Pesticides in Alberta's Agricultural Watersheds: A Synthesis

Alberta Agriculture and Rural Development

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Citation

Phelan, C. 2012. Pesticides in Alberta's Agricultural Watersheds: A Synthesis. Alberta Agriculture and Rural Development, Edmonton, Alberta, Canada.

Acknowledgements

This project was completed with a core team consisting of Alberta Agriculture and Rural Development (ARD) staff Harry Brook, Jollin Charest, Dale Chrapko, Ron Howard, Andrea Kalischuk, Paul Laflamme, and Chris Neeser; Alberta Environment (AENV) staff Gary Byrtus and Jock McIntosh; and Agriculture and Agri-Food Canada staff Bill Franz. Paul Laflamme and Jock McIntosh were representatives to the Federal, Provincial, Territorial Committee on Pest Management and Pesticides (FTP Committee) with the Pest Management Regulatory Agency.

Additional help was provided by ARD staff Sarah Depoe, Bonnie Hofer, Joanne Little, Jennifer Nitschelm, Scott Meers, Barry Olson, Kristen Lorenz, Bob Winter, Alan Efetha, Adelle Kientz, and Maureen Vadnais and AENV staff Anne-Marie Anderson.

Published by

Irrigation and Farm Water Division
Alberta Agriculture and Rural Development
Edmonton, Alberta, Canada

Printed in Canada.

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SUMMARY

One of the most comprehensive data sets in Canada on pesticides in agricultural watersheds was synthesized in this report to develop key messages that summarize the current understanding of pesticides in surface water, and develop an awareness and mitigation strategy to address risks of pesticides in agricultural surface water.

Alberta Agriculture and Rural Development, in partnership with others, monitored 68 pesticide compounds in 23 agricultural watersheds from 1999 to 2006 and 27 pesticide compounds at 80 sites in Alberta's irrigation districts in 2006 and 2007. In addition to summarizing the previously published databases, a literature review was conducted to assess the risk of pesticides to aquatic ecosystems, livestock health and sensitive crop species grown under irrigation. While the use of pesticides has allowed for increased crop production to feed a growing global population, there are non-target species that may be negatively impacted. The Canadian Council of Ministers of the Environment have developed guidelines for aquatic and agricultural uses of water, and these guidelines assist in quantifying risks to non-target species. However, little information exists on how pesticides in agricultural water may affect livestock or crops.

The key messages for pesticides in agricultural watersheds were:

1. Long-term monitoring has shown the presence of pesticides in streams through out Alberta's agricultural areas is related to pesticide sales, use, and physical characteristics.
2. Pesticides were commonly detected in Alberta's streams and irrigation canals within agricultural areas. Concentrations were generally low. Guidelines for livestock use and the protection of aquatic life were rarely exceeded. However, guidelines for irrigation were frequently exceeded, which may be a concern for sensitive crops.
3. Future studies should focus on determining whether exceedances of irrigation pesticide guidelines impact crop yields in Alberta.
4. Future work is needed to address the knowledge gap regarding the cumulative effects of multiple pesticide compounds, in addition to the added (or synergistic) effects of other substances in water.
5. Risk assessment needs to occur for those pesticides that are frequently detected but do not have guidelines.

It is unknown whether a problem currently exists in relation to pesticide presence in Alberta's surface waters as there are a number of risks that have no scientific consensus. These risks include cumulative impacts of multiple pesticides on non-target species (aquatic life and agricultural livestock and crops) and pesticide compounds that do not have guidelines but are frequently detected in Alberta's water. Next steps were identified to further investigate these risks and mitigation strategies.

Additional steps forward include increasing awareness of manufacturers, regulators, distributors, and producers on the presence of pesticides in agricultural surface waters and appropriate mitigation strategies. Tools may include product label amendments, fact sheets, and pesticide application certification.

PROJECT PURPOSE

A recent synopsis of province-wide pesticide water quality monitoring data collected under the Alberta Environmentally Sustainable Agriculture (AESA) Stream Survey (1999 to 2006) and other monitoring programs dating back to 1992 show that pesticide residues are reaching surface waters (Little et al. 2010; Lorenz et al. 2008; Anderson et al. 1999). The AESA Stream Survey demonstrated that agricultural pesticides are detected more frequently, in increasingly diverse mixtures, and in higher concentrations in watersheds where high intensity (dryland or irrigation) agriculture is practiced (Lorenz et al. 2008). Studies showed that pesticide concentrations exceeded water quality guidelines for irrigation or the protection of aquatic life. Further, Pesticide Toxicity Index scores suggested the potential for toxic effects on aquatic life in several watersheds due to multiple detections and the toxicity of compounds (Anderson 2008). The purpose of this report is to review the potential risks associated with the use of agricultural pesticides and summarize our current knowledge, as well as any unknown risks, with respect to pesticide presence in Alberta's streams and irrigation return flows.

This project was conducted as part of Agriculture and Rural Development's (ARD) Water Strategy developed by the Irrigation and Farm Water Division.

The approach taken to develop this report was to:

1) Conduct a literature review to assess potential risks to aquatic ecosystems, livestock health, and sensitive crop species grown under irrigated conditions;
2) Summarize relevant surface water quality data from Alberta;
3) Consult with a core team of ARD and Alberta Environment (AENV) representatives to develop key messages that summarize our understanding of the issue, and to discuss ways to create awareness and a mitigation strategy as a direction forward.

This report also documents the process utilized to derive the conclusions, including the discussions, decisions, and actions made by the core team during the duration of the project from October 2009 to December 2010.

LITERATURE REVIEW

The use of pesticides has allowed for increased crop production to feed a growing global population (Pimentel et al. 1992). Concern, however, is growing around the risks and negative impacts pesticides pose to non-target species in the environment. Non-target species, such as amphibians, are unintentionally exposed to pesticides and exposure could result in significant changes in growth, development, health, and reproductive success (Davidson 2004; Hayes et al. 2006). Agriculture is the largest user of pesticides, including herbicides, insecticides, and fungicides. In Alberta in 2008, approximately 12.5 million kg of pesticide active ingredient was sold in, or shipped into, Alberta (Byrtus 2011). This amount was the highest of all provinces excluding Saskatchewan which did not have sales survey data. Pesticides sold into the agriculture sector accounted for 96% of the active ingredient sold, the majority of which were herbicides (Byrtus 2011). Basins that had the largest areas of cultivated land such as the Oldman, Red Deer, North Saskatchewan, and Battle River had the highest pesticide sales (Byrtus 2011).

Pesticides can be in solid and liquid form and applied in different ways including aircraft or land vehicle, mixed with water and sprayed onto plants or soil, or incorporated or injected into soil. Once applied, pesticides can leave the site of application and move within the environment in a number of ways (Figure 1). Pesticides can be taken up and adsorbed by plants; can enter the atmosphere through volatilization and drift; can enter the soil column through adsorption, infiltration, and atmospheric deposition; can be ingested by vertebrates, invertebrates, and microorganisms; and can enter surface water and groundwater through leaching, runoff, or spills (ARD 2010). Many studies around the world have found pesticides in ground and surface waters (Albanis et al. 1998; Kookana et al. 1997; Larson et al. 1997; Barbash et al. 2001), including in Alberta (Anderson 2005; Lorenz et al. 2008; Little et al. 2010). The presence of pesticides in agricultural water bodies poses risks to the aquatic ecosystem, livestock health, and sensitive crop species.

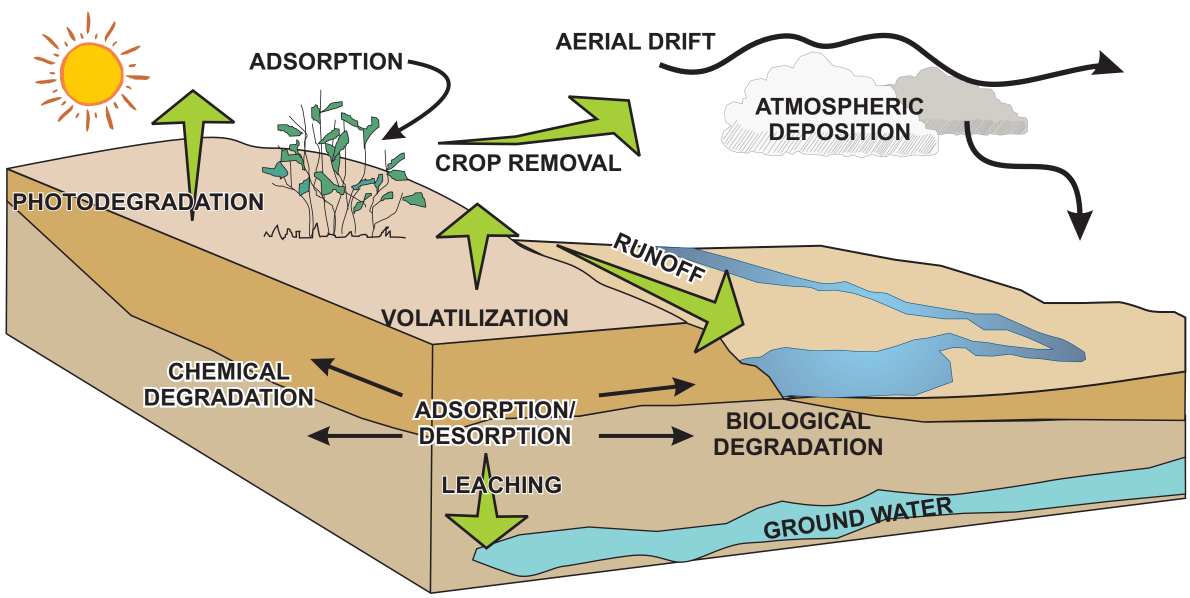

Figure 1. Modes of pesticide transport in the environment (ARD 2010).

Risks to Aquatic Ecosystems

When pesticides enter into aquatic ecosystems, the environmental risks can be high. The capacity of pesticides to harm fish and aquatic organisms is largely a function of toxicity, exposure time, dose rate, and persistence in the environment (Helfrich et al. 2009). Pollutants can have direct and indirect contaminant effects on the aquatic ecosystem (Fleeger et al. 2003). Direct effects would include fish kills or alteration of organism behavior (Helfrich et al. 2009). Indirect effects alter the ecosystem function, reduce habitat and food, reduce the reproductive success and abundance of organisms, cause behavioral impairment or physiological stress, and lower oxygen levels in water bodies (Helfrich et al. 2009). There can also be ripple effects from the impact on organisms in the ecosystem including an alteration of the trophic levels and competitive interactions (Fleeger et al. 2003).

Since the risk to the aquatic environment is variable depending on species, the aquatic habitat, and the concentration of the pesticide, the Canadian Council of Ministers of the Environment (CCME) developed guidelines for a number of pesticides to help quantify risk and protect aquatic life (CCME 2007). Guidelines were determined using previously collected data and values were selected based on the most sensitive species. Guidelines were set such that concentrations less than the guideline limit should have no short or long-term effects on biota (Donald et al. 1999). If pesticides concentrations are found to be above the pesticide guideline, effects on the biota would be dependent on the concentration and the species present. Pesticide concentrations from one- to ten-times the limit, could have an impact on growth, development, reproduction, or feeding efficiency at the most sensitive life stages of some aquatic species. It is important to note that the guidelines do not take into account effects of multiple pesticide exposure (which could have additive or synergistic impacts on aquatic life) and chronic exposure of pesticides on aquatic organisms.

Risks to Livestock Health

Within the literature there appears to be little information on how pesticides in water affect livestock. This may be related to a finding from Pimentel et al. (1992) who noted that when a farm animal poisoning occurs and little can be done for the animal, the farmer seldom calls a veterinarian but either waits for the animal to recover or destroys the animal. Thus, most cases go unreported.

In 1999, the CCME developed interim livestock water guidelines for many herbicides and insecticides. Many of these guidelines were based on laboratory studies carried out on rats, mice, birds, cattle, and other livestock such as goats and sheep. Effects on mammals included alteration of internal organs (e.g., exposure to trifluralin), weight loss (e.g., exposure to simazine), neurotoxicity (e.g., exposure to chlorpyrifos), and signs of poisoning (e.g., exposure to bromacil) (CCME 1999). However, some active ingredients were metabolized and excreted resulting in no observable impact (e.g., exposure to metolachlor, MCPA, and dicamba). It is important to note that CCME explicitly states that for many of the compounds more information and research are needed to move past the interim guidelines.

Risks to Sensitive Crops

Sensitive agricultural crops may be subject to non-target effects by a variety of unintended exposure mechanisms, including accidental spills or spray-drift from adjacent crop fields (Karthikeyan et al. 2003). The non-target effects occur because herbicides such as MCPA, 2,4-D, bromoxynil, dicamba, clopyralid, and mecoprop, are typically used on cereal, forage, and oil crops and when these herbicides come in contact with sensitive specialty crops such as field pea, potato, lentil, sunflower, buckwheat, canola, tomato, and sugar beet, damage may occur. These compounds may come in contact with sensitive specialty crops frequently as they are some of the top selling active ingredients in Alberta (Byrtus 2011).

Wall (1996) published a paper stating that herbicide injury to broadleaf crops (sensitive crops such as lentil, sunflower, and field pea) is common in western Canada with 70% of plant samples submitted to the Crop Diagnostic Centre of Manitoba Agriculture exhibiting injury in 1994. Damage was the result of spray drift and misapplication; however, there were also reports of producers using low doses of 2,4-D and MCPA for broadleaf weed control in sensitive crops.

Wall (1996) completed further studies documenting the tolerance of broadleaf crops (buckwheat, canola, field pea, lentil and sunflower) grown in western Canada to sublethal 2,4-D dosages that may occur as a result of spray drift or intentional application. The least sensitive crop to 2,4-D was field pea followed by buckwheat, canola, lentil, and most sensitive was sunflower. The results indicated the need for caution when applying phenoxy-type herbicides near broadleaf crops and further, deliberately applying these herbicides to broadleaf crops will often reduce yields.

Special crops that are grown in Alberta include dry bean, lentil, potato, and sugar beet (Hill et al. 2001; Winter 2009). In 2008, these four crops were seeded on 48,876 hectares in Alberta (Su 2009). Of the 48,876 hectares, 82% (40,078 hectares) were seeded in one of the irrigation districts (Winter 2009) and this included 95% of dry bean, 4% of lentil, 79% of potato, and 100% of sugar beet crops. With the overlap between irrigation waters that have pesticides exceeding irrigation guidelines (dicamba, MCPA, simazine, bromoxynil, bromacil; see below) and sensitive specialty crops in Alberta's irrigation districts, there is potential for crop damage to occur. It is important to note that crops can be exposed to pesticides from other sources, including rainfall (Hill et al. 2001). Rainfall samples from southern Alberta were found to have high concentrations of some pesticides including 2,4-D, bromoxynil, dicamba, and MCPA (Hill et al. 2001). The concentrations detected were found to be high enough to impact on sensitive specialty crops during indoor bioassays (Hill et al. 2001).

The above discussion generally only focuses on phenoxy-type herbicides (Group 4 herbicides) and typically, crops are more sensitive to ALS inhibitors (Group 2 herbicides), some of which can persist in the soil for several years (Chris Neeser, ARD, personal communication). It is important to keep in mind that all damage and losses must be viewed in terms of the available weed control options.

Another risk to sensitive crops has been found within the horticultural business. In Alberta in the past two years, Mirza (2011, 2012) has documented herbicide damage to tomato and bedding plants where owners have unknowingly used a water source that contained low concentrations of herbicides. Water sources causing damage have been found to have concentrations of clopyralid, MCPA, 2,4-D, and picloram in the parts per billion range (<0.03 µg/L to 0.5 µg/L). Although water sources in the highlighted cases were from a dugout where the banks were sprayed to control weeds, these concentrations are within the range of those found in agricultural streams in Alberta. These cases revealed the economic losses that can occur when herbicides are found in greenhouse water supplies and highlight the need to increase awareness. The true risk to the horticultural business is still unknown as often plant damage goes unreported and business owners settle with insurance companies (Dr. Mohyuddin Mirza, personal communication).

RELEVANT SURFACE WATER QUALITY DATA

Pesticides in Alberta's Agricultural Streams: Results from the AESA Stream Survey

The Government of Alberta initiated the AESA Stream Survey in 1999 to assess temporal and spatial patterns in water quality in watersheds with differing agricultural activity across Alberta (Lorenz et al. 2008). This is one of the most comprehensive pesticide surveys of agricultural watersheds in Canada. From 1999 to 2006, surface water samples were collected from 23 watersheds throughout the agricultural area of Alberta and analyzed for 68 pesticide compounds. Four of the 23 watersheds were under irrigated agriculture and the remainder were dryland. Results from the study suggest that pesticides were commonly found in agricultural streams throughout the province. Pesticides were found with greater frequency and in higher concentrations in watersheds of higher agricultural intensity as defined by pesticide sales, fertilizer sales, and manure production. Maximum pesticide concentrations were typically found in spring and during summer pesticide applications. Concentrations of detected pesticides occasionally exceeded existing water quality guidelines for either the protection of aquatic life or irrigation use (Table 1). In addition, there were 21 compounds that were detected but currently have no guidelines (Figure 2). Of these 21 compounds, 10 were detected in 1 to 10% of samples and 11 were detected in less than 1% of samples (Lorenz et al. 2008). Imazethapyr, a Group 2 herbicide, was among the 11 compounds detected in less than 1% of the samples. As discussed above, crops are extremely sensitive to Group 2 herbicides.

Table 1. Compliance with Canadian Water Quality Guidelines for the Protection of Aquatic Life (PAL) or Irrigation Use (IRRIG). Adapted from Lorenz et al. (2008).

Pesticide compound	Type of guideline	Percent samples where guideline exceeded* (%)	Guideline conc.** (µg/L)	Max. conc. detected (µg/L)	Median conc. (µg/L)	Number of samples where guideline exceeded
Dicamba	IRRIG	11.4	0.006	1.134	0.018	185
MCPA	IRRIG	11.2	0.025	7.279	0.018	183
Gamma-benzenehexachloride (Lindane)	PAL	0.5	0.01	0.03	0.015	8
Simazine	IRRIG	0.5	0.5	4.57	0.084	5
2,4-D	PAL	0.2	4	8.534	0.031	4
Triallate	PAL	0.2	0.24	0.464	0.015	3
Chlorpyrifos	PAL	0.2	0.0035	0.781	0.015	3
Bromoxynil	IRRIG	0.2	0.33	0.522	0.011	3
MCPA	PAL	0.2	2.6	7.279	0.018	1
Bromacil	IRRIG	0.1	0.2	0.297	0.158	1

* total number of samples collected n= 1627
** conc. = concentration

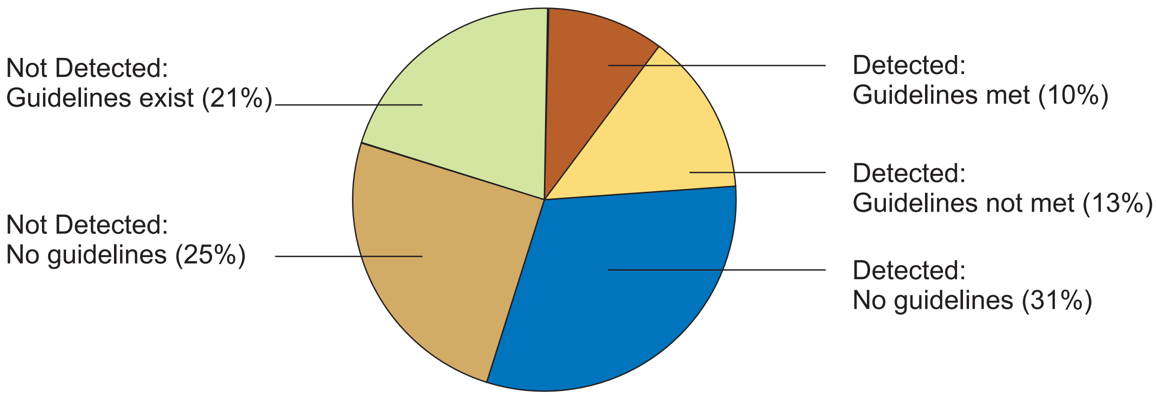

Figure 2. Comparison of pesticide detection and guideline compliance for the 68 compounds monitored from 1999 to 2006. Adapted from Lorenz et al. 2008.

Glyphosate Occurrence in Alberta's Agricultural Streams

Glyphosate, the active ingredient in Roundup®, was the top selling compound in Alberta in 1998, 2003, and 2008 (Byrtus 2011). Sales have continued to increase, and by 2008 glyphosate alone accounted for about 50% of all pesticide active ingredients sold in Alberta (Byrtus 2011). Glyphosate was not routinely included in the suite of pesticides analyzed in the AESA Stream Survey; however, it was included in 2007 (Lorenz 2011).

Glyphosate was detected in 33% of samples (n=256) and in all agricultural intensity watershed categories (Lorenz 2011). The highest detection frequency occurred in streams draining high agricultural intensity watersheds. Glyphosate was detected in nearly all months sampled (March to October) with the exception of August. However, glyphosate concentrations never exceeded protection of aquatic life, irrigation, or livestock drinking water quality guidelines.

Assessment of Water Quality in Alberta's Irrigation Districts

In 2006 and 2007, an assessment of water quality in Alberta's Irrigation Districts also examined 27 pesticide compounds in surface water. This project assessed the quality of source water used for irrigation from a food perspective, as well as suitability for livestock, and assessed changes in water quality as water travels from source water to returns (Little et al. 2010).

Pesticides were detected in 90% of samples (n=634). Similar to the AESA Stream Survey, irrigation guidelines for dicamba and MCPA were frequently exceeded (Little et al. 2010). More specifically, dicamba exceeded the guidelines for irrigation in 46% of samples, and MCPA exceeded irrigation guidelines in 33% of samples (n=634). Compounds without guidelines, such as clopyralid, dichlorprop, and mecoprop were detected in less than 13% of samples.

It was found that the quality of water changed from source to returns. Generally, pesticide concentrations and detection frequencies were greater at the return sites, followed by the secondary and primary sites (Little et al. 2010).

Key Messages for Pesticides in Agricultural Watersheds

1. Long-term monitoring has shown the presence of pesticides in streams throughout Alberta's agricultural areas is related to pesticide sales, use, and physical characteristics.

- Most frequently detected pesticide active ingredients are those with the highest sales, mobility, and/or persistence (e.g. herbicides 2,4-D and MCPA).
- Highest detection frequencies and concentrations of pesticides are found in dryland and irrigated areas of high intensity agriculture.

2. Pesticides were commonly detected in Alberta's streams and irrigation canals within agricultural areas. Concentrations were generally low. Herbicide guidelines for livestock use and protection of aquatic life were rarely exceeded. However, herbicide guidelines for irrigation were frequently exceeded, and this may be a concern for sensitive crops.

- Of the 1627 samples collected during the AESA Stream Survey, one or more pesticides were detected in 64% of water samples. There were no exceedances of livestock use guidelines, 1% of samples exceeded protection of aquatic life guidelines, and 19% of samples exceeded irrigation guidelines.
- Of the 634 samples collected during the Irrigation Water Quality Study, one or more pesticides were detected in 91% of water samples. There were no exceedances of livestock use guidelines, 1% of samples exceeded protection of aquatic life guidelines, and 57% of samples exceeded irrigation guidelines.

3. Future studies should focus on determining whether exceedances of irrigation pesticide guidelines impact crop yields in Alberta.

- Although CCME irrigation guidelines are based on irrigation rates higher than those used in Alberta, re-calculation of the guideline values using representative irrigation rates revealed that exceedances of MCPA and dicamba irrigation guidelines would still occur (Appendix 1).
- It is not known if negative impacts on crop yields occur when irrigation water containing concentrations of pesticides in excess of irrigation guidelines are applied to fields; however, no adverse effects have been previously been reported.
  - If exceedances of pesticide irrigation guidelines are found to have no negative impact on crop yield, the stringency of current irrigation guidelines should be evaluated and appropriate limits determined.
  - If exceedances of pesticide irrigation guidelines are found to negatively impact crop yield, mitigation strategies need to be implemented.
- Water sources that contain herbicides in concentrations above the irrigation guideline have been shown to damage horticultural crops including tomato and bedding plants in Alberta.

4. Future work should address the knowledge gap regarding the cumulative effects of multiple pesticide compounds, in addition to the added (or synergistic) effects of other water pollutants.

- Although pesticides tend to be detected in low concentrations, the occurrence of mixtures may pose a toxicity risk to aquatic life. A pesticide toxicity index, or similar tool, should be used to assess the risk to aquatic organisms.
- Similarly, tools should be developed to assess impacts of pesticide mixtures in irrigation water applied to crops and in water used for livestock consumption.
  - During the AESA Stream Survey, the median number of compounds per sample was three for high agricultural intensity dryland and irrigated watersheds; while 4% of 1627 samples had simultaneous exceedances of two or three guidelines.
  - During the Irrigation Water Quality Study, the median number of compounds per sample was two; while 22% of 634 samples had simultaneous exceedances of two or three guidelines.

5. Risk assessment needs to occur for those pesticides that are frequently detected but do not have guidelines.

- Further analysis and discussion should focus on assessing the risk associated with the presence of pesticide compounds without a water quality guideline (triclopyr, clopyralid, mecoprop, and imazamethabenz-methyl) in Alberta's agricultural streams.
  - These four compounds were each detected in 10 to 15% of AESA Stream Survey samples.
  - Compounds that are frequently detected and/or pose a high risk to aquatic life or agricultural production need to have guidelines developed.

Is There Really a Problem with Agricultural Pesticides in Alberta Surface Waters?

Generally, agricultural pesticide findings from recent ARD monitoring demonstrate that:

- pesticide detections correlate with sales and mobility; and
- few compounds exceed protection of aquatic life guidelines, and no compounds exceeded the livestock watering guidelines.

It is unknown whether a problem currently exists in relation to pesticide presence in Alberta's surface waters. There is no scientific consensus on the level of risk for the following:

- Cumulative impacts of multiple pesticides and the added effects of other substances in water on aquatic life, sensitive crop species, livestock, and downstream water users.
- Cumulative impact of MCPA and dicamba irrigation guideline exceedances in irrigation waters on sensitive specialty crop species.
- Pesticides that are currently without guidelines and frequently detected in Alberta's surface waters.

Therefore, an important next step is to further investigate and mitigate these risks. Other recommendations identified by the core team included increasing awareness of manufacturers, regulators, distributors, and producers of pesticide presence in surface waters and development of appropriate mitigation strategies, through:

- Federal label amendments;
- Fact sheets;
- Pesticide application certificates, farmer certification, and training; and
- Adding environmental data to pre-existing materials such as the Crop Protection Book and Pesticide Selector on ARD’s Ropin' the Web (Appendix 2).

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Appendix 1: Calculation of MCPA and Dicamba Guidelines

Since one of our recommendations is to look at the impact on crop yield when pesticides in the irrigation water exceeded irrigation guidelines we took a closer look at the current CCME irrigation guidelines. When calculating guidelines, CCME divides the Acceptable Application Rate (AAR) by the irrigation rate. When determining the irrigation rate for MCPA, CCME used the maximum irrigation rate found in Canada (1.2 x 107 L/ha or 1200 mm) (CCME 2001). When determining the irrigation rate for dicamba, CCME used the approximate Canadian annual irrigation rate (1.0 x 107 L/ha or 1000 mm) (CCME 1999). Both of these irrigation rates, however, greatly exceed irrigation rates in Alberta. The maximum average annual irrigation rate in Alberta's southern irrigation districts (1996 to 2000) was 546 mm (5.46 x 106 L/ha) for alfalfa (Irrigation Water Management Study Committee 2002). Other crop types including barley grain, barley silage, canola, sugar beet, and wheat was much lower at 232 mm (2.32 x 106 L/ha), regardless of crop type and location. Using back calculations and these new irrigation rates, more representative irrigation guidelines were estimated for the two active ingredients that exceeded irrigation guidelines most frequently during the AESA Stream Survey: MCPA and dicamba (Table 1; Lorenz et al. 2008).

MCPA

The irrigation guideline recommended by CCME is 0.025 µg/L using an irrigation rate of 1200 mm (CCME 2001). MCPA had two different AAR, one for ryegrass (1.87×10^{-3} kg/ha) and the other for lettuce (2.79×10^{-4} kg/ha).

Two scenarios are presented in the calculations below. The first calculation uses the maximum average annual irrigation application amount in southern Alberta to demonstrate a more conservative guideline. The second calculation uses the average annual irrigation amount in southern Alberta to demonstrate a more typical crop water demand and annual rainfall amount.

(Equation 1) AAR ÷ IR x unit conversion = guideline

Where:

AAR = Acceptable Application Rate
IR= Irrigation Rate

Scenario 1:
Ryegrass: 1.87×10^{-3} kg/ha ÷ 5.46×10^{6} L/ha x (1×10^{9} µg/kg) = 0.342 µg/L
Lettuce: 2.79×10^{-4} kg/ha ÷ 5.46×10^{6} L/ha x (1×10^{9} µg/kg) = 0.051 µg/L

Scenario 2:
Ryegrass: 1.87×10^{-3} kg/ha ÷ 2.32×10^{6} L/ha x (1×10^{9} µg/kg) = 0.806 µg/L
Lettuce: 2.79×10^{-4} kg/ha ÷ 2.32×10^{6} L/ha x (1×10^{9} µg/kg) = 0.120 µg/L

With the change of the irrigation rate, the most conservative irrigation guideline recommended by CCME of 0.025 µg/L is half the value of 0.051 µg/L.

Dicamba

Irrigation guidelines for dicamba are recommended for different crop types. Cereals, tame hay, and pasture have a guideline of 0.6 µg/L. Legumes have a guideline of 0.06 µg/L. Other crops have a guideline of 0.006 µg/L. The overall guideline recommended by CCME is 0.006 µg/L as it is the most conservative guideline for all crops. The dicamba guideline was determined using an irrigation rate of 1000 mm (1×10^7 L/ha). There was no AAR explicitly stated for dicamba on the dicamba factsheet (CCME 1999); however, guidelines using the Alberta irrigation rates (maximum and average irrigation rates) can still be calculated.

(Equation 2) Recommended guideline x CCME IR ÷ ARD IR = new guideline

Where:

CCME IR= CCME Irrigation Rate
ARD IR= ARD Irrigation Rate

Cereals, tame hay, and pasture:

0.6 µg/L x (1×10^7 L/ha) ÷ (5.46×10^6 L/ha) = 1.100 µg/L
0.6 µg/L x (1×10^7 L/ha) ÷ (2.32×10^6 L/ha) = 2.590 µg/L

Legumes:

0.06 µg/L x (1×10^7 L/ha) ÷ (5.46×10^6 L/ha) = 0.110 µg/L
0.06 µg/L x (1×10^7 L/ha) ÷ (2.32×10^6 L/ha) = 0.259 µg/L

Other crops:

0.006 µg/L x (1×10^7 L/ha) ÷ (5.46×10^6 L/ha) = 0.011 µg/L
0.006 µg/L x (1×10^7 L/ha) ÷ (2.32×10^6 L/ha) = 0.026 µg/L

With the change of the irrigation rate, the most conservative guideline recommended by CCME (0.006 µg/L) is half the value of 0.011 µg/L.

After taking a closer look at the MCPA and dicamba irrigation guidelines, we concluded that regardless of the crop type, for both herbicides, the more representative irrigation rate (half the amount used by CCME) nearly doubled the most conservative irrigation guidelines. Using the data from the AESA Stream Survey and water quality from primary, secondary, and return sites in Alberta's irrigation districts, the number of samples exceeding the more representative irrigation guideline is less than the CCME recommended irrigation guideline (Tables 2, 3, and 4). These percentages, however, may still be unacceptable, especially dicamba, which exceeded the guidelines between 31 and 41% of samples in irrigation source waters (Table 4).

Table 2. Percentage of samples exceeding guidelines in four irrigated AESA Stream Survey watershed, 1999 to 2006 (n=326).

	CCME recommended irrigation guideline	Irrigation guideline using southern Alberta irrigation rates
MCPA	0.025 (µg/L) 13 %	0.051 (µg/L) 7 %
Dicamba	0.006 (µg/L) 38 %	0.011 (µg/L) 32 %

Table 3. Percentage of samples exceeding MCPA guidelines in Alberta's irrigation primary, secondary, and return sites[z], 2006 to 2007.

	CCME recommended irrigation guideline (0.025 µg/L)	Irrigation guideline using southern Alberta irrigation rates 0.051 (µg/L)
Primary (n = 144)	22%	15%
Secondary (n = 255)	38%	16%
Return (n = 235)	35%	20%

[z] Primary site: where main source water enters the irrigation district
Secondary site: where canals branch off within the district for on-farm water supply
Return site: where water exits the irrigation district (Little et al. 2010)

Table 4. Percentage of samples exceeding dicamba guidelines in Alberta's irrigation primary, secondary, and return sites[z], 2006 to 2007.

	CCME recommended irrigation guideline 0.006 (µg/L)	Irrigation guideline using southern Alberta irrigation rates 0.011 (µg/L)
Primary (n = 143)	32%	31%
Secondary (n = 254)	42%	41%
Return (n = 235)	57%	57%

[z] Primary site: where main source water enters the irrigation district
Secondary site: where canals branch off within the district for on-farm water supply
Return site: where water exits the irrigation district (Little et al. 2010)

Appendix 2: Discussions and Details from Core Team Meetings

General

The original project intent was to look at two different emerging contaminants, pesticides and pharmaceuticals, as both were identified as products that may pose a risk to aquatic life, humans and livestock, and sensitive crops. A decision was made with the core team to narrow the scope as it was agreed that pharmaceuticals cannot be mitigated in the same fashion as pesticides due to major differences in their functions. It was, however, agreed that pharmaceuticals will still need to be addressed in the future as they are emerging contaminants and have previously been detected in surface water in agricultural areas of Alberta (Forrest et al. 2006).

The group identified four issues that could help reduce the presence of pesticides in Alberta's surface waters and noted that extension is currently targeting these issues:

- Riparian areas – Healthy riparian areas may help to reduce the amount of pesticides reaching the surface water by reducing the risk of drift and transport.
- Sprayer calibration – A calibrated sprayer is important for the proper application rate of pesticides.
- Spray drift – Those who spend time with producers indicate that frequently, spraying occurs while pushing the weather window of opportunity. This includes certified custom sprayers who are typically quite busy throughout the growing season.
- Sprayer technology – Sprayer equipment modifications can reduce the risk of movement of agrochemicals to non-target areas. Variable rate technology reduces the amount of agrochemicals used in crop production and released into the environment.

Creating Awareness in Alberta

Creating awareness about the risks of pesticides needs to be targeted towards the manufacturer, regulator, distributor, producer, and possibly the consumer.

Overall, fact sheets were thought to be the best way to create awareness, however, they would need to be tailored to each group we are trying to reach. Fact sheets can be shortened versions of the messages with a very short introduction and a section that includes what one can do next with Government of Alberta programs and information resources that are already established (i.e., beneficial management practice (BMP) information, pesticide certification, farmer pesticide training).

Possible target groups/events were identified for fact sheets:

- Ag Service Board.
- Ag Fieldsman's Association.
- Agronomy Update Conference.
- AESA extension staff.
- CCME.
- Certified Crop Advisors.
- County newsletters.
- CropLife Canada.
- Farm Tech.
- Grower groups.
- Irrigation districts.
- Municipality regional conferences.
- Other Alberta Agriculture and Rural Development divisions including Bio-Industrial Technologies and Agriculture Research Division.
- Pest Management Regulatory Agency.
- Ropin' the Web.

Mitigation

In terms of mitigation, it was mentioned that previous producer surveys show that awareness is extremely high in terms of knowledge of herbicides and BMP adoption (Serecon Management Consulting Inc. 2007). It was questioned whether the BMPs we are targeting are effective. There was group consensus that the dominant modes of introduction to surface waters is uncertain (i.e., drift, run-off, leaching, atmospheric deposition), so solutions or specific BMPs are difficult to recommend.

Other mitigation measures included discussing federal pesticide labels with PMRA. Maintaining concise and consistent wording throughout all sections of the label may help to eliminate applicator confusion and mitigate the risk of pesticides reaching water bodies. In addition, there is little information offered on pesticide labels in regards to protecting irrigation water, other than leaving a buffer. Establishing a period of time between pesticide application and irrigation could be considered in the future for those pesticides frequently used in irrigated areas.

The core team supported adding environmental data to the Crop Protection Book and the Pesticide Selector on Ropin' the Web. A concept that inspired the group came from Quebec, which has a French information tool (SAgE; http://www.sagepesticides.qc.ca/). SAgE provides information on the toxic effects of pesticide ingredients on human health and other non-target life forms to enable users to understand risks and make more informed choices (Government of Quebec 2002). The Government of Quebec does not plan to develop an English version of SAgE.

- In terms of selecting the information tools to update, the Crop Protection Book is used more than the online herbicide selector.
- It was cautioned that the Crop Protection Book already is lengthy and contains a lot of information. It was suggested that we keep the update simple and use a symbol to indicate leaching potential.
- New (beginning 2011) additions to the Alberta Crop Protection Book (compiled by Harry Brook and Mark Cutts, ARD) included a small section on pesticide residues found in Alberta water sources (section referred to AESA data) and highlighting environmental precautions for each active ingredient.