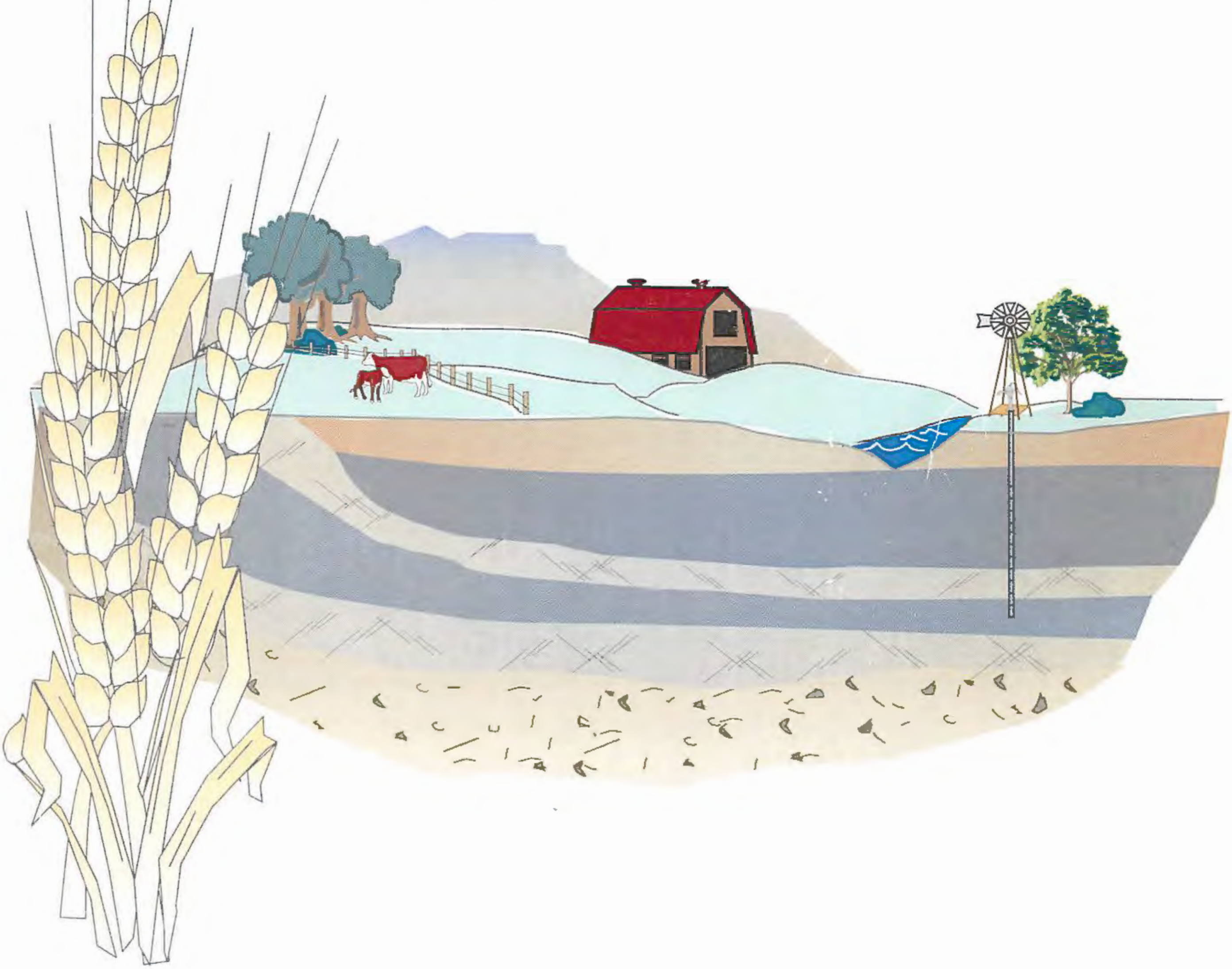
CAESA Canada - Alberta Environmentally Sustainable Agriculture Agreement

AGRICULTURAL IMPACTS ON WATER QUALITY IN ALBERTA

- An Initial Assessment -



Canada Agriculture - Building a Healthy Environment Alberta

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- An Initial Assessment -

CAESA

Canada - Alberta Environmentally Sustainable Agriculture Agreement

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* *former committee member*

In Memory of Elliot Allison

1943 - 1994

Elliot Allison was a dedicated and valuable member of the CAESA Water Quality Committee until his untimely passing. He is particularly remembered for promoting and initiating the Provincial Farmstead Water Quality Survey. This survey has proven to be a vital part of the Water Quality Study.

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LIST OF FIGURES.

LIST OF TABLES.

ABOUT THE REPORT

This report presents the findings of the Water Quality Study, conducted under the Canada-Alberta Environmentally Sustainable Agriculture (CAESA) agreement. [Figure 1 shows the geographic locations of the monitoring and research projects which comprise the basis of the study.]

Section 1. Background
Provides information on the study background: 1) CAESA and its mandate, 2) the growth of Alberta's agricultural industry, and 3) the need for baseline water quality information.

Section 2. Study Approach
Provides information on methodology, data analysis and constraints of the study.

Section 3. Key Study Findings
Summarizes the key findings of the study. This core document gives general and specific results, and recommendations derived from these results.

Section 4. Farm Application of Study Results
Provides some practical applications of the study results for agricultural producers, particularly in terms of management practices for an environmentally sustainable agricultural economy.

Appendix A. Project Summaries
Provides the supporting data for the key findings. A summary is presented for each of the major CAESA water quality monitoring or research projects, as well as for associated projects which relate specifically to the water quality study.

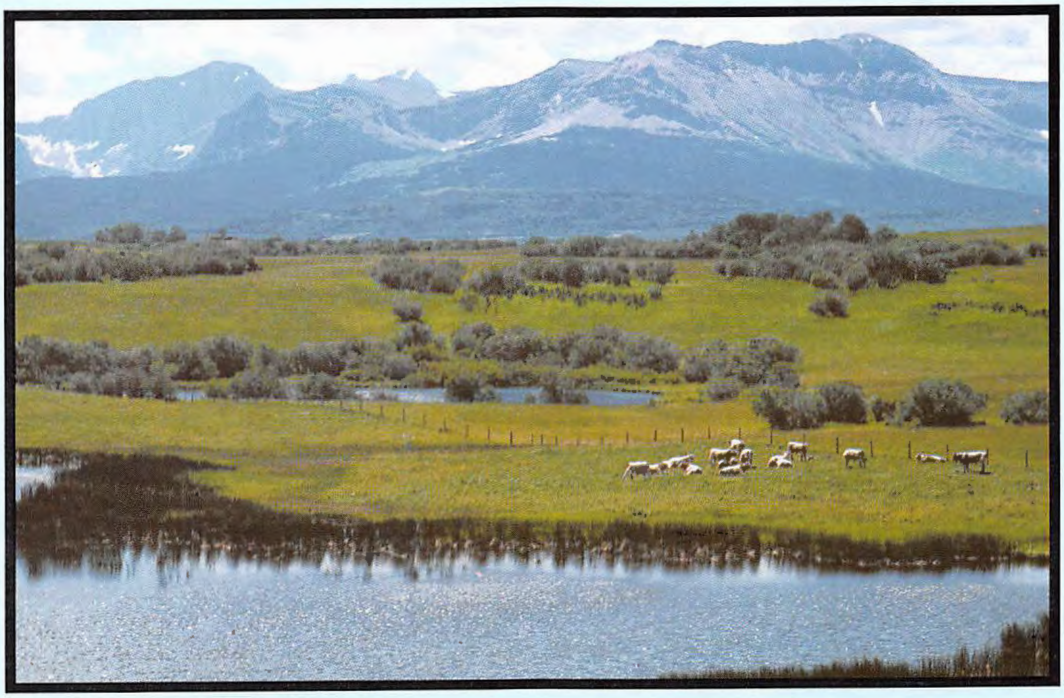
Appendix B. Detailed Assessment
A detailed assessment and discussion of the overall data. Contaminant detections from the monitoring work are compared to water quality guidelines.

Appendix C. For More Information

1. A glossary is provided to help readers with non-technical backgrounds more fully understand the concepts and discussion in the report.
2. Complete references for the specific project documents on which this report is based.

Section 1.

Background



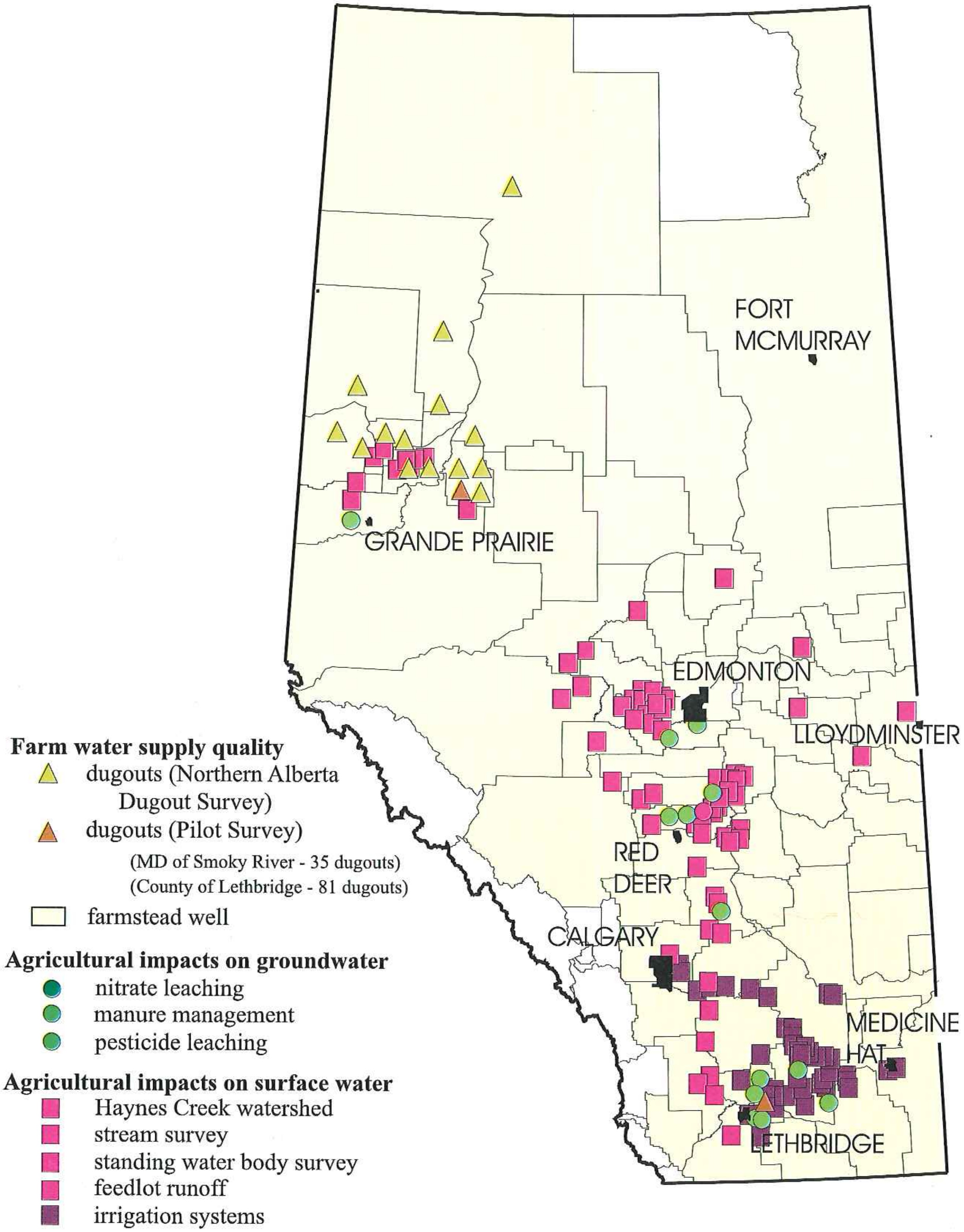


Figure 1. Locations of CAESA water quality project sites.

BACKGROUND

Human Impacts on Water Quality

Water quality is of critical concern because it influences the health of humans and other living organisms. Human activities can affect water quality, either directly or indirectly, by affecting land use. Agriculture, municipal land use, forestry, resource extraction, and the processing of primary materials are among the many activities that can impact water quality. Figure 2 provides an overview of potential water quality impacts.

Agricultural sources of water contaminants include:

- field runoff, which can carry sediments, pesticides and nutrients into surface waters;
- runoff from livestock operations, which can contribute nutrients and disease-causing organisms to surface waters; and
- the leaching of pesticides and nutrients into groundwater from agricultural activities.

Growth of Agriculture

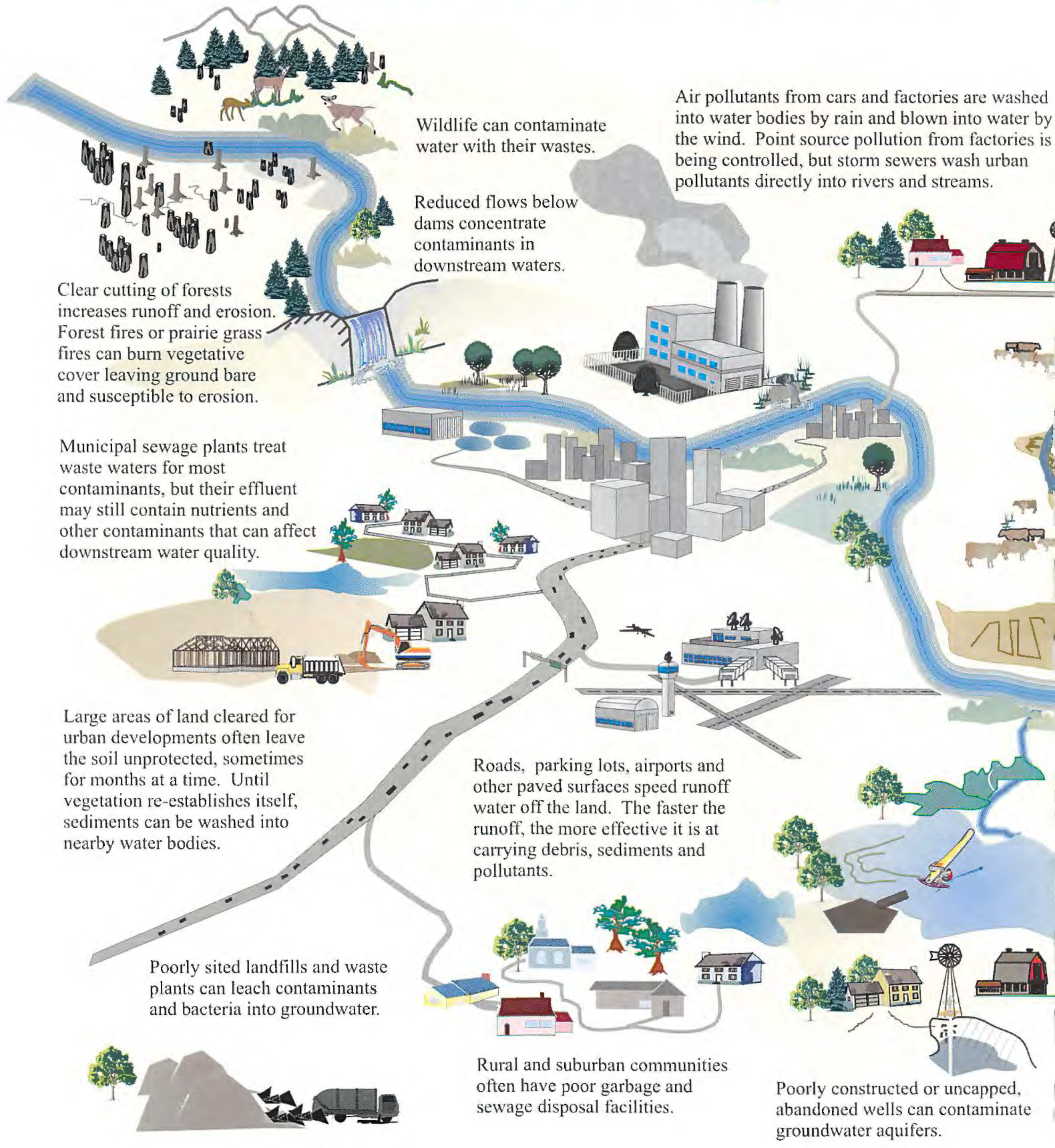
The agricultural industry, in Alberta and elsewhere, has experienced significant growth in the last 25 years. Farm acres on which commercial pesticides and fertilizers are used have almost tripled in Alberta. The number of cattle has increased more than 50%, with the province now producing almost 40% of all beef raised in Canada. More than 65% of Canada's beef cattle are finished in Alberta's feedlots.

Assessments of future international market opportunities for Alberta's food products support the growth of the primary agricultural sector from $6 billion to $10 billion by 2005. These assessments also show opportunities exist to support the growth of the value-added processing sector from $6 billion to $20 billion by that year. If not properly managed, this kind of agricultural growth has the potential to put Alberta's water resources under increased risk of degradation.

Successful Alberta farmers realize that balancing this agricultural growth with a clean environment is a vital part of doing business in today's world marketplace. In many parts of the world, our reputation for clean soil, clean water and clean food has given our agricultural industry a significant competitive edge. Compared to the United States — where U.S. government agencies now estimate 50% to 70% of their assessed surface waters have been contaminated by agriculture — Canada has a 'green' image. In the many global markets looking for environmentally friendly and healthy foods, that image translates into healthy profits.

The agricultural industry has an important role to play in protecting water quality in Alberta, in part because agriculture occupies such a large proportion of the province's land base, and in part because agricultural producers are themselves major users of water resources. Further growth of an industry with such a critical resource base will be an enormous challenge, one requiring good farm management practices and more information on agriculture and the environment.

Figure 2. *IMPACTS ON WATER QUALITY*



Wildlife can contaminate water with their wastes.

Air pollutants from cars and factories are washed into water bodies by rain and blown into water by the wind. Point source pollution from factories is being controlled, but storm sewers wash urban pollutants directly into rivers and streams.

Reduced flows below dams concentrate contaminants in downstream waters.

Clear cutting of forests increases runoff and erosion. Forest fires or prairie grass fires can burn vegetative cover leaving ground bare and susceptible to erosion.

Municipal sewage plants treat waste waters for most contaminants, but their effluent may still contain nutrients and other contaminants that can affect downstream water quality.

Large areas of land cleared for urban developments often leave the soil unprotected, sometimes for months at a time. Until vegetation re-establishes itself, sediments can be washed into nearby water bodies.

Roads, parking lots, airports and other paved surfaces speed runoff water off the land. The faster the runoff, the more effective it is at carrying debris, sediments and pollutants.

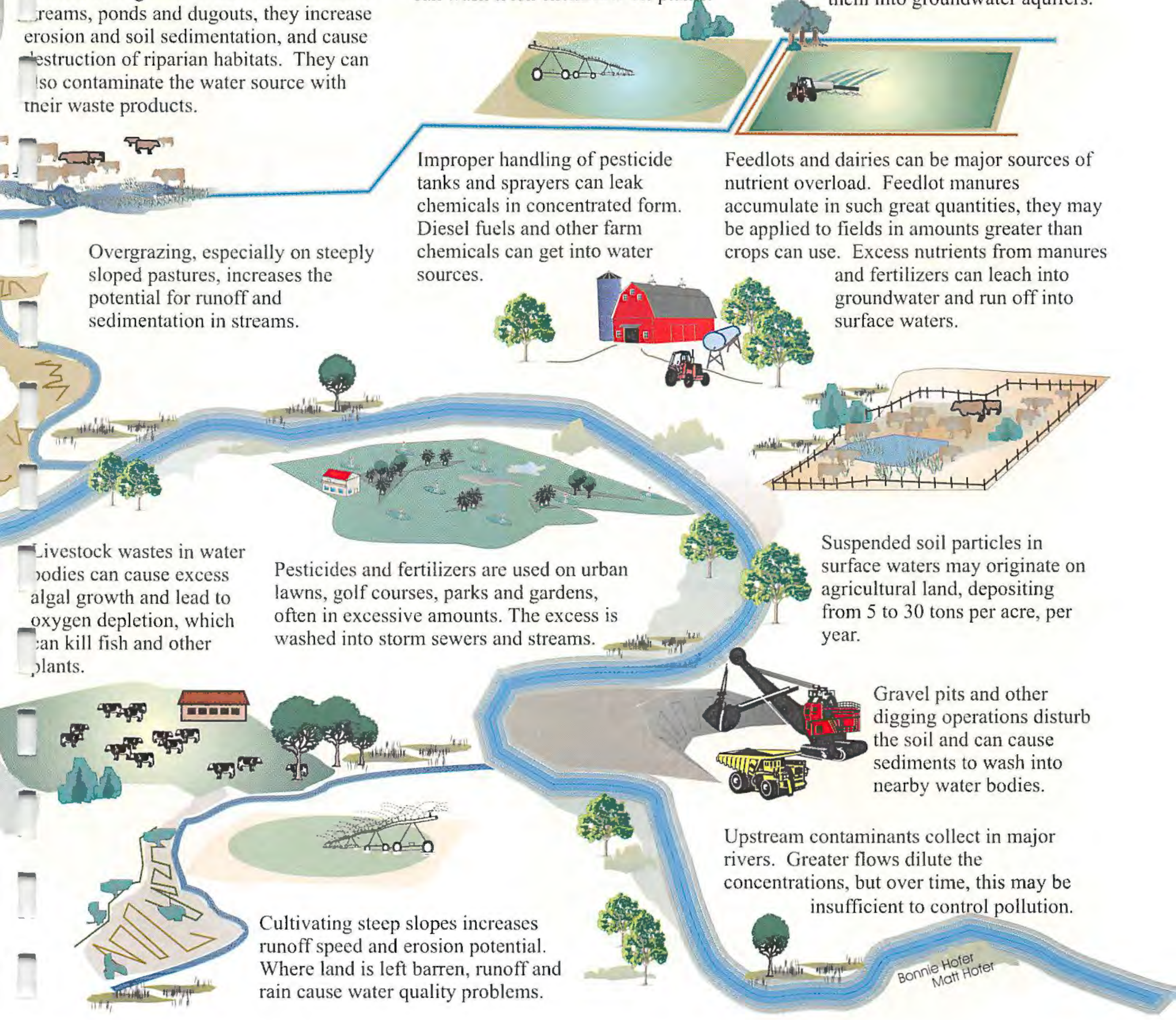
Poorly sited landfills and waste plants can leach contaminants and bacteria into groundwater.

Rural and suburban communities often have poor garbage and sewage disposal facilities.

Poorly constructed or uncapped, abandoned wells can contaminate groundwater aquifers.

- AN OVERVIEW

This booklet is about the possible impacts of agriculture on the water quality of our streams, lakes and groundwater resources. However, industry, municipalities, and just plain living can also have negative impacts on water quality. Here are some of the ways the water we need for drinking, food production, personal hygiene and recreation can be adversely affected by the things we do.



Feeding grounds and cattle wintering sites are often located near natural water sources or dugouts. When livestock enter streams, ponds and dugouts, they increase erosion and soil sedimentation, and cause destruction of riparian habitats. They can also contaminate the water source with their waste products.

Irrigation return flows can add field runoff and contaminants to streams. Poorly timed irrigation, spring snow melt or storm events can wash fresh chemicals off plants.

Rain and irrigation water can wash pesticides and fertilizers into streams and ponds and leach them into groundwater aquifers.

Improper handling of pesticide tanks and sprayers can leak chemicals in concentrated form. Diesel fuels and other farm chemicals can get into water sources.

Feedlots and dairies can be major sources of nutrient overload. Feedlot manures accumulate in such great quantities, they may be applied to fields in amounts greater than crops can use. Excess nutrients from manures and fertilizers can leach into groundwater and run off into surface waters.

Overgrazing, especially on steeply sloped pastures, increases the potential for runoff and sedimentation in streams.

Livestock wastes in water bodies can cause excess algal growth and lead to oxygen depletion, which can kill fish and other plants.

Pesticides and fertilizers are used on urban lawns, golf courses, parks and gardens, often in excessive amounts. The excess is washed into storm sewers and streams.

Suspended soil particles in surface waters may originate on agricultural land, depositing from 5 to 30 tons per acre, per year.

Gravel pits and other digging operations disturb the soil and can cause sediments to wash into nearby water bodies.

Upstream contaminants collect in major rivers. Greater flows dilute the concentrations, but over time, this may be insufficient to control pollution.

Cultivating steep slopes increases runoff speed and erosion potential. Where land is left barren, runoff and rain cause water quality problems.

The Need for Water Quality Information

In addition to the growth of the agricultural industry, other factors pointed to the need for more information on water quality in the province. By 1992 reports from Europe and other parts of North America identified agriculture as a major cause of water quality degradation.

The situation in Alberta was not well defined. Federal and provincial monitoring efforts focused mainly on fixed locations in major river basins in the National Parks, at provincial and international boundaries, and at key locations above and below major cities. Information from these monitoring stations is currently being compiled to assess overall water quality in the main river systems.

However, few long-term sampling sites were located on tributary streams and small lakes in agricultural areas. Limited information on groundwater quality existed for the province. The few field studies that specifically evaluated agricultural impacts on water quality suggested the potential for negative impacts.

CAESA and Water Quality

The overall goal of the CAESA agreement was to improve resource management and growth of the agri-food industry by promoting environmentally sustainable practices in agricultural production and processing. Developed through consultations with industry and other stakeholder groups, the agreement's mandate identified water quality as an emerging environmental issue in Alberta's agricultural areas. CAESA also recognized that protecting water quality is important for the agricultural industry, because good quality water is needed to produce healthy crops and livestock.

It was also apparent that minimizing impacts on water quality is necessary to maintain the advantage the province enjoys as a producer and marketer of clean food in a clean environment. As a member of the world community, it is felt Alberta should play its part in safeguarding the world's water resources.

To achieve these aims, the Water Quality Committee was formed, with representatives from Alberta Agriculture, Food and Rural Development, Agriculture and Agri-Food Canada (Research Branch and Prairie Farm Rehabilitation Administration), Alberta Environmental Protection, Alberta Health, and Environment Canada. Additional support was provided by the Regional Health Authorities and the Irrigation Districts. Farmers, livestock producers and others in the industry cooperated in field studies and lent additional support.

Funding and Support

Funding for the water quality projects was provided through several CAESA programs and through non-CAESA sources. The CAESA water quality monitoring component provided $1.6 million to complete 10 monitoring and research projects during the 5-year program. A further $3.2 million was provided by Alberta Agriculture, Food and Rural Development, Agriculture and Agri-Food Canada, Alberta Environmental Protection, and Alberta Health. The CAESA Research Program funded six other water quality projects, to the amount of $758,000. The results of several research and monitoring projects, carried out by other government and non-government agencies, were also incorporated into this study. All primary source reports used in this study are referenced in Appendix D.

Water Quality Study Objectives

The five-year CAESA Water Quality Study was developed to provide data on the impacts of primary agriculture on water quality in Alberta's agricultural areas. The data are essential to provide researchers, program planners and policy makers with information on the current state of Alberta's resources, and as a basis for developing appropriate policies and programs.

CAESA water quality projects were designed to:

- conduct baseline water quality monitoring on Alberta's surface waters, groundwater, and farmstead water supplies, to gain a better understanding of the state of the water resource in agricultural areas;
- research and assess the potential for agriculture to impact water quality;
- develop communications to provide the agricultural industry with the best available information on protecting water quality.

Section 2.

Study Approach

STUDY APPROACH

The CAESA Water Quality Study incorporated information from a number of projects carried out during the five-year program. The following gives a brief description of the major projects completed.

Monitoring Projects

Results from three major monitoring projects were used to develop the baseline information for this study.

Farmstead Wells and Dugouts

In 1994, 190 farm wells or dugouts, in three municipalities, were selected at random for a pilot project. Based on this work, an additional 824 farmstead wells, randomly selected from nearly every rural municipality in the province, were sampled on a one-time basis in 1995 and 1996. In addition, 14 farmstead dugouts in northern Alberta were tested more frequently, to study annual variations in dugout water quality (Figure 3).

Surface Waters

A representative selection of surface water bodies in agricultural areas were monitored and analysed for potential farm contaminants. A total of 27 streams and 25 lakes, from runoff-prone landscapes, were selected in areas representing the full range of agricultural intensity. Figures 4 and 5 show the location of the selected streams and small lakes, respectively.

Data from the 1991 Census and other information on livestock density, fertilizer expenses and pesticide sales defined the factors used for the selection of representative project areas. Figure 6 shows fertilizer and pesticide sales, and livestock densities for the selected survey streams.

"High Intensity" areas include those in the top 25% of livestock numbers, and pesticide and fertilizer sales for the province. "Moderate Intensity" areas include the middle 26% to 75%, of chemical inputs and livestock numbers. "Low Intensity" areas include the bottom 25%.

Irrigation Canals

Results were summarized from a number of monitoring projects which had been conducted on southern Alberta's irrigation canals from 1992 to 1996, in six irrigation districts. The initial work was carried out by the Irrigation Districts, or by Alberta Agriculture, Food and Rural Development, separately from CAESA work. Sampling was carried out at several locations where water enters an irrigation district and at return flow sites, where unused irrigation water flows back to the river or main channels (Figure 7).

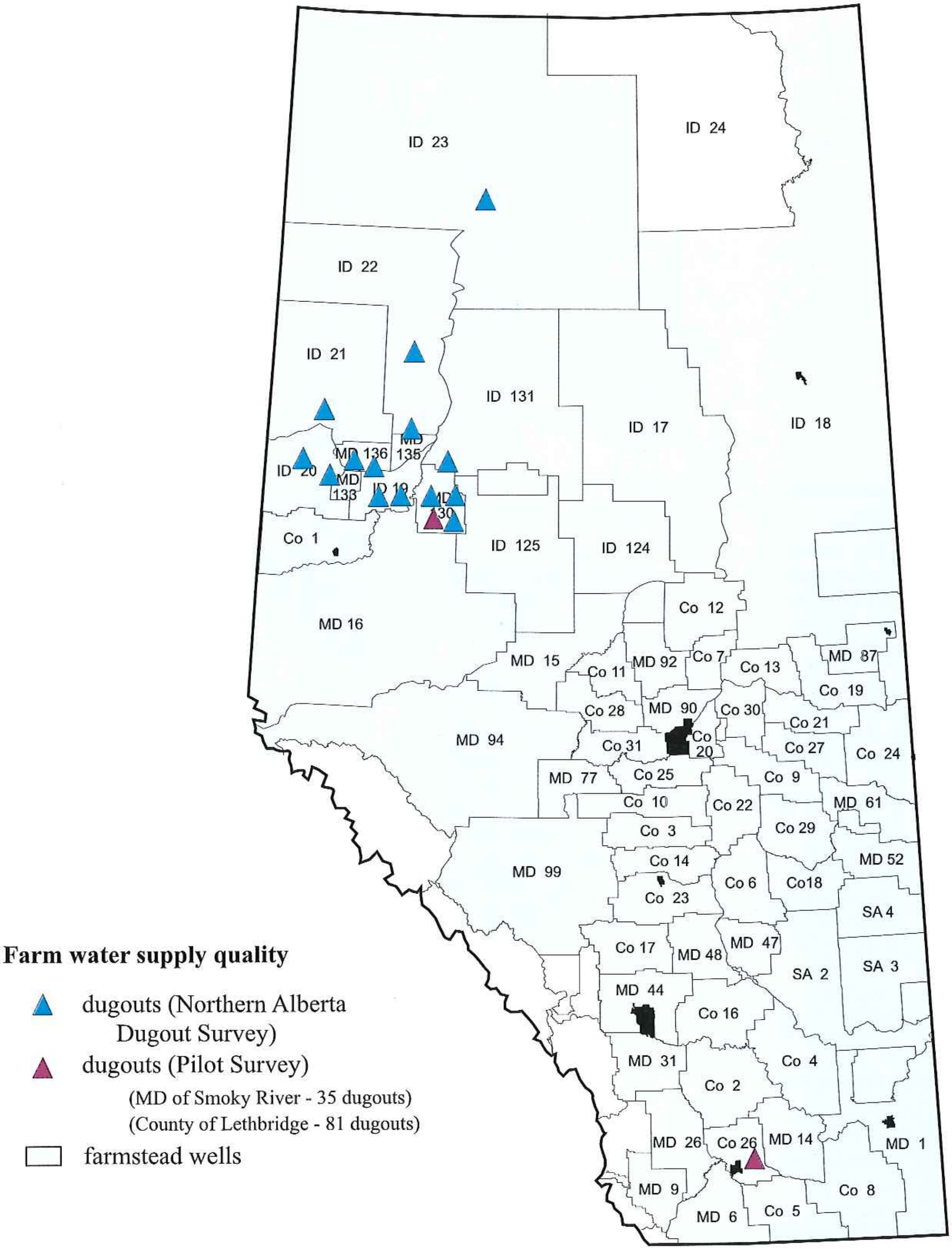


Figure 3. Farmstead water quality survey sites.

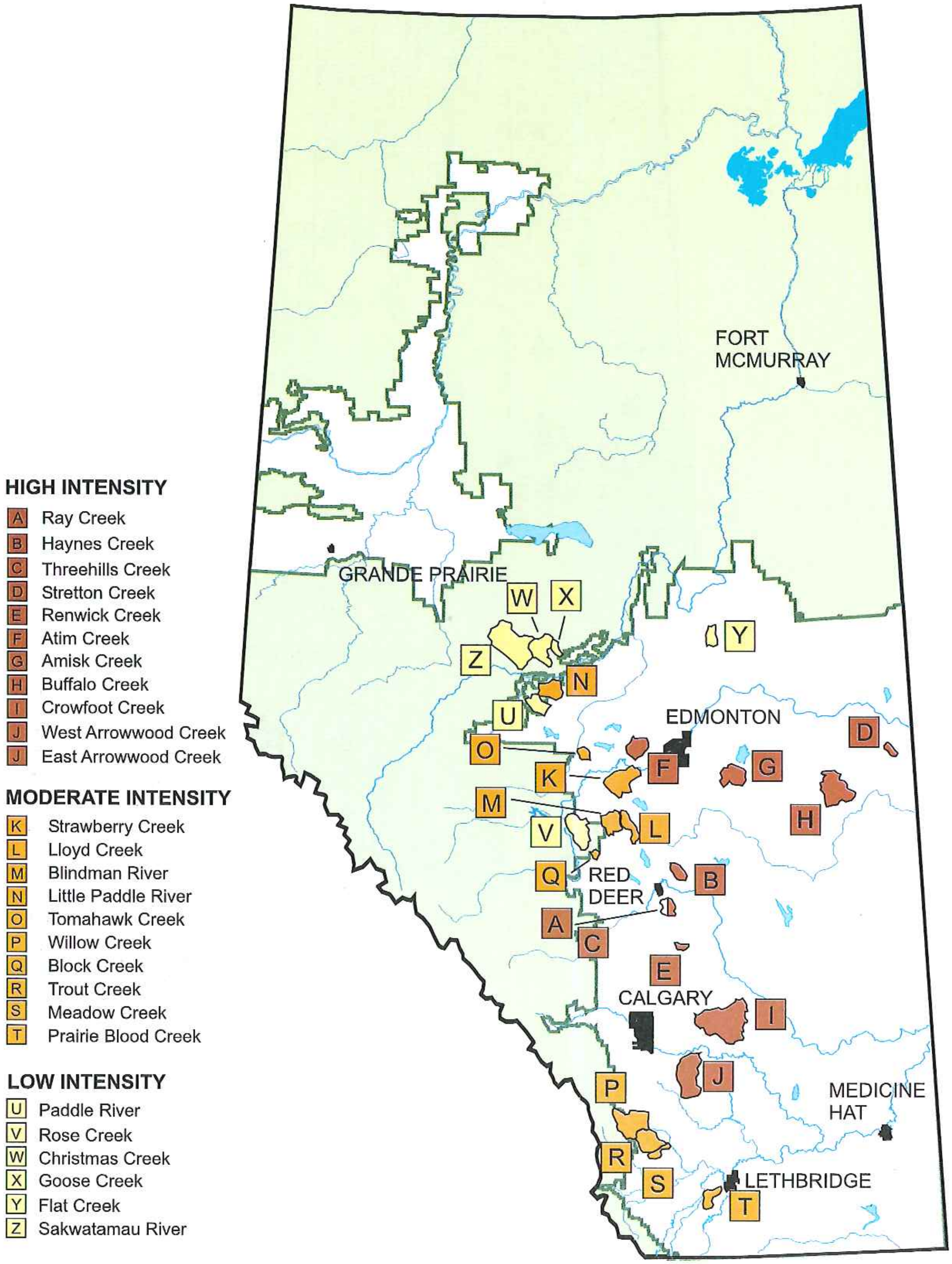


Figure 4. Location of survey streams.

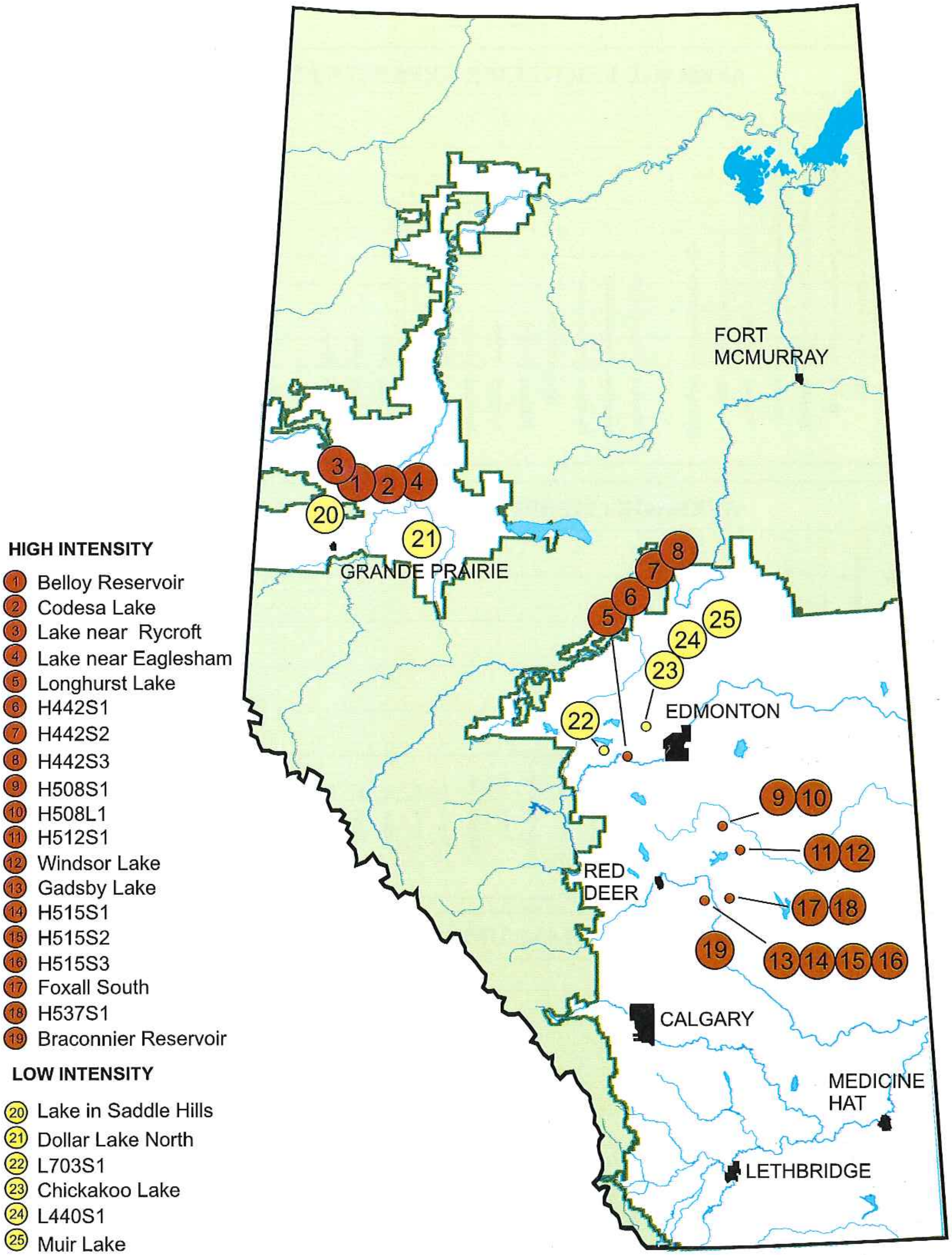


Figure 5. Location of survey lakes.

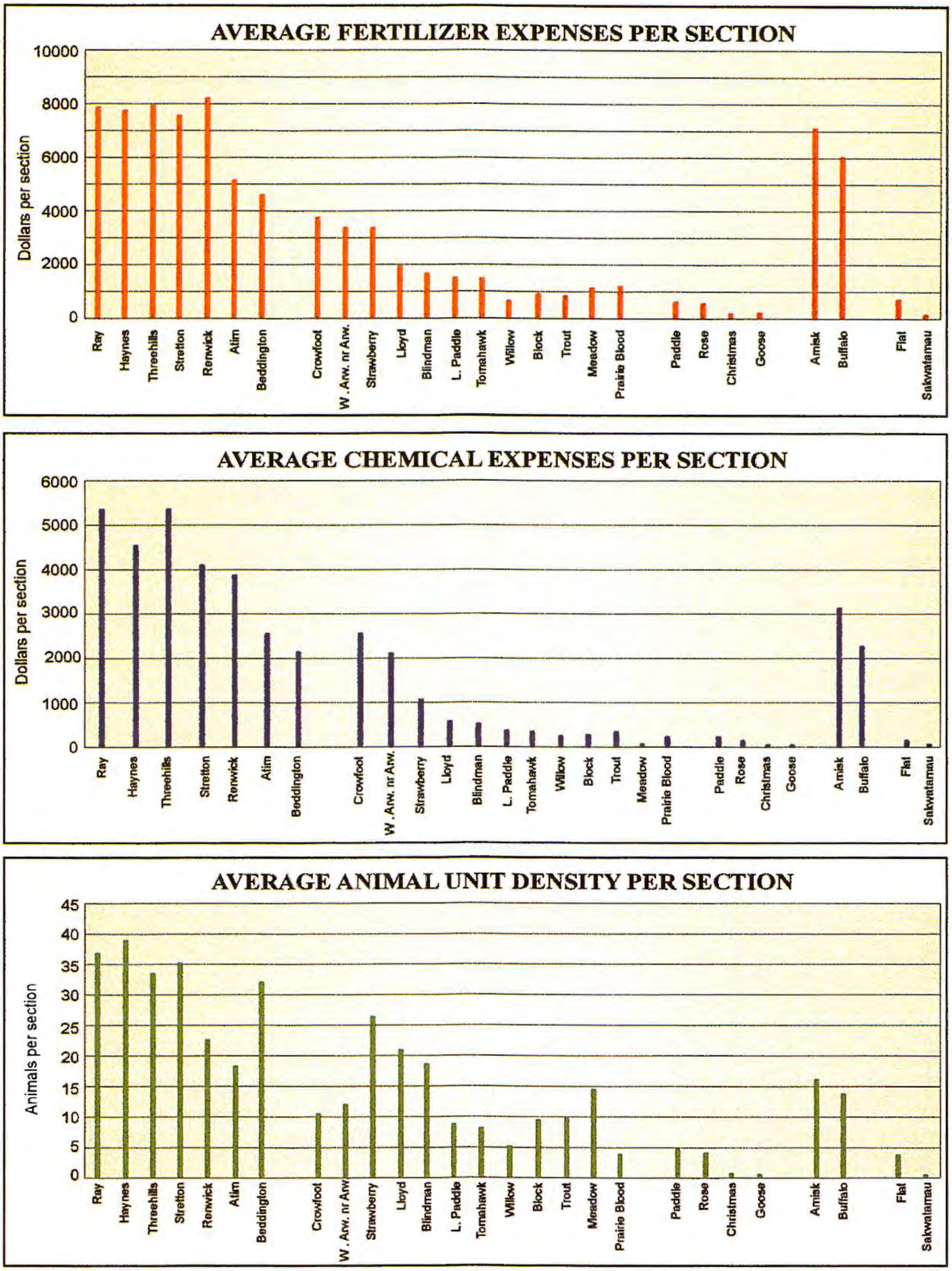


Figure 6. Comparison of drainage basins based on agricultural intensity data per section.

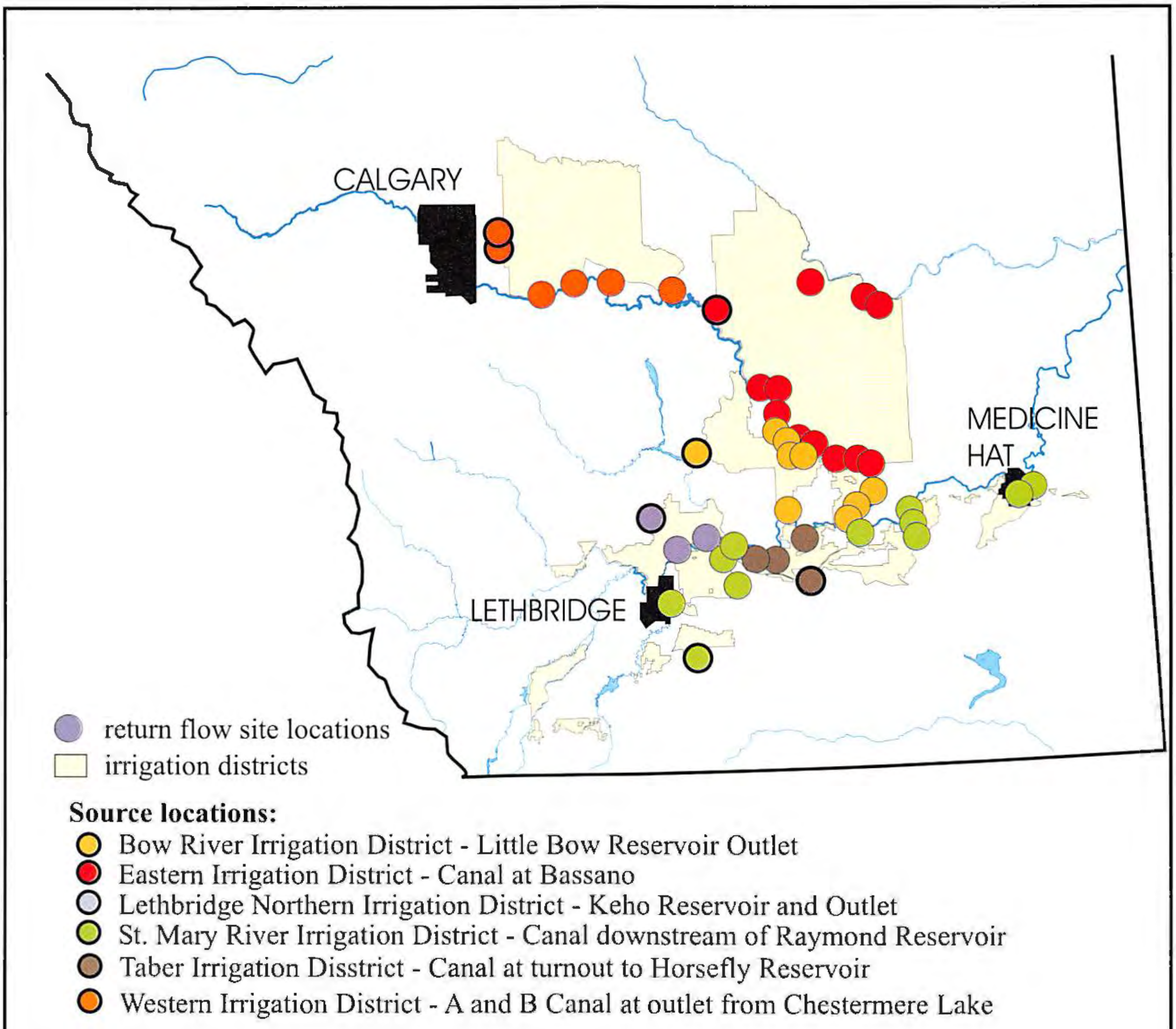


Figure 7. Irrigation district sampling sites.

Other Work

In addition to the surveys, more intensive monitoring work was carried out on one of the selected stream basins, Haynes Creek (Figure 8). A similar study of a second selected stream basin, Crowfoot Creek, was conducted by Alberta Agriculture, Food and Rural Development (Figure 9).

Research projects were also undertaken in other parts of the province to investigate the potential for agriculture to impact both surface and ground water resources.

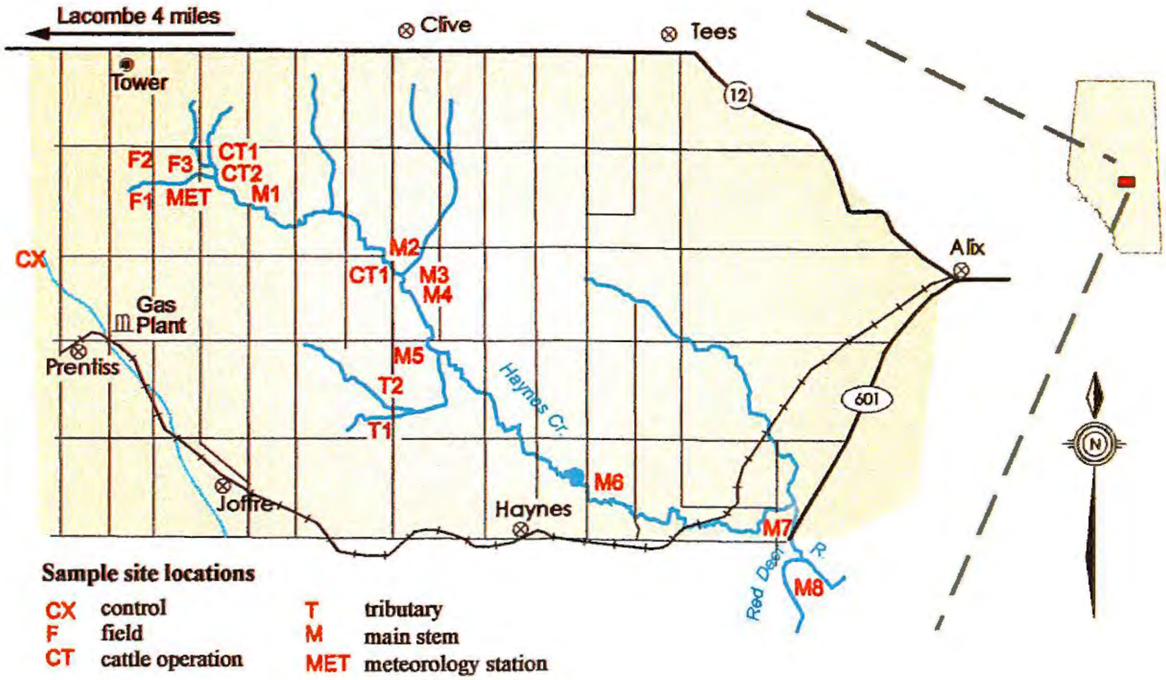


Figure 8. Haynes Creek Drainage Basin sampling site locations

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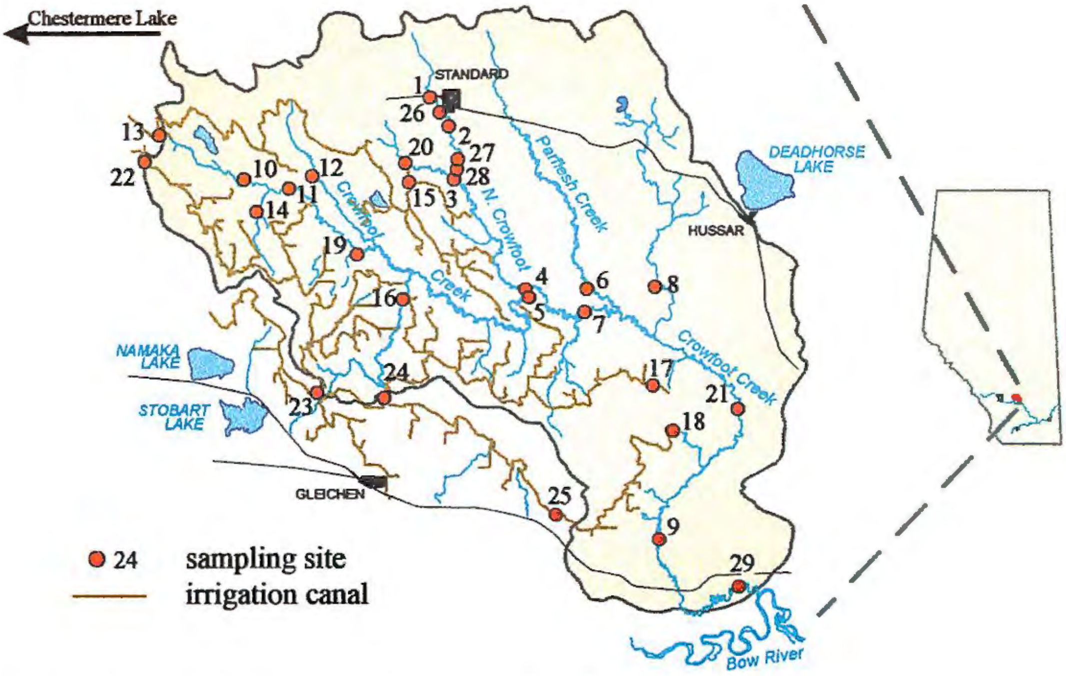


Figure 9. Crowfoot Creek Drainage Basin sampling site locations.

Data Analysis

Study results were analysed for compliance with federal and provincial water quality guidelines for different uses, as outlined below. Water samples were tested for such contaminants as coliform bacteria, pesticides (mainly herbicides), and nutrients (mainly phosphorus and nitrogen) for the five major water uses.

Human Drinking Water: Federal drinking water guidelines apply to water used for all domestic purposes, including cooking, laundry and personal hygiene. They are based on current scientific knowledge regarding human health, and assume life-long consumption of the water being tested.

Livestock Watering: Federal guidelines for livestock drinking water are based on current knowledge on the effects of regular use of the water for livestock and on human health concerns related to consumption of the animals. For this study cattle were used as the representative livestock species.

Aquatic Life: Guidelines for the protection of aquatic life are designed to help ensure the survival of plants and animals that live in or near water bodies.

Irrigation: Federal guidelines for water applied to irrigated crops are based on current knowledge of crop reactions to regular use of the water, and on human health concerns related to consumption of the irrigated crops.

Recreation: Guidelines for recreation are based largely on the coliform bacteria content of the water, when used for swimming.

Guidelines for the contaminants tested in this study are shown in Tables 1 - 3. The maximum allowable concentrations given in the guidelines typically provide a protection factor of 10 to 100 times the identified safe limits. Pesticides monitored included those commonly used by agricultural producers in the study areas. Not all pesticides shown in Table 3 were monitored at every site.

Table 1. Canadian Water Quality Guidelines for Selected Nutrients

	Maximum Acceptable Concentration - in ppm			
NUTRIENT	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**
Total Nitrogen (TN)	N/G	N/G	1.00	N/G
Total Phosphorus (TP)	N/G	N/G	0.05	N/G
Nitrate + Nitrite ($N0_3 + N0_2$)	10	100	N/G	100
Total Ammonia (NH_3)	N/G	N/G	1.13-1.18**	N/G
Nitrate ($N0_3$)	10	100	N/G	N/G

** temperature & pH dependent   ppm = parts per million   N/G = No Guidelines

Note: There are no recreation guidelines for nutrients.

Table 2. Canadian Water Quality Guidelines for Selected Bacteria

	Maximum Acceptable Concentration (in counts per 100 ml)				
BACTERIA	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
Fecal Coliforms	0	N/G	N/G	100	400
Total Enterococci	N/G	N/G	N/G	N/G	70
E. Coli	N/G	N/G	N/G	N/G	400

Table 3. Canadian Water Quality Guidelines for Selected Pesticides

PESTICIDE (H) Herbicide (I) Insecticide	**Maximum Acceptable Concentration (MAC) - in ppb**			
	Human Drinking	**Livestock Drinking**	**Aquatic Life**	**Irrigation**
Atrazine (H)	60	60	2	10
Bromoxynil (H)	5	11	5	0.35
Dicamba (H)	120	122	10	0.006
2,4-D (H)	100	100	4	100
Diclofop-methyl (H)	9	9	6.1	0.18
MCPA (H)	UR	25	2.6	0.03
Lindane (I)	4	N/G	0.01	N/G
Triallate (H)	230	230	0.24	N/G
Trifluralin (H)	45	45	0.1	N/G
Ethalfluralin (H)	N/G	N/G	N/G	N/G
Imazamethabenz (H)	N/G	N/G	N/G	N/G
Picloram (H)	190	190	29	N/G
Fenoxaprop-ethyl (H)	N/G	N/G	N/G	N/G

UR = Under Review   ppb = parts per billion   Note: There are no recreation guidelines for pesticides.

Study Constraints

This study attempted to identify if and where agriculture was impacting water quality in the province. However, budget and manpower limitations, combined with the relatively short span of the water quality study, necessitated the selection of representative areas and projects, rather than attempting to study every water resource in the province. For example, the study focussed on small streams, but did not assess their impact on main river systems.

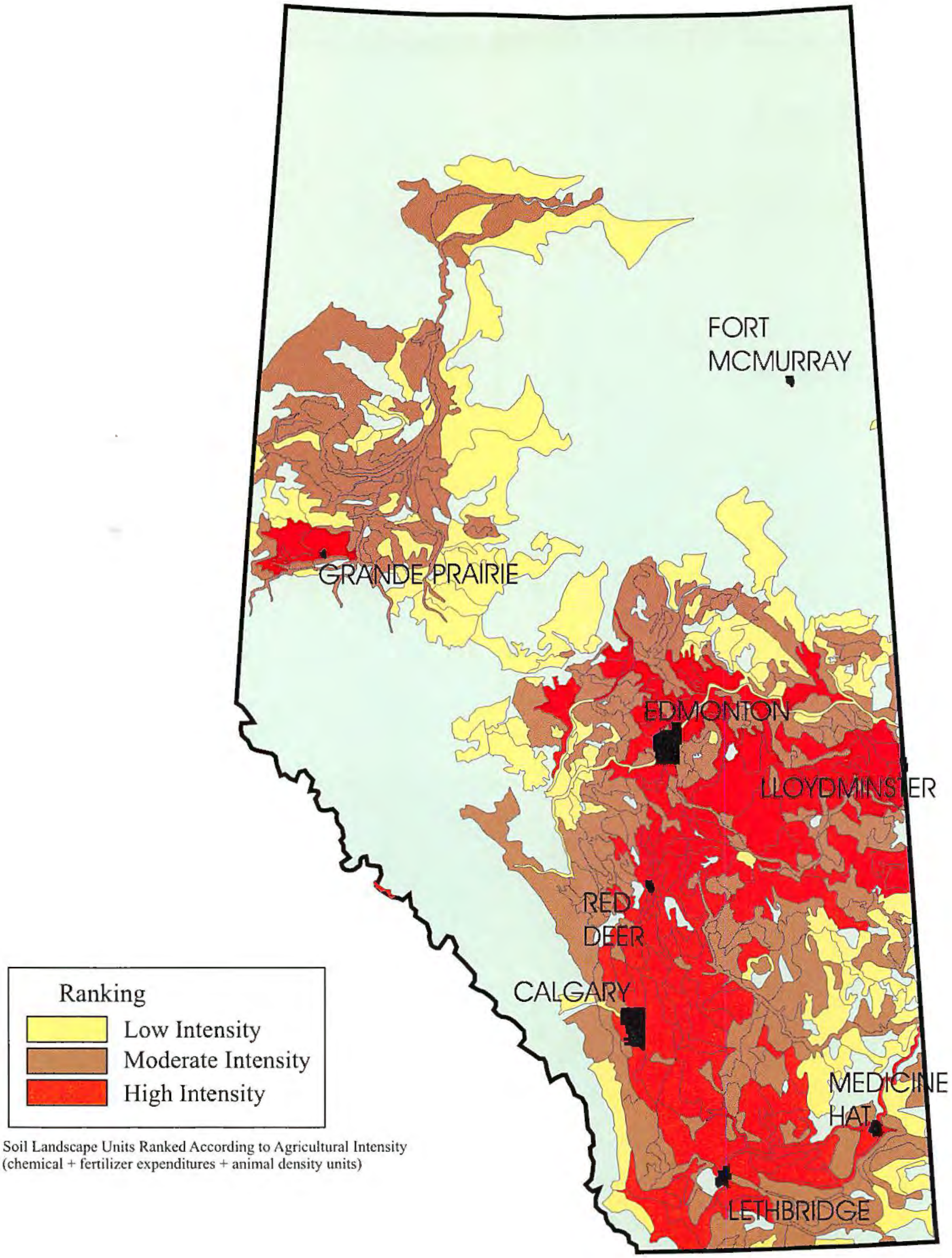
These restrictions also meant that every contaminant was not always monitored. The cost of analysing water samples is very expensive, particularly for pesticides. The total cost of analysing a single water sample for key contaminants identified in this study can easily exceed $450. Issues which became controversial during the course of the study, such as the occurrence of the parasites *Cryptosporidia* and *Giardia*, were not monitored.

The study did not attempt to evaluate the contributions of specific cropping practices or livestock production relative to identified water quality problems. Although water quality was the consistent theme among the projects undertaken for this study, significant differences often existed in project design, contaminants monitored, and monitoring methods. Integration of these numerous and varied databases proved to be more difficult and time consuming than originally anticipated.

While the study results provide a reasonable baseline measurement of agriculture's impact on surface and groundwater resources within the province, it is recognized that information gaps do exist. Continuous, integrated monitoring should be carried out to more accurately identify agriculture's impact on Alberta's water resources and the specific causes of those impacts.

Section 3.

Key Study Findings



Soil Landscape Units Ranked According to Agricultural Intensity (chemical + fertilizer expenditures + animal density units)

Figure 10. Agricultural intensity in Alberta.

KEY STUDY FINDINGS

Agricultural practices are contributing to the degradation of water quality.

Although nutrients and bacteria occur naturally in the environment, their concentrations in shallow groundwater and in surface waters in agricultural areas tended to be high, often exceeding water quality guidelines. Pesticides were detected frequently, sometimes at concentrations which exceeded guidelines.

Only rarely were agricultural contaminants found in any of the 448 deep groundwater wells monitored throughout the province. Where detections occurred, poor well design and poor maintenance were considered the major cause, not primary agricultural activities.

The likelihood of exceedences varied considerably. However, as agricultural intensity increased, the potential for contaminant detections and exceedence of the water quality guidelines also increased.

The risk of water quality degradation by agriculture is highest in those areas of the province which use greater amounts of fertilizer and herbicides, and have greater livestock densities.

Based on the research and monitoring work conducted, the risk of water quality degradation appears to be significant for areas of the province where intensive agriculture is practised, as measured by fertilizer or herbicide inputs or by animal unit density. Figure 10 shows the areas of Alberta which are at high, moderate and low risk for water quality degradation, based on the level of agricultural intensity.

The risk is greatest in those areas where overall agricultural intensity, based on all input factors, is high. However, the potential for water quality degradation exists where any one of the input factors is high.

Table 4. SUMMARY OF NUTRIENT DATA

WATER SOURCE		Non-Compliance with Guidelines* - % of Samples				
		Nutrient Tested	**# Samples Tested**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**
DEEP WELLS		Nitrate + Nitrite	**448**	0.6%	0%	N/G
SHALLOW WELLS		Nitrate + Nitrite	**376**	13%	0.3%	N/G
DUGOUTS	**Pilot Study**	Nitrate + Nitrite	**112**	0%	0%	N/G
	Northern Study	Nitrate + Nitrite	**78**	0%	0%	N/G
STREAMS	High Intensity	Total Nitrogen	**214**	N/G	N/G	87%
		Total Phosphorus	**220**	N/G	N/G	99%
		Nitrate+Nitrite	**206**	0%	0%	N/G
		Ammonia	**70**	N/G	N/G	0%
	Moderate Intensity	Total Nitrogen	**343**	N/G	N/G	65%
		Total Phosphorus	**341**	N/G	N/G	88%
		Nitrate+Nitrite	**303**	0%	0%	N/G
		Ammonia	**126**	N/G	N/G	0%
	Low Intensity	Total Nitrogen	**163**	N/G	N/G	32%
		Total Phosphorus	**164**	N/G	N/G	89%
		Nitrate+Nitrite	**129**	0%	0%	N/G
		Ammonia	**162**	N/G	N/G	0%
LAKES	High Intensity	Total Phosphorus	**69**	N/G	N/G	96%
	Low Intensity	Total Phosphorus	**23**	N/G	N/G	38%
IRRIGATION CANALS	Supply Source	Total Phosphorus	**183**	N/G	N/G	16%
		Nitrate+Nitrite	**109**	0%	0%	N/G
	Return Flow	Total Phosphorus	**1034**	N/G	N/G	61%
		Nitrate+Nitrite	**875**	0%	0%	N/G

*Canadian Water Quality Guidelines (CCME 1997) for nitrate+nitrite and for ammonia;
Alberta Surface Water Quality Interim Guidelines (AEP 1993) for total phosphorus and total nitrogen.
High, Medium and Low refer to agricultural intensity in the drainage basin.
N/G = NO GUIDELINE   Note absence of irrigation and recreation guidelines for nutrients.

SPECIFIC FINDINGS

NUTRIENTS

Nitrogen and phosphorus often exceeded water quality guidelines for the protection of aquatic life in streams in high and moderate intensity agricultural areas. Phosphorus often exceeded water quality guidelines for the protection of aquatic life in small lakes in high intensity areas, and in irrigation canals. Nutrient levels did not exceed guidelines for human and livestock consumption.

High levels of nitrogen and phosphorus in surface waters are a significant problem because they can cause excessive aquatic plant growth and eutrophication, where decaying plants cause oxygen depletion, thereby impacting the ability of aquatic life forms to survive. The study did not specifically evaluate which agricultural activity caused the buildup of nutrients in the water. Runoff associated with livestock operations and cropping practices are sources of the total phosphorus.

Dissolved phosphorus was found to be a major component of total phosphorus detections in the surface waters studied. Dissolved phosphorus is more readily available as a source of plant nutrient, and poses a more immediate risk to aquatic life, than phosphorus associated with sediments.

Nitrate concentrations in shallow groundwater exceeded drinking water quality guidelines on some occasions.

Exceedences of nitrate-nitrogen were found in shallow farmstead wells, but the source is unclear. Specific research projects indicated that excessive manure and fertilizer applications are likely to result in more widespread problems with nitrate in the shallow groundwater. Unconfined shallow aquifers are at particular risk .

Table 4 summarizes the water quality guideline exceedences of nutrients from the study projects

Table 5. SUMMARY OF BACTERIA DATA

WATER SOURCE		Non-Compliance with Guidelines* - % of samples			
		# of Samples	Human Drinking	Irrigation Guidelines	Recreation
DEEP WELLS		FC = 448	2%	0%	N/A
SHALLOW WELLS		FC =376	5%	0%	N/A
DUGOUTS	Pilot Survey	FC = 112	68%	0%	0%
	Northern Survey	FC = 80	20%	0%	0%
STREAMS	High Intensity	FC = 32 TE = 32	94% N/G	25% N/G	9% 38%
	Moderate Intensity	FC = 25 TE = 17	100% N/G	68% N/G	44% 82%
	Low Intensity	FC = 31 TE = 31	90% N/G	16% N/G	6% 39%
LAKES		no bacteria samples taken			
IRRIGATION CANALS	Supply Source	FC = 91	96%	14%	8%
	Return Flow	FC = 407 E. coli = 159	95% N/G	33% N/G	18% 27%

*Canadian Water Quality Guidelines (CCME 1997); re-sample criteria for fecal coliform and E.coli.

Note absence of guidelines for livestock watering and protection of aquatic life.

FC = fecal coliforms; TE = total enterococci; E.coli = Escherichia coli

High, Moderate and Low Intensity refer to agricultural intensity in the stream drainage basin

N/G: No Guideline N/A: Not Applicable

FECAL COLIFORM BACTERIA

Fecal coliform bacteria from agricultural sources often caused surface water resources and irrigation systems to exceed human and livestock drinking water guidelines. Fecal coliforms can also occur from non-agricultural sources; for example, where wildlife have access to streams and lakes.

Fecal coliform levels nearly always exceeded human drinking water quality guidelines in small streams in all agricultural areas. For dugouts, drinking water guidelines were exceeded more often in southern Alberta, than in the Peace River area of northern Alberta.

Fecal coliform levels met irrigation water quality guidelines more often for source water, than for return flows.

As has been recognized for some years, fecal coliform contamination of surface waters is widespread, from a variety of sources. While agriculture is a contributor to fecal coliform contamination, other sources, including wildlife and other human activities, also contribute to the problem. Health officials have long recommended all water sources be treated before domestic use. Unfortunately, the study showed a significant number of farm families do not test or treat their domestic water supplies.

Table 5 summarizes the water quality guideline exceedences of fecal coliform bacteria from the study projects

Table 6. SUMMARY OF PESTICIDE DATA

WATER SOURCE	# Samples	Non-Compliance with Guidelines* - % of Samples			
		Human Drinking	Livestock Drinking	Aquatic Life	Irrigation Guidelines
DEEP WELLS	**448**	0%	0%	0%	dicamba < 1% bromoxynil < 1%
SHALLOW WELLS	**376**	2,4-D <1%	2,4-D < 1% bromoxynil < 1%	bromoxynil < 1% triallate < 1% trifluralin < 1%	dicamba 1% MCPA 1%
DUGOUTS **Pilot Survey**	**112**	0%	0%	0%	dicamba 13% MCPA 15%
Northern Survey	**78**	0%	0%	MCPA 1% trifluralin 1%	dicamba 26% MCPA 21%
STREAMS **High Intensity**	**31**	0%	0%	lindane < 1%	dicamba 6% MCPA 25% bromoxynil < 1%
Moderate Intensity	**45**	0%	0%	0%	dicamba 6%
Low Intensity	**20**	0%	0%	0%	0%
LAKES **High Intensity**	**92**	0%	0%	0%	dicamba 9% MCPA 26% bromoxynil < 1%
Low Intensity	**27**	0%	0%	0%	MCPA 7%
IRRIGATION CANALS	**170**	0%	0%	2,4-D 1% MCPA 1% triallate 1%	dicamba 33% MCPA 33% bromoxynil 3%

*Canadian Water Quality Guidelines (CCME 1997)

Note absence of guidelines for recreation.

High, Moderate and Low Intensity refer to agricultural intensity in the stream drainage basin

PESTICIDES

Pesticides from agricultural sources were not found to be a significant contaminant for human and livestock consumption, and for the protection of aquatic life.

However, very low level herbicide detections were frequently found in many surface waters and some groundwater. Most detections were below water quality guidelines. The single insecticide studied (lindane) was detected only once and found to exceed water quality guidelines for the protection of aquatic life. For surface waters, many of the detections were related to spring snowmelt events, suggesting herbicide persistence in the soil is longer than originally thought. Specific research studies conducted in central and southern Alberta also indicate herbicides can leach into shallow groundwater.

Two of the herbicides studied, MCPA and dicamba, frequently exceeded irrigation water quality guidelines in irrigation canals. These two herbicides were also found to exceed irrigation guidelines in streams and small lakes in high intensity agriculture areas.

The study showed herbicide concentrations were generally higher in irrigation canals than in other water sources in the province. Potential impacts on crop yields may result from the exceedence of these irrigation guidelines. Herbicide levels in canals generally increased from upstream to downstream, with maximum levels found at return flow locations, where the water returned to the river.

Table 6 summarizes the water quality guideline exceedences of pesticides from the study projects

RECOMMENDATIONS

TECHNOLOGY TRANSFER

1. **Initiate a more intensive education program to increase the rate of adoption by Alberta farmers of management and production practices that protect water quality.**

   The results of this study clearly show that current agricultural management practices on many farms are not adequate to sustain water quality, particularly in the high and moderate intensity agricultural areas of Alberta. More work must be initiated to encourage producers to improve management of livestock wastes and crop inputs.

2. **Increase efforts to encourage Alberta farm families to test and treat all water supplies prior to domestic use.**

   The Farmstead Water Quality Survey of wells and dugouts revealed that a significant number of families in rural Alberta are drinking water from untreated surface and groundwater sources. About 60% of the nearly 1,000 households surveyed had not tested their drinking water in the last five years or had never tested it at all. A similar percentage of these households were not using any form of water treatment. This is a major concern because of the health problems associated with poor quality water. More effective education and awareness programs are required to ensure that all water is tested, and where required, treated before domestic use.

RESEARCH

3. Assess the effectiveness of current agricultural management practices and, where required, develop new practices and technologies to better protect water quality.

There is insufficient data to properly evaluate the effectiveness of some recommended farm management practices. More effort is needed to establish which practices are most effective in preventing water quality problems. Where required, new practices and technologies must be developed and adopted for Alberta conditions.

4. Determine whether existing irrigation water guidelines accurately predict herbicide impact on crop yields.

The study found evidence of exceedences of irrigation water quality guidelines for herbicides in a number of irrigation canals in southern Alberta. The impact of these herbicides on irrigated crop growth, under Alberta conditions, should be assessed as there is no experience to suggest crop yields are being affected by regular use of irrigation water from these canals. The irrigation water quality guidelines for herbicides are extremely sensitive, particularly for the herbicide dicamba. This needs to be evaluated.

5. Identify sources and mechanisms of contaminant movement into water resources.

While this study showed that contaminants are present in surface and groundwater, it did not attempt to determine the specific causes and processes of contaminant movement. The development of agricultural practices needed to protect water resources requires a better understanding of specific sources of contaminants, and how they move in groundwater and surface water resources.

6. Increase the knowledge of the effects of water contaminants on human health.

Drinking water quality guidelines do not exist for a number of the contaminants detected in water. For example, many of the pesticides commonly used in Alberta have no drinking water guidelines. In addition, it is not known if human health is affected by low levels of multiple pesticides in drinking water. Research must be carried out to better understand the impacts of agricultural contaminants, and develop appropriate drinking water guidelines.

7. **Improve analytical methods for identifying *Giardia*, *Cryptosporidia* and other disease-causing organisms.**

   These two parasites are emerging problems related to water quality in Alberta. At present, analysis of water for these parasites is very time consuming and expensive. Further research is required to reduce the analysis time required to determine whether these parasites are a problem.

MONITORING

8. **Develop a comprehensive, integrated, long-term water quality monitoring program to determine trends and assess water quality impacts associated with agriculture.**

   The CAESA Water Quality study provides the first baseline assessment of agriculture's impact on water quality in the province. The study did not assess all agricultural activities, nor did it evaluate the specific causes of the water quality impacts or evaluate the impact on major rivers. It is important that continued long-term monitoring of water quality be carried out to determine the causes of water quality problems, and evaluate whether improvements in agricultural management are having positive effects.

9. **Obtain baseline data for *Cryptosporidia, Giardia* and other disease-causing organisms in water resources.**

   The current study did not analyse for these two parasites, nor does any representative baseline information exist for the occurrence of these parasites in surface and groundwater sources in Alberta. Priority should be given to collecting baseline information on Cryptosporidia, Giardia and any other organisms that are becoming water quality issues, as part of a long-term monitoring program.

REGULATION

10. Review the adequacy and enforcement procedures for existing environmental and public health regulations to protect water quality.

Sustainable agricultural growth in Alberta depends on good water quality. It is recognized that in agriculture, as in other segments of society, there exists a small number of poor managers who do not abide by the rules and codes designed to protect society as a whole. This not only harms the environment, but also hurts Alberta's world-wide reputation as a supplier of high quality, safe food products. Environmental regulations must be in place, and enforced, to deal with producers who deliberately or consistently contaminate water resources.

11. Encourage the development of appropriate water quality guidelines for all pesticides before these products are registered.

The study found that neither federal nor provincial guidelines exist for a number of the commonly used pesticides detected in surface and groundwater sources. It is therefore impossible to assess what levels are harmful to human, animal and plant life. All pesticides used in Alberta should be tested and guidelines should be developed prior to their registration and sale.

Section 4.

Farm Application of Study Results

FARM APPLICATION OF STUDY RESULTS

Although the CAESA Water Quality Study was designed primarily to collect baseline information on water quality, the results have practical applications for farm managers. The results of many projects emphasized the need to follow known good farming practices. Other projects indicated ways to improve management techniques already in use.

The CAESA Water Quality Study, and especially CAESA's Farm Based Program, were active in communicating management practices that protect water quality, through demonstrations, tours, printed publications and videos. Many farmers have already adopted appropriate practices. They recognize that protecting water quality means better health for the environment, for people, and for their crops and livestock. Adoption of sustainable management practices can also result in better economic returns through reduced inputs, and more productive crops and livestock. A number of widely accepted good management practices, with results supported by the water quality projects, are outlined below.

Nutrients

Soil test regularly and apply nutrients according to crop needs.

The results from several of the projects clearly confirmed the need for soil testing, so farmers can ensure nutrient applications do not exceed crop needs. Proper nutrient management is important economically as well as environmentally.

The study results emphasized the consequences of excessive nutrient application. Several projects showed that high nitrogen application rates increase the risk of nitrates moving through the soil profile into groundwater.

One project found that a high proportion of nutrients in water samples were in dissolved form. This is significant because nutrients in a dissolved state are readily available for aquatic plant growth. As these plants die and decompose, the water's oxygen level is reduced, suffocating fish and other aquatic organisms.

This same project also found nutrient losses due to runoff from some fields represented a significant proportion of the total nutrients applied to the field. These nutrient losses were a considerable economic loss to the farmer.

Prevent livestock manure from entering streams and lakes.

The study detected coliform bacteria in several different water sources. Cattle wintering sites located next to streams were identified as one source of manure contamination. Allowing livestock direct access to water bodies is another.

The following are known ways to prevent animal wastes and manured runoff from entering water.

- Locate cattle wintering sites away from water bodies.
- Increase the size of cattle wintering sites to decrease cattle density and move cattle often to decrease manure concentrations.
- Provide a vegetated buffer strip along water bodies, where animals are present.
- Pump clean water to troughs so cattle do not have to wade into water bodies to drink.
- Fence water bodies to prevent livestock from having direct access.
- Avoid spreading manure on steeply sloped lands or near water bodies.
- Avoid spreading manure on frozen, wet or snow-covered fields.
- Divert offsite runoff around areas of manure accumulation.
- Incorporate manure into soils as soon as possible after spreading.
- Inject liquid manure directly into the soil.

Prevent soil nutrients from reaching streams and lakes.

The study results clearly show that areas with moderate to high intensity agriculture are at risk for water quality degradation. However, areas currently in low intensity agriculture often are in landscapes with a high potential for moving contaminants into water sources. Therefore, all farmers need to use good management practices to protect water quality.

The following are known practices to reduce the movement of sediments, nutrients and pesticides from farm fields into streams and lakes.

- Reduce or eliminate tillage where possible.
- Reduce cultivated summerfallow.
- Keep erodible lands under permanent cover, such as perennial forages.
- Construct and maintain grassed waterways.
- Cultivate across, not with, the slope of the land.

Prevent nitrates from entering groundwater.

One project showed that repeated application of manure in excess of crop requirements increases the risk of nitrate-nitrogen moving into groundwater. It should be recognized that manure will release nutrients for crop uptake several years after spreading.

The following are known practices to reduce movement of nitrate-nitrogen into groundwater.

- Test the soil each year to determine nutrient requirements.
- Test the manure to determine the amount of nutrient present.
- Apply only the amount of manure required by the specific crop.
- Do not pile manure on fields prior to spreading.

Bacteria

Test drinking water supplies and treat as required before consumption.

The study showed that all dugouts and wells used for drinking, cooking or bathing can have water quality problems that need treatment. Water may be treated by the addition of chlorine or ozone, or by filtration or distillation. Regional Health Authorities can provide specific advice on water treatment.

Properly construct and maintain wells.

The study found that agricultural impacts on farmstead well water quality were minimal. Where agricultural impacts were occurring, better management practices near the well head, and improved well maintenance would likely alleviate the problems. Coliform bacteria were only rarely present in well water, indicating the contamination was probably from nearby septic systems, compromised surface seals, or livestock too close to the well head, rather than from contamination of the aquifer.

The following are known practices to maintain well water quality.

- Replace rusted casings.
- Replace well pits with pitless adaptors.
- Plug all abandoned or unused farmstead wells.
- Maximize the distance between livestock and household drinking water sources.
- Design and maintain septic systems properly.

Limit livestock access to water sources.

Livestock wastes can enter water resources, contaminating them with fecal coliform bacteria and other products, when animals are allowed direct access to streams, lakes and dugouts. Studies have shown cattle gain weight faster and stay healthier when they drink from a trough, rather than wading into a dugout water source or pond to drink. Following are two common approaches used to provide good water.

- Pump clean water to troughs. Many producers use solar powered pumps if electrical power is not close.
- Prevent or limit livestock access to water bodies by fencing and/or providing access ramps.

Prevent runoff and leaching from feedlot pens.

The feedlot project results indicated that compaction by cattle hooves prevented leaching of contaminants into the groundwater. Runoff volumes from the pens were lower than expected, in part because hoof depressions and the packed manure layer trapped surface water. However, because feedlot runoff water quality is very poor, feedlot managers should take every precaution to reduce runoff and leaching.

The following are known methods to prevent runoff and leaching.

- Install good drainage systems and proper catch basins.
- Thoroughly clean unused feedlot pens promptly after cattle are removed.
- Remove snow and manure from feedlot pens before the ground thaws in spring.
- Locate feedlot facilities on gently sloping sites, away from watercourses.
- Avoid sites with porous soils and areas with shallow groundwater.

Pesticides

Prevent pesticides and other chemicals from entering well water and dugouts.

Three percent of the farmstead wells tested in the study had detectable pesticide levels. Researchers believe these detections were due to careless practices around the well, rather than to widespread aquifer contamination. Forty-eight percent of the tested dugouts had detectable pesticide levels. Most dugout contamination probably derived from field runoff.

The following are known ways to prevent pesticides from contaminating water sources.

- Install back siphon protection valves on water systems to prevent contaminated water or farm chemicals from entering the water supply.
- Use a nurse tank to haul clean water to spray tanks.
- Never mix, load or handle farm chemicals near water sources.
- Locate fuel tanks at least 50 metres from water wells or dugouts.
- Clean spraying equipment over field crops or thick vegetation to reduce the risk of chemical-laden runoff.
- Triple-rinse and dispose of empty or outdated pesticide containers in proper waste management facilities.
- Take courses to learn safe and economical ways of applying pesticides.

Prevent pesticides from entering shallow ground water.

The study results show that shallow groundwater is vulnerable to contamination from pesticides due to leaching. Following are known ways to reduce the risk of shallow groundwater contamination by pesticides.

- Use the appropriate pesticide, read the product labels, and apply at the appropriate rate with the correct sprayer calibration and correct timing of application.
- Avoid applying pesticides immediately before planned irrigation or anticipated heavy rainfalls.
- Delay irrigation as long as possible after applying pesticides and nutrients, and do not over-water.

Prevent pesticides from entering surface water.

The study results confirm that streams in intensive agricultural areas are at risk for pesticide contamination. Project results also found that pesticides applied in one spring season can persist until the following spring, and can move off the fields with snowmelt. On occasion, pesticides that had not been applied to nearby fields were detected in some water samples, suggesting aerial deposition or drift may sometimes be a factor in water resource contamination.

The following are some known ways to prevent pesticides from entering streams and lakes.

- Check and recheck sprayer calibrations to prevent over-application of pesticides.
- Use pesticides with lower water and soil mobility ratings, and shorter half-lives.
- Use pesticides labeled non-toxic to birds, bees and fish.
- Watch for pesticide damage to un-sprayed crops, as a sign of aerial deposition.
- Avoid spraying farm chemicals on windy days.
- Avoid unnecessary spraying.

General

Get more information

Researchers and specialists do not have all the solutions for preventing agricultural impacts on water quality. Nevertheless, much can be done based on current knowledge. More information on how farmers can protect water quality is available from Alberta Agriculture, Food and Rural Development, Agriculture and Agri-Food Canada (the Prairie Farm Rehabilitation Administration and the Research Branch,) from other government agencies and non-government organizations, and from the agricultural industry. A large number of publications also give advice on environmentally sustainable farm management practices.

Appendix A.

Project Summaries

This section provides summary documentation for the projects which formed the basis of the CAESA Water Quality Study.

Alberta Farmstead Water Quality Survey

Darcy A. Fitzgerald et al. 1997

The majority of Albertans live in large cities where their drinking and household water is supplied through municipal treatment systems. These systems supply water which meets government water quality guidelines.

In contrast, about half a million rural Albertans depend on private wells or dugout water for their drinking and household supplies, as well as for livestock and gardens. In northern Alberta, these dugouts are most often filled with rain, snowmelt and runoff. In southern Alberta, dugout supplies are often filled with water from irrigation systems, as well as from runoff and precipitation.

Testing and treating farmstead wells and dugouts is left to the farm owner, who may not realize the impact water quality can have on his family's health and livelihood. Often, farmstead water supplies are untested and untreated.

Potential health risks from using untreated water range from gastro-intestinal upsets and allergies, to disease and brain damage. Poor water quality can also contribute to weight loss and poor health in livestock.

Previous studies show most farmstead well water problems are caused by poorly built, poorly maintained well systems or accidental spills. Old-fashioned well pits, the lack of back-siphon protection devices, and uncapped, abandoned wells are the primary causes of well water problems in rural areas.

Natural conditions also cause well water problems. Aquifers may flow through rock formations containing sodium and other readily dissolvable substances, resulting in unpalatable or unsafe water supplies. Fluoride, for example, may naturally occur in groundwater, at levels greater than recommended.

Nitrate and nitrite are often an indication of contamination from manure or fertilizers, but are also created by natural decomposition of organic materials. While little can be done to alter the conditions which cause these water problems, the water itself can be easily treated to make it safe and palatable.

Project Results:

Approximately 32% of the wells tested in the project exceeded drinking water guidelines for at least one health-related contaminant. Fluoride, arsenic, zinc, selenium, manganese, and lead were among the substances found in farmstead wells (Table 7.)

About 93% of the well water samples exceeded at least one aesthetic or physical guideline (taste, odor, colour, etc.).

Table 7. FARMSTEAD WELL WATER TRACE ELEMENTS (partial list of detections)

Element	Maximum Detection	MAC or AO	% above MAC or AO
Aluminum	1414 ppb	200 ppb*	3%
Arsenic	119 ppb	25 ppb	2.5%
Barium	2.75 ppm	1 ppm	1%
Chloride	3150 ppm	250 ppm	6%
Chromium	71 ppb	50 ppb	0.2%
Fluoride	6.37 ppm	1.5 ppm	13%
Iron	31.4 ppm	0.3 ppm	35%
Lead	137 ppb	10 ppb	2%
Manganese	5334 ppb	50 ppb	35%
Selenium	94 ppb	10 ppb	3%
Sodium	2100 ppm	200 ppm	65%
Uranium	585 ppb	100 ppb	> 1%
Zinc	17.6 ppm	5 ppm	1.3%

ppm = parts per million   ppb = parts per billion   * Under Review
MAC = maximum allowable concentration   AO = aesthetic objective

Most of these groundwater contaminants derive from the natural geology of the aquifers, rather than from human impacts.

About 14% of the well water samples had detections of total coliforms and 6% had fecal coliform bacteria detections. Of those wells in which coliforms were present, a few had very high levels. Deep wells had fewer coliforms than shallow wells. As fecal coliforms do not normally survive long in well conditions, the contamination was thought to be from nearby septic systems, compromised surface seals, or livestock too close to the well head, rather than from contamination of the aquifer.

Approximately 92% of the dugouts, in both the pilot project and the Northern Alberta project, had detectable levels of coliform bacteria. Coliform counts rose sharply in late spring, under the influence of snowmelt and runoff.

In fact, concentrations of most dugout contaminants were highest in spring, with levels decreasing over the summer. Researchers noted this was probably influenced by the decrease in water levels in the dugouts. It also confirmed the considerable influence of snowmelt or spring runoff events in causing surface water contamination.

Dugout and well samples were also tested for eight herbicides. Only 3% of the wells had detectable herbicides, in comparison with 48% of the dugouts. Researchers felt most of the well water detections were due to careless practices, such as filling herbicide tanks without back-flow protection, rather than wide-spread aquifer contamination. Most dugout contamination probably derived from field runoff.

FARMSTEAD WELL WATER SURVEY

Number of sites tested	824
Number of residents	2877
Shallow wells	46%
Wells over 100 ft. deep	54%
Water is used for drinking	84%
Water never tested - unaware of test	24%
Water is not treated	41%
One or more unused/abandoned wells	43%

About the project:

The CAESA Farmstead Water Quality Survey was initiated in 1994, to develop a database for Alberta's farm water supplies, and to evaluate agricultural impacts on those supplies. The project also helped determine the suitability of farm water supplies for domestic and livestock uses.

A pilot survey of 190 farm wells and 103 farm dugouts was undertaken, with water samples taken once at each site during the 1994 growing season. Where detections were high, water was re-sampled and owners were notified of remedial actions.

Following the pilot survey, wells at 824 farmsteads, in almost every municipality in the province, were tested (Figure 11). As the pilot data indicated great seasonal variability in the quality of the dugout supplies, it was decided to test the dugouts separately from ground water wells. Fourteen dugouts in northern Alberta were sampled every two months during 1996 and 1997.

Sampling procedures included analysis for nutrients, pesticides, bacteria, trace metals, suspended and dissolved solids, salinity, hardness, pH, colour, and other water quality attributes.

Property owners were also asked to provide information indicating how their water was used, whether it was tested or treated, and whether the family had any concerns about their water quality. On site inspections of well systems were also conducted.

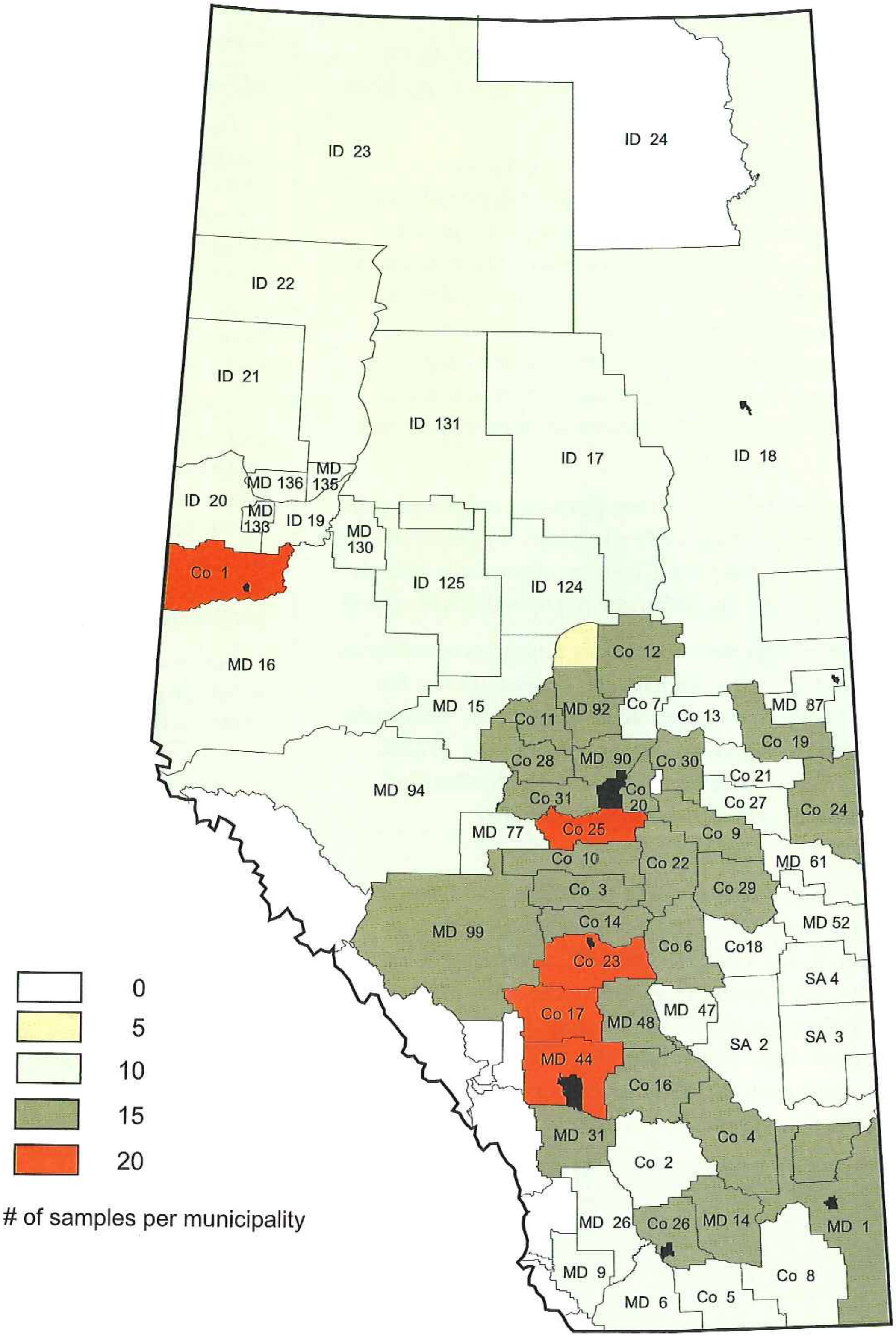


Figure 11. Farmstead well water quality survey sites.

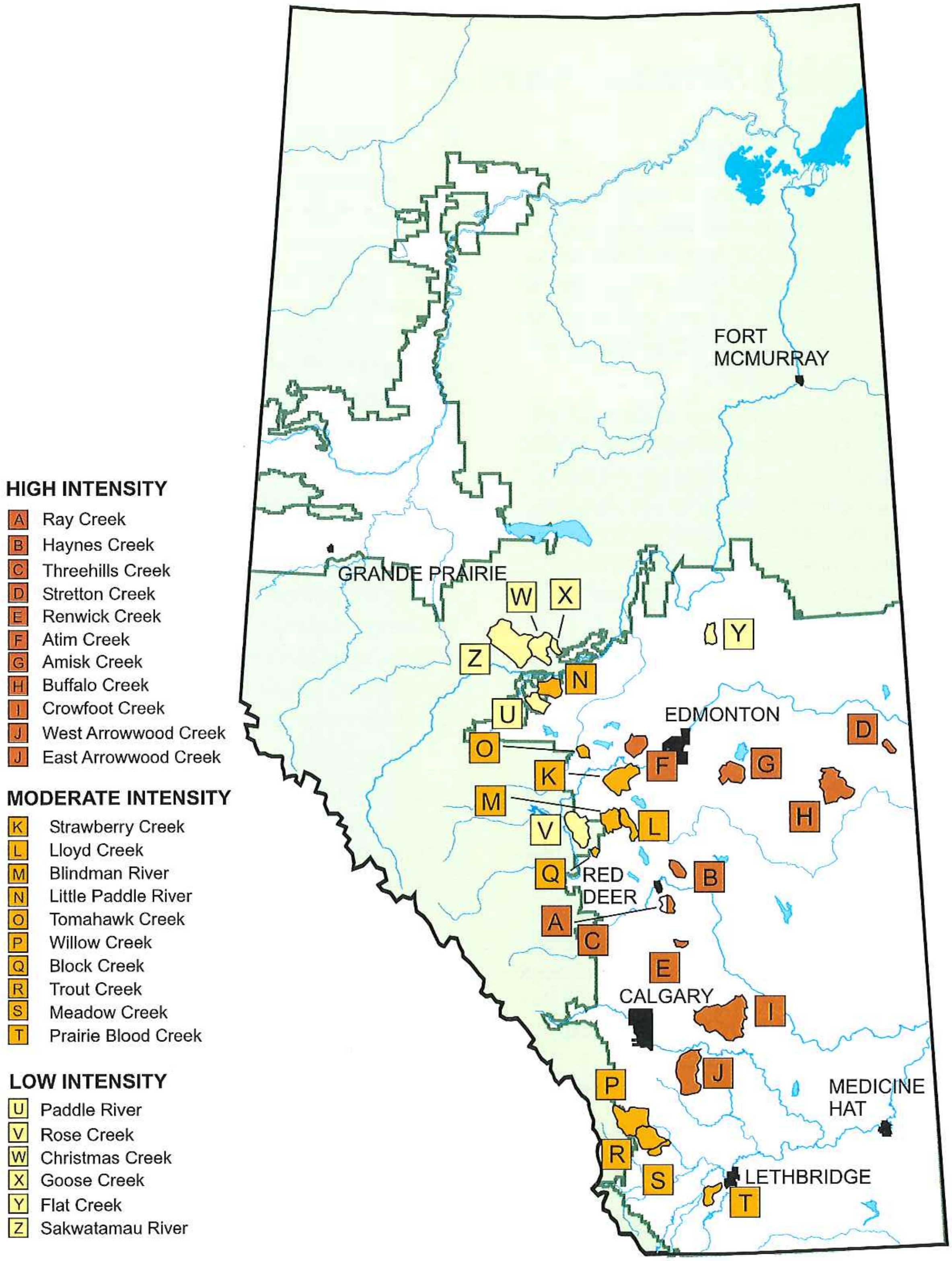


Figure 12. Location of survey streams.

Provincial Stream Survey *Anne-Marie Anderson et al. 1997*

Until recently, water quality in Alberta's smaller streams had not been tested in any systematic way. Many of these streams lie in agricultural drainage basins, where they may be influenced by field runoff, livestock operations and other farm activities. Many are sources of livestock drinking water. Some supply irrigation systems or may be used for watering gardens. All are critical for aquatic life.

One of the key objectives of the CAESA water quality study was to obtain baseline data on these small streams, to determine if they were being impacted by agriculture. Because monitoring all creeks and small rivers would be a monumental task, even if time and money were not critical factors, 27 representative streams were studied (Figure 12).

One of the selected streams, Haynes Creek, was studied more extensively in a separate CAESA project. An extensive study of Crowfoot Creek, another of the selected streams, is being conducted by Alberta Agriculture, Food and Rural Development.

Site selection relied on extensive searches in large databases. All selected streams drain areas with the same type of soil or landscape features, but agricultural intensity of the basin ranged from high to low. Researchers restricted their selection to streams which did not receive discharges from major industrial or municipal sources, and those which already had government-maintained flow gauging stations.

Livestock density and farm chemical expenses were used to define the degree of agricultural intensity. Specific land use patterns (the percentage of each drainage basin under cultivation, pasture or hay land, or not used for agricultural activities), were also considered. This data strongly separated high and low intensity drainage basins and confirmed the selection criteria based on agricultural inputs.

Project Results:

Based on the water analyses, there appears to be a direct correlation between stream water quality and levels of agricultural inputs in small stream basins. Streams which drain land farmed with more agricultural inputs had more contaminant detections than streams which drained low intensity agricultural land. This was especially true with regard to nitrogen and phosphorus contamination.

Guidelines for total phosphorus and total nitrogen were met less frequently in streams draining high intensity land, than in streams draining low intensity land (Figures 13 & 14). Almost 87% of the high intensity streams failed to meet guidelines for nitrogen. Almost 100% failed to meet guidelines for phosphorus. However, all samples complied with guidelines for nitrate and ammonia.

Not only did streams in high intensity areas have higher nutrient concentrations, they also had a higher proportion of dissolved nutrients (nitrate, ammonia and dissolved phosphorus) than low intensity stream basins.

Hydrologic or runoff factors also played a key role in the transport of sediments and contaminants from crop lands, skewing water quality trends related to agricultural intensity.

For example, suspended solids and particulate forms of nutrients tended to be highest in streams with high rates of discharge. In Alberta, these streams are located primarily in areas of low agricultural intensity. High intensity stream basins were generally located where snowmelt is the significant runoff event.

Bacterial sampling in the study was limited, but streams in low intensity basins tended to bave the lowest bacteria counts.

About the project:

Sampling on the 27 selected streams started in March 1995 and ended in October 1996. About 20 samples a year were collected from most streams. Sampling frequency was flow weighted, thus increased during periods of high flow, (during snowmelt or after storm events.) Samples were collected even more frequently on Haynes Creek and Crowfoot Creek. Water was sampled in both years for nutrients, organic and inorganic chemistry, suspended solids, color, pH, and in most cases, bacteria. In 1996, temperature records were also kept.

The stream basins selected for the study ranged in size from 42.5 square kilometres to 1360 square kilometres. Ten of the streams are usually intermittent and flow mainly during spring snowmelt. They are located in the mixed grassland or parkland areas of central Alberta. Typically, they drain intensively farmed land. Crowfoot Creek was the only study stream which drains irrigated land. Because of the irrigation, the stream flow is steady from spring through fall. The land is also intensively farmed.

Eleven of the selected streams have high flows during spring snowmelt, but also flow regularly during the summer in response to rainfall. They drain land which ranges from having fairly high intensity agriculture, to low intensity. Most are located in west and north central Alberta, with drainage basins that vary from boreal forest, to foothills parkland and foothills fescue grassland. Two of the streams are located in southwestern Alberta. Both have relatively high summer flows.

At many of the streams in the study, 1996 was an exceptionally high flow year, as a result of heavy snowpack and above average rainfall. Haynes Creek received higher than average flows during the spring. Crowfoot Creek had higher than average flows during the summer. Four of the streams in the southern part of the province had exceptionally high flows in 1995 as well, as a result of torrential rains in late spring and early summer. Haynes Creek and two other streams had slightly lower than average runoff in 1995.

However, high bacteria readings did occur in all stream groups. Researchers attributed the variable pattern of bacteria detections to both the low sample size and the varied distribution of livestock near all survey streams. Generally, streams with high fecal coliform counts, had more enterococci.

Agricultural pesticides were detected in 44% of the samples in the surveyed streams, though detections for most pesticides were below guideline levels for most water uses.

Non-compliance with irrigation water guidelines, however, occurred frequently. Herbicide levels above the guidelines may lead to lower crop yields, but further research is needed to determine the extent of yield losses.

The survey showed pesticide detections were directly correlated to the amount of pesticide applied locally. However, the research also showed that some herbicides persisted on the soil longer than originally thought. Several pesticides applied the previous year were still present in field runoff the following spring.

Researchers also noted that detection frequencies in this study were significantly higher than pesticide detections in existing databases. The smaller size of most streams surveyed in this project may be one factor. The lower detection limits used for water quality analyses today compared to the past, may also account for some of this discrepancy.

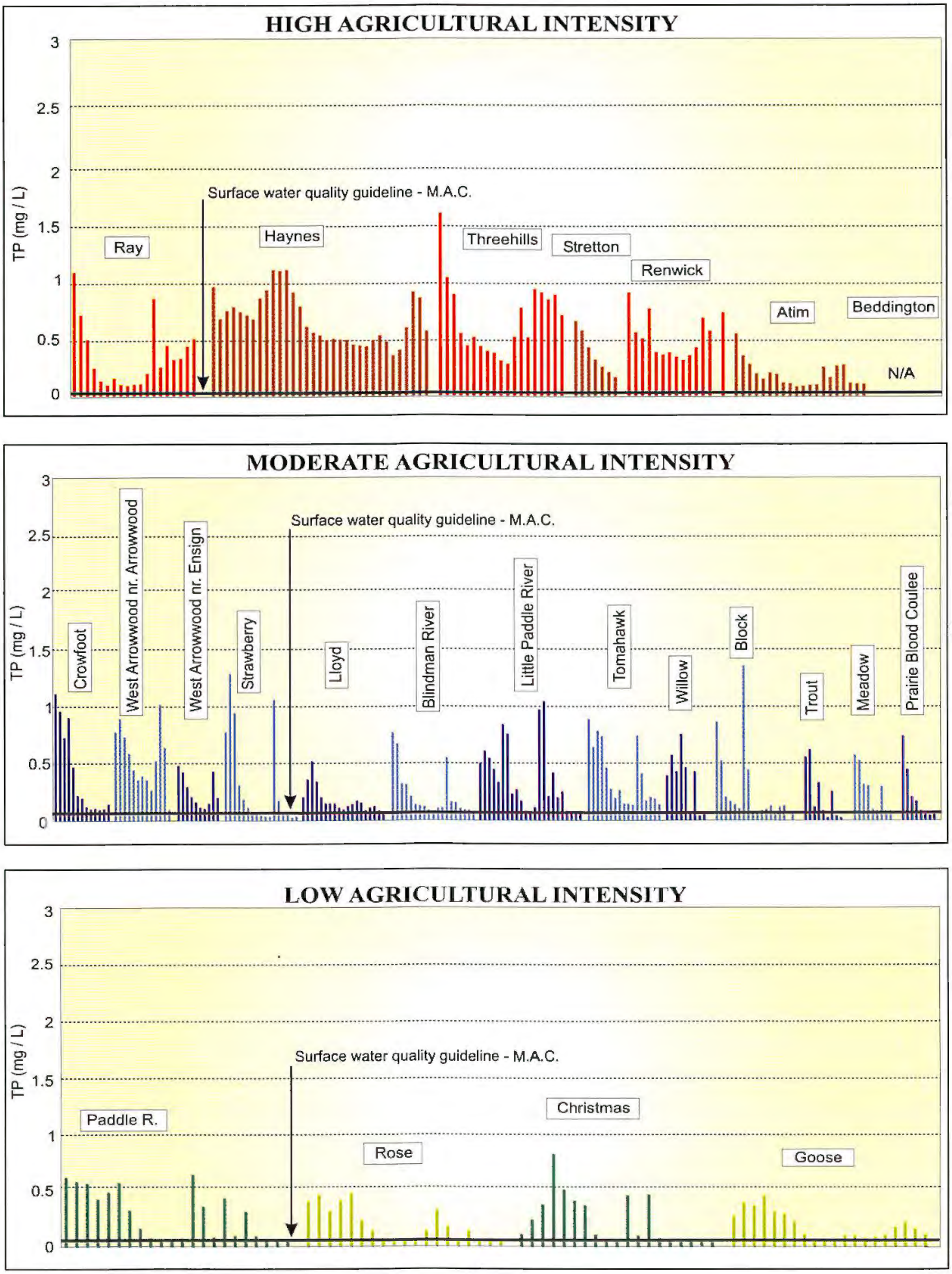


Figure 13. Total phosphorus in survey streams, open-water season 1996.

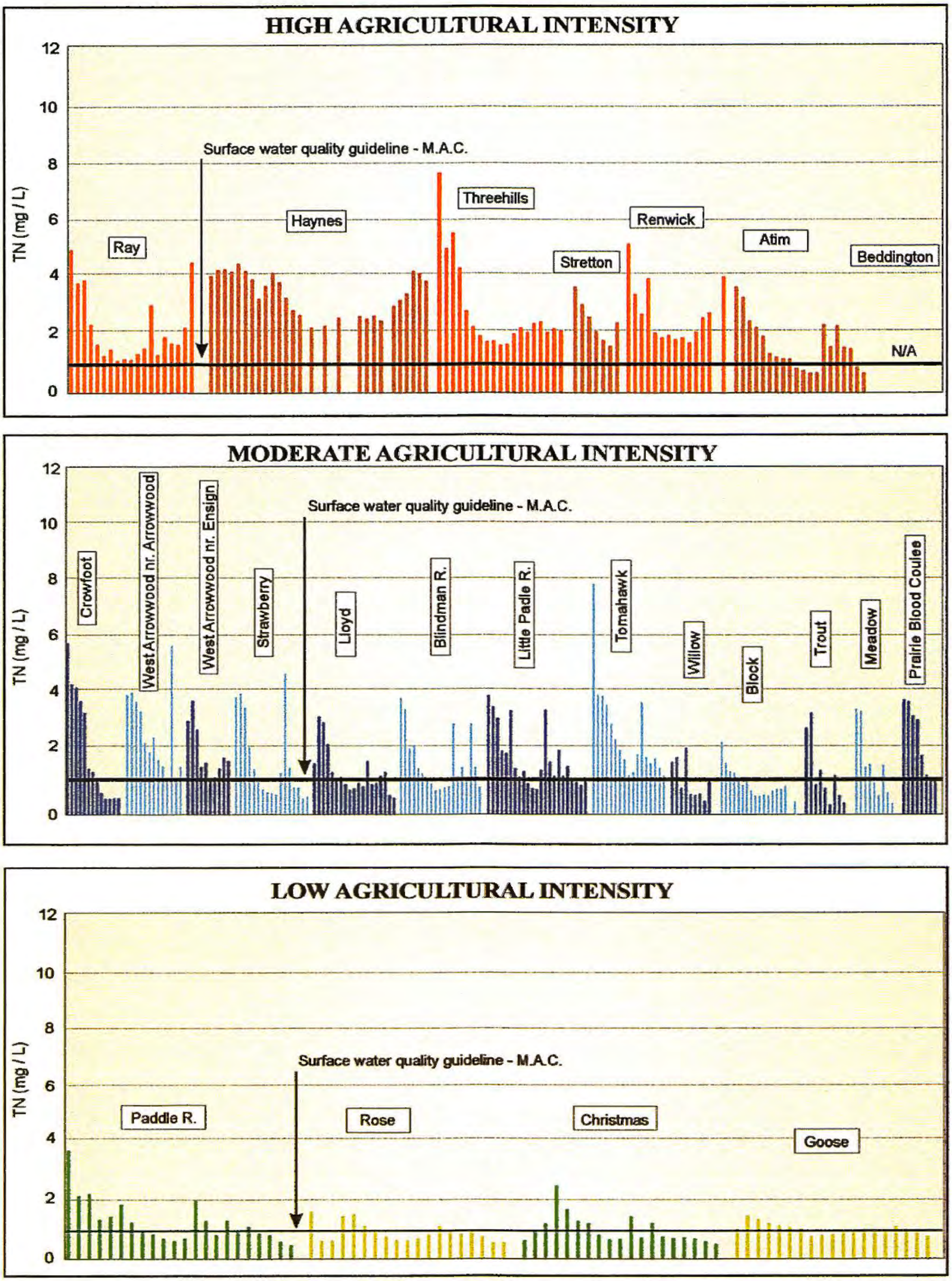


Figure 14. Total nitrogen in survey streams, open-water season 1996.

Provincial Lake Project *Anne-Marie Anderson et al. 1997*

Prior to the CAESA studies, most of the pesticide data for Alberta's surface water bodies had been limited to findings for major rivers. Few long-term sampling sites were located in intensive agricultural areas and no data existed for small lakes. As part of the provincial surface water quality survey, 25 representative small lakes were sampled for pesticides (Figure 15). Samples were also analysed for chlorophyll-*a* and phosphorus.

Project Results:

Over half the samples collected showed detectable levels of at least one pesticide. In many samples, more than one pesticide was found.

Seven of the pesticides were detected in both years. MCPA and 2,4-D were most commonly found, with detection frequencies of 21% and 31% respectively. In all, there were 105 pesticide detections. Though the greatest number of detections came from locations of high pesticide use, even low use areas showed a significant number of detections. Not all detections in low use areas could be explained by local use patterns. It is suspected that atmospheric transport and deposition contributed to surface water contamination.

In areas with high pesticide use, detection frequency was 90% for lakes located in areas of high runoff. Concentrations of the detected pesticides were also highest in areas of high pesticide use and high runoff. All detections but one (for triallate) complied with surface water quality guidelines for aquatic life.

A total of 24 sediment samples were collected from 22 of the lakes. Analysis found a total of 16 detections, of five different pesticides, from 15 lakes.

About the project:

As in the stream survey, researchers conducted searches in large databases to locate areas with specific characteristics. Twenty five small lakes or ponds, in high and low use pesticide areas, were chosen. The lakes were located in high, moderate and low runoff zones.

Samples of water, lake sediments and biological specimens were taken in 1995 and 1996 and tested for 13 pesticides, (11 herbicides, 1 insecticide and 1 fungicide.) The herbicides for which lake water samples were analyzed are in high use in the province, as well as across the prairies.

Lake water was sampled once after both spring and fall herbicide applications in 1995. At least one additional sample was taken from each lake in June 1996. Six of the lakes were sampled monthly, throughout the open water season, to trace possible seasonal variations.

Sediments from the lakes were sampled in summer and fall of 1995. Biological (*biota*) samples were taken in mid-summer and consisted mostly of algae, small crustaceans and fine organic debris. Biota densities in about half the lakes were low and sufficient material could not be collected for a valid pesticide analysis.

Analyses for chlorophyll-*a* and for phosphorus concentrations were conducted in 1995 and 1996. Total dissolved solid concentrations, major ions and related variables were measured for both years.

A total of 123 pesticide samples were taken over the two years. The water was sampled for the same 13 pesticides as in the stream survey.

Triallate was most commonly found. About 85% of the lake detections were from heavy pesticide-use areas.

Biota samples were collected from 12 of the lakes. Triallate was the only pesticide detected. It was found in a single sample from an area of high pesticide use and low runoff. Triallate was also detected in the sediment from this lake, but not in the lake water itself.

The lake survey confirmed conclusions from the stream survey that pesticide detections and concentrations are directly correlated to agricultural pesticide use. Pesticide detections in Alberta's surface waters were fairly frequent, though detections were generally in compliance with water quality guidelines.

Phosphorus concentrations were generally higher in lakes in high intensity agricultural areas. Based on chlorophyll-*a* concentrations, five of the lakes sampled were oligotrophic (low in nutrients, low in chlorophyll-*a*) seven were mesotrophic (had intermediate levels of nutrients and chlorophyll-*a*,) and six were eutrophic (had high levels of nutrients and chlorophyll-*a*).

Seven of the lakes were hyper-eutrophic (had very high levels of nutrients and chlorophyll-*a*). The eutrophic and hyper-eutrophic lakes were generally found in areas of high agricultural intensity.

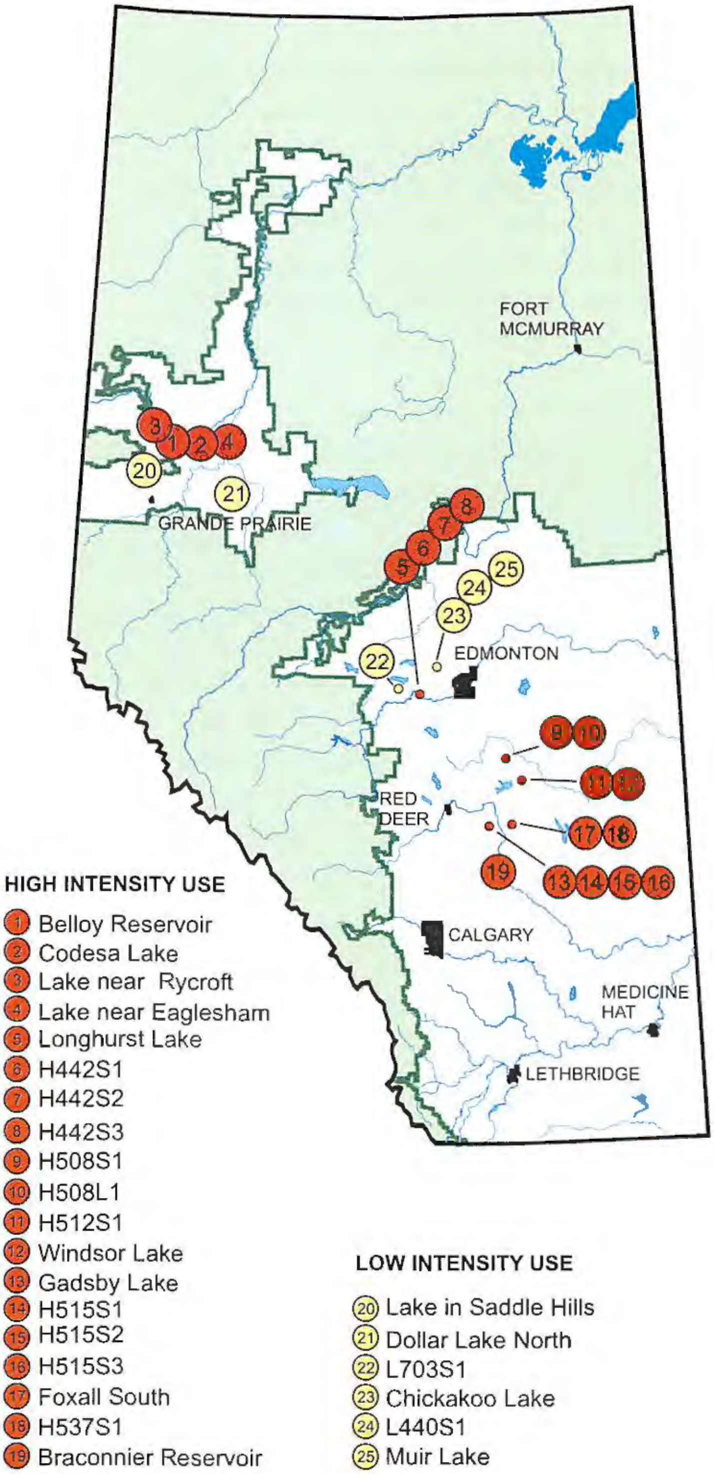


Figure 15. Location of survey lakes.

Haynes Creek Monitoring Project *A.-M. Anderson et al. 1997*

As part of the provincial stream survey, more extensive monitoring was conducted on one stream, selected as representative of an area with very intensive agricultural activity on a landscape prone to water erosion (Figure 16). Haynes Creek, a small drainage basin located near Lacombe, was selected for the study.

About the project:

Eighteen sampling stations were located in the Haynes Creek drainage basin and were monitored from spring 1995 through fall 1996. Stations were placed at four cattle wintering sites, three cultivated fields, nine stream sites, one site on the Red Deer River, and a control site, west of the creek. The control site was located on land covered by aspen and underbrush, used for light grazing. Over the two years, water samples were analyzed for nutrients, pesticides, bacterial content, suspended solids and colour.

Almost half the land in the drainage basin was planted to cereal crops. Other field uses included canola, hay, peas, summerfallow and pasture. Treed lots and wetlands accounted for 10% of land use.

Project Results:

Based on results of this two-year project and the provincial stream survey, Haynes Creek appears typical of streams in runoff-prone landscapes which drain intensively farmed land. The stream water has higher nutrient levels and more frequent pesticide detections than streams which drain medium or low intensity farmland. Researchers feel the farming practices they monitored at Haynes Creek would have similar effects on water quality in other high intensity drainage basins.

On the creek itself, there was great variability in water quality, related to stream flow. For most attributes, lower contaminant concentrations were associated with higher spring runoff flows. However, suspended solid, turbidity and particulate nutrient concentrations increased as stream flow increased.

During the two-year sampling program, runoff occurred only during spring snowmelt. Though researchers expected rainstorms to induce runoff during the open water season, precipitation was insufficient to cause such movement. Hence, effects of field runoff in the open water season were not documented.

Runoff from the field sites was greater than at the control site during spring snowmelt. Snowmelt on the bare fields was rapid, while at the control site the water ran off very slowly, seeped into the ground, or evaporated.

In 1996, there was no snowmelt-induced runoff from the control site. Snowmelt runoff from cropped fields was significant. Runoff from the field sites had higher nitrogen and nitrate levels, and a greater proportion of dissolved nutrients than runoff from the control site. Phosphorus, colour and carbon levels were not significantly higher.

Nutrient losses from some fields in 1996 represented almost 39% of the nitrogen and over 16% of the phosphorus applied in the previous growing season. Most nitrogen lost was in the form of nitrate. Most phosphorus lost was in dissolved form. The runoff of these nutrients is a significant economic loss to the farmer, as well as a threat to water quality.

Runoff from a field with a grassed waterway had lower nutrients, suspended solids and turbidity than runoff from a field with a non-functional grassed waterway.

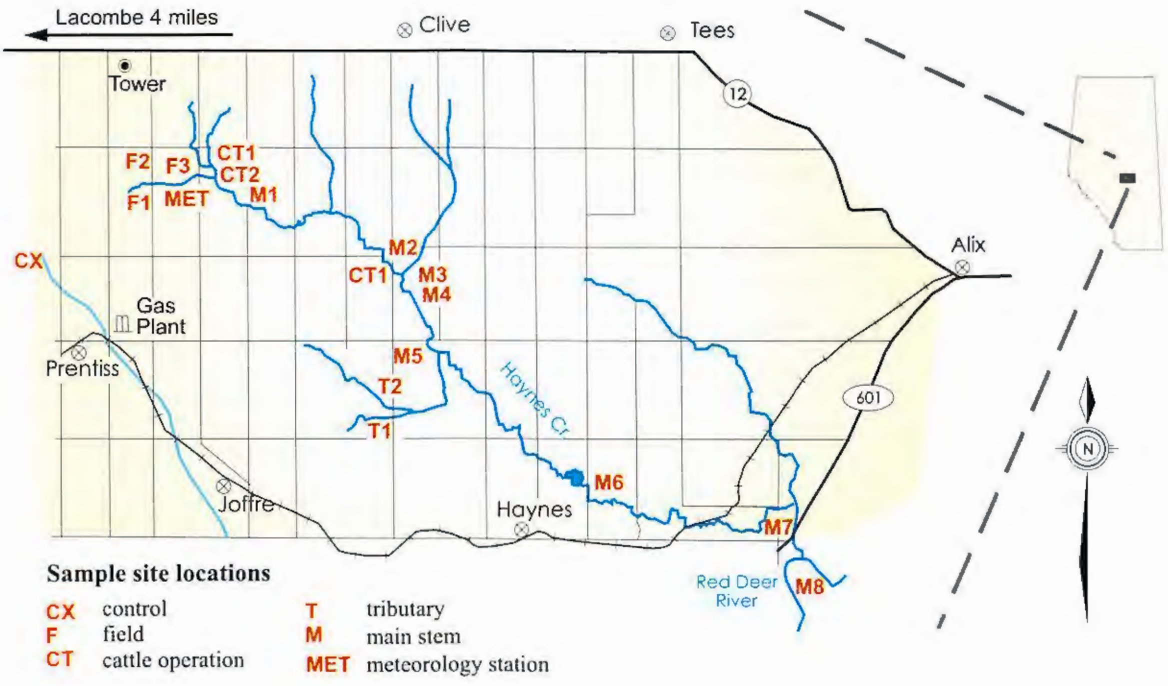


Figure 16. Haynes Creek Drainage Basin sampling sites.

Runoff from the cattle wintering grounds contained high levels of nutrients, suspended solids, colour, fecal coliform bacteria and fecal enterococci. Water downstream of the cattle wintering sites complied less frequently with guidelines than water upstream of the sites.

During flood conditions in April 1996, the cattle site in the flood plain contributed a substantial load of nutrients and suspended solids to the stream. Overall, however, nutrient detections were considerably higher in 1995 than in 1996 (Table 8).

Four of the 13 pesticides which had been applied to fields in the previous year were detected in spring runoff from these fields. This indicates pesticides applied in one spring season can persist in soils till the following spring, then move off the fields with snowmelt. Some pesticides which had not been applied to the fields in recent years were detected in the runoff, suggesting that drift from nearby fields or atmospheric transport and deposition may also be pathways of contamination.

Of the 67 samples taken from Haynes Creek, 73% had at least one pesticide detection. Although pesticide levels in these samples were usually low, concentrations of trifluralin and triallate in some samples exceeded guidelines for the protection of aquatic life. Concentrations of MCPA and bromoxynil exceeded guidelines for irrigation water in some samples.

Table 8. NUTRIENT DETECTIONS IN HAYNES CREEK

Year	Total Phosphorus - parts per million		Total Nitrogen - parts per million	
	median concentration	FWMC	median concentration	FWMC
1995	0.898	1.96	4.0	6.685
1996	0.625	0.765	3.4	4.11

FWMC = flow weighted mean concentration

Agricultural Impacts on Water Quality in Crowfoot Creek Drainage Basin

Gary Buckland et al. 1997

Reports from the 1991 Bow River Water Quality Task Force showed nutrient, coliform bacteria and trace element detections were being found in the river, and were most likely coming from agricultural areas downstream of Calgary. A review of water quality in the Eastern and Western Irrigation Districts also found high levels of fecal coliforms, as well as *E.coli* bacteria. High levels of aluminum, iron, copper, and manganese were also found.

In response to these findings, a committee was formed to further investigate whether primary agriculture was impacting water quality in the drainage basin of Crowfoot Creek, a small tributary of the Bow (Figure 17). The study team was asked to identify the land uses which might contribute to water quality deterioration in the region, and where possible, to recommend remedial measures.

About the project:

Stream flow and mapping of the area's agricultural production, topography, and soils was initiated in the summer of 1996. Flow data was gathered and water sampling stations were installed within the drainage basin. Based on preliminary 1996 data, sampling stations were added and the pesticide testing was increased in 1997.

The project design closely followed the protocols developed and used for the CAESA-funded Haynes Creek project, though the intensity of livestock production is somewhat lower in the Crowfoot Creek area. The project will run from 1997 through the year 2000.

In 1997, water samples were collected weekly, from early May through late October, at 29 sites. Samples were also taken during spring snowmelt.

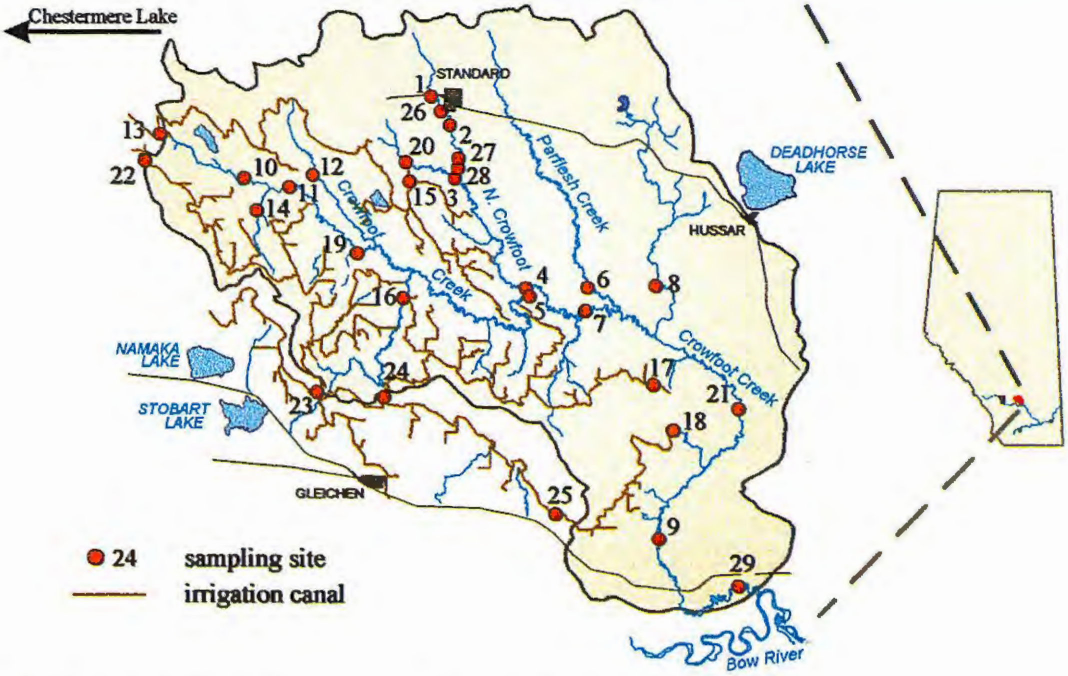


Figure 17. Crowfoot Creek Drainage Basin sampling site locations.

Project Results:

Preliminary 1996 data showed consistently high bacteria counts and high sodium and phosphorus levels. Though nitrate detections were frequent, most were below the guideline levels.

Analyses were conducted for 39 pesticides used in the region, but detections of only six were found. Most of the detections levels were very low, however, almost 80% of the samples showed levels of dicamba above irrigation water quality guidelines.

Results of the 1997 tests are being evaluated (Tables 9a & 9b). Of major concern are the high levels of bacteria in both Crowfoot Creek and the WID canal system.

Table 9a. Pesticides Detected in Crowfoot Basin - 1997 (in ppb)

STATION	DATE	2,4-D	Atrazine	Dicamba	MCPA	Bromoxynil
SOUTH CANAL Chestermere Lake	May 26	0.32	.031	.034	0	0
	June 2	.476	.038	.058	0	0
	June 9	.23	.028	.03	0	0
	June 16	.408	.067	.055	.152	.019
	June 30	.213	.04	.044	.043	0
	July 7	.084	.017	.021	.018	0
MID-BASIN	May 28	.036	0	.037	0	0
	June 4	.166	.007	.075	0	0
	June 11	.138	.019	.024	.063	0
	June 18	.155	.009	.012	.132	.014
	July 2	.222	.028	.122	.056	0
	July 9	.14	.051	.106	0	0
RETURN FLOW	May 28	.067	.013	.026	0	0
	June 4	.096	.013	.026	0	0
	June 11	.07	.017	.38	.038	0
	June 18	.199	.015	.159	.395	.016
	July 2	.838	.035	.30	.04	0
	July 9	.517	.041	.244	.032	0

None of the 1996 or 1997 samples met drinking water quality guidelines for fecal coliform bacteria. The bacteria detections may be associated with the large numbers of grazing cattle that currently have direct access to the stream. Most samples also showed high total phosphorus levels, especially during spring snowmelt and precipitation events.

While all samples met nitrate-nitrogen drinking water guidelines, total nitrogen levels at many sites were higher than recommended in Alberta's Surface Water Quality Guidelines for the Protection of Aquatic Life.

Herbicide detections were frequent, but mostly at low levels. Atrazine was found in 95% of the samples; dicamba was found in 97%; mecoprop in 98%; and 2,4-D in 100%. All but two detections of dicamba exceeded guidelines. Most other herbicide detections were within guideline limits.

Detections at the irrigation canal intakes were slightly lower than those at the return flow sampling site near Highway 1.

Table 9b. CROWFOOT CREEK BASIN Non-Compliance - Fecal Coliform Guidelines

REACH	FLOW	Drinking Water	Recreation Irrigation
North Crowfoot	Spring	100%	10%
	Rain Event	100%	70%
	Normal	100%	79%
Lower Crowfoot	Spring	100%	9%
	Rain Event	100%	0%
	Normal	100%	29%
WID return flows	Spring	100%	3%
	Rain Event	100%	10%
	Normal	100%	69%
WID Inflows	Spring	100%	0%
	Rain Event	100%	0%
	Normal	100%	9%

Herbicide Leaching into Shallow Groundwater

K.N. Harker, B. D. Hill et al. 1997

Herbicide residues in southern Alberta groundwater were first detected in 1991, in studies conducted on Lethbridge area clay loam soil with an organic matter content of 2%. *(Hill et al. 1992)* Triallate, MCPA, diclofop, bromoxynil and 2,4-D were detected in up to 65% of the sampled wells in two separate tests. Most detections were well below drinking water guideline recommendations. The highest detections occurred after heavy irrigation.

In a similar project, *(Miller et al. 1992)* research teams found even higher levels of 2,4-D, bromoxynil, diclofop, MCPA, dicamba, and mecoprop in groundwater samples from test sites near Taber. While most samples were low, some did exceed water quality guidelines.

This most recent project sought to determine if contamination of shallow groundwater in southern Alberta was a localized phenomenon, or whether contamination might be occurring in other parts of the province, under different conditions.

About the project:

In this CAESA project, stainless steel test wells were installed near Lacombe, on a field site with no previous record of herbicide use. Water samples were tested for six commonly-used herbicides, over a period of three years. All but one of the herbicides (fenoxaprop) are known to have a high potential for leaching (Table 10a).

The central Alberta sites differed from sites previously tested in southern Alberta in two important ways. Rainfall in the central region is somewhat higher than at the Lethbridge sites, but no irrigation is used. There was also more organic matter in the soil to absorb the herbicides. It was thought the herbicides would not leach into groundwater unless heavy rain occurred soon after the chemical applications.

The four test blocks in the project were on a sandy loam soil with 9% organic matter. Mean annual precipitation is 450 mm. Tank mixes, of 2,4-D + dicamba, bromoxynil + MCPA, and diclofop-methyl + fenoxaprop-ethyl, were applied at the manufacturers' recommended rates, at the 4-5 leaf stage of the wheat crop. Two of the four blocks were irrigated with 57 mm of water the next day, to simulate a heavy rainfall.

Project Results:

Starting in late June 1994, samples were taken at various locations from the field itself, and from eight peripheral wells located 10 metres off the field. In the first year, five of the six herbicides were detected on the two irrigated plots, at intervals of 6, 11, 40 and 77 days after application. Only one detection of 2,4-D was found on the dryland plots, 77 days after application. No detections were found in peripheral wells (Table 10b).

In 1995, the same five herbicides were detected on the irrigated blocks at intervals of 7 to 77 days after application. Significantly, the same herbicides were also detected on the dryland blocks at intervals of 10 to 77 days. The herbicides appeared to move into the groundwater and dissipate in a concentrated band. Dicamba and diclofop were detected in two of the peripheral wells in spring 1995.

In 1996, there were numerous detections of the same five compounds on both the dryland and irrigated blocks. A 39-mm rainfall, 41 days after herbicides were applied, flushed 2,4-D, bromoxynil and MCPA into the groundwater and resulted in detections in almost all 36 field wells.

Table 10a. HERBICIDE DETECTIONS IN GROUNDWATER - LACOMBE

		1994	1995	1996	1997*
Total detections, irrigated		23	20	110	26
Total detections, dryland		1	23	111	19
TOTAL DETECTIONS		24	43	221	45
DETECTIONS BY HERBICIDE - (with Canadian Drinking Water Guidelines - CDWG)					
	CDWG	**range of concentrations in ppb** (and # of detections)			
Dicamba	120 ppb	**.05 to 0.12** (5)	**0.05 to 3.2** (15)	**0.06 to 0.15** (14)	**0.22** (1)
MCPA	no guideline	**0.13** (1)	**0.15 to 0.5** (3)	**0.05 to 1.4** (47)	**0.05 to 0.16** (9)
2,4-D	100 ppb	**0.13 to 2.7** (13)	**0.05 to 3.3** (20)	**0.05 to 0.84** (81)	**.05 to 0.21** (23)
Bromoxynil	5 ppb	**0.06 to 0.11** (4)	**0.08 to 0.11** (3)	**0.05 to 1.4** (72)	**0.05 to 0.12** (6)
Fenoxaprop	no guideline	(0)	(0)	(0)	(0)
Diclofop	9 ppb	**0.69** (1)	**0.16 to 0.34** (2)	**0.06 to 0.16** (7)	**0.07 to 0.22** (6)

* No herbicides or irrigation applied in 1997. Sampling frequency reduced. ppb = parts per billion N/G = no guidelines

The study demonstrated herbicides could rapidly leach into groundwater, if irrigation or a heavy rainfall followed soon after application. It also showed leachable herbicides eventually moved into the groundwater, even under dryland conditions. Widespread, low-level contamination of the groundwater will occur if leachable chemicals are repeatedly applied to the same field.

Funding from the AARI Farming for the Future program allowed a fourth year of sampling. No irrigation or herbicides were applied in 1997. Only 16 wells were sampled, compared to 36 from 1994 through 1996. MCPA, dicamba, 2,4-D, bromoxynil and diclofop were still detected in the groundwater, one year after the last application. The 45 detections were all considerably below water quality guidelines. The 1997 work confirmed that residues from previous herbicide applications remained in the soil profile and could still leach into Lacombe groundwater supplies.

Table 10b. HERBICIDE DETECTIONS IN GROUNDWATER - SOUTHERN ALBERTA

		Taber 1991	**Lethbridge 1991**	**Lethbridge 1992**	**Lethbridge 1993**
Total detections, irrigated		78	10	31	13
Total detections, dryland		N/A	12	27	11
TOTAL DETECTIONS		78	22	58	24
DETECTIONS BY HERBICIDE (with Canadian Drinking Water Guidelines - CDWG)					
	CDWG	**range of concentrations in ppb** (and # of detections)			
Dicamba	120 ppb	**0.9 to 15.0** (12)	N/A	N/A	N/A
MCPA	N/G	**0.5 to 114** (7)	(0)	**0.2 to 0.3** (2)	(0)
2,4-D	100 ppb	**0.5 to 29** (27)	**0.1 to 0.2** (3)	**0.1 to 5.2** (14)	**.05 to 0.2** (12)
Bromoxynil	5 ppb	**0.7 to 56** (18)	**0.1 to 0.9** (8)	**.05 to 8.4** (28)	**.05 to 0.1** (6)
Mecoprop	N/G	**0.6 to 4.8** (9)	N/A	N/A	N/A
Diclofop	9 ppb	**0.5 to 2.1** (8)	**0.1 to 11.0** (8)	**0.1 to 11.0** (8)	**.05 to 0.1** (2)
Triallate	230 ppb	N/A	**.05 to 0.1** (6)	**.05 to 0.1** (6)	**0.1 to 0.4** (4)

N/A = not applicable (either not sampled for or never applied at the site) N/G = no guideline ppb = parts per billion

Nitrate Leaching and Crop Rotation

Barry, Olson et al. 1997

Nitrogen is a key component of the air we breath and an essential nutrient for all plant life. As an agricultural input, nitrogen is applied both in the form of livestock manures or as a chemical fertilizer. Once in the soil, nitrogen in organic compounds can be converted to plant-available nitrate (NO_3). Nitrate in excess of plant needs, however, is left as a residue in the soil, where it is extremely mobile. Previous studies have shown that large amounts of water, whether from rainfall, snowmelt or irrigation, facilitate the movement of nitrate residues to soils below the root zone. This speeds up the leaching of the nitrate into groundwater aquifers.

Nitrate contamination of groundwater has been reported world-wide, including eastern Canada. This project was designed to test whether nitrate would be found below the root zone, where it could more readily leach into groundwater, at several long-term crop rotation study sites in Alberta. It also sought to identify crop rotation practices that might contribute to nitrate contamination of groundwater.

Project Results:

The project found that the addition of nitrogen compounds to the soil, either from commercial fertilizers or manures, generally caused an increase in soil nitrate accumulations in the upper part of the root zone, especially where fertilizer application exceeded crop needs. No one cropping system was found to promote or retard nitrate leaching.

For example, comparisons of zero tillage and conventional tillage were made at four project sites. Differences in nitrate distribution in the soil profile between these practices were not significant at any of the sites.

About the project:

For this project, no water samples were taken. Instead, the research team looked at nitrate levels in the soil profile to determine the potential for groundwater contamination.

Soils were sampled at 20 plots, from as far south as Lethbridge and Bow Island, and as far north as Beaverlodge and La Corey (Figure 18). Where possible, multiple samples were taken, at depths up to 390 cm into the soil profile.

The sites represent a wide range of soil types, tillage practices, fertilization practices and crop rotations. Most study samples were taken in 1993.

Soil nitrate was generally low under continuous grass coverage. However, soil samples from unbroken fields varied. At the native plant cover or long-term pasture sites in Lacombe, Breton, Ellerslie and Beaverlodge, very little nitrate was detected. The soil nitrate present was evenly distributed throughout the soil profile, at very low levels.

However, at Lethbridge, nitrate-nitrogen content was low in the upper 200 cm, but increased with depth below that. Nitrate-nitrogen content at the 360 to 390 cm depth at the Lethbridge unbroken grassland site was one of the highest values measured in the project. Researchers believe these high levels could be attributable either to naturally high levels in the subsoil, or to fluctuating water tables and irrigation moving nitrate into the lower soil profile.

Where used, legume crops and legumes used as a green manure increased soil nitrate content, because they increase the nitrogen-supplying ability of the soil.

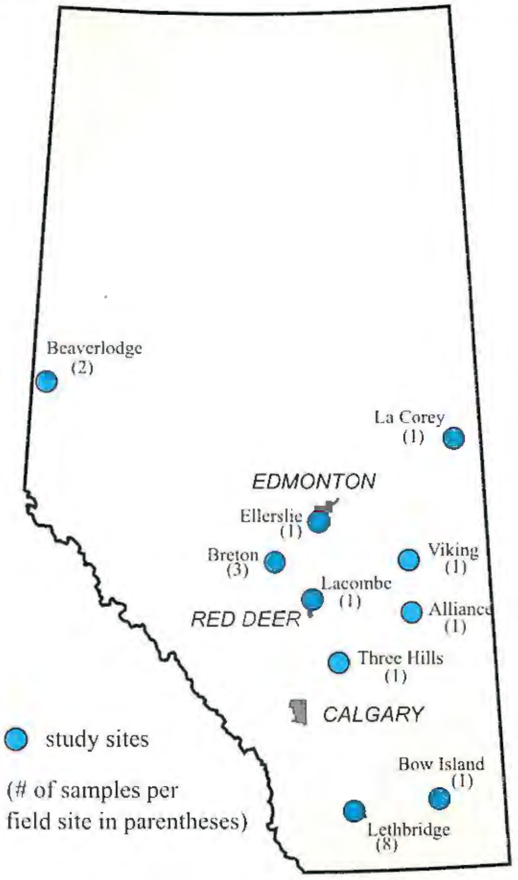


Figure 18. Location of nitrate leaching study sites.

Soil nitrate levels at the southern Alberta sites were generally about five and a half times higher than those in central Alberta (Figure 19). Generally speaking, nitrate-nitrogen content in the soil decreased from south to north. Whether this is due to higher levels of soil nitrate in the south, or the depletion of soil nitrate through greater rainfall and increased plant uptake in central Alberta isn't known.

Based on previous research, it was felt that soils with nitrate-N content greater than 165 kg per hectare in the root zone (0-120 cm) were considered at risk for nitrate leaching. More than 25 kg per hectare of nitrate-N in the 120 to 390 cm depth was an indication leaching from the root zone had occurred.

Using these criteria, 13% of the sites sampled in this project were at risk. Amost all these sites were in southern Alberta. About 85% of all sampled sites exceeded the second criteria, indicating accumulations of nitrate below the root zone were common throughout the province.

More research is needed to determine whether this is caused by nitrate leaching from the root zone, whether the nitrate is due to naturally high soil levels, or whether it is a result of the distribution of the nitrate by upward movement of water.

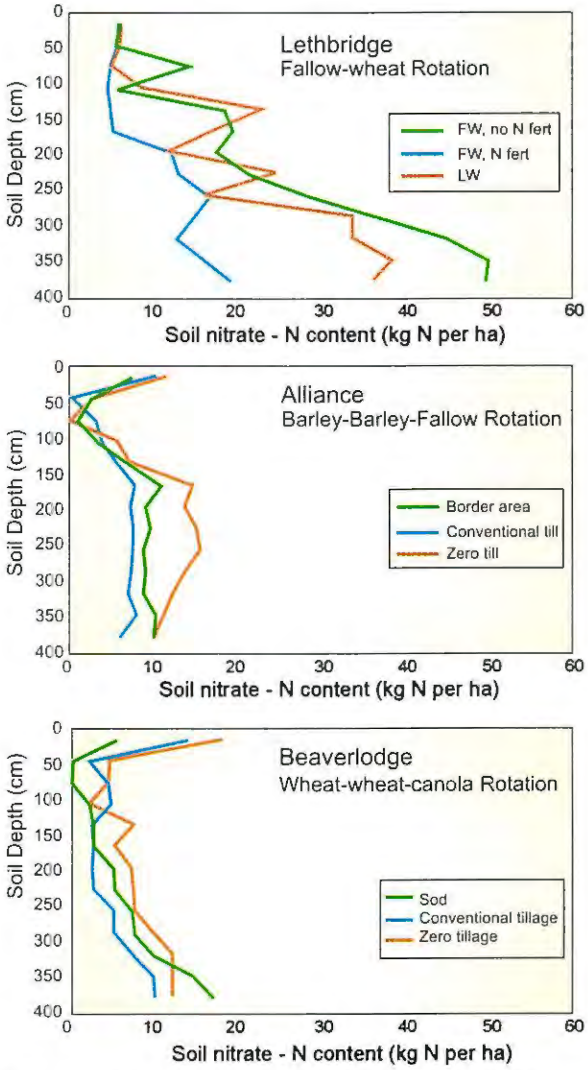


Figure 19. Soil nitrate content - crop rotations.

Effects of Manure and Nutrient Management on Soil & Water Quality *Barry Olson et al. 1997*

Two CAESA studies, to assess the potential risk to groundwater resources from manure and nitrogen urea fertilizers, were undertaken at research sites in southern and central Alberta. The overall objectives of the research were to develop improved manure and nutrient management practices, and to maximize the economic value of nitrogen treatments, while minimizing impacts on soil and shallow groundwater quality.

About the projects:

The two southern Alberta sites were located on irrigated land north of Lethbridge. One was on a medium-textured loam to clay loam soil; the other on a coarse-textured loamy sand. The water table was about two metres below the soil surface. Manure treatments were applied in the fall of 1993, 1994 and 1995 at both sites. Barley was seeded on each plot the following spring.

The two central Alberta sites were established the following year, one on a loam soil near Ponoka, the other on a silty clay loam near Lacombe. The water table was about 6.5 metres below the soil surface. The study design was similar at all locations, except the southern sites were irrigated, while the central Alberta sites were watered through natural precipitation events only.

Each site was divided into six plots: a control plot, a plot which received urea fertilizer, (60 kg N/ha,) and four manure treatments plots at rates of 20, 40, 60 and 120 tonnes per hectare of wet manure. Each of these plots were further split in two, with some sub-plots receiving additional nitrogen as chemical fertilizer. Soil samples were taken prior to the manure being incorporated into the soil in fall 1995 and 1996. Phosphorus was applied at spring seeding.

Baseline groundwater samples were collected in the initial year, and then on a monthly basis during the growing season of subsequent crop years. Samples were analyzed for nitrate content.

Project Results:

The project showed nitrate did accumulate and move down the soil profile under high annual manure applications. To this point in time, however, nitrate has not been detected in the groundwater.

At the Lethbridge medium-textured site, baseline nitrate levels in the soil were low throughout the soil profile, but accumulated in the upper soil profile during the study, particularly at the higher manure application rates (Figure 20).

At the coarse-textured Lethbridge site, baseline nitrate readings were already high. Nitrate actually decreased in the lower part of the soil profile at all manure application rates. Some nitrate accumulated near the soil surface.

At the Lacombe site, nitrate content near the soil surface increased under the higher manure application rates. No differences were observed among the nitrogen manure and fertilizer treatments at the Ponoka site (Figure 21).

Groundwater nitrate content at the Lethbridge coarse-textured site ranged from 10 to 107 ppm before the manure treatments were even applied. The manure treatments did not appear to affect the nitrate content at this site, except under the highest application rate, which did cause nitrate levels to increase.

At the southern medium-textured sites, baseline groundwater nitrate readings were much lower, (1 ppm to 35 ppm,) and there was no evidence of impacts from the manure.

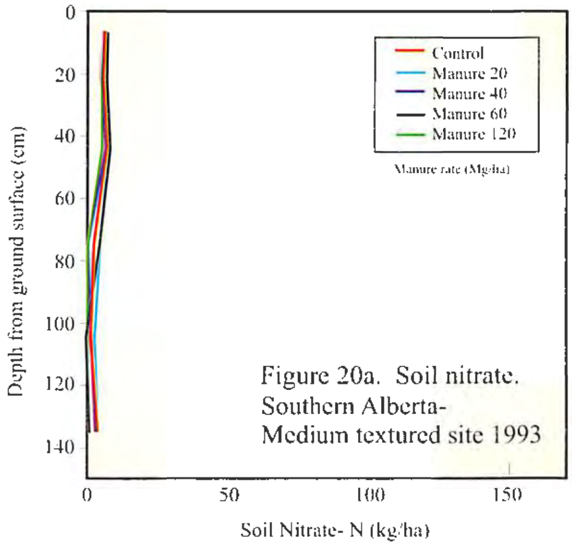


Figure 20a. Soil nitrate. Southern Alberta- Medium textured site 1993

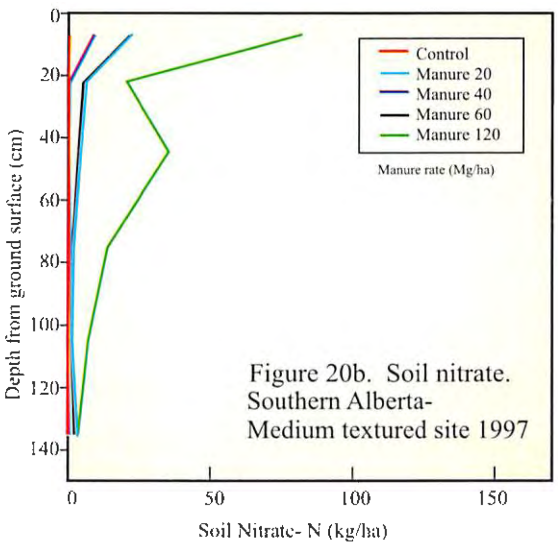


Figure 20b. Soil nitrate. Southern Alberta- Medium textured site 1997

Researchers believe the nitrate accumulations have not yet reached the water table. There was no evidence of groundwater contamination from the nitrate at either of the central Alberta sites.

The overall lack of effect on the groundwater at most of the test blocks may be due to the long time the leachates take to reach the water table. To study the effects of the nitrogen applications over a longer period, tests at the southern Alberta sites are being continued through 1998 under an Alberta Agricultural Research Institute, 'Farming for the Future' grant.

Manure and fertilizer were applied in 1997 at both sites. At the coarse-textured site, groundwater nitrate levels increased, ranging from 29 ppm to 232 ppm in 1997. Average groundwater nitrate content ranged from 2 ppm to 30 ppm at the medium-textured site in 1997, again showing no evidence of increased levels.

However, nitrates are continuing to accumulate and move down the soil profile at the higher application rates. Researchers estimate it will take two to three years for this excess nitrate to reach groundwater.

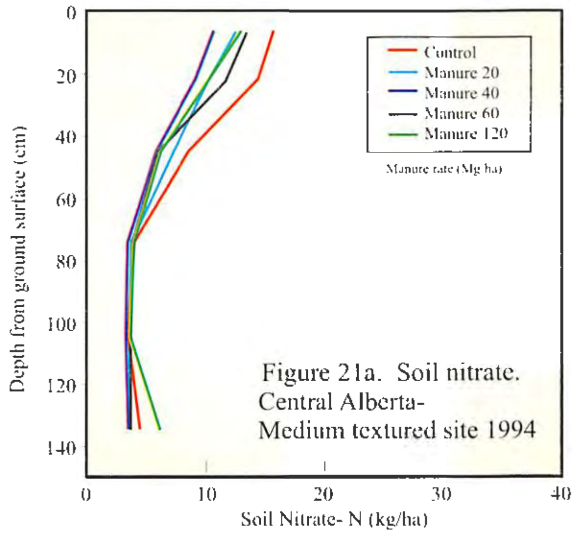


Figure 21a. Soil nitrate. Central Alberta- Medium textured site 1994

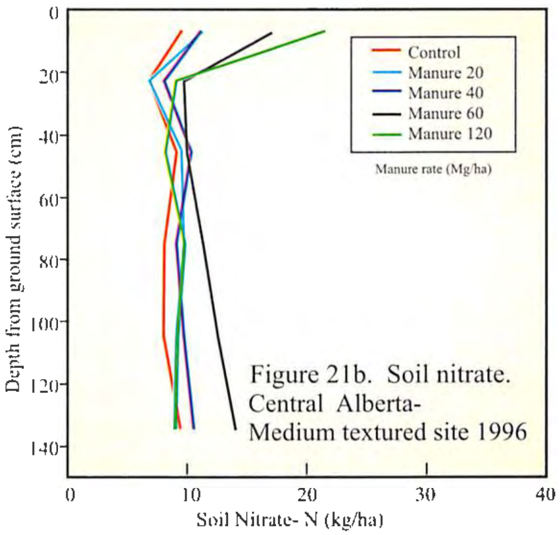


Figure 21b. Soil nitrate. Central Alberta- Medium textured site 1996

Feedlot Runoff Impacts

Brian Kennedy et al. 1997

Alberta's cattle feedlots process almost two million animals a year, with each animal producing approximately a tonne of manure during its stay. In recent years, technical literature and the media have identified this manure, from the feedlots, and from field runoff after the manure is spread, as a major contributor to water quality contamination.

Feedlot manure contains large amounts of nitrogen, phosphorus, potassium, sodium, organic material and bacteria. Spread on fields, the nutrients are valuable plant foods and the organic matter is a useful soil conditioner. However, spreading rates are often higher than warranted for environmental sustainability. A Code of Practice for the safe and economic handling of these manures is currently being revised.

To clarify the role of feedlot manure in water quality contamination, a research team undertook a four-year study of a large, relatively new feedlot, north of Vegreville, Alberta. The specific objectives of the project were to measure the runoff volume of the watershed containing the feedlot, to measure the chemical parameters of the runoff, and to test for microbiological contaminants, including fecal coliform and fecal streptococcal bacteria.

The data obtained from the project would also be used to help define sustainable manure application protocols for the industry and to revise the Code of Practice.

Project Results:

Two types of storm events were recorded in the feedlot area: short duration, high intensity summer thunderstorms, and long duration, low intensity frontal storms. The first type of rain event produced a small amount of runoff immediately.

The second type of storm produced significant amounts of runoff after 24 hours. During this time, the feedlot surface was absorbing moisture and becoming saturated. Approximately 25 mm of rain was needed to fully saturate the surface under these conditions. Over the four years of the project, 26 storm events produced measurable runoff. Fifteen of these events occurred in 1994, a high runoff year, with two very intense storms.

There was no measurable snowmelt runoff due to the design and operation of the feedlot. Runoff yield from individual storm events varied greatly, ranging to as much as 73.7% of the rain that fell on the pens.

In general, runoff volumes were lower than expected, with the system retaining 60% to 85% of summer rainfall. Compaction from the cattle's hooves made the soil beneath the pens almost impenetrable, and created micro-depressions which acted as traps for excess water. As well, the packed manure layer absorbed much of the rainfall.

However, during long-duration storms, once the manure pack was saturated, almost all the rain was directed to runoff. The movement of manure through the pen system increased as the runoff continued.

Structures to deal with solid manure loads in the collection system upstream of the catch basin were suggested. It was also recommended that catch basin volumes be calculated to store runoff from the wettest year of an average ten-year cycle, rather than for the storage of a single severe storm event.

Chemical analyses of the feedlot runoff showed extreme variability, both during individual storm events and from year to year.

Bacteria counts were variable, based on seasonal temperatures and other factors. Bacteria become dormant and persisted longer when temperatures were low. Warm, sunny weather caused microbial die-off.

Traditionally, spreading rates have been based largely on the amounts of plant-available nitrogen in the manure. However, the project results indicate phosphorus, potassium and sodium should be the limiting factors for land application rates. Spreading rates over 2.4 tonnes per hectare for silage production apply phosphorus in excess of plant needs (Table 11.)

Similarly, applications above 5.9 tonnes per hectare on silage and 1.3 tonnes per hectare on grain crops led to accumulations of potassium. It was recommended manure application rates be based on phosphorus or potassium levels, with additional nitrogen applied from commercial fertilizers.

The researchers also found excess sodium in the soil profile, from repeated manure applications. It was recommended feedlot rations be evaluated to reduce sodium levels, and manure applications be rotated to avoid excess build-ups.

Table 11. IMPACT ON SOILS WHEN IRRIGATING WITH FEEDLOT RUNOFF

	Soil Depth	NO_3-N (ppm)	PO_4-P (ppm)	Na (ppm)	K (ppm)
Oct. 4/94 before irrigation	0-149 cm	9	18	32	150
	150-299	6	2	47	77
	300-450	5	(bdl)	60	107
Oct. 7/94 after irrigation	0-149 cm	30	27	153	360
	150-299	5	3	100	124
	300-450	2	1	68	95
May 15/95 following spring	0-149 cm	59	25	172	336
	150-299	11	4	105	110
	300-450	6	(bdl)	99	101

NO3-N = nitrate/nitrogen PO4-P = phosphate/phosphorus

Na = sodium K = potassium bdl = below detection limits

About the project:

The feedlot chosen for the project, Highland Feeders, was established in 1986 and was designed as a state-of-the-art facility. It is located on 150 acres of glacial till, on a very slight slope, adjacent to 28 quarter sections of cropland. During pen construction, about 12 inches of topsoil was removed, exposing the relatively impermeable clay-soil base. Facilities include clay-lined lagoons to collect runoff, and lined storage ponds for solid manure.

At the start of the project, in 1994, Highland Feeders processed approximately 12,000 head in two groups of pens. By 1996, the operation had grown to 25,000 head and four pen areas.

The cattle holding pens were constructed to drain to the back and away from feedbunks into the holding ponds. The operation's 92 pens are scraped regularly, even during winter. Waste-laden snow from the feedlot is also scraped and carefully stockpiled.

Flow recording equipment and sampling stations were established in the culverts which drain runoff from the feedlot pens. Devices to measure infiltration rates were installed at a three-year old pen, a new pen, and a pen area where the manure had been removed. A weather station was also installed, to gauge micro-climatic conditions throughout the feedlot operation.

Stored manure and material from the lagoons was spread on the operation's croplands in 1994, 1995 and 1996. Soil tests were conducted where the manure was applied.

Nitrate below irrigated fields in southern Alberta

Joan Rodvang et al. 1997

A detailed investigation of nitrate in soil and groundwater below five irrigated fields was conducted in southern Alberta between 1993 and 1996. The project's objective was to collect information on the occurrence, source and fate of groundwater nitrates in the area.

About the project:

Geology at all sites consisted of lake, river or wind-deposited sediments, overlying at least 11 metres of glacial till (Figure 22). Bedrock consisted of finely interbedded sandstone, siltstone and shale.

Site A covered 60 hectares in the Bow River Irrigation District (BRID). The site has been cropped and irrigated since 1927. Most recently, the dominant crop has been soft wheat, with some rotation to peas and alfalfa. The field was fertilized at rates based on soil testing, averaging 100 kg of nitrogen per hectare each year.

Site B is a small agricultural research plot in the BRID, managed by Agriculture and Agri-Food Canada. The plot has been sown to a corn-sorghum rotation and fertilized with 134 to 168 kg nitrogen per hectare.

Site C is a 1.4 hectare plot in the St. Mary River Irrigation District (SMRID), owned by AAFC. The plot was ploughed from grass cover in 1987 and has been sown to a wheat-wheat-oats rotation since. Fertilizer rates varied from 0 to 200 kg nitrogen per hectare

Sites D and E are regional. Site D covers 3100 hectares in the BRID. It has been cropped and irrigated since the 1920s, most recently with wheat, sugar beets, potatoes, barley, peas, alfalfa and pasture.

Site E covers 7700 hectares in the Lethbridge Northern Irrigation District. A shallow unconfined aquifer, composed of coarse-textured river deposits, underlies 9000 hectares in the region. The area contains 45 intensive livestock operations, and over 400,000 animals.

Project results:

Preliminary data indicate nitrate in irrigated areas leaches below the root zone if manure or fertilizer are applied in excess of crop needs. Shallow groundwater is particularly vulnerable to contamination from agricultural sources. Agricultural nitrate was present below all irrigated cropped fields, in both oxidized till and oxidized lake deposits.

Fertilizer rates over 100 kg nitrogen per hectare resulted in significant leaching to groundwater.

The nitrate was only detected near the water table adjacent to manure and fertilizer sources. Shallow groundwater not located near fertilizer or manure did not contain nitrate. Nitrate concentrations in the shallow groundwater tended to increase with higher fertilizer or manure availability.

Agricultural nitrate was detected at a maximum depth of seven metres, and a maximum concentration of 286 parts per million (ppm), or 28 times greater than the Canadian Drinking Water Guideline.

Natural geologic nitrate occurred in glacial till between the depths of six and sixteen metres, at levels ranging from 100 to 500 ppm. This nitrate was detected even below native rangelands. Progressive downward leaching of agricultural nitrate over the three-year test period was documented at several sites.

In very shallow or coarse-textured soils, nitrate levels tended to fluctuate with time, indicating horizontal or downward movement of the nitrate. Horizontal movement of the groundwater was measured at rates up to twelve cm per year through till, and up to 45 cm per year through coarse river or lake deposits.

Vertical movement of the leading edge of nitrate plumes in the groundwater averaged 41 cm a year at site B, and 72 cm a year at site C. The centre mass of the nitrate plume travelled at about half those speeds.

At site E, nitrate was present in almost 80% of the samples collected from the unconfined aquifer. The shallow, unconfined aquifer in the Battersea drainage basin is susceptible to contamination from agricultural sources at the surface because it is not overlain by deposits with low permeability.

Groundwater discharge from unconfined aquifers also has a much greater potential to affect surface water, than does discharge from finer-textured deposits like till. The researchers noted that shallow, unconfined aquifers are generally economically important and should receive priority in protection and research efforts.

The researchers also concluded that denitrification, the conversion of nitrate to nitrogen or nitrous oxide gas, is probably insufficient to completely remove nitrate from groundwater at the project locations.

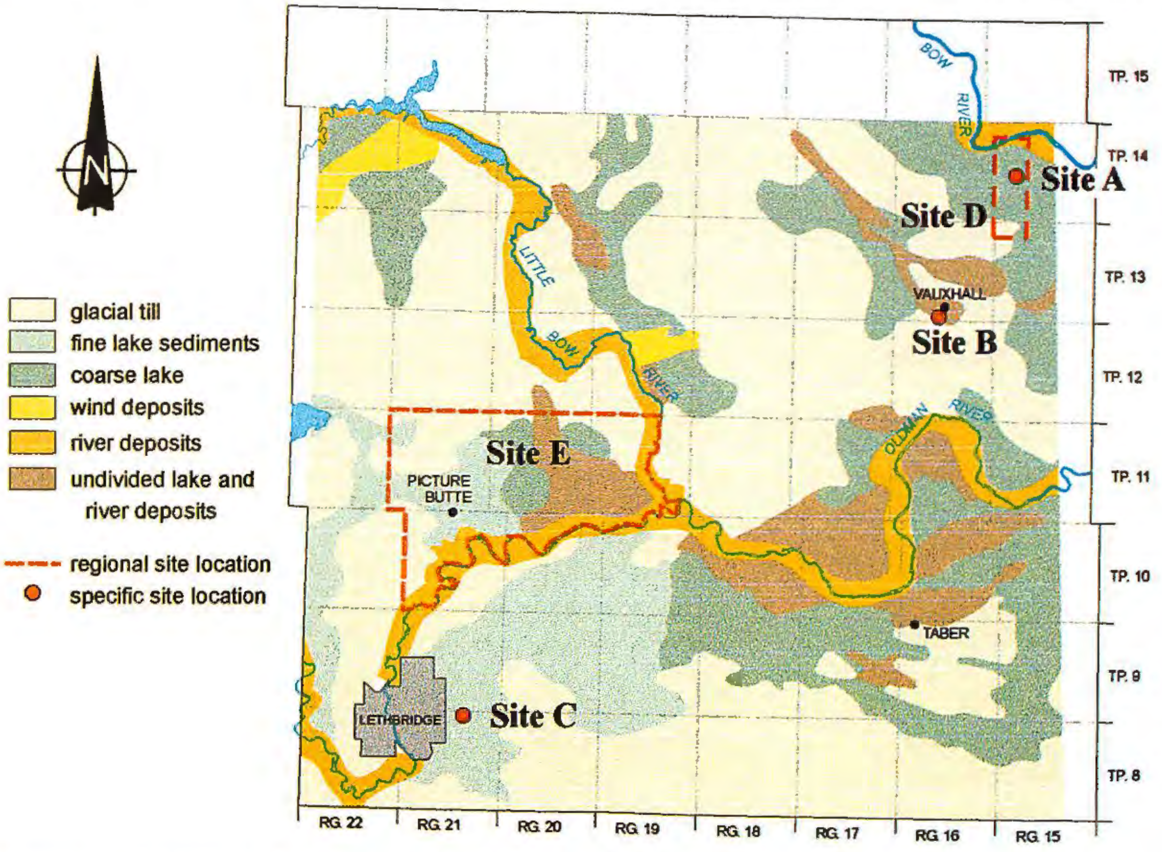


Figure 22. Location of nitrate sites in southern Alberta.

Water quality in Alberta's irrigation districts

Patsy Cross (Madawaska Consulting) 1996

Alberta's irrigation districts were established to allow farmers to band together to construct and manage irrigation developments that would provide water for the semi-arid land in the southern part of the province. Despite many administrative changes, the 13 irrigation districts remain essentially farmer-owned cooperatives.

While water quantity remains the priority resource issue for the irrigation districts, water quality has become an important concern. Monitoring of water in the irrigation districts has been conducted by various agencies.

For example, in 1977 and 1978, Alberta Environmental Protection collected return flow data on phosphorus loading, for a database on the South Saskatchewan River Basin. More recently, data have been collected under the auspices of the irrigation districts, Alberta Agriculture, Alberta Environmental Protection, and the County of Wheatland.

As part of the CAESA Water Quality monitoring and research program, a review of existing water quality data for the irrigation districts was undertaken by Madawaska Consulting. The review summarizes data collected from 1977 through 1996 at the sites shown in Figure 23.

Project Results:

The data indicate a change in irrigation water quality as the water moves from source intakes to return flows. Concentrations of salinity, total phosphorus and pathogens increased. However, nitrate + nitrite levels decreased, probably due to incorporation into biological material and the conversion of nitrate to nitrogen gas into the atmosphere.

Concentrations of nitrate + nitrite were generally within guideline limits in both source water and return flows. Source water usually complied with guidelines for irrigation use and recreation in most of the six districts. In the return flows in all six districts, however, there were several detections which exceeded irrigation guidelines for salinity.

About the review:

The review summarized existing data on return flows, spillways, drains, natural channels and source waters for the Eastern Irrigation District (EID), St. Mary River Irrigation District (SMRID), Bow River Irrigation District (BRID), Western Irrigation District (WID), Lethbridge Northern Irrigation District (LNID), and Taber Irrigation District (TID).

The number of samples taken, and the period of sampling for each site varied greatly. At the Battersea Drain site, in the LNID, data from 99 samples, taken over the years 1977 to 1996, was used in the review. At one BRID drain, data from only ten samples, from 1982 through 1984, was used.

Results were analysed by compiling source water data for the six districts for total dissolved solids and other salinity measurements, phosphorus, nitrates, and fecal coliforms. A similar process compiled data from all return flows. Data from individual sites within each district were analysed for similarities.

Data were compared to water quality guidelines, considering median and extreme values, for various water uses. A separate analysis for the combined return flows was conducted to explore seasonal trends. Information on trace metal detections and pesticide detections was also summarized.

Total phosphorus exceeded Alberta surface water quality guidelines for the protection of aquatic life 16% of the time in the irrigation source water, and 61% of the time in return flow water.

Fecal coliforms nearly always exceeded human drinking water guidelines, in both source and return flow water. Fecal coliform and *E. coli* bacteria counts exceeded recreation guidelines 33% of the time in return flows, but only seldom in source waters.

Three of the detected herbicides (MCPA, dicamba and bromoxynil,) exceeded irrigation water guidelines 33%, 33% and 3% of the time, respectively.

The detections only seldom exceeded water quality guidelines for the protection of aquatic life. Human and livestock drinking water guidelines for pesticides were never exceeded.

In the LNID, water quality concentrations for most parameters were generally higher in the return flows than in source waters. However, a 1989-1991 study of several laterals on the LNID irrigation system indicated there was no degradation of water quality upstream to downstream. A similar 1991-1992 project did show a slight increase in salinity and nitrate levels between the diversion sites and the return flows.

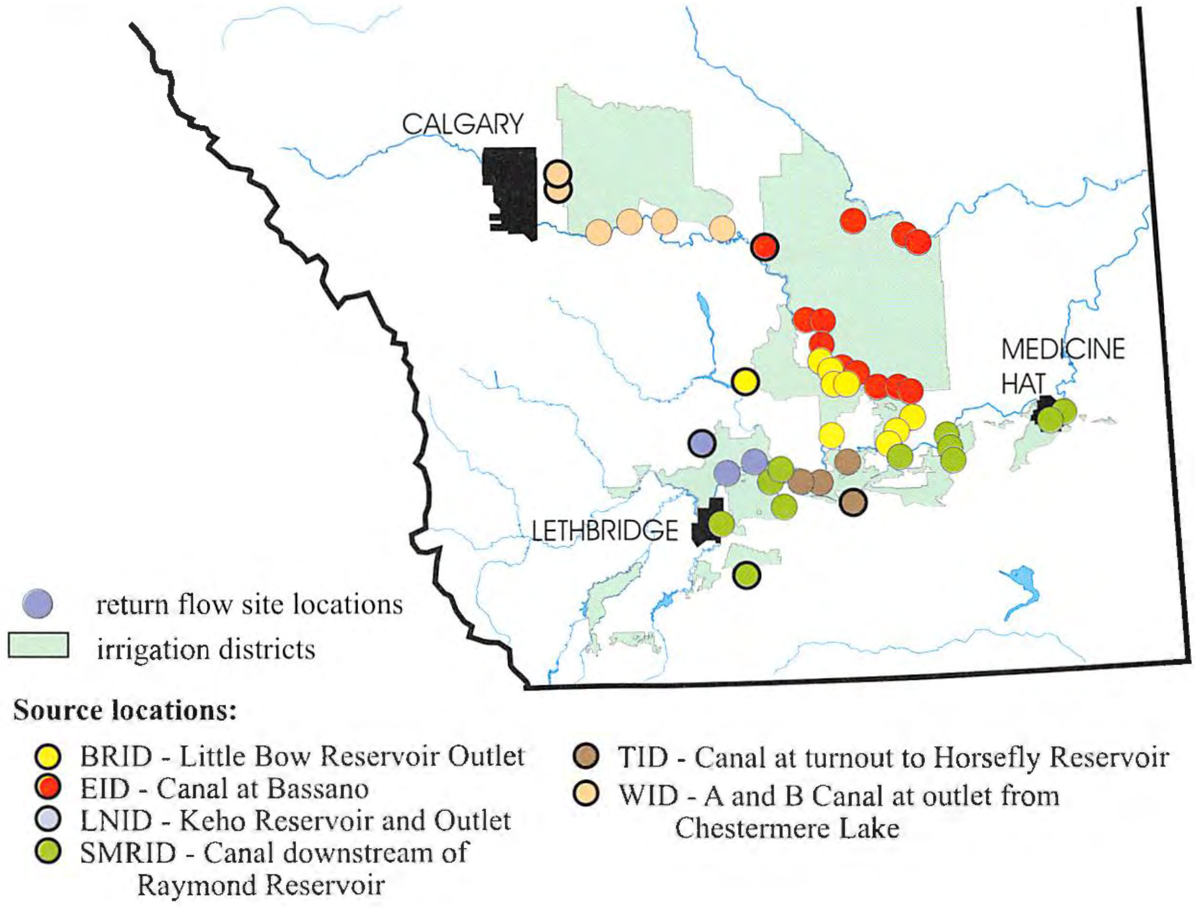


Figure 23. Irrigation district sampling sites.

A 1994 project in the Battersea drainage basin showed large increases in salinity, sodicity and total dissolved solids between Picture Butte Outlet and the Haney Drain return flow. Half the samples taken at the Haney Drain violated nitrate guidelines for human drinking water, possibly as a result of cattle being allowed free access to the water.

Return flows in the TID had generally higher concentrations of the measured parameters than source water, though most samples met guidelines for irrigation and recreation. Phosphorus levels in return flows often exceeded guidelines for the protection of aquatic life. Phosphorus and salinity levels were also high in the EID return flows.

In the SMRID salinity increased from upstream to downstream in the canal. Fecal coliform counts were generally below guideline limits for irrigation and recreation, but concentrations were high at particular sites.

Herbicides were monitored in the SMRID from late May to September 1995 and from late May to August 1996. Detections were frequent, but generally at very low levels. Irrigation guidelines for MCPA were exceeded 21 times in 1995, and once in 1996. For other herbicides, exceedences occurred only once or twice a year, or not at all.

Overall, the percent of herbicide detections in the SMRID water samples was significantly higher in 1995 (Table 12). This was attributed to 1995 being a wetter year, with more runoff. However, the concentrations were lower, due to increased dilution.

Herbicide sampling, in conjunction with canal bank spraying, was conducted at two sites in the SMRID, to test for atmospheric drift. There were no detections in the canals at either site.

Table 12. Herbicide Detections in the St. Mary River Irrigation District

	Detections (% of total samples)	
herbicide	**1995**	**1996**
2,4-D	87%	67%
dicamba	40%	15%
MCPA	43%	5%
bromoxynil	17%	3%
triallate	17%	2%
fenoxaprop	0	0
diclofop-methyl	8%	0

Sampling in the BRID, LNID and TID detected trace amounts of most herbicides for which tests were conducted. Concentrations were always below water quality guidelines for drinking and livestock water. Irrigation water guidelines for various crops were sometimes exceeded, as were guidelines for aquatic life.

Irrigation guidelines for trace metals were generally not violated in the six districts. There were occasional exceedences of surface water quality guidelines for aquatic life for copper, aluminum, and chromium, and to a lesser extent for lead, iron, manganese and zinc. The only drinking water guidelines exceeded were for iron and manganese, though median levels met the guidelines.

Most of the studies concluded that irrigation water impacts on major rivers were slight. No long-term trends in return flow quality were obvious from this data analysis.

Appendix B.

Detailed Assessment

DETAILED ASSESSMENT

Introduction

This section integrates results from the numerous projects carried out by the CAESA Water Quality Committee and provincial and government agencies. Nutrients, Bacteria and Pesticides were analysed for five water sources, including deep groundwater, shallow groundwater, dugouts, streams, small lakes, and irrigation canals. The study results are discussed relative to federal and provincial water quality guidelines for human drinking water, livestock drinking, irrigation, the protection of aquatic life, and recreation.

Nutrients

OVERVIEW

Nitrate + nitrite were analysed in 824 domestic wells and 87 dugouts. Nitrogen (nitrates + nitrites, total nitrogen and ammonia) and total phosphorus were analysed for the 25 streams and 27 lakes surveyed. Nitrate + nitrite and total phosphorus were analysed for the irrigation canals reviewed for the study. Table 1 (page 19) depicts the Water Quality Guidelines for Nutrients.

Provincial Assessment of Nutrient Analyses (by water resource)

GROUNDWATER

Of the 824 wells tested, 448 were deep, (greater than 100 feet,) while the remaining 376 were shallow, (less than 100 feet deep.) Ninety four of the deep wells and 229 of the shallow wells had detectable levels of nitrate + nitrite. The causes of these detections are not clear, but research carried out in central and southern Alberta shows that annual fertilizer and manure applications in excess of crop needs result in nitrate leaching below the root zone, eventually reaching the shallow groundwater. Shallow, unconfined aquifers are particularly vulnerable. Table 13 summarizes the study results on nutrients in groundwater.

Human Drinking Water Quality Guidelines

All the deep wells surveyed in this study had nitrate + nitrite concentrations below the maximum acceptable concentration (MAC) of 10 parts per million (ppm), as set out in the Canadian Drinking Water Quality Guidelines. Of the 376 shallow wells surveyed, 46 (13%) had nitrate + nitrite concentrations which exceeded 10 ppm. These 46 wells averaged 50 feet in depth, were an average of 26 years old, and had average nitrate + nitrite concentrations of 27 ppm.

Livestock Drinking Water Guidelines

Maximum acceptable concentrations (MAC) for livestock in the Canadian Water Quality Guidelines are generally less stringent than the human drinking water guidelines. In this study only 1 shallow well (of 376 sampled) exceeded the livestock MAC for nitrate + nitrite.

Table 13. Nutrients in Groundwater (nitrate+nitrite)

		Non-Compliance with Guidelines - % of Samples				
GROUNDWATER	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
Deep Wells	448	0.6%	0%	N/A	0%	N/A
Shallow Wells	376	13%	0.3%	N/A	0%	N/A

N/A=Not Applicable

DUGOUTS

Nitrate + nitrite was monitored in dugouts as part of the Farmstead Water Quality Survey pilot project and for the Northern Alberta Dugout Survey (1996). Nitrate + nitrite was detected in 25% of the 112 dugouts monitored in the pilot survey and in 55% of the 78 samples taken from the 14 dugouts monitored in the Northern Alberta Dugout Survey. Water quality guidelines for nitrate + nitrite exist for human and livestock drinking water only. Table 14 summarizes the study results on nutrients in dugouts.

Human and Livestock Drinking Water Guidelines

None of the nitrate + nitrite detections in either survey exceeded these guidelines.

Table 14. Nutrients in Dugouts (nitrate + nitrite)

		Non-Compliance with Guidelines - % of Samples				
DUGOUTS	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
Pilot Survey	112	0%	0%	N/G	N/G	N/G
Northern Survey	78	0%	0%	N/G	N/G	N/G

STREAMS

Nitrate was detected in nearly all streams sampled, but concentrations were very low, relative to the guidelines, regardless of whether the stream was located in high, moderate or low agricultural intensity areas. At these concentrations, there is no threat to either livestock or human drinking water.

Total Nitrogen (TN) and Total Phosphorus (TP) were also detected in all streams sampled. Both the TN and TP detections often exceeded the MAC for the Protection of Aquatic Life under the Canada Surface Water Quality Guidelines. The guidelines for TN and TP were met less frequently in streams draining intensively farmed land, than in streams draining land farmed with moderate or low intensity. As well, the degree with which all samples exceeded guidelines was also greatest for the high agricultural intensity stream group.

Ammonia (NH_3) detections occurred in most of the streams sampled, but always complied with the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. Table 15 summarizes the study results on nutrients in streams.

Table 15. Nutrients in Streams

			Non-Compliance with Guidelines - % of Samples				
STREAMS	**Nutrient**	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
High Intensity	Total Nitrogen	214	N/G	N/G	87%	N/G	N/G
	Total Phosphorus	220	N/G	N/G	99%	N/G	
	Nitrate+Nitrite	206	0%	0%	N/G	0%	
	Ammonia	70	N/G	N/G	0%	N/G	
Moderate Intensity	Total Nitrogen	343	N/G	N/G	65%	N/G	N/G
	Total Phosphorus	341	N/G	N/G	88%	N/G	
	Nitrate+Nitrite	303	0%	0%	N/G	0%	
	Ammonia	126	N/G	N/G	0%	N/G	
Low Intensity	Total Nitrogen	163	N/G	N/G	32%	N/G	N/G
	Total Phosphorus	164	N/G	N/G	89%	N/G	
	Nitrate+Nitrite	129	0%	0%	N/G	0%	
	Ammonia	162	N/G	N/G	0%	N/G	

SMALL LAKES:

Total Phosphorus (TP) was detected in all samples taken in the 25 lakes surveyed. Exceedence of the Maximum Acceptable Concentration (MAC) for the Protection of Aquatic Life occurred in 96% of the samples from lakes located in the high intensity agriculture areas. From lakes in low agriculture intensity areas, 38% of the samples exceeded the MAC. Table 16 summarizes the study results on nutrients in lakes.

Table 16. Nutrients in Lakes (Total Phosphorus)

		Non-Compliance with Guidelines - % of Samples				
SMALL LAKES	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
High Intensity	69	N/G	N/G	96%	N/G	N/G
Low Intensity	23	N/G	N/G	38%	N/G	N/G

IRRIGATION CANALS:

In addition to irrigation, canals supply water for a variety of purposes to towns, municipalities and rural residents. Commercial production of trout and grass carp fish in dugouts and small reservoirs is expected to increase, and reduced oxygen in the water because of excessive phosphorus may be a concern. About 80 large reservoirs located in southern Alberta are supplied almost exclusively with water from irrigation district canals. It is not known whether the excessive phosphorus in the canals has any detrimental affect on the aquatic life in these reservoirs. Table 17 summarizes the study results on nutrients in irrigation canals

Human and Livestock Drinking Water Guidelines

Nitrate - nitrite concentrations in the irrigation canals were always low, significantly below the human and livestock drinking water quality guidelines.

Irrigation Water Guidelines

Nitrate - nitrite concentrations in the irrigation canals were always significantly below Canadian Water Quality Guidelines for irrigation water.

Protection of Aquatic Life Guidelines

Total phosphorus exceeded the Alberta Water Quality Guidelines for the Protection of Aquatic life 16% of the time at source sites and 61% of the time at return flow sites. High phosphorus levels result in accelerated growth of aquatic plants, which can reduce water flow in the canals. Removal of these aquatic plants to ensure efficient operation of the canals is costly and time-consuming for Irrigation Districts. Decaying plant material also reduces oxygen levels in the water.

Table 17. Nutrients in Irrigation Districts

			Non-Compliance with Guidelines - % of Samples				
IRRIGATION CANALS	**Nutrient**	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
Supply Source	Total Phosphorus	183	N/G	N/G	16%	N/G	N/G
	Nitrate + Nitrite	109	0%	0%	N/G	0%	N/G
Return Flow	Total Phosphorus	1034	N/G	N/G	61%	N/G	N/G
	Nitrate + Nitrite	875	0%	0%	N/G	0%	N/G

N/G=No Guideline

CONCLUSIONS ON NUTRIENT CONTAMINATIONS

Based on the guidelines for the protection of aquatic life, nitrogen and phosphorus were significant contaminants in streams in high and moderate intensity agriculture areas. Phosphorus was a significant contaminant in small lakes in high intensity agriculture areas, and in irrigation canals.

Nitrate concentrations in groundwater exceeded drinking water quality guidelines only occasionally. However, specific research projects carried out during the study indicated that excessive manure and fertilizer applications are likely to result in unacceptable levels of nitrates in the shallow groundwater over time. At high risk are areas with shallow, unconfined aquifers.

High levels of nitrogen and phosphorus in surface waters are a significant problem because they can cause excessive aquatic plant growth. Decaying plants can cause oxygen depletion, thereby impacting the ability of aquatic life forms to survive. The study did not specifically evaluate which agricultural activity caused the buildup of nutrients in the water. Runoff associated with livestock operations and cropping are implicated.

Dissolved phosphorus was found to be a major component of total phosphorus detections in the surface waters. Dissolved phosphorus is more readily available as a source of plant nutrient than phosphorus associated with particulate matter, and poses more risk to aquatic life.

Bacteria

OVERVIEW

The detection of fecal coliforms, a sub-group of the coliform group, may indicate the presence of fecal contamination. Some species of bacteria in the fecal group will occur naturally in soil and on vegetation. However, one species within the group, *Escherichia coli* (E. Coli) is a definite indicator of the presence of fecal contamination from a warm-blooded animal source.

Provincial Assessment of Bacteria Analyses (by water resource)

GROUNDWATER

Ninety-four percent of the 824 wells tested were free of fecal coliform bacteria, and 86% of the wells were free of both fecal and total coliforms. Total coliforms were detected in 44 (10%) of the deep wells and 70 (19%) of the shallow wells tested. Fecal coliforms were detected in 11 (2%) of the deep wells and 19 (5%) of the shallow wells tested. All wells that tested positive for coliform bacteria were retested. The owners were asked to refrain from drinking the water until the problem could be resolved.

Ideally, very few coliform bacteria should be present in well water because these organisms require a nutrient source to survive. These bacteria are generally associated with plant and animal life processes that do not occur in deep wells. A well with a high coliform count likely has some form of contamination from sources such as a septic system, the presence of a damaged surface well seal, vermin having entry into the well, or livestock living too close to the well head. Table 18 summarizes the study results on bacteria in groundwater.

Table 18. Bacteria in Groundwater (Fecal Coliforms)

		Non-Compliance with Guidelines - % of Samples				
GROUNDWATER	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
Deep Wells	448	2%	N/G	N/A	0%	N/A
Shallow Wells	376	5%	N/G	N/A	0%	N/A

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

DUGOUTS

Ninety-six (86%) of the 112 dugouts tested in the 1994 pilot study had coliform detections. Of those 96 dugouts, 68 (71%) exceeded the Canadian Drinking Water Quality Guidelines. More importantly, 76 (68%) of the 112 dugouts had fecal coliform detections, all of which exceeded the Canadian Drinking Water Guidelines.

The study found that 42% of farmers surveyed did not treat their dugout drinking water, and many (27%) have never had their water quality tested. The results of this survey underscores the importance for regular testing and continuous treatment of all dugout water used for drinking. Table 19 summarizes the study results on bacteria in dugouts.

Table 19. Bacteria in Dugouts (Fecal Coliforms)

		Non-Compliance with Guidelines - % of Samples				
DUGOUTS	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
Pilot Survey	112	68%	N/G	N/G	0%	0%
Northern Survey	80	20%	N/G	N/G	0%	0%

N/G=No Guideline

STREAMS

Fecal coliforms and total enterococci were measured in 25 streams monitored in the survey. In the high intensity agricultural areas, fecal coliforms and total enterococci were detected in 94% of the samples. In the moderate intensity areas, 100% of the samples contained both fecal coliforms and total enterococci. For the low intensity areas, fecal coliforms and total enterococci were detected in 90% of the samples. Table 20 summarizes the study results on bacteria in streams.

Human Drinking Water Guidelines

All fecal coliform detections were above Canadian Water Quality Guidelines for human drinking water.

Irrigation Water Guidelines

All stream groups (high, moderate and low agricultural intensity) had non-compliant samples for fecal coliforms and total enterococci. Fecal coliforms exceeded Canadian Water Quality Guidelines for irrigation in 25% of samples from streams located in high agriculture intensity areas, 68% of samples from streams in medium agriculture intensity areas, and 16% of samples from streams in low agriculture intensity areas.

The reason for the relatively high exceedence rate for fecal coliforms and total enterococci in the "moderate" streams is unclear, but may be influenced by the distribution of local livestock operations near the sampling locations.

Recreation Water Guidelines

Fecal coliforms and total enterococci detections in high intensity areas exceeded Canadian Water Quality Guidelines for recreation in 9% and 38% of samples, respectively. In moderate intensity areas, 44% of the samples exceeded fecal coliform guidelines, and 82% exceeded total enterococci guidelines. In low intensity areas stream detections exceeded fecal coliform and total enterococci guidelines 6% and 39% of the time, respectively.

Table 20. Bacteria in Streams

		Non-Compliance with Guidelines - % of Samples				
STREAMS	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
High Intensity	Fecal Coliform - 32	94%	N/G	N/G	25%	9%
	T. Enterococci - 32	N/G	N/G	N/G	N/G	38%
Moderate Intensity	Fecal Coliform - 25	100%	N/G	N/G	68%	44%
	T. Enterococci - 17	N/G	N/G	N/G	N/G	82%
Low Intensity	Fecal Coliform - 31	90%	N/G	N/G	16%	6%
	T. Enterococci - 31	N/G	N/G	N/G	N/G	39%

T.Enterococci=total enterococci

SMALL LAKES

Bacteria sampling was not carried out as part of the lake survey, due to restrictions of time and resources.

IRRIGATION CANALS

Monitoring for fecal coliforms was carried out in the irrigation canals mostly at return flow sites, though some source water sites were also monitored. Monitoring for *E. coli* was conducted only at return flow sites. Fecal coliforms were detected in the water 96% of the time, and were nearly always significantly higher at the return flow locations than in the source water sites. *E. coli* were detected in the return flow sites 98% of the time. Table 21 summarizes the study results on bacteria in irrigation canals.

Human and Livestock Drinking Water

Fecal coliform concentrations in the water which enters the irrigation districts nearly always exceeded water quality guidelines for human and livestock drinking. Further deterioration of the water quality occurred as the water moved from the source to the return flow channel. Daily monitoring from April - October, 1996 of Crowfoot Creek, which acts as a major return flow channel for the Western Irrigation District, showed that fecal coliform levels significantly exceeded human and drinking water guidelines. This study clearly points out the need to treat all surface water which is to be used for drinking.

Irrigation Water Guidelines

The results from this study indicate that the source water quality for the six irrigation districts is generally acceptable for irrigation. Fecal coliform guidelines for source water were exceeded 14% of the time during this study. A very intensive study of fecal coliform bacteria entering the Eastern Irrigation District indicated that from 1991 to 1994, irrigation guidelines were met 76% of the time.

The frequency of violations of the water quality guidelines for irrigation increased at the return flow sites, where unused irrigation water flows from the irrigation districts to the rivers. Fecal coliform guidelines for irrigation were exceeded 33% of the time at the return flow sites monitored during this study.

Recreation Water Guidelines

Recreational guidelines for fecal coliform bacteria were exceeded 8% of the time in the source water (water entering an irrigation district). However, guidelines were exceeded 18% of the time in the return flow water. E.Coli exceeded recreation guidelines 25% of the time at the return flow sites.

Children commonly swim in irrigation canals during the summer months, and exceedence of recreation guidelines can be a concern. Given that most of the exceedences were at the return flow sites, it is difficult to ascertain whether the risk for swimming is high in upstream sections of irrigation canals.

Table 21. Bacteria in Irrigation Canals

		Non-Compliance with Guidelines - % of Samples				
IRRIGATION CANALS	**# Samples**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**	**Recreation**
Supply Sources	Fecal Coliforms - 91	96%	N/G	N/G	14%	8%
Return Flows	Fecal Coliforms - 407 E. Coli - 159	95% N/G	N/G N/G	N/G N/G	33% N/G	18% 25%

N/G=No Guideline

CONCLUSIONS ON BACTERIAL CONTAMINATION

Fecal coliform bacteria from agricultural sources are a significant contaminant in surface waters. They are also a problem under natural conditions, and can be easily and economically treated.

Fecal coliform levels commonly exceeded drinking water guidelines in streams and always exceeded human drinking water guidelines in irrigation canals, both in source waters and return flows. There is no explanation why the moderate intensity agriculture areas showed higher levels than the high intensity agriculture areas. It was expected high intensity agricultural areas would show similar results as the moderate areas.

Source water for irrigation districts usually met irrigation water quality guidelines, but return flows always exceeded these guidelines. For dugouts, drinking water guidelines were exceeded more often in southern Alberta than in the Peace area of northern Alberta.

As has been recognized for some years, fecal coliform contamination of surface waters is widespread, and results from a variety of sources. While agriculture is a contributor to fecal coliform contamination, humans and wildlife also contribute to the problem. Health officials have long recommended all water sources be treated before domestic use. Unfortunately, the study showed that a significant number of farm families do not test or treat their domestic water supplies prior to use.

Pesticides

OVERVIEW

Pesticides commonly used in Alberta were analysed in groundwater (824 wells) and surface water (27 streams and 25 lakes) locations, representing the diversity of agricultural lands in the province. In addition, irrigation canals in the St. Mary River Irrigation District (SMRID), Bow River Irrigation District (BRID) and Western Irrigation District (WID) were also monitored.

Provincial Assessment of Pesticide Analyses (by water resource)

GROUNDWATER

Of the 824 wells sampled, 27 had detectable levels of herbicides. While some of the 27 wells with detectable concentrations were likely the result of improper handling of herbicides at the wellhead, 63% of these well owners indicated the wells were not used for herbicide spray water. Average depth and age, and the activities occurring around the wells, were similar in wells where herbicide detections did not occur and wells with herbicide detections. A possible explanation is that landscaping or herbicide application to adjacent lawns may have contributed to some of the detections.

Research carried out in southern and central Alberta shows that herbicides can leach into the shallow groundwater, particularly into unconfined aquifers, under both dryland and irrigation conditions. It is also important to note that herbicides can leach into the groundwater over an extended period of time, long after the initial application. The persistence of herbicides in the soil needs to be further investigated. Table 22 summarizes the study results on herbicide detections in groundwater.

Human and Livestock Drinking Water Guidelines

The Canadian Water Quality Guidelines have similar Maximum Acceptable Concentrations (MAC) of pesticides for both human and livestock drinking water. In this study, of the 27 wells where herbicides were detected, only three exceeded existing human and livestock drinking water guidelines. These three wells were subsequently re-sampled, and no herbicide was detected.

Irrigation Water Guidelines

In this study, pesticide detections seldom exceeded guidelines for irrigation water. Maximum acceptable concentrations (MAC) of herbicides for irrigation water are generally very low under the Canadian Water Quality Guidelines. While groundwater is not used in Alberta for commercial irrigation development, it may be used for watering domestic and market gardens. It is therefore important to regularly test irrigation water to determine its suitability for crop watering.

Table 22. Pesticides in Groundwater

		Non-Compliance with Guidelines - % of Samples			
Groundwater	**Detections**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**
Deep Wells 448 Samples	dicamba - 1	0%	0%	0%	< 1%
	MCPA - 5	N/G	0%	0%	0%
	bromoxynil - 2	0%	0%	0%	< 1%
	fenoxaprop - 1	N/G	N/G	N/G	N/G
Shallow Wells 376 Samples	dicamba - 4	0%	0%	0%	1%
	MCPA - 9	N/G	0%	0%	0%
	bromoxynil - 2	< 1%	< 1%	< 1%	< 1%
	2,4-D - 3	< 1%	< 1%	0%	0%
	triallate - 1	0%	0%	< 1%	N/G
	trifluralin - 1	0%	0%	< 1%	N/G

There are no recreation guidelines for pesticides. N/G=No Guideline

DUGOUTS

Commonly used herbicides were detected in 54 of the 112 dugouts sampled in the 1994 pilot study and 10 of the 14 dugouts sampled in northern Alberta in 1996. Herbicides detected include dicamba, MCPA, 2,4-D, picloram, trifluralin and diclofop-methyl.

It is not clear why herbicides are being detected in the dugouts. Most dugouts in northern Alberta are filled from surface runoff during the spring snowmelt period, suggesting that herbicides are successfully overwintering in the upper soil profile and being tranported to the dugouts during the spring. Wind drift during herbicide applications on lawns, gardens and fields may also result in herbicide movement into adjacent dugouts. Table 23 summarizes the study results on herbicide detections in dugouts.

Human and Livestock Drinking Water Guidelines

The Canadian Water Quality Guidelines have similar Maximum allowable concentrations (MAC) for herbicides for both human and livestock drinking water. In this study, none of the herbicides detected in the dugouts exceeded human and livestock drinking water quality guidelines.

Irrigation Water Guidelines

The pilot project and Northern Alberta project found that dicamba detections exceeded irrigation guidelines 13% and 26% of the time respectively. MCPA detections exceeded irrigation guidelines 15% and 21% of the time respectively. Dugouts in northern Alberta are seldom used for irrigation, though those in the south can be used for both irrigation and watering of gardens.

Table 23. Pesticides in Dugouts

		Non-Compliance with Guidelines - % of Samples			
DUGOUTS	**Detections**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**
Pilot Survey 112 Samples	dicamba - 15	0%	0%	0%	13%
	MCPA - 17	N/G	0%	0%	15%
	bromoxynil - 3	0%	0%	0%	0%
	diclofop-methyl - 1	0%	0%	0%	0%
	2,4-D - 41	0%	0%	0%	0%
Northern Survey 78 Samples	dicamba - 20	0%	0%	0%	26%
	MCPA - 16	N/G	0%	1%	21%
	diclofop-methyl - 1	0%	0%	0%	0%
	2,4-D - 8	0%	0%	0%	0%
	picloram - 2	0%	0%	0%	N/G
	trifluralin - 1	0%	0%	1%	N/G

There are no recreation guidelines for pesticides.

STREAMS

Of the 13 pesticides analyzed, nine (2,4-D, MCPA, triallate, dicamba, bromoxynil, picloram, lindane, trifluralin and imazamethabenz) were detected in stream water. In both years (1995, 1996), 2,4-D, MCPA and triallate were detected most often in the high intensity agricultural areas. These herbicides were found in 38%, 129% and 19% of all samples, respectively. On average, the remaining compounds occurred in less than 10% of the samples.

In streams which drain land with high runoff and high erosion potential, significant differences in pesticide detection were seen between areas of high, medium and low pesticide use. Detection frequency of individual compounds is also correlated to pesticide use patterns. Most pesticide detections were made in April, the time of year when most of the runoff occurs. Table 24 summarizes the study results on herbicide detections in streams.

Human and Livestock Drinking Water Guidelines

Canadian Water Quality Guidelines for Human and Livestock Drinking have been set for nine of the 13 pesticides analyzed. There are no guidelines for fenoxaprop-p-ethyl, ethalfluralin, carbathiin or imazamethabenz. The absence of guidelines is only an issue in the assessment of the imazamethabenz detections, because the other three compounds were not detected.

Relative to the Canadian Water Quality Guidelines, none of the pesticides detected were close to the Maximum Acceptable Concentrations (MAC) for human and livestock drinking.

Guidelines for the Protection of Aquatic Life

Canadian Water Quality Guidelines for the Protection of Aquatic Life exist for nine of the 13 pesticides analyzed. There are no guidelines for fenoxaprop-p-ethyl, ethalfluralin, carbathiin or imazamethabenz. The absence of guidelines is only an issue in the assessment of the environmental significance of imazamethabenz detections, because the three other compounds were not detected.

Among the 96 pesticide detections made in the survey streams, there was only one detection (lindane) which did not comply with guidelines. The detected concentration was about five times higher than the recommended guideline.

Irrigation Water Guideline

Canadian Water Quality Guidelines for irrigation exist for four of the thirteen compounds (dicamba, bromoxynil, MCPA and diclofop-methyl) analyzed in this study. Guidelines were exceeded by all five of the dicamba detections, 11 of the 17 MCPA detections and one of the six bromoxynil detections. As there are no irrigation guidelines for picloram, trifluralin, triallate and lindane, the significance of the detections cannot be assessed. Except for one dicamba record in an area of moderate pesticide use, all non-compliance occurred in areas of high pesticide use.

Herbicide detections were more common in streams located in high pesticide use areas than streams located in moderate and low intensity areas. Most of the streams sampled in this study are not used for irrigation. However, Crowfoot Creek (east of Calgary) is used by irrigation farmers in the Western Irrigation District. Water monitoring in the area during 1996 showed that both MCPA and dicamba exceeded irrigation guidelines throughout the irrigation season. This is a significant concern.

Table 24. Pesticides in Streams

		Non-Compliance with Guidelines - % of Samples			
STREAMS	**Detections**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**
High Intensity 31 Samples	dicamba - 2	0%	0%	0%	6%
	MCPA - 9	N/G	0%	0%	25%
	2,4-D - 12	0%	0%	0%	0%
	bromoxynil - 4	0%	0%	0%	< 1%
	picloram - 2	0%	0%	0%	N/G
	trifluralin - 2	0%	0%	0%	N/G
	triallate - 6	0%	0%	0%	N/G
	lindane - 1	0%	N/G	< 1%	N/G
	imazamethabenz - 8	N/G	N/G	0%	N/G
Moderate Intensity 45 Samples	dicamba - 3	0%	0%	0%	6%
	MCPA - 4	N/G	0%	0%	0%
	2,4-D - 10	0%	0%	0%	0%
	triallate - 2	0%	0%	0%	N/G
	imazamethabenz - 2	N/G	N/G	N/G	N/G
Low Intensity 20 Samples	triallate - 1	0%	0%	0%	0%

There are no recreation guidelines for pesticides. N/G=No Guideline

SMALL LAKES:

Just over 50% of the 119 samples collected in 1995 and 1996 contained detectable quantities of at least one pesticide. In almost half of these samples (25% of the total), more than one pesticide was detected.

Of the thirteen pesticides analyzed, seven were detected in both years. Overall, 2,4-D and MCPA were found most commonly, with detection frequencies of 31% and 21%, respectively. Triallate and imazamethabenz were detected 11% of the time. The remaining pesticides were detected less than 10% of the time. Ethalfluralin, carbathiin, lindane and fenoxaprop-p-ethyl were not detected in either year.

The data showed that while more detections were made in high pesticide use areas, a substantial number of detections were made in low pesticide use areas. Triallate, 2,4-D, MCPA, bromoxynil and picloram were all detected in lakes which drain land with low pesticide use. These detections may be attributed to long range transport by wind, and deposition through precipitation. Spraying of roadsides by municipal governments to control weeds may also contribute to detections. Table 25 summarizes the study results on herbicide detections in lakes.

Protection of Aquatic Life Guidelines

Canadian Water Quality Guidelines for the protection of aquatic life exist for seven of the eight pesticides detected. All detected concentrations complied with these guidelines, except for one sample containing triallate.

Irrigation Water Guidelines

For dicamba, all eight detections exceeded the 0.006 ppb guideline. For MCPA, 25 of 26 detections exceeded the lowest guideline value of 0.03 ppb. For bromoxynil, the 0.35 ppb guideline was exceeded for all four detections.

The implications of these findings are not clear. While most of the monitored lakes are not used for irrigation, other lakes and standing water bodies in central and southern Alberta are. At present, irrigation development guidelines do not include water quality testing for pesticides as part of the process.

Table 25. Pesticides in Lakes

		Non-Compliance with Guidelines - % of Samples			
LAKES	Detections	Human Drinking	Livestock Drinking	Aquatic Life	Irrigation
High Intensity 92 Samples	dicamba - 8	0%	0%	0%	9%
	MCPA - 24	N/G	0%	0%	26%
	2,4-D - 30	0%	0%	0%	0%
	bromoxynil - 3	0%	0%	0%	< 1%
	picloram - 1	0%	0%	0%	N/G
	trifluralin - 2	0%	0%	0%	N/G
	triallate - 9	0%	0%	0%	N/G
	imazamethabenz - 13	N/G	N/G	N/G	N/G
	diclofop-methyl - 1	0%	0%	0%	0%
Low Intensity 27 Samples	MCPA - 2	N/G	0%	0%	< 1%
	2,4-D - 8	0%	0%	0%	0%
	bromoxynil - 1	0%	0%	0%	0%
	triallate - 4	0%	0%	0%	N/G
	picloram - 1	0%	0%	0%	N/G

There are no recreation guidelines for pesticides. N/G=No Guideline

IRRIGATION CANALS

Herbicides were analysed in the SMRID in 1995 and 1996, the BRID in 1995, and Crowfoot Creek in the WID in 1996. The number of herbicide detections was much lower in 1996 than in 1995. It appears that in a wetter year, such as 1995, there is a more general release of herbicides into the irrigation canals and drains through runoff from surrounding fields. Sampling in conjunction with canal bank spraying at two sites indicated that no herbicides were detected in the canals during the spraying. Table 26 summarizes the study results on herbicides in irrigation canals.

Human and Livestock Drinking Water Guidelines

Neither human or livestock drinking water guidelines were exceeded in this study.

Guidelines for the Protection of Aquatic Life

Freshwater aquatic life guidelines were exceeded in 1% of the samples. MCPA, triallate and 2,4-D were the detected herbicides.

Irrigation Water Guidelines

Irrigation guidelines were exceeded for MCPA and dicamba in all detections. Although there have been no obvious concerns raised by irrigation farmers to date, these results raise significant concerns about potential crop damage during the irrigation season .

Table 26. Pesticides in Irrigation Canals

		Non-Compliance with Guidelines - % of Samples			
Irrigation Canals	**Detections**	**Human Drinking**	**Livestock Drinking**	**Aquatic Life**	**Irrigation**
170 Samples	dicamba - 57	0%	0%	0%	33%
	MCPA - 57	N/G	0%	1%	33%
	2,4-D - 138	0%	0%	1%	0%
	bromoxynil - 17	0%	0%	0%	3%
	triallate - 15	0%	0%	1%	N/G
	diclofop-methyl - 5	0%	0%	0%	0%
	fenoxaprop-ethyl - 7	N/G	N/G	N/G	N/G
	atrazine - 2	0%	0%	0%	0%

There are no recreation guidelines for pesticides. N/G=No Guideline.

CONCLUSIONS ON PESTICIDE CONTAMINATIONS

Pesticides from agricultural sources were not found to be a significant contaminant for human and livestock drinking water, or for the protection of aquatic life. Two of the 12 herbicides studied, MCPA and dicamba, frequently exceeded irrigation water quality guidelines in irrigation canals. These two herbicides were also found to exceed irrigation guidelines to a lesser extent in streams and small lakes in high intensity agriculture areas. While large-scale irrigation does not generally use water from these streams and small lakes, the water may be used for market gardens and farmstead vegetable gardens. The one insecticide studied was not thought problematic.

Very low level herbicide detections were frequently found in many surface waters and some groundwater. For surface waters, many of the detections were related to spring snowmelt events, suggesting that herbicide persistence in the soil is longer than originally thought. Specific research studies conducted in central and southern Alberta clearly show that herbicides can leach into the shallow groundwater much faster than originally thought. Even soils with high organic matter, such as those found at the Lacombe Research Centre, allowed applied herbicides to move relatively rapidly through the soil profile.

The study showed herbicide concentrations were generally higher in irrigation canals than for other water sources in the province. The exceedence of irrigation water guidelines by irrigation water is of considerable concern because of potential impacts on crop yields. Herbicide levels in canals generally increased from upstream to downstream, with maximum levels found at return flow locations, where the water returned to the river. Water at these locations is seldom used for irrigation, but may contribute to river water quality degradation.

Appendix C.

For more information

1. *Glossary*
2. *References*

GLOSSARY

Aquifer: A porous, underground geologic formation capable of holding water in amounts suitable for use. Alberta's aquifers usually consist of layers of sand and gravel, or limestone. When layers of impermeable material trap the water, the aquifer is confined. When the upper surface is at the water table, or is a layer of unconsolidated till or other permeable material, the aquifer is unconfined. Unconfined aquifers tend to be more susceptible to contamination. The water within an aquifer is called groundwater.

Clay: Sediment particles, smaller than 0.005 mm in diameter. Clays are readily compacted and can form barriers to water absorption and leaching, thus making them excellent base materials for feedlots.

Coliform Bacteria: Coliforms are a large group of naturally occurring bacteria, commonly found in topsoil, bodies of water and animal wastes. Fecal coliforms, a particular group of coliform bacteria which live in the digestive systems of warm and cold-blooded animals, help the body to process food. *Escheria coli (E. coli)* bacteria are the most common type of fecal coliform. In water analyses, fecal coliforms are used as an indicator of the presence of animal wastes.

Colour: A measurement of the clarity of a water sample, after all suspended particles are removed. Some waters are naturally coloured, but safe to use. Primarily an aesthetic consideration. *(See turbidity)*

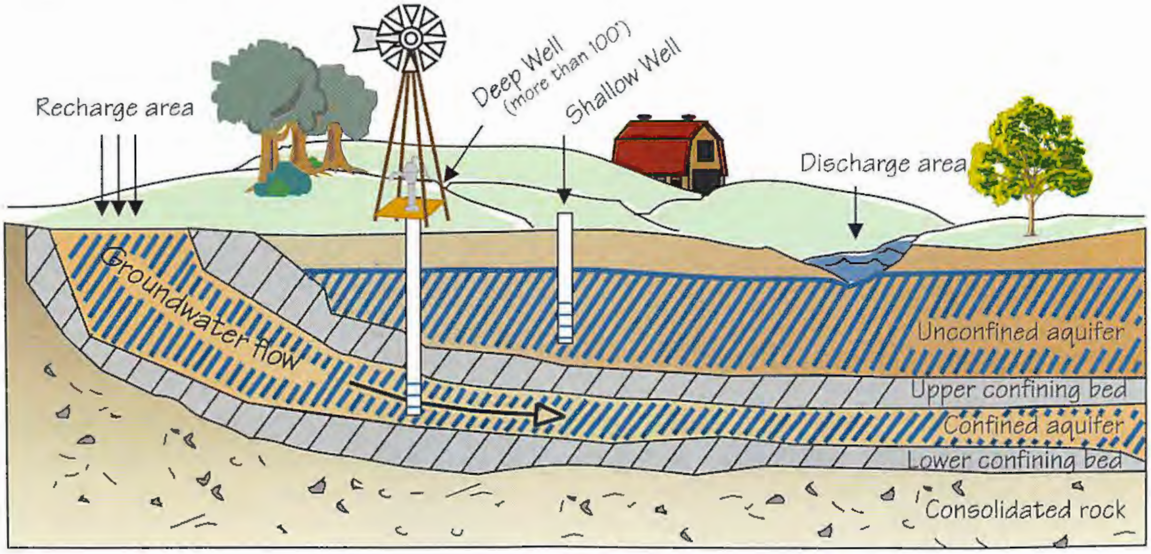
Drainage Basin: A network of land and water bodies which all drain to a single water channel for which the drainage basin is named. Hence, the Battle River drainage basin includes all streams which empty into that river, and the land which drains water into those streams. A drainage divide separates drainage basins.

Eutrophication: Loss of oxygen in lakes and streams, caused by the excessive growth of algae or other aquatic plant forms. The excessive plant growth is usually stimulated by nutrients in the water, particularly phosphorus, but can be initiated by warm temperatures in shallow, naturally-enriched waters.

Exceedence: A word commonly used in environmental publications to indicate non-compliance with water quality guidelines.

Grassed Waterway: A vegetated, wide, shallow channel that usually follows the natural drainage patterns of the landscape. Grassed waterways are used to control farm runoff and prevent gully erosion.

Groundwater: Water in porous rock strata or soils. Groundwater may come to the surface naturally in seeps, springs or other water bodies. Wells are used to tap groundwater sources for human use. Groundwater is the greatest source of freshwater on the planet.



Hydrology: The science of the earth's natural water systems, including the study of the cycle of atmospheric moisture, precipitation, surface waters and groundwater.

Inputs: Fertilizers, pesticides, seed, fuel, feeds and other supplies purchased to operate a farm. Inputs are an important measure of agricultural intensity.

Leaching: The process in which substances are dissolved by water flowing over or through them. Nitrogen leached from soils by irrigation or rain water can enter groundwater aquifers, where they accumulate.

Loam: A soil mixture of approximately equal parts of sand, silt and clay particles, and organic material.

Nitrate + Nitrite: Nitrate and nitrite are nitrogen-oxygen compounds which provide essential nutrients for plant life. Water may be tested for total nitrogen content and for the presence of individual nitrates, nitrites and other nitrogen compounds (e.g. ammonia).

Nutrients: Essentially nitrogen, phosphorus and potassium, which form the basic components of plant nourishment. Excess nitrogen and phosphorus promote excessive growth of aquatic plants.

Parts Per Billion (ppb): A comparison used for measuring extremely small quantities of dissolved, colloidal or other combined materials. A detection of one part per billion is the equivalent of one microgram of a substance in a litre of water. In other terms, it would be the approximate equivalent of one second in 32 years. Parts per million (ppm) is the equivalent of one milligram of a substance in a litre of water.

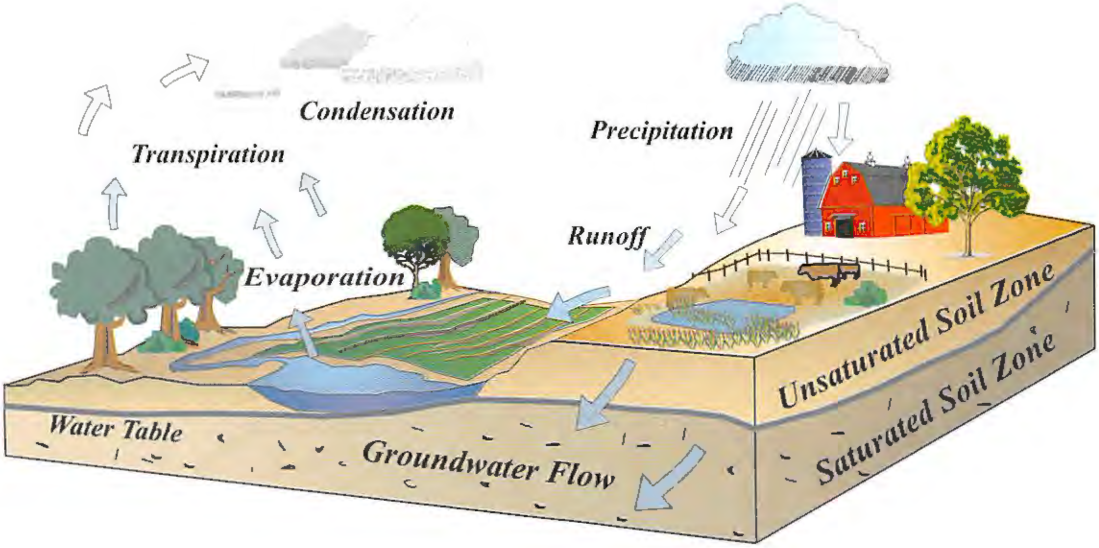
Pesticides: Chemical compounds designed to destroy specific unwanted species. Herbicides, fungicides and insecticides are types of pesticides.

Return Flow: Water from an irrigation system that is not lost through evaporation or used by plants, and which can run into streams, lakes or back to the irrigation system itself.

Runoff: Runoff is the excess water, not immediately used by plants or absorbed by soil, which moves over the land surface to streams, lakes and other water bodies. Depending on its speed and turbulence as it moves, runoff can transport significant amounts of sediments, chemicals and other agricultural materials.

Turbidity: A measurement of all suspended particles in a water sample.

Watershed: The total land area drained by a stream or river system.



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