Aerial Spraying Guidance for the Protection of Watercourses

Final Report

15/02/2013

Published by CREW – Scotland's Centre of Expertise for Waters. CREW connects research and policy, delivering objective and robust research and expert opinion to support the development and implementation of water policy in Scotland. CREW is a partnership between the James Hutton Institute and all Scottish Higher Education Institutes supported by MASTS. The Centre is funded by the Scottish Government.

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Please reference this report as follows: Troldborg M, Hough RL, Baggaley NJ, and Dawson JJC. (2013). Aerial Spraying Guidance for the Protection of Watercourse. Available online at: crew.ac.uk/publications

Dissemination status: Unrestricted

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Background

The existing operational protocol for aerial spraying of Asulam by helicopter for the purpose of bracken control has been developed by the Chemical Regulation Directorate (CRD) [1]. According to this protocol, when using low drift nozzles, aerial spraying must maintain a minimum 50 meter no-spray buffer zone from all surface water bodies, wells, boreholes and springs.

It is unclear:

- If this 50 m buffer zone is adequately protective/appropriate;
- What the operational definition of a surface water body is.

Objectives of Study

This report is in response to a request by Scottish Water to determine;

1) What is the science behind the 50 meter buffer zone value?
2) What is the definition of a "watercourse" in upland catchments that could be used for this guidance? Concern is that in upland catchments the watercourse is not clearly defined, rather it is an area that is being drained. What are the characteristics of catchments that dictate these potential control zones?

Key findings and recommendations

- **The 50m buffer zone is based on research by Robinson et al. [2] who recommended a 30 m buffer. This was increased to 50 m by the Environment Agency and Scottish Environment Protection Agency in order to protect private water supplies.**
- **We suggest the 50 m buffer under the spraying restrictions as defined in the regulations provides adequate protection of sensitive species, e.g. aquatic plants, but resultant concentrations in water may not necessarily meet drinking water standards.**
- **A watercourse is not just the stream channel, but also incorporates adjacent wetland and flush areas that have connectivity to the channel.**
- **We do not see any condition under which the buffer zone distance (50 m) should be reduced and it should potentially be increased under wet antecedent conditions when adjacent saturated soils may increase rapid transport of Asulam to the watercourse.**

What is the science behind the 50 meter buffer zone value?

The 50 m buffer zone is based on the study of Robinson et al. [2] who investigated drift effects following two large-scale (7.4 ha; 4.3 ha) applications of Asulam by helicopter at moorland sites in the UK (see Table 1 for full details). They measured drift as well as toxicity (bioassay - Common Sorrel, *Rumex acetosa*) over time and distance. The results showed that levels of Asulam deposition decreased rapidly downwind of the treated areas and were below 1% of the applied dose at 50 m downwind. The bioassay indicated a zero-effect level of 100 g/ha after 7 weeks.

While Robinson et al. [2] recommended a 30 m buffer zone; the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA) approved a 50 m buffer zone to ensure protection of species more sensitive than Common Sorrel, as well as to protect private water supplies.

What is the definition of a "watercourse" in upland catchments that could be used for this guidance?

A watercourse is not necessarily just the visible channel or that designated on an Ordnance Survey (or other) map. Proximal wetland and flush areas may have increased connectivity to stream channels during wetter periods thus spraying should be designated as 50 m from this saturated area.

The CRD guidance states: *"All surface water bodies, wells, boreholes and springs will be protected by a minimum 50 metre no-spray zone. "* As such, watercourses and wetland areas as described above would be included within this measure.

The definition of a) surface water and b) wetland is provided by the Water Environment and Water Services Act 2003.

a) "Surface water" means inland water (other than groundwater), transitional water and coastal water.

b) "Wetland" means an area of ground the ecological, chemical and hydrological characteristics of which are attributable to frequent inundation or saturation by water and which is directly dependent, with regard to its water needs, on a body of groundwater or a body of surface water.

Chemical Regulations Directorate website:

http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/A/application_plan_bracken_and_asulam_Scotland.doc

Key words

Asulam, bracken control, aerial spraying, definition of watercourse

1.0 INTRODUCTION

When spraying with pesticides, buffer zones are typically imposed to protect watercourses and sensitive, non-target species from spray drift, drain flow and run-off. The dimensions of buffer zones will usually depend on the method of application, type of pesticide and/or the site and soil characteristics of the areas concerned. The existing operational protocol for aerial spraying of Asulam for bracken control in Scotland has been developed by the Chemicals Regulation Directorate (CRD) [1]. According to this protocol, when using low drift nozzles, aerial spraying by helicopter must maintain a minimum 50 m no-spray buffer zone from all surface water bodies, wells, boreholes and springs. Scottish Water (SW) has asked CREW to investigate the scientific justification behind imposition of a 50 m buffer zone. This also entails the production of suitable explanatory text that can be used by SW employees to inform aerial spraying contractors and relevant land managers of the reasoning behind imposition of the buffer zone.

1.1 Objectives of study

This report is in response to a request by Scottish Water to determine;

1) What is the science behind the 50 meter buffer zone value?
2) What is the definition of a "watercourse" in upland catchments that could be used for this guidance? Concern is that in upland catchments the watercourse is not clearly defined and rather is an area that is being drained. What are the characteristics of catchments that dictate these potential control zones?

2.0 THE SCIENCE BEHIND THE 50 m BUFFER ZONE VALUE

A limited number of scientific studies have specifically investigated the buffer zone size required to protect watercourses (and/or sensitive species) from drift effects following application of Asulam (or other pesticides) by helicopter; these studies are summarised in Table 1. The existing 50 m buffer zone appears to be based on research undertaken by Robinson et al. [2] and is described in more detail below.

Robinson et al. investigated the drift effects following large-scale applications of Asulam by helicopter at two upland moorland sites in the UK. At both sites, the helicopters used were fitted with Raindrop drift-reducing, hollow-cone nozzles. At the first site, spray was applied to a 7.4 ha block within an extended area of uniform, low-density bracken (approx. 50 cm tall) across a 10–30° concave slope, and the drift was monitored on slightly rising ground. At the second site, spray was applied to a 4.3 ha block of vigorous, uniform bracken (75-100 cm tall) across a 10° slope. Table 1 presents information on the pesticide application method, wind speed, methods for monitoring pesticide deposition and some of the results from the two experimental sites in this study. The mean Asulam doses applied to the sites were 3.6 and 4.4 kg active ingredient/ha, respectively. The recommended dose for bracken eradication is 4.4 kg active ingredient/ha [2]. Site 1 was sprayed in gusty wind conditions with a mean wind speed of 16.7 km/h, while site 2 was sprayed at a mean wind speed of 11.1 km/h. According to the UK Civil Aviation Authority, the maximum wind speed limit for aerial spraying is 18.5 km/h at spraying height [3].

The experimental setup at the two sites is illustrated in Figure 1. At both sites pesticide deposition under the helicopter and drift levels downwind were monitored along two transects (A and B) using the following four different approaches:

1. Water-sensitive papers were laid out on tables to visualise spray deposits. Sampling carried out at 1 m intervals from the zero-line to 50 m downwind; and at 5 m intervals from 50 m to 100 m downwind.
2. 'Astralux' paper cards were laid out on sampling tables to sample the spray deposits. Sampling carried out at 2 m intervals from -30 m (i.e. upwind of the baseline) to 50 m downwind; at 5 m intervals from 50 m to 100 m downwind; and at 10 m intervals from 100 m to 200 m.
3. Vertical drift sampling 'strings' on 10 m masts were used to sample levels of airborne drift downwind of the target area. Masts were erected at 50 m, 100 m and 150 m downwind.
4. Potted seedlings of *Rumex acetosa* (Common Sorrel) were used as bioassays to monitor spray deposition. *R. acetosa* was chosen as a bioassay because it grows rapidly and uniformly from seed and is sensitive to Asulam. The bioassay pots were placed at the same interval as the Astralux paper cards.

Table 1: Overview of existing studies on aerial pesticide spraying by helicopter

	Robinson et al. (2000)		**Marrs and Frost (1996)**	**Payne et al. (1990)**
	Site 1	**Site 2**	**Site 2 - 4**	
Type of pesticide	Asulam	Asulam	Asulam	Glyphosate
Spraying height [m]	2 - 3	3 - 5	3 - 6	3 **
Nozzles (number/type)	36 RD3	16 RD7	36 Raindrop + 36 Cone; Standard Simplex + Modified raindrop	52 Hayrake (Microfoil); 62 Burr (Thru Valve Boom); 32 D8-46 hollow cone
Boom width [m]	10.5	8.5	12	7.9 – 9.1
Applied dose [kg/ha]	3.6	4.4	4.4	2.1
Mean wind speed [km/hr]	16.7	11.1	14.4 - 25.2	1.4 – 3.2
Methods used for monitoring pesticide deposition	1) Water-sensitive paper 2) 'Astralux' paper card 3) Vertical sampling string 4) Bioassays (*R. acetosa*)		1) Water-sensitive paper 2) Bioassays (*R. acetosa*; *Adiantum*) 3) Lithium tracer	1) 'Rotorod' samplers 2) Polyethylene sheets 3) Red alder (for foliar deposits)
Asulam dose 15 m downwind [g/ha]	100 (3%)*	150 (3%)	(~40%)	-
Asulam dose 50 m downwind [g/ha]	25 (0.7%)	10 (0.3%)	(~3%)	0.02-25.5 (0.001-1.2%)
Asulam dose 100 m downwind [g/ha]	10 (0.3%)	3.5 (0.1%)	(~0.4%)	<0.05 (<0.002%)
Suggested buffer zone [m]	50	50	160	25 - 30

* The number in brackets is the dose given as percentage (%) of the applied dose.

** The spraying height above canopy

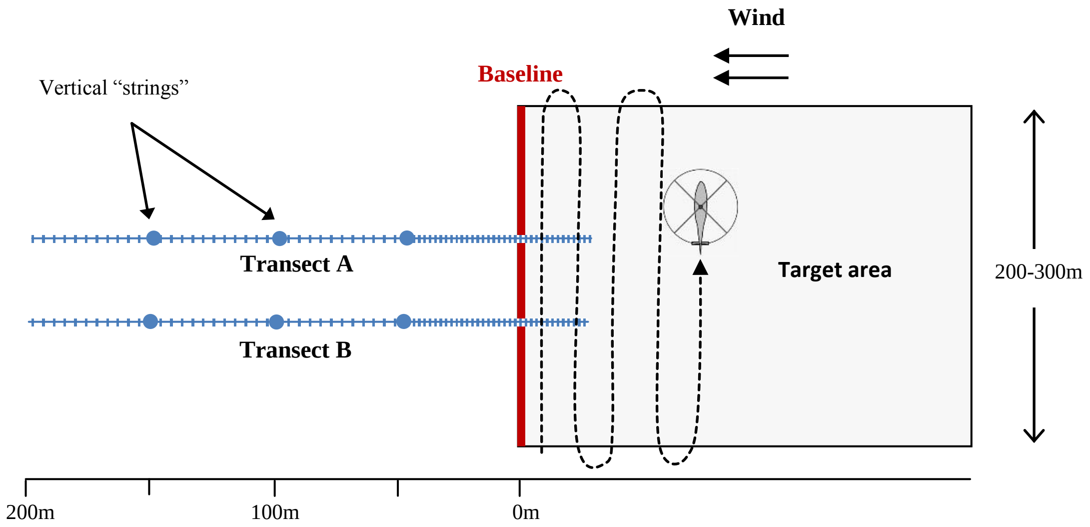

Figure 1: Experimental setup in Robinson et al.

The results from Robinson et al. showed that levels of Asulam dropped rapidly downwind of the treated zones at both sites (see Table 1). For both sites the Asulam levels were well below 1% of the applied dose at 50 m downwind of the base-line. Higher levels of fallout were recorded beyond 25 m at site 1, which was attributed to the greater wind speeds at site 1. Higher fallouts were observed within 25 m at site 2 due to the higher dose applied and greater flying height. Robinson et al. estimate that the total drift fallout accounted for between 0.4% and 0.61% of the total applied Asulam. They concluded that these estimates are comparable to the percentage of droplets smaller than 100 μm in diameter quoted for RD Raindrop nozzles, which agrees well with the fact that it generally is the smallest droplets that are likely to be transported the furthest before depositing on the ground or a non-target receptor. By comparing these results with drift data for tractor spraying from a previous study, Robinson et al. concluded that beyond 15 m from the sprayed areas, drift levels from the helicopters fitted exclusively with RD raindrop nozzles proved similar to those reported from tractor-operated boom-sprayers. Furthermore, Robinson et al. noted that the bioassay data correlated well with Asulam fallout. A zero-effect level of 100 g/ha after 7 weeks suggested a buffer zone of 15 m, which was doubled to 30 m to allow for inaccurate flying, late shut-off, dosage errors and species with greater sensitivity than *R. acetosa*. On the basis of the work by Robinson et al., and also to protect private water abstractions, the Environment Agency and SEPA approved a 50 m buffer zone for helicopters fitted exclusively with RD Raindrop nozzles.

Two further studies assessed spraying under different conditions and nozzle types, producing contrasting results; explanations as to why these results may differ are outlined below. The drift effect following spraying of Asulam by helicopter was investigated by Marrs and Frost [4]. Using an experimental setup similar to the one by Robinson et al., they carried out three experiments to determine safe buffer zone distances downwind of sprayed areas (see Table 1). However, unlike the study by Robinson et al., where commercial scale application of Asulam was considered, Marrs and Frost only investigated the drift following a limited number of helicopter passes (along the baseline, Fig. 1). They observed a similar pattern of drift, but the fallout rates were greater than in the study by Robinson et al. Specifically the deposition levels at 50 m downwind appear to be approximately 3% of the applied dose in the three experiments, which is about 10 times higher than the drift levels reported in the Robinson et al. study. Explanations for the discrepancies observed in these two studies are i) that the helicopters in the Marrs and Frost study were not exclusively fitted with RD Raindrop nozzles, which is likely to have increased drift levels and ii) the generally higher wind speeds in the Marrs and Frost study, particularly for their experiment 2, where the wind speed was above the maximum permissible limit of 18.5 km/h. Deposition and impact on bioassays were observed up to 180 m downwind of sprayed area. Based on their results, Marrs and Frost suggested a ‘’no-spray’’ buffer zones of at least 160 m to minimise risk to the bioassay.

Payne et al. [5] carried out three experiments to investigate the off-target deposits following aerial spraying of glyphosate with helicopters equipped with different nozzle types. They generally found drift levels to be lower than the drift levels reported in both Robinson et al. and Marrs and Frost (see Table 1), which can be explained by the lower wind speed in the Payne et al. study. The highest drift levels were observed when using the nozzle type (D8-46) that produced the highest proportion of fine droplets (< 100 μm in diameter). At 50 m downwind, the glyphosate deposition using the optimal nozzle type (‘Microfoil’) was up to one-hundred times lower than when using the most imprecise nozzle type. Based on their results, Payne et al. suggested a 25-30 m buffer zone around water bodies to protect fish and aquatic invertebrates from glyphosate applied via helicopter. This buffer zone width was estimated to limit glyphosate concentration in the water bodies to below 1 mg/L (a value estimated to cause less than 10 % mortality of certain salmonid species).

2.1 Direct drift impact on watercourses

If it is assumed that approximately 1% of the applied dose concentration (i.e. corresponding to about 40 g/ha, if the recommended dose of 4.4 kg/ha for bracken eradication is applied) would reach a water body located 50 m downwind of a sprayed area, then it is possible to calculate what the resulting Asulam concentration in the water would be. Assuming a water depth of 0.5 m and instantaneous mixing of the Asulam “dose” in the water, 1% deposition results in a concentration of 8 μg/l, which is almost 100 times greater than the EU drinking water standard for pesticides (0.1 μg/l). However, ecotoxicity studies of Asulam suggest that EC_{50} values for aquatic plant growth (i.e. the concentration level where algae growth rate is affected by 50%) are generally greater than 100 μg/l, while other aquatic organisms such as *Daphnia* and fish show a greater tolerance to Asulam (e.g. reported No Observed Effect Concentration values for aquatic invertebrates and fish are 6.4 mg/l and 119.1 mg/l, respectively) [6,7].

Asulam concentrations have been calculated for water bodies with different water depths and at different distances downwind of the sprayed area (Table 2). These results suggest that for a watercourse located 50 m downwind of the sprayed area, the resulting concentrations will generally be below 100 μg/l and most aquatic species are therefore, not likely to be at risk. In order to comply with the EU drinking water standard of 0.1 μg/l, a buffer zone of at least 100 m is required, and to protect very shallow watercourses a buffer of 200 m may be needed. However, it should be noted that with additional non-impacted water contributions via bank seepage, groundwater and other stream tributaries, then the “dose” of Asulam will be diluted with distance downstream to concentrations less than 0.1 μg/l.

Table 2: Calculated Asulam concentrations (in μg/l) in water bodies with different water depths and located at different distances downwind of a sprayed area. Numbers in brackets are lower and upper values.

Downwind distance [m]	**Dose [%]**	**Water depth [m]**			
		0.1	0.5	1	5
25	5 (0.5-10)	200 (20-400)	40 (4-80)	20 (2-40)	4 (0.4-8)
50	**1 (0.3-3)**	**40 (12-120)**	**8 (2.4-24)**	**4 (1.2-12)**	**0.8 (0.2-2.4)**
100	0.1 (0.02-0.5)	4 (0.8-20)	0.8 (0.16-4)	0.4 (0.08-2)	0.08 (0.02-0.4)
200	0.01 (0.001-0.1)	0.4 (0.04-4)	0.08 (0.01-0.8)	0.04 (<0.4)	0.008 (<0.08)

2.2 Summary of existing evidence and recommendations

Of the described studies on aerial spraying, the research by Robinson et al. seems to be the most comprehensive and rigorous. The Asulam concentrations observed at greater distances by Marrs and Frost can be mainly explained by increased wind speeds and less precise nozzle types. In addition, these results may be less reliable as one experiment failed to provide useful results and the uncertainty related to the use of tracers to assess drift. Based on the current evidence, the 50 m buffer zone appears to give adequate protection provided spraying is undertaken using drift-reducing nozzles and within the regulatory wind speed limits. It is important to note that drift from aerial spraying is affected by a range of factors, which include method of application, the speed of the vehicle/aircraft the spray is applied from, height of released spray relative to the crop canopy, droplet size (which depend on the nozzle types and spray pressure), wind direction and speed, air stability, relative humidity and temperature. Both empirical and mechanistic models exist that can be used to predict downwind spray drift and deposition to explore effects of different atmospheric conditions, application method etc. on spray drift [e.g. 8].

The worst-case drift conditions occur when the weather is hot and dry (which will reduce the size of spray droplets because of evaporation and increase the risk of spray drift) and/or when there is little or no wind under a clear sky (presence of a stable boundary layer) and when air layers therefore do not mix, as any drift may hang over the treated area and unexpected air movements may move it to other places [9]. The safest conditions in which to spray are when it is cool and humid with a steady wind of 3.2 to 6.5 km/hr blowing away from potentially sensitive areas.

3.0 DEFINITION OF A WATERCOURSE

Understanding the definition of a watercourse in upland catchments is paramount for delineating an area of bracken to be sprayed and ensures compliance (50 m buffer zone) with regulations related to aerial spraying of Asulam.

In terms of catchment characteristics, in upland systems, watercourses are not always clearly defined and increased connectivity to a stream could possibly be down slope from flush areas or via larger moss/wetland areas. To clarify this, we raised with SEPA whether these areas were considered part of the watercourse with respect to this guidance.

A Senior Policy Officer at the Land Unit at SEPA provided the following response:

The 'Application plan for the aerial spraying of pesticides (bracken control with Asulam in Scotland)' available from the Chemical Regulations Directorate website, who are now the UK competent authority for aerial spraying, includes a measure stating;

"All surface water bodies, wells, boreholes and springs will be protected by a minimum 50 metre no-spray zone. " As such watercourses and wetland areas as described above would be included within this measure.

The definition of a) surface water and b) wetland is provided by the Water Environment and Water Services Act 2003 [11].

c) "Surface water" means inland water (other than groundwater), transitional water and coastal water.
d) "Wetland" means an area of ground the ecological, chemical and hydrological characteristics of which are attributable to frequent inundation or saturation by water and which is directly dependent, with regard to its water needs, on a body of groundwater or a body of surface water.

Chemical Regulations Directorate website:

http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/A/application_plan_bracken_and_asulam_Scotland.doc

Therefore, a watercourse is not necessarily just the visible channel or that designated on an Ordnance Survey or other map or derived from terrain analysis. Ground truthing, should be utilised to identify potentially proximal wetland and flush areas with connectivity to stream channels.

Furthermore, soil type and the drying and wetting of soils influences connectivity of proximal soils to their associated watercourse. Following significant antecedent rainfall, areas connected to the watercourse may expand as soils become saturated. Buffer zones for aerial spraying should then be designated as 50 m from these newly saturated areas as the likelihood of a more rapid hydrological response (transport of water via overland flow and shallow sub-surface flow) is enhanced. This may then increase the rapid transport of newly sprayed Asulam to the watercourse.

The precautionary principle would suggest that we do not see any condition that the aerial spraying buffer distance (50 m) from watercourse should be decreased. In fact, it should be potentially increased under wet antecedent conditions.

3.1 Modelling transport and fate of Asulam

Site-specific assessments would be required to optimally model the potential transport and fate of deposited Asulam to ground and surface waters, particularly when followed by a major rainfall event. Transport to watercourses may be either i) rapid, by overland runoff and shallow sub-surface flow or ii) slower via percolation and subsequent transport to stream channels through the deep sub-surface with flowing groundwater. Furthermore, the transport and fate of Asulam is dependent on its physico-chemical properties. Asulam is very soluble, does not adsorb strongly to the organic matter in soil, and therefore, would be expected to travel in the water phase. However, available data also suggests that Asulam is fairly non-persistent with a half-life in soil of *ca*. 5-10 days under aerobic conditions [7].

Fate and transport modelling assessments require information on catchment spatial characteristics, such as soil type, hydraulic conductivity, topography and hydrogeology in addition to hydrometeorological (including precipitation and stream flow) conditions. These determine the hydraulic residence time of Asulam from the point where it hits the ground surface to the point to where it reaches receiving waters; the longer this residence time, the lower the potential impact. Deeper sub-surface transport will usually be relatively slow (e.g. a few cm per day) and it is therefore considered unlikely that this pathway will pose a risk, as most of the Asulam is likely to have degraded before reaching receptors. However, Asulam can be transported more rapidly in surface runoff, particularly when the Asulam spraying is followed by a heavy rainfall event and the sprayed area is located on slowly permeable or water saturated soil and/or on a steep slope, potentially posing a much greater risk.

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