.3 Case C

The well was sampled twice, on July 18, 1989 and March 25, 1992. Atrazine and its degradation product, des ethyl atrazine, were detected in both samples (Table E.3). Nitrate-N levels in the well exceeded the MAC of 10 mg/L in the first sample and were below this level in the second. Bacteria were not detected in the well.

Table E.3 Detection history - case study C.

Analyte	Date Sampled (and Sample Number)	
	July 18, 1989	March 25, 1992
	(1)	(2)
Atrazine (μg/L)	0.040	0.040
Des Ethyl Atrazine (μg/L)	0.100	0.080
Nitrate-N (mg/L)	10.90	9.29
Bacteria (counts/100 ml)	N.D.	N.S.

N.D. = Not Detected N.S. = Not Sampled

The well is reported to be a bored well, 60 feet deep, 1.5 inches in diameter with 60 feet of casing. The well is buried under the basement floor and thus could not be uncovered for detailed inspection. No information was provided on the proximity of the well to the septic system. The well owner is not a farmer, so information on the proximity to agricultural facilities is inapplicable.

The farmer cropping the fields adjacent to the well was interviewed and indicated that atrazine had not been used on the fields during the study period, or for many years prior. No records of specific use existed.

No point sources of contamination were identified at this site. Therefore, it appears that the sources of atrazine and nitrate contamination at this site were non-point.

E.4 Case D

The well was sampled twice, on June 29, 1989 and March 25, 1992. Atrazine and its degradation product, des ethyl atrazine, were detected in both samples (Table E.4). Nitrate-N exceeded the MAC of 10 mg/L in both samples. Bacteria were not detected in this well.

Table E.4 Detection history - case study D.

Analyte	Date Sampled (and Sample Number)	
	June 29, 1989	March 25, 1992
	(1)	(2)
Atrazine (μg/L)	0.650	0.310
Des Ethyl Atrazine (μg/L)	0.220	0.170
Nitrate-N (mg/L)	23.00	21.90
Bacteria (counts/100 ml)	N.D.	N.S.

N.D. = Not Detected N.S. = Not Sampled

Well records indicate that the well is a drilled well 155 feet deep, 6 inches in diameter, with 62 feet of casing. The well is buried and was not uncovered for detailed inspection. The well was reported to be 45 feet from the septic system and 400 feet from the manure storage facility (roofed concrete pit).

Atrazine was reported as being used on the farm in all of the last 6 years (1988 through 1992), but was applied by custom operator. Therefore no pesticide storage or sprayer loading and cleaning takes place on site. The farmer does not soil test, and does not use purchased fertilizer. All nutrient results from fall application and incorporation of chicken litter.

No point sources of contamination were identified at this site. Therefore, it appears that the sources of atrazine and nitrate contamination at this site were non-point.

E.5 Case E

The well was sampled once, on July 4, 1989. No follow up sampling was conducted at this site. Atrazine (0.030 μg/L) and its degradation product, des ethyl atrazine (0.080

μg/L) were detected in the sample. Nitrate-N was found at 14.50 mg/L which exceeded the MAC of 10 mg/L. Bacteria were also detected at a level of 15 counts/100 ml. This exceeded the action limit of 10 counts/100 ml.

Inspection of the well revealed that it is an old dug well 14 feet deep and 4 feet in diameter. It consists of rocked up sidewalls from bottom to top with a wooden cover. Results of the well inspection indicate that it is susceptible to surface runoff from the surrounding lawn and adjacent field.

The well is located approximately 250 feet from the septic system. Information on proximity to agricultural facilities was not provided. The well owner reported that atrazine had probably not been used on the adjacent land since before 1982.

Given the susceptibility of the well to surface water contamination, it was concluded that the bacterial and nitrate contamination resulted from point sources as overland flow. With atrazine reportedly not being used on the site for at least ten years, it is unknown whether atrazine contamination resulted from non-point sources or the residue of an old point source event.

E.6 Case F

The well was sampled twice, on August 3, 1989 and March 25, 1992. Atrazine and its degradation product, des ethyl atrazine, were detected in both samples (Table E.5). Nitrate-N levels were above the MAC of 10 mg/L in the first sample and below in the second. Bacteria were not detected in this well.

Table E.5 Detection history - case study F.

Analyte	Date Sampled (and Sample Number)	
	August 3, 1989	March 25, 1992
	(1)	(2)
Atrazine (μg/L)	0.250	0.200
Des Ethyl Atrazine (μg/L)	0.110	0.090
Nitrate-N (mg/L)	10.80	9.65
Bacteria (counts/100 ml)	N.D.	N.S.

N.D. = Not Detected N.S. = Not Sampled

This site contains two drilled wells which are combined as a single source. Well records indicate that the first well is 200 feet deep, 6 inches in diameter, with 70 feet of casing. The second well is 108 feet deep, 6 inches in diameter with 70 feet of casing. No distances to septic system or agricultural facilities were reported.

It was reported that atrazine has not been used on the fields adjacent to the site since before 1986. However, chlorothalonil has been used and was not detected in the well.

No point sources of contamination were identified at this site. Therefore, it appears that the sources of atrazine and nitrate contamination at this site were non-point.

E.7 Case G

The well was sampled twice, on August 16, 1989 and March 25, 1992. Atrazine and its degradation product, des ethyl atrazine, were detected in both samples (Table E.6). Nitrate-N was found to exceed the MAC of 10 mg/L in the first sample, but was below it in the second. Bacteria were not detected in this well.

Table E.6 Detection history - case study G.

Analyte	Date Sampled (and Sample Number)	
	August 16, 1989	March 25, 1992
	(1)	(2)
Atrazine (μg/L)	0.060	0.060
Des Ethyl Atrazine (μg/L)	0.080	0.070
Nitrate-N (mg/L)	11.80	6.74
Bacteria (counts/100 ml)	N.D.	N.S.

N.D. = Not Detected N.S. = Not Sampled

The well is buried and was not uncovered for detailed inspection. The well was reported to be a sand point, 25 to 30 feet deep, 1.25 inches in diameter with 25 to 30 feet of casing. No data on distances to septic system or agricultural facilities were reported.

No conclusions could be reached regarding the source of contamination for this well.

E.8 Case H

This well was sampled three times between July 27, 1989 and March 25, 1992. Atrazine and its degradation product, des ethyl atrazine, were detected in both samples (Table E.7). Nitrate-N levels in the well exceeded the MAC of 10 mg/L in all samples. Bacteria were reported in the wells in two of the samples, with a maximum level reported of 150 counts/100 ml.

Table E.7 Detection history - case study H.

Analyte	Date Sampled (and Sample Number)		
	July 27, 1989	Aug. 22, 1989	Mar. 25, 1992
	(1)	(2)	(3)
Atrazine (μg/L)	0.320	N.S.	0.400
Des Ethyl Atrazine (μg/L)	1.650	N.S.	1.900
Nitrate-N (mg/L)	17.20	16.00	18.50
Bacteria (counts/100 ml)	16	150	N.S.

N.D. = Not Detected N.S. = Not Sampled

Well records indicate that this is a drilled well, 65 feet deep, 6 inches in diameter, with 40 feet of casing. Inspection revealed that well is equipped with a pitless adaptor and the casing extends about six inches above ground. No obvious problems were found with the construction of the well that would lead to contamination but the well is located in a wet area and may be experiencing surface water infiltration.

The septic system was reported to be located approximately 35 feet from the well, with a pesticide storage area located approximately 120 feet from the well. The well is also located approximately 400 ft. down-gradient from an old manure holding pond which is no longer in use.

The well owner is not a farmer, however, an interview with the farmer who farms the adjacent lands, indicated that atrazine has not been used on the surrounding fields for "many" years.

Given the lack of use of atrazine, and the nature of the well, it was concluded that the atrazine contamination is likely non-point in nature. The presence of bacteria in the well would tend to indicate a well construction problem, but no clear source of bacterial or nitrate contamination could be identified. Therefore no conclusion could be reached on the source of the nitrate and bacterial contamination at this site.

E.9 Case I

The well was sampled once on July 25, 1989. Metribuzin (0.010 μg/L) was detected in the well. Nitrate-N was detected at 22.30 mg/L. This exceeded the MAC of 10 mg/L. Bacteria were not detected.

The well owner is deceased. As a result, the case was closed and no conclusions reached.

E.10 Case J

The well was sampled for inorganic parameters only on September 14, 1989. Nitrate-N levels of 46.10 were found. These exceeded the MAC of 10 mg/L.

Immediately upon receipt of the test results, the well owner abandoned the well. He reported that it was a shallow dug well with leaking crocks and was susceptible to overland flow from neighbouring fields and the yard of a poultry operation next door.

It was concluded that the well became contaminated by point sources through overland flow into a poorly constructed well.

E.11 Case K

This well was sampled twice, on September 7, 1989 and August 20, 1992. Nitrate-N levels exceeded the MAC of 10 mg/L in both samples (Table E.8). Bacteria were not detected in the well.

The well was reported to be a shallow well point, 2 inches in diameter of unknown depth. Due to buried nature of the well and its unknown location, no inspection was possible. No information was provided on the proximity of the well to the septic system. The well owner is not a farmer, so information on proximity to agricultural facilities is inapplicable.

No information was available on pesticide/fertilizer use on the fields adjacent to the well. No other sources of contamination were identified.

Due to the unavailability of data, no conclusions on contamination sources were possible.

Table E.8 Detection history - case study K.

Analyte	Date Sampled (and Sample Number)	
	September 7, 1989	August 20, 1992
	(1)	(2)
Pest Control Products	N.S.	N.S.
Nitrate-N (mg/L)	24.70	26.0
Bacteria (counts/100 ml)	N.S.	0

N.D. = Not Detected N.S. = Not Sampled

E.12 Case L

This well was sampled twice, on September 7, 1989 and August 20, 1992. Nitrate-N levels exceeded the MAC of 10 mg/L in both samples (Table E.9). Bacteria were not detected in the well.

Table E.9 Detection history - case study L.

Analyte	Date Sampled (and Sample Number)	
	September 7, 1989	August 20, 1992
	(1)	(2)
Pest Control Products	N.S.	N.S.
Nitrate-N (mg/L)	21.5	19.5
Bacteria (counts/100 ml)	N.S.	0

N.D. = Not Detected N.S. = Not Sampled

The well was reported to be an old well point of unknown depth, condition, or location. No well inspection was therefore possible. A new well was drilled in late 1992 to a depth of 45 feet with 40 feet of casing. A sample collected from this well showed a nitrate-N level of 21.0 mg/L. No data on proximity to septic system, agricultural operations and pesticide use were available.

Given that the new drilled well had nitrate levels almost equal those of the old well, it was concluded that the aquifer in this area may be contaminated. Therefore, the conclusion reached was that the original well became contaminated by non-point sources.

E.13 Case M

This well was sampled twice, on September 14, 1989 and August 20, 1992. Nitrate-N levels exceeded the MAC of 10 mg/L in both samples but the levels were considerably lower in the second sample (Table E.10). Bacteria were not detected in the well.

Table E.10 Detection history - case study M.

Analyte	Date Sampled (and Sample Number)	
	September 14, 1989	August 20, 1992
	(1)	(2)
Pest Control Products	N.S.	N.S.
Nitrate-N (mg/L)	32.8	13.6
Bacteria (counts/100 ml)	N.S.	0

N.D. = Not Detected N.S. = Not Sampled

Inspection of the well revealed that it is an old dug well 28 feet deep and 3 feet in diameter. It consists of rocked up sidewalls from bottom to top with a wooden cover. Since the well has a rocked wall construction, it may be subject to surface water contamination. No nearby sources of contamination were identified.

Well construction was the most likely reason for the elevated nitrate-N levels found, however, no clear evidence was found. Therefore it was determined that this case would be recorded as source unknown.

E.14 Case N

This well was sampled three times between July 20, 1989 and August 20, 1992, for inorganic parameters and bacteria. Nitrate-N levels were found to be very low in all samples (Table E.11). However, bacteria levels were found to exceed the action limit of 10 counts/100 ml in two of the three samples.

Table E.11 Detection history - case study N.

Analyte	Date Sampled (and Sample Number)		
	July 20, 1989	July 10, 1990	Aug. 20, 1992
	(1)	(2)	(3)
Pest Control Products	N.S.	N.S.	N.S.
Nitrate-N (mg/L)	0.38	0.37	0.05
Bacteria (counts/100 ml)	260	0	20

N.D. = Not Detected N.S. = Not Sampled

The well was reported to be an old, spring-fed well. Inspection of the well revealed that it consisted of two, 3 ft.- diameter concrete crocks sitting on top of one another to a depth of 4 feet. The concrete cover was cracked and there was evidence of surface water contamination. On the day of inspection, two dead field mice were found in the well. The homeowner added a new spring-fed well in the same area as the old well but with a greater depth and better construction. Due to the superior water quality of the new well, the homeowner was advised to discontinue use of the old well.

Both wells are located along the brow of the South Mountain in an area where springs are known to occur. The water is gravity fed to the house which is over 500 feet downslope from the wells. As such the wells are also up-gradient from the septic system and other sources of agricultural contamination.

It was concluded that the old well became contaminated with bacteria as a result of point sources and poor well construction.

E.15 Case O

This well was sampled three times between August 10, 1989 and May 26, 1992. Alachlor and chlorothalonil were found in the well during at least one of the sampling periods (Table E.12). Nitrate-N levels were found to be low or non-detected, but the well was found to contain bacterial contamination.

The well was reported to be a shallow, spring-fed well consisting of one crock in the ground. The well is located along the side of the North Mountain in an area where springs are known to occur. The water is gravity fed to the house which is over 500 feet downslope from the well. The well is up-gradient from the household septic system but there are cropped fields around the general area of the well that could act as a source of contamination.

Table E.12 Detection history - case study O.

Analyte	Date Sampled (and Sample Number)		
	Aug. 10, 1989	July 5, 1990	Mar. 26, 1992
	(1)	(2)	(3)
Alachlor (μg/L)	N.D.	0.10	N.S.
Chlorothalonil (μg/L)	0.065	N.D.	N.S.
Nitrate-N (mg/L)	0.86	0.35	N.D.
Bacteria (counts/100 ml)	80	N.S.	0

N.D. = Not Detected N.S. = Not Sampled

Chlorothalonil was reported to have been used in close proximity to the well in each of the years from 1988 through 1992. As well, malthion was reported to have been used in 1988 and permethrin in 1990.

Given the location of the well and the proximity to chlorothalonil spray, it is concluded that the chlorothalonil detected in 1989 resulted from spray drift into a susceptible well (i.e. point source contamination). It was concluded that the bacterial contamination was also the result of poor well construction.

E.16 Case P

This well was sampled three times between August 3, 1989 and August 20, 1992. Pesticides were not detected at this site (Table E.13) and nitrate-N levels were found to be low. Bacteria levels greatly exceeded the action limit of 10 counts/100 ml in the first sample.

Well records indicate that this is a drilled well, 300 feet deep, 6 inches in diameter, with 35 feet of casing. Inspection revealed that well is equipped with a pitless adaptor and the casing extends about one foot above ground. The owner reported a problem with earwigs in the well which was most likely the cause of the high bacteria result in the first sample. A new, screened well cap was installed and subsequent testing indicated bacteria counts of 0 and 2. Due to the low bacteria count in the last sample, the well owner was advised to disinfect the well again as it may not have been complete the first time. No other problems were found with the construction of the well.

Table E.13 Detection history - case study P.

Analyte	Date Sampled (and Sample Number)		
	July 20, 1989	July 10, 1990	Aug. 20, 1992
	(1)	(2)	(3)
Pest Control Products	N.D.	N.S.	N.S.
Nitrate-N (mg/L)	0.60	0.48	1.10
Bacteria (counts/100 ml)	260	0	2

N.D. = Not Detected N.S. = Not Sampled

The well was reported to be located 250 feet from the septic system and 170 feet from the manure storage facility. Pesticides are not stored on the site. The well owner did not have records on pesticide use.

It was concluded that this well became contaminated by bacteria as a result of a point source problem (earwigs).

E.17 Case Q

This well was sampled three times between July 4, 1989 and August 20, 1992. Atrazine and its degradation products, des ethyl atrazine and des isopropyl atrazine, were detected in at least one sample (Table E.14). Nitrate-N was found to exceed the MAC of 10 mg/L in two samples, and the well was found to contain bacteria exceeding the 10 counts/100 ml action limit in one sample.

Inspection of the well revealed that it is a dug well 14 feet deep and consisting of 3 ft.-diameter concrete crocks. The top crock extends 1.5 feet above ground level and is fitted with a concrete cover. The top crock was observed to be displaced and there was evidence of surface water seepage between the top two crocks. The well is located adjacent to a cropped field and down-gradient from a private garden. It was reported that the septic system was located 250 feet from the well. No agricultural facilities are located on the site so proximity to these was not reported.

Table E.14 Detection history - case study Q.

Analyte	Date Sampled (and Sample Number)		
	July 4, 1989	Mar. 25, 1992	Aug. 20, 1992
	(1)	(2)	(3)
Atrazine (μg/L)	0.260	0.220	N.S.
Des Ethyl Atrazine (μg/L)	0.230	0.190	N.S.
Des Isopropyl Atrazine (μg/L)	0.010	N.D.	N.S.
Nitrate-N (mg/L)	18.90	22.80	N.S.
Bacteria (counts/100 ml)	12	0	0

N.D. = Not Detected N.S. = Not Sampled

No records of pesticide use were available, but the well owner indicated that atrazine had not been used for at least 10 years. Fertilizer and manure records did not exist for the field, however, the well owner reported using 200 lbs. of 12-24-24 on the garden every year.

The location and construction of the well were determined to be the primary factors leading to contamination by nitrate-N and bacteria. Given the lack of atrazine use in recent years, it is unknown whether atrazine contamination was due to non-point sources or an old point source event.

APPENDIX F: GLOSSARY OF TERMS

Alluvium: Material such as clay, silt, sand, and gravel deposited by modern rivers and streams.

Aquifer: Stratum or zone below the surface of the earth capable of producing water as from a well.

Atrazine: A triazine herbicide, 6-chloro-N^2-ethyl-N^4-isopropyl-1,3,5-triazine-2,4-diamine, used as a selective pre- and post- emergence herbicide used to control many weeds in asparagus, forestry, grasslands, grass crops, maize, pineapple, roses, sorghum, sugarcane and non-selectively in non-crop areas.

Azinphosmethyl: An organophosphorus insecticide, S-3,4-dihydro-4-0x0-1,2,3-benzotriazin-3-=ylmethyl 0,0 diethyl phosporodithioate, used as a non-systemic insecticide and acaricide with good ovicidal properties and long persistence on cotton, top fruit, grapes, vegetables and other crops to control species in the orders Coleoptera, Homoptera, and Lepidoptera.

Basalt: Any fine-grained, dark-coloured igneous rock.

Bedrock: Any solid rock exposed at the surface of the earth or overlain by unconsolidated material.

Captan: A phthalimide fungicide, N-(trichloromethylthio)cyclohex-4-ene-1,2-dicarboximide, used to control diseases of many fruit, ornamental and vegetable crops, including Venturia inaqualis of apples and V. pririna of pears. It is also used as a spray, root dip or seed treatment, to protect young plants against rots and damping-off.

Chlorfenvinphos: An organophosphorus insecticide, 2-chloro-1-(2,4-dichloro-phenyl)vinyl diethyl phosphate, used for the control of root flies, rootworms, cutworms, colorado potato beetles, leaf hoppers, and stem borers.

Chlorothalonil: A chlorophenyl fungicide , Tetrachloroisophtalonitrile, used as a broad spectrum foliage protectant fungicide effective against pathogens of vegetable, agronomic, ornamental tree and small fruit crops and turf.

Conglomerate: Rounded waterworn fragments of rock or pebbles, cemented together by another mineral substance.

Contamination: The presence of a deleterious or unwanted substance.

Deltamethrin: A pyrethroid insecticide, (S)- -cyano-3-phenoybenzyl (1R)-cis-3-(2,2-dibromovinyl)-=dimethylcyclopropanecarboxtlate. Crop protection uses include: Coleoptera, Heteroptera, Homoptera, Lepidoptera, and Thysanoptera. It controls Acrididae and is recommended against locusts. Soil surface sprays control Noctuidae.

It is used against crawling and flying insects and pests of stored grain and timber: Blattodea, Culicidae, and Muscidae. Dip or spray and pour-on applications give good control of Muscidae, Tabanidae, Ixodidae and other Acari an cattle, sheep and pigs etc.

Des ethyl atrazine: A daughter or degradation product of atrazine generally formed as a result of microbial decomposition.

Dimethoate: An organophosphorus insecticide, 0,0-Dimethyl S-(methylcarbamoyl-methyl) phosporodithioate, used for control of aphids, mites, leafminers, thrips, and leafhoppers on specific ornamentals, forest plantations and various fruits, vegetable, forage and grain crops.

Glacial till: Unstratified glacial drift deposited directly by the ice and consisting of clay, sand, gravel, and boulders intermingled in any proportion.

Glaciofluvial: Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces.

Granite: Any light-coloured, coarse-grained igneous rock.

Groundwater: Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

Hydraulic conductivity: The rate at which water can flow through bedrock or soil material under saturated conditions (expressed in cm per second).

Igneous rocks: Formed by the solidification from a molten or partially molten state.

Malthion: An organophosphorus insecticide, diethyl (dimethoxyphosphinothioyl-thio)succinate, used as a non-systemic insecticide and acaricide to control Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera in a wide range of crops including cotton, pome, soft and stone fruit, potatoes, rice, and vegetables. Used extensively to control major arthropod disease vectors (Culicidae) in public health programs, ectoparasites (Diptera, Acari, Mallophaga) of cattle, poultry, dogs and cats, human head and body lice (Anoplura), household insects (Diptera, Orthoptera) and for protection of stored grain.

Metamorphosed: Formed in the solid state in response to pronounced changes of temperature, pressure and chemical environment.

Metasediments: Partly metamorphosed sedimentary rocks.

Net recharge: The amount of water per unit area of land which penetrates the ground surface and reaches the water table.

Palaeozoic: One of the eras of geologic time - that between the Precambrian and Mesozoic - comprised of rocks between approximately 240 and 570 million years old.

Parameter: Any quantifiable or qualifiable entity that is measured or assessed in an experiment (i.e. if measuring growth, parameters might include height, width, weight etc.).

Permeable: Allowing the penetration and transmission of gases or liquids.

Permethrin: A pyrethroid insecticide, 3-=phenoxybenzyl (1RS)-cis-trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate, used as a contact insecticide effective against a broad range of pests. It controls leaf- and fruit-eating lepidopterous and coleopterous pests in cotton, fruit, tobacco, vine and other crops, and vegetables. It has good residual activity on treated plants. It is effective against a wide range of animal ectoparasites, provides residual control of biting flies in animal housing and is effective as a wool preservative.

Pest control product: Any product or agent, either chemical or biological used for the control of insect, fungal, disease, or weed pests.

Pesticide: See pest control product.

Pleistocene: The earlier of the two epochs of geologic time that constitute the Quaternary Period and comprised of strata deposited between 10,000 and 2 million years ago (also known as the glacial age).

Quartzite: A granulose metamorphic rock consisting essentially of quartz, i.e. metamorphosed sandstone.

Sandstone: A cemented or otherwise compacted sedimentary rock composed predominantly of quartz grains.

Shale: A laminated sedimentary rock in which the constituent particles are predominantly of the clay grade.

Siltstone: A very fine-grained sedimentary rock composed predominantly of particles of silt grade.

Slate: A fine-grained metamorphic rock that cleaves naturally into thin, smooth-surfaced layers, i.e. metamorphosed shale.

Sub-basin: The area drained by a tributary stream within a watershed.

Surficial geology: Pertaining to the unconsolidated residual, alluvial or glacial deposits lying on bedrock.

Triassic: The earliest of the three periods of the Mesozoic era and comprised of strata deposited between 205 and 240 million years ago.

Vadose zone: The zone above the water table which is unsaturated.

Vorlex: A synergistic pre-plant soil fumigant, 20% methyl isothiocyanide and 80% chlorinated C_3 hydrocarbons, possessing broad activity against fungi, nematodes, weeds and soil insects.

Watershed: The area drained by a river.

Well water: Water from an artificial opening in the ground made for the purpose of exploring or obtaining water.