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Guide for managing contamination at shooting ranges

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Contents

Acknowledgements

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- Field & Game Australia
- Sporting Shooters Association Australia, Victoria
- Victorian Amateur Pistol Association
- Victorian Clay Target Association
- Victorian Rifle Association
- Victorian Sporting Clays Association

EPA also appreciates the contributions from the following Victorian government agencies:

- Department of Economic Development, Jobs, Transport and Resources (DEDJTR)
- Department of Environment Land Water and Planning (DELWP)
- Department of Health and Human Services (DHHS)
- Sport & Recreation Victoria (SRV) [division of DHHS]
- Victoria Police
- Victorian Planning Authority
- WorkSafe Victoria

EPA's role

EPA protects the environment and people of Victoria by preventing and reducing harm from pollution and waste. We do this in several ways, including equipping community and business by providing clear advice and guidance that supports compliance with environmental obligations.

EPA provides support to prevent pollution, such as this guide, but also has the authority to respond to harm and enforce the law with actions such as remedial notices.

EPA wants to support owners and operators of outdoor shooting ranges to prevent harm to human health and the environment and ensure the longevity of these valuable community sports.

Glossary

Term	Definition
Approved shooting range	A shooting range that has been approved by the Victoria Police Chief Commissioner under section 179 of the *Victorian Firearms Act 1996*.
Australian Simulated Field	Shooting discipline reproducing hunting situations using a shotgun and clay targets.
Background level	The 'background level' of a material is the level (or range of levels) found in the local area, before the level has been affected by contamination (State Environment Protection Policy [Prevention and Management of Contamination of Land]). The background level can be determined by comparing the levels of material present in nearby and geologically similar uncontaminated land.
Berm	A triangular shaped mound of earth or soil that stops shot and/or bullets or provide a noise or visual barrier.
Bullet	A metal projectile fired from a rifle, pistol, or other firearm that is typically cylindrical and pointed.
Bullet trap	A physical structure designed to capture and contain projectiles and projectile fragments located behind a target at a rifle or pistol range. There are a wide variety of designs and construction materials used.
Cartridge	A cylinder of metal (rifle/ pistol) or plastic/cardboard (shotgun) containing a bullet or shot and an explosive substance. Cartridges are used in both rifles, pistols and shotguns. It is what goes into the firearm.
Clay target	Saucer, or disc-shaped, piece of breakable material targeted at shotgun ranges.
Contamination	The condition of land or water where any chemical substance or waste has been added at above background level representing, or potentially representing, an adverse health or environmental impact. Definition from National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended 2013).
Down the line (DTL)	See trap (sport).
Environment	The physical factors of the surroundings of human beings including the land, waters, atmosphere, climate, sound, odours, tastes, the biological factors of animals and plants and the social factor of aesthetics; (source: *Environment Protection Act 1970, s.4*).
Firing point	The position from which firing occurs at a shooting range. It may take the form of a point for an individual firearm, a line for a number of firearms or an area for one or more firearms firing from different positions.
Impact area	The area where projectiles land at a range.
Metal jacket	A metal coating or shell surrounding the soft core (often lead) of a bullet designed to protect the bullet core and improve performance.
Net	A lightweight physical structure designed to stop shot at a shot gun range.
Projectile	The part of the cartridge that is projected out of a firearm. Projectiles can be either bullets or shot. A shotgun usually fires multiple projectiles (shot) while a rifle or pistol fires only one projectile (bullet).

Term	Definition
Pollution	A change in the environment that makes air, land or water any of the following: • noxious, poisonous or offensive to humans • harmful or potentially harmful to humans, animals or plants • detrimental to any beneficial use. Beneficial uses are uses and values of the environment that communities want to protect, such as human health and wellbeing, local amenity and aesthetic enjoyment. Note: Pollution is not specifically defined in Victoria's *Environment Protection Act 1970* see part I Section 4 of the Act. This definition is taken from EPA's *Guide to the Environment Protection Acts*.
Polycyclic aromatic hydrocarbons (PAH)	A group of more than 100 different chemicals that are released from the burning of organic substances such as coal, oil, gas and timber. Several PAHs are classified as carcinogenic (*IARC 2010*).
Range danger area (RDA)	Those areas of land or water, together with a specified air space within which danger to life, limb or property may be expected to occur arising from the use of specified firearm and ammunition at a shooting range. This is defined in Victoria Police's *Firearms Ranges – Standards for Approval* document.
Skeet (sport)	A shotgun sport with targets launched from two separate trap devices, one high and one low on either side of the shooter, on trajectories that intersect in front of the shooter.
Shooting field	The area of a shooting range used during practise and competition by shooters, it is the area over which shot or bullets both pass and impact.
Shooting range	In this guide, 'shooting range' refers to the total area approved by Victoria Police for a shooting range operator to use for rifle, pistol or shotgun shooting sports. A shooting range operator may have approval from Victoria Police for multiple adjacent ranges for different sports. In this guide, a 'shooting range' refers to the combination of these.
Shooting range operator (SRO)	The entity responsible for the administration, management and operation of a shooting range. This may also be known as the range 'controlling authority'.
Shooting station	The area where firing takes place at range. A shooting station is usually made up of several firing points. At a rifle or pistol range it is generally known as the firing line.
Shot	Small, generally spherical metal projectiles, fired from a shotgun. A single shot gun cartridge can contain 300-500 individual pieces of shot.
Shot barrier	Physical structure designed to contain shot at a shotgun range.
Shot fall zone	The area of a shotgun range over which shot lands.
Sporting clays	Shooting discipline reproducing hunting situations using a shotgun and clay targets
Stop butt	A barrier located behind the target/s at a rifle or pistol range designed to stop and contain bullets. Generally made from a mound of earth but can also be constructed from timber or other materials. Can also be a natural hillside or slope.
Trap (device)	A mechanical device that launches a clay target at a shotgun range.
Trap (sport)	A shotgun sport in which clay targets are launched from a single trap device, generally away from the shooter.
Wad	A component of a shotgun shell which contains shot and separates it from powder. It is nearly always made of plastic.

Term	Definition
Waste	The Victorian *Environment Protection Act 1970* defines waste to include: • any matter whether solid, liquid, gaseous or radio-active which is discharged, emitted or deposited in the environment in such volume, constituency or manner as to cause an alteration in the environment • any greenhouse gas substance emitted or discharged into the environment • any discarded, rejected, unwanted, surplus or abandoned matter ○ any otherwise discarded, rejected, abandoned, unwanted or surplus matter intended for— recycling, reprocessing, recovery or purification by a separate operation from that which produced the matter, or sale, and • any matter prescribed to be waste.

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Section 1 – About this guide

Shooting sports play a valuable role in the community. The Victorian Government is committed to supporting these sports and ensuring they continue to provide benefits to the Victorian community.

Activities at shooting ranges can cause environmental contamination – but this contamination can be managed. This guide provides Victorian outdoor shooting ranges with information to help them prevent, manage and contain contamination from their activities.

All shooting ranges are unique and there are many ways to manage contamination. This guide assists operators and land owners to assess risks from contamination and make informed decisions about how to best control those risks. There are options for all shooting ranges to control contamination, some of which are easy to implement.

A range of potential contaminants are common at shooting ranges but lead usually has the greatest potential to harm human health and the environment. For this reason, this guide will primarily focus on lead, but other contaminants are also often controlled with the same methods.

For clarification on what contamination is and how it can result in pollution, refer to *Prevention and management of contamination of land in Victoria* (publication 854).

What this guide covers

- Current outdoor shooting ranges firing either shot or bullets (for example shotgun, rifle, and pistol ranges).
- Waste that is unique to shooting ranges, such as from ammunition and clay targets.
- Contaminants resulting from shooting activities, primarily lead but also others such as polycyclic aromatic hydrocarbons (PAH), copper, zinc, antimony, arsenic, nickel, tin, strontium, magnesium, barium, and mercury.
- Risks to human health and the environment associated with outdoor shooting activities.

Organisations who are planning new shooting ranges will find much of the content in this guide useful, however they will need to seek further advice from planning authorities and the land manager or administrator.

What it does not cover

- General information about managing rubbish and site environmental management, such as providing bins for visitors or recycling. For information about this visit the Sustainability Victoria website.
- Health and safety risks from shooting ranges administered by WorkSafe and Victoria Police.
- Noise. Refer to *Noise from outdoor shooting ranges* (publication 1508).
- Remediation, or clean up, of contaminated sites.
- Former shooting ranges.
- Indoor shooting ranges.
- Temporary shooting ranges.

How this guide is structured

1. Sections 1, 2 and 3 of this Guide provide the background information to understand contamination and assess a shooting range's level of risk.
2. Sections 4 'Shotgun ranges' and 5 'Rifle and pistol ranges' provide information about risks at these specific different types of ranges and outlines options to control contamination.
3. The Guidance Sheets provide further detail about options for managing contamination at shooting ranges.
4. Appendix 1 provides a brief overview of the legal responsibilities of shooting ranges operators.

Table 1. Relevance of sections in this guide for shotgun and rifle/pistol ranges

Section	Title	Shotgun	Rifle/Pistol
Section 1	About this guide	✓	✓
Section 2	Risks to human health	✓	✓
Section 3	Assessing contamination risk	✓	✓
Section 4	Shotgun ranges	✓	-
Section 5	Rifle and pistol ranges	-	✓
Guidance sheet 1	Controlling access	✓	✓
Guidance sheet 2	Alternative ammunition and clay targets	✓	✓
Guidance sheet 3	Vegetation management	✓	✓
Guidance sheet 4	Water management	✓	✓
Guidance sheet 5	Shotgun range design	✓	-
Guidance sheet 6	Shot barriers	✓	-
Guidance sheet 7	Stop butt design	-	✓
Guidance sheet 8	Bullet traps	-	✓
Guidance sheet 9	Environmental management plans	✓	✓
Guidance sheet 10	Lead recovery	✓	✓
Bibliography	Bibliography	✓	✓
Appendix 1	Relevant laws	✓	✓

Section 2 – Risks to human health

Traditional ammunition contains a wide range of metals. These can include antimony, arsenic, copper, zinc, nickel, tin, strontium, magnesium, barium, and mercury – but the metal most likely to impact human health is lead. Every lead-based shot that's fired can introduce it into the environment (*Bannon et al 2009; Kelebemang et al 2017*).

Lead makes up the largest part of most types of ammunition and significant levels of it can be released at shooting ranges (*Sorvari 2011*). At some larger shotgun ranges it can be up to tens of tonnes a year[1].

Clay targets can also contain PAH. As these are only relevant to shotgun ranges, they will be discussed in Section 4 'Shotgun ranges'.

It is important to manage contamination because:

- Exposure to lead can harm people's health. This is discussed more below in 'Lead and human health'.
- It can spread and contaminate nearby land such as other sports grounds, parks, housing or farmland. Areas might become unusable for certain activities, such as farming or sports, and land values could be affected.
- Grazing livestock can ingest contaminants. People can be harmed if they consume contaminated meat and dairy products.
- The local environment and animals can be harmed, especially foraging animals and aquatic animals if water is contaminated.
- It is a requirement under the *Environment Protection Act 1970* that organisations protect human health and the environment.

Lead and human health

Note: This section has been provided by Department of Health and Human Services.

Contact with lead can cause a range of serious health effects. Exposure to small amounts of lead over a long period of time (chronic exposure) may result in lead poisoning. Lead accumulates in the body and is stored in bones. There is no known safe level of lead exposure.

Humans can absorb lead by:

- inhaling lead dust
- accidental ingestion
- drinking contaminated water
- using former shooting ranges for residential, recreational or agricultural purposes
- consuming meat and dairy products from animals that have grazed on contaminated land.

Young children and pregnant women are particularly vulnerable to the health effects of lead. Lead exposure can permanently damage the brain and impair intellectual development. Children under five years of age are especially vulnerable to lead exposure because:

- they frequently put their hands to their mouths (accidental ingestion)
- they absorb and retain more lead from their gut and airways than adults do
- their developing brains are more sensitive to the effects of lead.

Unborn babies are also at risk, since exposure by the pregnant mother to lead readily passes through the placenta. Breastfeeding mothers can also pass on lead to their infants via their breast milk.

[1] The firing of 360 000 x (28 gram) shotgun cartridges a year equals approximately 10 tonnes of lead

Some of the symptoms of chronic lead exposure include:

- irritability
- lack of energy
- loss of appetite
- learning disabilities
- behavioural problems
- poor school performance
- poor coordination; and
- impaired growth.

Many of these symptoms could be caused by other conditions, so it is important to see a doctor if you are worried.

Further information on health effects of lead is available on the Better Health Channel:

https://www.betterhealth.vic.gov.au/health/HealthyLiving/Lead-exposure-and-your-health

Health effects for shooters

Shooters can have long term exposure to high levels of lead and should take precautions to protect themselves and others. Small amounts of lead dust are released after firing and when a bullet hits a hard surface. Shooters can inhale or swallow this dust and carry it into their homes on their clothing. Shooters should be aware of lead hygiene and take precautions such as washing hands and changing clothes at the shooting range after shooting. Another precaution is to wash clothes used for shooting separately.

It is easy for the health effects from lead exposure to go unnoticed as symptoms can be blamed on other causes. For example, a symptom of lead poisoning can be memory and concentration problems but few people who find themselves having such problems would blame them on lead poisoning, particularly if they've been exposed to it without their knowledge.

As stated above, children are especially vulnerable to lead so it is important to consider how they could be exposed. Under Victorian law, children under 12 cannot operate a firearm at a shooting range.

For more information see the Department of Health and Human Services publication Information for gun shooters - managing exposure to lead. If you are concerned about your exposure to lead, you can see a doctor. A blood test can indicate if you have elevated blood lead levels.

Section 3 – Assessing contamination risk

Every shooting range is different, and risks vary. By understanding the unique situation at a shooting range, the right actions can be taken to control them.

This section discusses some ways that people can become exposed to contamination. Shooting ranges can conduct their own risk assessments for these scenarios to find out how relevant they are for them.

EPA has written a step-by-step guide to risk management in *Assessing and controlling risk* (publication 1695). This risk management framework can be applied at shooting ranges. Figure 1 below outlines the steps in this process.

In this section, step 1 'identify hazards' and step 2 'assess risks' will be discussed in relation to shooting ranges. This can be complex as there are many factors which influence risk, and these factors are often intertwined. Steps 3 and 4 are about controlling risk, this will be covered in the guidance sheets of this guide.

For more detailed information about assessing risk at contaminated sites see National Environment Protection (Assessment of Site Contamination) Measure NEPM 1999.

Step	Action	Description	Section of Guide
1	**Identify hazards**	What hazards are present that might cause harm.	Section 3 Section 4 Section 5
2	**Assess risks**	What is the level or severity of risk, based on likelihood and consequence.	
3	**Implement controls**	What measures are suitable and available to the business to eliminate or reduce a risk.	Guidance sheets
4	**Check controls**	Review controls to ensure they are effective.	

Figure 1. Steps in assessing and controlling risk.

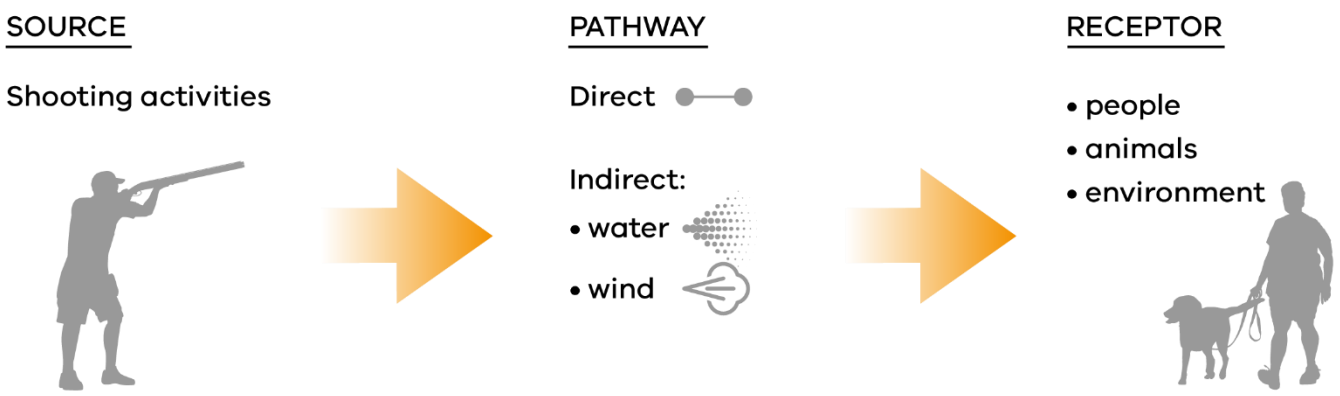
Source, pathway, receptor

When assessing the risk of exposure to contamination, it's helpful to think about the *source*, *pathway* and *receptor*.

- Source: The source of contamination.
- Pathway: The ways that contamination can reach a receptor.
- Receptor: Something that can be harmed by contamination.

Below is an image which demonstrates this. It includes the activities and pathways relevant for shooting ranges.

Table 2. Source - Pathway - Receptor



For contamination to cause an impact, all three (source, pathway and receptor) must be present. Below is a source, pathway and receptor example based on a shooting range without controls in place:

Table 3. Example of source, pathway, receptor from a shooting range.

	Source	Pathway	Receptor
Example	The ground of a shooting range becomes contaminated.	Water flushes lead into an adjacent dam used for irrigating crops.	People are exposed to contamination by eating these crops.

3.1 Source

When identifying the source of contamination at a shooting range, it is important to look first at what activities are taking place, and what types of risks these pose.

Shooting at the range

The types of ammunition used at a range, specifically if it is lead, will have a major impact on contamination risk. There are different forms of ammunition and clay targets which contain low levels of lead or PAH, or none. Using these will greatly reduce the risk of contamination.

For more information on these see *Alternative Ammunition and Clay Targets* (guidance sheet 2).

It is also important to consider the length of time shooting has been occurring at the range and how much shooting has occurred over this time. This helps to determine how much lead has been deposited onto the ground.

Range danger area

Approved shooting ranges in Victoria are required to have an identified and documented range danger area (RDA). This is a requirement in the Victoria Police *Firearms Ranges – Standards for Approval* document. An RDA identifies where projectiles will land and is a good place to start in identifying potentially contaminated areas at a shooting range.

Sections 4 and 5 of this guide provide specific information for shotgun and rifle/pistol ranges to help assess where bullets or shot land.

RDA at shotgun ranges

At shotgun ranges, shot is dispersed across a wide area. It is likely that the entire RDA will be contaminated.

RDA at rifle/pistol ranges

Rifle and pistol range operators could consider their contaminated area to be the RDA up to, and including, the stop butt. Stop butts capture the overwhelming majority of projectiles, often more than 99 per cent, so in most cases the risk of contamination beyond the stop butt is low.

Key things to consider include:

- *Does the RDA extend beyond the property boundary of the range*?
  It is very important that contaminated areas are not used for other sensitive purposes, such as harvesting hay or other sports. If the RDA extends beyond the range boundary onto public or private land, Victoria Police requires range operators to have written authority from landholders (See *Firearm Ranges – Standards for Approval* pages 1-2).
- *Is there adequate fencing*?
  Fencing contaminated areas is a very effective way to reduce the risk of exposure. Fences should prevent all unauthorised access always, whether the range is in use or not. At a shotgun range the entire RDA should be fenced and at a rifle/pistol range the RDA from firing point up to and including the stop butt should be fenced. Fences can also help meet safety obligations as they can reduce the risk of people accidently getting shot. Victoria Police *Firearms Ranges – Standards for Approval* outlines specific requirements for fencing. For more information on this see *Controlling access* (guidance sheet 1).
- *Is there adequate signage?*
  It's important that people do not unknowingly become exposed to contamination. People can be alerted through signage at the perimeter, or within the range about specific contaminated areas. Victoria Police *Firearms Ranges – Standards for Approval* outlines specific requirements for signage. For more information on this see *Controlling access* (guidance sheet 1).
- *Have conditions changed*?
  Shooting activities and local conditions might have changed and there may be a new risk to manage. For example, residential development might be encroaching on the range.

Sampling
Soil and water can be sampled and tested to determine the level of contamination in a specific area. Sampling and testing can:

- accurately measure the level and extent of impacted soil, surface water or groundwater
- inform decisions on which controls to use, where to focus attention, and
- allow for ongoing monitoring of lead levels to check if controls are working as planned.

Sampling and testing can be complex and will require the engagement of a suitably qualified person or consultant. For information about how to engage a consultant see the EPA webpage Engaging consultants. Sampling can be costly and time consuming, so it may not be appropriate for all shooting ranges and those with limited resources may choose to prioritise the implementation of controls.

This section of the guide, as well as sections 4 and 5, outline how to identify potentially impacted areas and ways people could be exposed. For many shooting ranges this might be enough for them to make informed decisions about controlling risks. When it is necessary to gain a better understanding of contamination, soil and water monitoring may also be used.

3.2 Pathways

There are two main pathways for contamination from a shooting range to cause harm. These are:

- **Direct** pathways.

Or by spreading through:

- **Indirect** pathways, which are:
  - **Water**, or
  - **Wind.**

3.2.1 Direct

In this guide, a direct pathway refers to projectiles or clay targets landing directly on a receptor. Contaminants do not need to become mobile and travel any further to reach receptors. If there are risks relating to direct pathways, then controlling these should be prioritised.

Direct pathways present the greatest risk because contamination levels can be higher in these areas compared to those indirectly impacted through water or wind. Soil is more likely to become contaminated with direct pathways increasing the chance that people could be exposed through skin contact and ingestion.

Table 4 below outlines some examples of direct pathways from shooting ranges.

Table 4. Examples of direct pathways

Type	Example
Buildings	Projectiles landing on or around houses, shops or community buildings
Recreational land	Projectiles landing on parkland, conservation land or a sporting oval
Agricultural land	Projectiles landing on grazing, cropping or horticultural land
Environment	Projectiles landing in a river or wetland
Access	Members of the public walking onto a shooting range and becoming exposed

Figures 2 and 3 on the next page demonstrate how sensitive areas can exist within the shot or bullet fallout zones. In these examples, interaction between lead and these receptors would pose a significant risk to human health.

This image depicts direct pathways at a shotgun range. The shot fall zone extends beyond the perimeter fence onto agricultural, recreational and residential land.

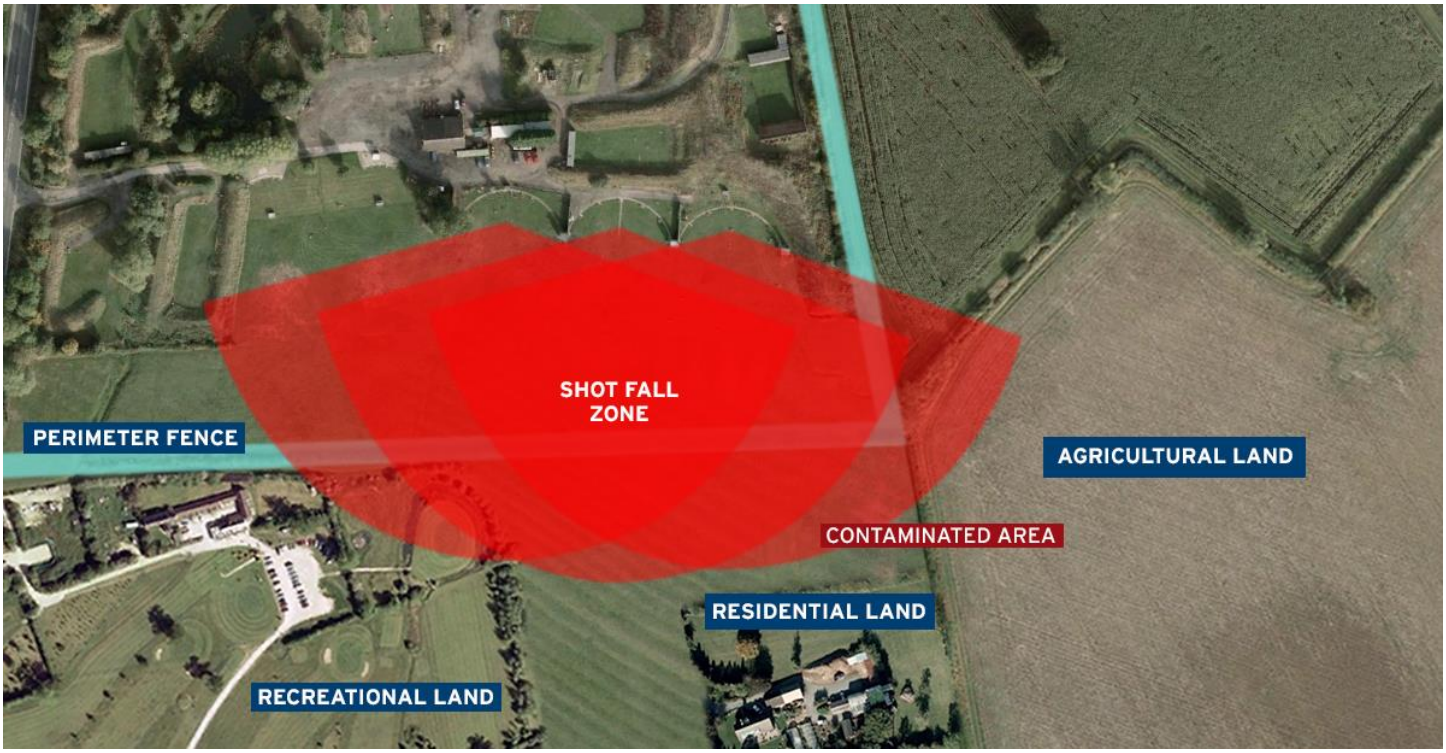


Figure 2. Example of direct pathways at a shotgun range.

This image depicts a rifle/pistol range where the contaminated area is also used for agricultural purposes.

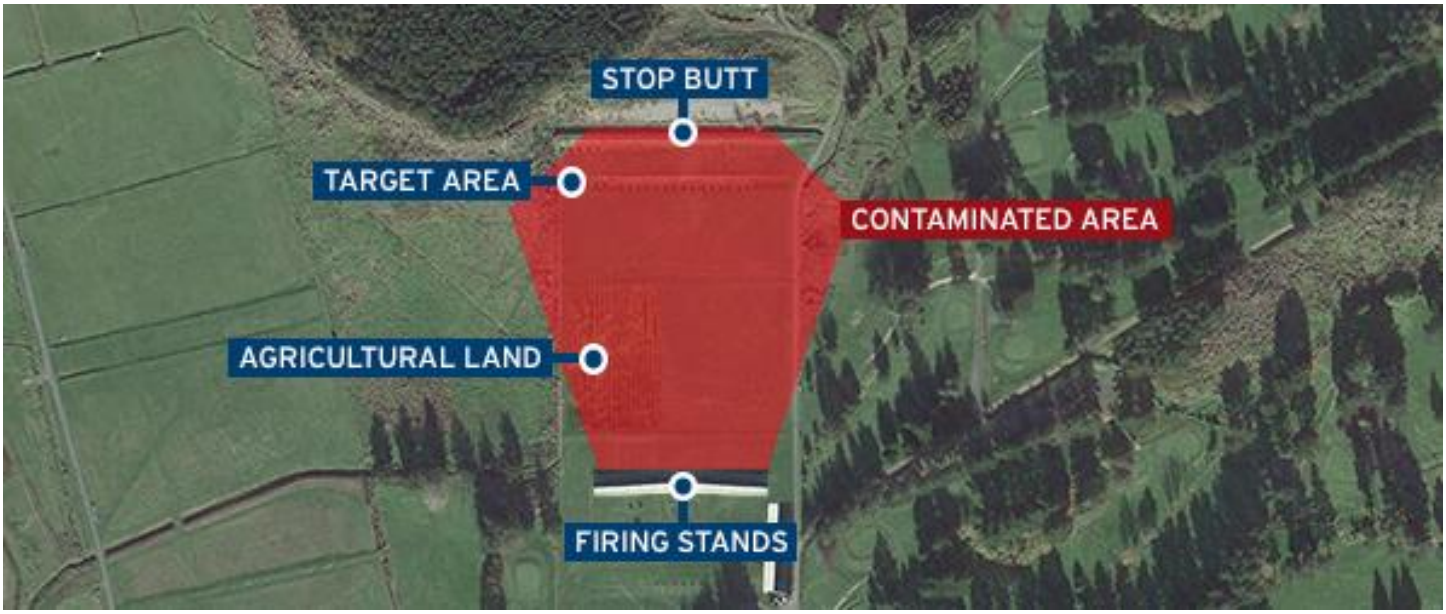


Figure 3. Example of direct pathways at a rifle/pistol range.

In some instances, contact with land that projectiles or clay targets have landed upon, can also cause contamination to spread further. For example, people, vehicles or livestock travelling across a contaminated area can transport impacted soil which can also potentially expose these people or animals.

3.2.2 Indirect pathway – water

Water can move dissolved lead or fine lead in particles which has bonded to soil or organic matter. When lead is in its solid metallic form it is least likely to spread, but after it is weathered and exposed to air, soil and water it can become soluble and more mobile. Dissolved lead can be washed away by rainwater and flushed into rivers, lakes, dams and groundwater. Contaminated water can be consumed by people or livestock and used for recreation (for example fishing), or for agriculture (for example irrigation).

Rivers, streams and waterways

As lead can spread in water, it is very important to consider nearby rivers and streams where water can flow after rain. Rivers, streams and other waterways are sensitive ecosystems themselves also used for many activities such as fishing and swimming. Rivers and streams can spread contamination downstream into wetlands, towns, and farms, and can also be used for drinking and household water as well as irrigation. The distance which contamination can spread varies and depends on many factors such as the water flow speed.

Groundwater

Groundwater is both a pathway and receptor. When impacted water reaches groundwater, the contamination can continue to travel underground. As this may be used for drinking water and irrigation, once groundwater is impacted it is very difficult to remediate. So it is important to prevent contamination from reaching groundwater in the first place.

Understanding the local groundwater is important for understanding risk. A consultant with land and groundwater experience may be required to properly assess this.

There are resources available to assist with understanding groundwater and the role it plays in a local area. Understanding groundwater on water.vic.gov.au is a good source of information, as is the Visualising Victoria's Groundwater database.

Rainfall

The more rainfall, the more likely it is that surface water will spread contaminants. It is also important to consider how long water remains on the surface of the range. In boggy and wet conditions lead can weather more easily and become more mobile.

Slope of the land

The slope of the land gives a good indication of how water can spread contamination. It is important to consider both the surface runoff that may flow onto a range as well as runoff leaving a range.

pH of soil

Lead is more likely to spread in acidic soils (pH 1-6). In a pH range of 6.5 – 8.5 lead is least likely to spread (*US EPA 2005*).

Type of soil

The type and chemistry of soil can influence the spread of contaminants. For example, contaminants can spread easier in sandy soil than in clay soil.

3.2.3 Indirect pathway – wind

Wind can blow potentially hazardous dust particles to other areas. There are two kinds of dust which are relevant to shooting ranges, soil dust and lead dust.

Soil dust – Soil can become contaminated by lead. This can happen in two ways:

- Small lead fragments can become scattered throughout soil.
- Lead can corrode and chemically attach to soil particles.

(*EAEST 1996).*

When conditions are suitable, fine particles of contaminated soil may be blown from a shooting range as dust.

There are many conditions which influence the likelihood that dust could become airborne and the distance it could travel. These include:

- Windy conditions.
- Dry soil conditions, such as during summer and drought.
- Fine soil particles. Fine soil is often created when the ground is cultivated or disturbed, such as from vehicle use.
- Lack of wind breaks, such as trees, which can reduce windy conditions.
- Lack of ground cover such as grasses and other vegetation. This helps to prevent the spread of dust. For more information on this see *Vegetation management* (Guidance sheet 3).

A combination of these conditions can be a strong indicator that wind could carry dust to a receptor. Similarly, if they are not present then it is less likely that wind poses risks.

Lead dust – Small amounts of lead dust can be released after firing. This dust is heavier than soil dust so is not likely to travel as far, but it could potentially expose nearby people such as shooters and visitors to a shooting range (*Laidlaw et al. 2017*).

3.2.4 Assessing pathway risk

It is important for a shooting range to assess their situation to determine whether direct, or indirect (water or wind) pathways are something they need to address.

Once this is understood, controls can be put in place for these pathways. Table 5 on page 19 shows which controls can be applied to different pathways.

This diagram demonstrates the potential for contamination to spread from a shooting range through water and wind. In this example there are no preventative controls in place.

It is indicative only and not to scale. There are many factors which influence whether water or wind pathways create risks. The previous sections discuss these factors.

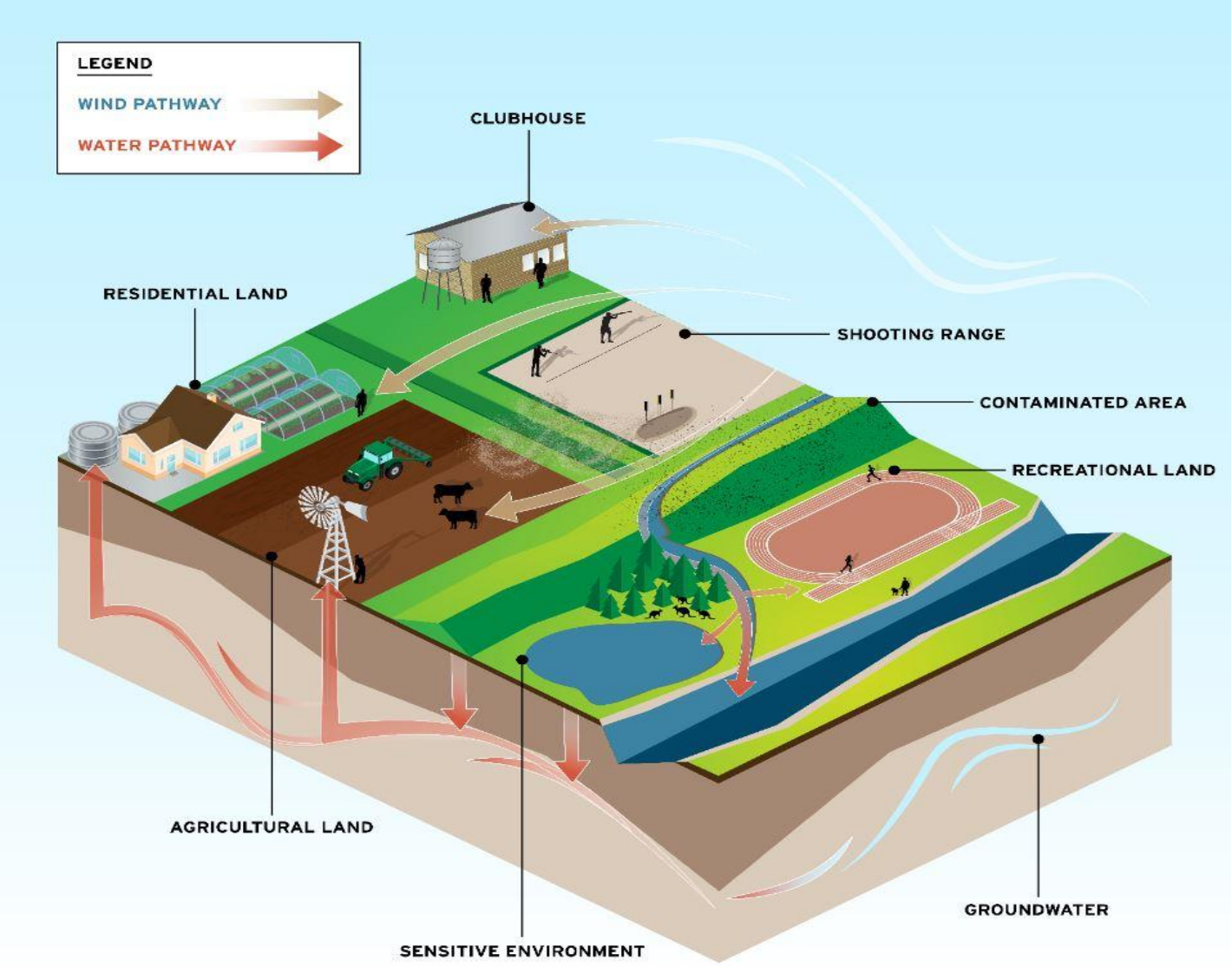


Figure 4. Contamination spreading from a shooting range through water and wind.

Table 5: Controls that can be applied to different pathways

		Controls									
		Guidance sheet 1	Guidance sheet 2	Guidance sheet 3	Guidance sheet 4	Guidance sheet 5	Guidance sheet 6	Guidance sheet 7	Guidance sheet 8	Guidance sheet 9	Guidance sheet 10
		Controlling access	Alternative ammunition & clay targets	Vegetation	Water management	Shotgun range design	Shot barriers	Stop butt design	Bullet traps	EMPs	Lead recovery
Pathway	Direct	✔	✔			✓	✔			✓	✓
	Water		✔	✔	✔	✔	✔	✔	✔	✓	✓
	Wind		✔	✔	✔	✓		✓		✓	

✔ **Large ticks show the main controls that should be used to address the risks.**

✓ **Small ticks indicate contributing controls that can be used.**

3.3 Receptors

People and animals are the receptors which are most at risk from exposure to contamination at shooting ranges. In this section, four key land uses or types which are often found nearby shooting ranges are discussed. These are indicators that people and/or animals could potentially become exposed. The sections are:

- buildings
- recreational land
- agricultural land
- environment.

Young children and pregnant women are especially vulnerable to lead. This is discussed in more detail in section 2. When identifying receptors, it is particularly important to consider these groups and the potential for them to become exposed.

Buildings`

Nearby buildings are strong indicators that there are people who regularly use the area. If the area becomes impacted, people could be exposed to contamination.

If there are buildings near the range, consider the following:

What type of building is it? Particularly sensitive buildings include houses and schools. Below is a table of common building types.

Table 6. Common building types

Type	Examples
Residential	Houses, units, farmhouses
Recreational	Sports grounds, club houses
Commercial	Shops, offices, businesses
Industrial	Warehouses, garages, factories
Agricultural	Barns, sheds, silos

How close is the building? It is important to consider if the building is close enough to be at risk of exposure through direct contact, or indirectly through water or wind. See the information in Section 3.2 ‘Pathways’, beginning on page 14.

Captured rainwater in tanks has been known to become contaminated by airborne lead (O'Connor et al. 2009). Tanks in close proximity to shooting ranges may be at risk if lead dust, or impacted soil dust, is airborne.

Recreational uses

The land adjoining shooting ranges can sometimes be used for other recreational purposes. If the recreational land becomes impacted, people using it could be exposed to contamination. The table below shows some examples.

Table 7. Examples of recreational land uses

Type	Common activities and uses
Active recreation	Sporting ovals, running tracks, swimming pools.
Passive recreation	Picnic areas, camping, hunting, bushwalking, fishing.

Agricultural land

It is common for shooting ranges to be located near agricultural land. If agricultural land becomes impacted, people and animals could become exposed.

Grazing land

Grazing livestock, such as sheep and cattle, can ingest lead and PAH through consuming plants and soil from contaminated land. People or other animals can be exposed by consuming contaminated meat or food products (*Sorvari 2011*). Livestock travelling across a contaminated area can also transport impacted soil.

Cropping land

Like with grazing land, small fragments of lead can attach to cereal, fruit and vegetable crops. People or animals who consume these crops, especially leafy vegetable crops, can be exposed to contamination (*Sorvari 2011; Thomas and Guitart 2013*).

Cropping land is sensitive to lead spreading by water irrigation. If irrigated water becomes contaminated, then this contamination can be spread over the crops.

Environment

Our environment enables Victoria to remain healthy and highly liveable, while enabling our economies, such as agriculture, to thrive. Contamination from shooting ranges can harm the environment in many ways. It is important to understand and manage this risk.

Victoria is diverse and there are many types of environments across the state. Checking with your local council is often a good place to start in understanding what sensitive environments might be present in the nearby area. Some online information sources that may assist are included in the bibliography of this guide.

Key environmental receptors to look for include:

- rivers and streams
- wetlands, lakes and dams
- forests/woodlands
- native plants and animals
- bays/ocean.

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Section 4 – Shotgun ranges

This section covers the risks and controls relevant to shotgun ranges using lead shot. If non-lead shot is used, many of these risks can be reduced.

Due to the nature of shooting, shot is spread over almost the entire surface of the shot fall zone. Also, because shot is made up of a large number of small lead spheres (typically 200-500 individual pieces of shot per cartridge), there is a large surface area where lead could oxidise and spread into soil or water. This creates some challenges for controlling contamination.

When considering the environment, shotgun sports can be broadly placed into two categories; confined and dispersed.

Confined shotgun ranges (Skeet and Trap)

With sports such as skeet and trap, shooting takes place at a number of fixed firing stations that typically all shoot in the same general direction. This makes it easy to work out where projectiles will land and which controls should be implemented. However, lead can build up quickly in these areas.

Dispersed shotgun ranges (Australian Simulated Field and Sporting Clays)

With Australian Simulated Field and Sporting Clays there are typically 5-9 different shooting stations, sometimes as many as 36, firing in different directions. This results in lead becoming dispersed across a wide area. Firing stations can be in bushland or vegetated areas which can create challenges for managing impacted areas and it is not always clear where or how to focus efforts.

Reorganising the layout of the range can be effective for dispersed shotgun ranges. For more information on this see *Shotgun range design* (guidance sheet 5).

Image of an Australian Simulated Field shooting range courtesy of Field & Game Australia.

Clay targets

Clay targets can contain a range of polycyclic aromatic hydrocarbons (PAH), including some that have been identified as likely to be carcinogenic (cancer-causing) (*Rodríguez-Seijo et al. 2017*). When clay targets become weathered, these contaminants can leach into the environment (*Lobb 2006*). It is important that broken targets and target fragments are removed from the shooting range to prevent contaminants spreading. There are clay targets available with no or only very low levels of PAH which are discussed in *Alternative ammunition and clay targets* (guidance sheet 2).

Image courtesy of Field & Game Australia.

PAH and human health
PAH are a group of more than 100 different chemicals that are released from the burning of organic substances such as coal, oil, gas and timber. The hazard posed varies depending on the type and amount of PAH compounds present. Several PAHs are classified as carcinogenic to humans and can be absorbed through skin contact, ingestion or inhalation. Potential health effects are largely linked to levels of exposure. Some PAH are persistent in the environment and build up (bio-accumulate) in food chains *(ATSDR 1995)*. This may be an issue for shooting ranges using PAH containing clay targets near or on agricultural land.

One common type of PAH found in clay targets is called benzo(a)pyrene (BaP). The full effects of BaP on human health are unknown, however exposure by ingestion, inhalation or skin contact may cause irritation of the respiratory tract, skin, or gastrointestinal tract. Prolonged or significant exposure may damage the reproductive system and cause cancer *(IARC 2012)*. The World Health Organisation International Agency for Research on Cancer has designated BaP as a probable carcinogen (*IARC 2010*).

For more information about PAH and its toxicology, consult the TOXNET database. There is a link to this in the bibliography of this guide.

Wads
Wads may create a waste issue at shotgun ranges. In a modern shotgun cartridge, the wad separates the shot from the powder, it also contains the shot until it exits the barrel. Wads are generally made of plastic although fiber wads are available. They travel with the shot after firing and typically land 15 to 20 m from the firing position (*ITRC 2005*).

Wads can create plastic waste which, if not managed, may harm the environment. They can be collected and disposed of as part of the ongoing management of a shooting range. There are also alternative wads available which claim to be degradable, these are discussed in *Alternative ammunition and clay targets* (guidance sheet 2).

Identifying the shot fall zone
The first stage in managing lead at a shotgun range is to know where shot lands. This area is known as the shot fall zone, and it will have the highest level of contamination on the range. Once the shot fall zone has been identified decisions can be made about which controls and methods are appropriate.

Area of maximum contamination – skeet and trap
Within the shot fall zone at a skeet or trap range, there is an area of maximum lead contamination starting approximately 100 m from the firing position and extending out to approximately 180 m (*Finnish Ministry of the Environment 2014*). While the areas closest to (< 100 m), and furthest from (> 180 m), the firing position are comparatively less contaminated, they are still likely to have high levels of lead contamination compared to normal background levels in agricultural environments. For this reason, shooting ranges should not neglect these areas and actively manage the entire shot fall zone.

Figure 5 below demonstrates this level of contamination.

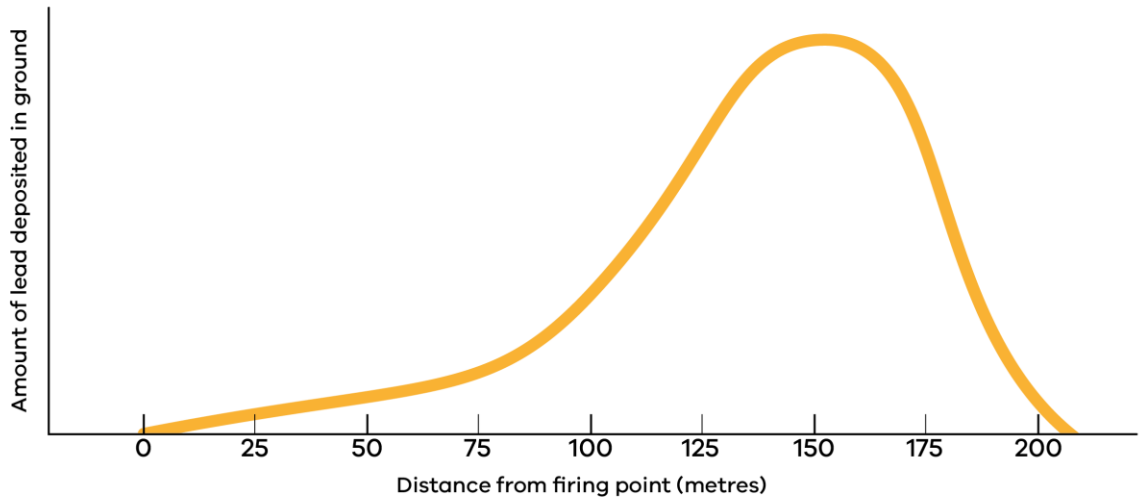

Figure 5. Lead contamination at a skeet or trap range based on distance from the firing point.

The Victoria Police range danger area method
The Victoria Police *Firearms ranges – standards for approval* document provides detailed information on how to determine the shot fall zone at a shotgun range. In the document, this area is known as the range danger area (RDA). For shooting ranges to be approved by Victoria Police, operators must calculate danger areas for the firing stands/shooting stations, ammunition and firearms used at their range. These individual danger areas are then combined into the total RDA for a shooting range. This is the most accurate way for a shotgun range to determine their total shot fall zone.

For some shooting ranges, this process may be challenging or may have been undertaken a long time ago. For this reason, an alternative method is described below which is based on the information in the Victoria Police *Firearms Ranges – standards for approval* document.

Using generic diagrams
A shotgun range can use a combination of the following three options, depending on the type of shooting undertaken, to determine their shot fall zone.

Dispersed shotgun ranges
At dispersed shotgun ranges trap positions, and the direction which targets are launched, can vary. This can create challenges for identifying contaminated areas.

Shooting range operators can use the diagram in Figure 6.1 for every position and direction of every individual shooting station used at their range. Other ranges could use also use this method if it is appropriate to them. This method is based on 12-gauge pelleted ammunition template on page 3-13 of *Firearms ranges – standards for approval*. The angle in this diagram is set to 46 degrees based on a static target. This may not be wide enough to account for the arcs when shooting at moving targets. It is important to consider the full extent of the target run to determine the potential spread of shot.

Trap ranges can use diagram in Figure 6.2 for every trap or down the line shooting station. This is based on down the line trap layout on page 5-3 of *Firearms ranges – standards for approval*.

Skeet ranges can use diagram in Figure 6.3 for every skeet shooting station. This is based on Australian skeet field layout on page 5-3 of *Firearms ranges – standards for approval*.

Note that the distances in these diagrams must be adjusted for the type of shot used. The distances for normal competition ammunition as set out in the *Firearms ranges standards for approval* document are described on the next page.

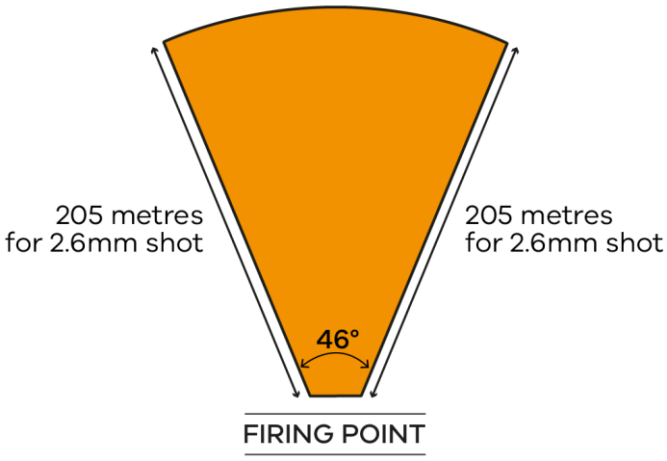

Figure 6.1. Shot fall at individual shooting firing point.

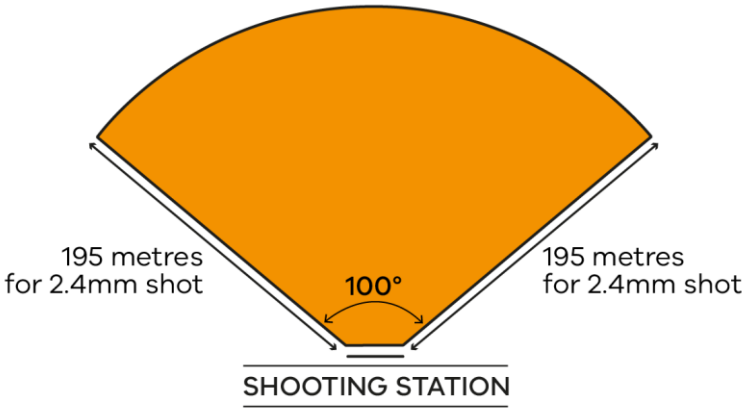

Figure 6.2. Shot fall at a trap range.

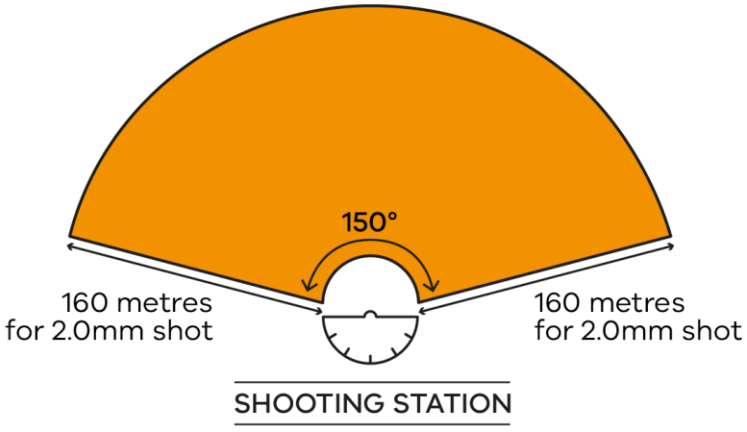

Figure 6.3. Shot fall at a skeet range.

Determining shot distance

Table 8 below shows the distance that shot can travel based on diameter. This can be used to identify the perimeter of a shot fall zone. It is also important to remember that distance is influenced by many factors such as the firearm, angle fired, and geographic variables such as the slope of the land, wind, and altitude (*Victoria Police. Undated*).

The table is based on information in Victoria Police *Firearms ranges – standards for approval,* section 5.2. The Victoria Police table was based on UK shot sizes, the table below has added shot sizes from other international sources. This information came from the Victorian Game Management Authority's Shotgunning Education Program *Handbook*. All information is based on commercially available ammunition, not 'reloaded' ammunition.

Table 8. Distance lead shot travels by international shot sizes

	United States		UK & Norwegian		Italian		German, French & Spanish	
Shot size	Shot diameter (mm)	Distance travelled (m)	Shot diameter (mm)	Distance Travelled (m)	Shot diameter (mm)	Distance Travelled (m)	Shot diameter (mm)	Distance Travelled (m)
No. 6	2.8	**220**	2.6	**205**	2.8	**220**	2.8	**220**
No. 6.5	-	**-**	2.5	**200**	-	**-**	-	**-**
No. 7	2.5	**200**	2.4	**195**	2.5	**200**	2.5	**200**
No. 7.5	2.4	**195**	2.3	**185**	2.4	**195**	2.4	**195**
No. 8	2.3	**185**	2.2	**175**	2.3	**185**	2.3	**185**
No. 8.5	2.2	**175**	-	**-**	-	**-**	2.2	**175**
No. 9	2.0	**160**	2.0	**160**	2.0	**160**	2.0	**160**

Managing contamination at shotgun ranges

Once the shot fall zone and risk at a shooting range is understood (see section 3), appropriate controls can be implemented. Deciding on which controls to implement depends on the risks that are present; such as if there are nearby receptors such as houses, recreational or agricultural land, and whether contamination can reach them through direct or indirect pathways (water or wind).

There are many controls which work in different ways and achieve different outcomes, and it is important to implement several, depending on the risks (*US EPA 2005*). Controls at shotgun ranges can be placed in two categories:

1. ***Physical controls***
   Barriers, structures or controls which reduce or prevent contamination from spreading or people coming into contact with contamination. Examples include using non-lead shot, berms, nets, and methods to concentrate the shot fall zone.
2. ***Management controls***
   Activities, practices, management systems or administrative controls. Examples include environmental management plans and optimising firing locations.

To effectively manage impacted areas, several controls from each of the two categories may be required. The next page contains some examples of the different types of controls that are available. Each has a dedicated guidance sheet which goes into more detail.

List of controls for shotgun ranges

<table>
<tr><th colspan="4">Physical controls</th></tr>
<tr>
<td>Controlling access (guidance sheet 1)
Description: Prevents people and animals from being exposed to contamination. Usually achieved with fencing.
When you could use this: This should be regarded as a critical control and always be considered.
Cost (1-3): $ - $$
Effectiveness (1-3): ⊕⊕⊕</td>
<td>Water management (guidance sheet 4)

Description: This control manages water runoff which is the main pathway for lead to spread.
When you could use this: When the neighbouring land, buildings, or ecosystems are threatened by contaminated surface water flowing from the shooting range.
Cost (1-3): $ - $$$
Effectiveness (1-3): ⊕⊕ - ⊕⊕⊕</td>
<td>Vegetation (guidance sheet 3)

Description: Ground covering vegetation can reduce the spread of pollution through dust, surface water or erosion.
When you could use this:
• bare ground with the potential for dust
• high winds
• high rainfall or flooding
• boggy conditions.
Cost (1-3): $ - $$
Effectiveness (1-3): ⊕⊕</td>
<td>Shot barriers (guidance sheet 6)

Description: Shot barriers are physical structures which contain shot. This dramatically reduces the size of the shot fall zone, making contamination easier to manage.
When you could use this:
When there is a risk that lead can spread outside of the range danger area and contaminate surrounding land.
Cost (1-3): $$$
Effectiveness (1-3): ⊕⊕⊕</td>
</tr>
<tr><th colspan="4">Management controls</th></tr>
<tr>
<td>Alternative ammunition and clay targets (guidance sheet 2)
Description: Alternatives can eliminate, or significantly reduce, the release of lead and PAH into the environment.
When you could use this: Every shooting range should closely consider using alternative ammunition and clay targets.
Cost (1-3): $ - $$
Effectiveness (1-3): ⊕⊕⊕</td>
<td>Environmental management plans (guidance sheet 9)
Description: An environmental management plan (EMP) is a site-specific plan that ensures appropriate actions are undertaken to control contamination.
When you could use this: EMPs could benefit many shooting ranges; however, they would benefit larger, or higher risk shooting ranges the most.
Cost (1-3): $$
Effectiveness (1-3): ⊕ - ⊕⊕</td>
<td>Lead recovery (guidance sheet 10)

Description: Lead recovery involves collecting and removing bullets and shot, from the ground at a shooting range for recycling or appropriate disposal.
When you could use this: It should be considered by all shooting ranges as a key management practice.
Cost (1-3): $ - $$
Effectiveness (1-3): ⊕⊕</td>
<td>Shotgun range design (guidance sheet 5)

Description: The shot fall zone can be contained and concentrated by optimising the location and design of trap devices and shooting grounds. This can greatly assist in managing contamination.
When you could use this:
• When there are sensitive receptors close to the shot fall zone.
• When there are multiple shooting fields at a range.
• When other works are taking place.
Cost (1-3): $$ - $$$
Effectiveness (1-3): ⊕ - ⊕⊕⊕</td>
</tr>
<tr>
<td colspan="4">KEY
Low cost: $
High cost: $$$
Low effectiveness: ⊕
High effectiveness: ⊕⊕⊕</td>
</tr>
</table>

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Section 5 – Rifle and pistol ranges

Right image courtesy of Field & Game Australia.

This section discusses information relevant to outdoor rifle and pistol ranges. This section assumes that lead ammunition is used as this is current common practice. If non-lead ammunition is used many risks are eliminated or reduced.

Contaminated areas at rifle and pistol ranges

Contamination can build up in the areas outlined below. This is also illustrated in Figure 7.

Stop butt
Stop butts, also known as backstops, capture the overwhelming majority of projectiles, often more than 99 per cent. Most of the contamination controls at rifle and pistol ranges will need to focus on this area.

Firing area
Lead concentrations can also be elevated at the firing stand area due to lead dust from firing. The concentration of lead is influenced by several factors. In particular, a well-ventilated area with lots of airflow will reduce this concentration (*Laidlaw et. al. 2017*).

Intermediate area
A small number of bullets end up in the intermediate area because of missed shots or ricochets.

Other
A small number of stray bullets can also end up in other parts of the stop butt or range.

(*Finnish Ministry of the Environment 2014*).

Adapted from Finnish Ministry of the Environment (2014).

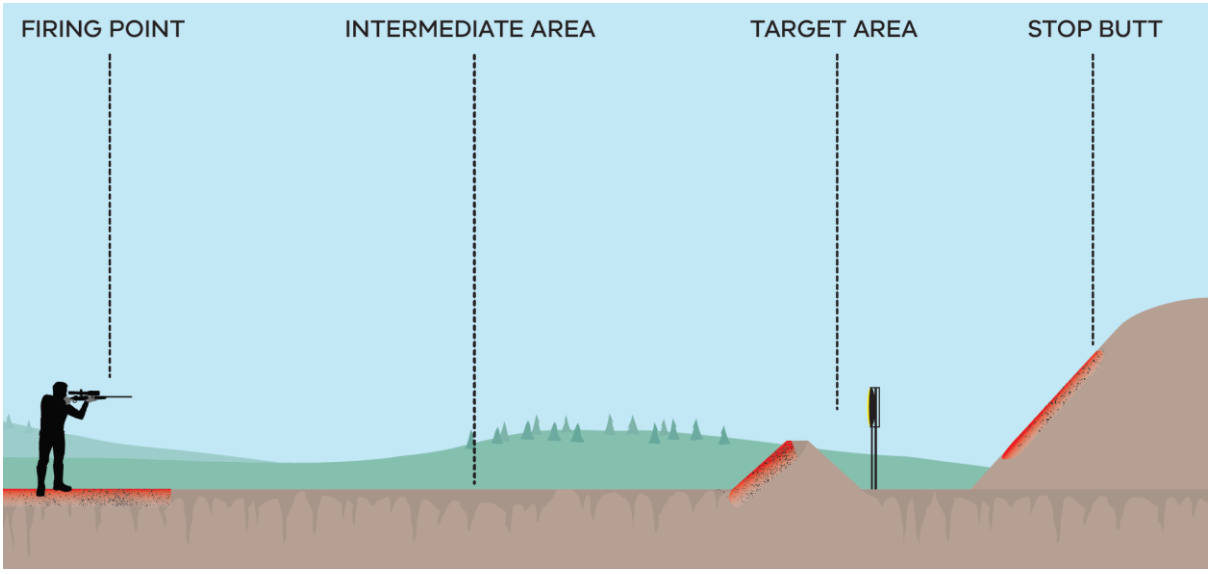

Figure 7. Contamination hotspot areas at a rifle or pistol range.

Projectile design

The metal jacket around most bullets has pros and cons for managing lead:

- Pros:
  - the jacket provides a protective barrier and can reduce projectile fragmentation and slow the breakdown of lead.
- Cons:
  - introduces more contaminants into the environment such as copper and zinc.
  - the rate of corrosion is increased due to the combination of different metals.
  - the other metals in the brass jacket may make lead less valuable for during lead recovery.

(*Finnish Ministry of the Environment 2014*).

Managing contamination at rifle and pistol ranges

Once the severity and nature of risk is understood (see section 3), appropriate controls can be implemented. Deciding on which controls to implement depends on the risks that are present; such as if there are nearby buildings, recreational or agricultural land, and whether contamination can reach them through direct or indirect pathways (water or wind).

There are many controls which work in different ways and achieve different outcomes, and it is important to implement several, depending on the risks (*US EPA 2005*).

Controls at rifle and pistol ranges can be placed in two categories:

1. ***Physical controls***
   Barriers, structures or controls which reduce or prevent contamination from spreading or people coming into contact with contamination. Examples include using non-lead bullets, bullet traps and stop butt designs.
2. ***Management controls***
   Activities, practices, management systems or administrative controls. Examples include environmental management plans and lead recovery.

To effectively manage contamination several controls from each of the two categories may be required.

The next page contains some examples of the different types of controls that are available. Each has a dedicated guidance sheet which goes into more detail.

List of controls for rifle and pistol ranges

Physical controls				
Controlling access (guidance sheet 1) Description: Prevents people and animals from being exposed to contamination. Usually achieved with fencing. When you could use this: This should be regarded as a critical control and always be considered. Cost (1-3): $ - $$ Effectiveness (1-3): ⊕⊕⊕	**Water management (guidance sheet 4)** Description: This control manages water runoff which is the main pathway for lead to spread. When you could use this: When the neighbouring land, buildings, or ecosystems are threatened by contaminated surface water flowing from the shooting range. Cost (1-3): $ - $$$ Effectiveness (1-3): ⊕⊕ - ⊕⊕⊕	**Vegetation (guidance sheet 3)** Description: Ground covering vegetation can reduce the spread of pollution through dust, surface water or erosion. When you could use this: • bare ground with the potential for dust • high winds • high rainfall or flooding • boggy conditions. Cost (1-3): $ - $$ Effectiveness (1-3): ⊕⊕	**Bullet traps (guidance sheet 8)** Description: Bullet traps capture and contain projectiles fired at rifle and pistol ranges. When you could use this: Bullet traps are useful at medium to large firing ranges, with high numbers of shooters. Cost (1-3): $$ - $$$ Effectiveness (1-3): ⊕⊕⊕	**Stop butt design (guidance sheet 7)** Description: Stop butts can be designed to better manage contamination. When you could use this: As all rifle/pistol ranges will have a stop butt anyway, this should be considered by all ranges. Cost (1-3): $ - $$ Effectiveness (1-3): ⊕⊕
Management controls				
Alternative ammunition and clay targets (guidance sheet 2) Description: Alternatives can eliminate, or significantly reduce, the release of lead and PAH into the environment. When you could use this: Every shooting range should closely consider using alternative ammunition and clay targets. Cost (1-3): $ - $$ Effectiveness (1-3): ⊕⊕⊕	**Environmental management plans (guidance sheet 9)** Description: An Environmental Management Plan (EMP) is a site-specific plan that ensures appropriate actions are undertaken to control contamination. When you could use this: EMPs could benefit many shooting ranges; however, they would benefit larger, or higher risk shooting ranges the most. Cost (1-3): $$$ Effectiveness (1-3): ⊕ - ⊕⊕⊕	**Lead recovery (guidance sheet 10)** Description: Lead recovery involves collecting and removing bullets and shot, from the ground at a shooting range for recycling or appropriate disposal. When you could use this: It should be considered by all shooting ranges as a key management practice. Cost (1-3): $ - $$ Effectiveness (1-3): ⊕⊕		
KEY Low cost: $ High cost: $$$ Low effectiveness: ⊕ High effectiveness: ⊕⊕⊕				

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Guidance sheet 1 – Controlling access

Description

Controlling access to a shooting range will prevent people and animals from being exposed to contamination. Preventing access through adequate and well-maintained fencing and signage on all boundaries is also essential to ensure peoples safety.

Type of control

Physical control.

What can it achieve?

- Fences can reduce the risk of harm to people from contamination at a shooting range. They can be used around the perimeter of a shooting range to control overall access, or within a range to restrict access to highly contaminated areas.
- Fences can be used to restrict access by livestock and other animals. This can prevent exposure to impacted areas and restrict the spread of contamination.
- Fencing and signage can also help meet other health and safety obligations, such as those under the *Occupational Health and Safety Act (2004)*. Unknowing or unauthorised people on a shooting range are at risk of being injured or killed by stray projectiles. Fences help prevent this.

What can it not achieve?

- Fences do not control contamination. They do not reduce contamination at a range or prevent it spreading off site.

When would you use this?

Fences should be regarded as a critical control and always be considered. The more people and livestock that have access to, or are located near a range, the more important fences become.

Considerations

- Victoria Police has specific requirements for fencing and signage which are outlined in *Firearms ranges – standards for approval.*
- At shotgun ranges, it is crucial that the fence restricts access to the entire shot fall zone, not just the most contaminated areas and the firing stations.
- Fencing should be used along with clear and visible signage, raising awareness of contamination and other hazards at a shooting range.

- Every range is different and deciding what type of fencing is suitable depends on many factors. For example, a fence in a populated urban area may need to be more focused on security than a fence in a rural area, where the main purpose is to restrict livestock.
- Access for management purposes and emergency services must be considered and maintained.
- Controlling access should always be considered alongside other controls and is not a solution to contamination alone.

Costs

Low to medium.

The cost of fencing varies significantly depending on the type of fence, amount of fencing and where it is being built. Compared to many other controls, and considering its effectiveness, it is generally a cost-effective solution.

Effectiveness

High.

Although controlling access does not prevent pollution, it is very effective at reducing the risk of people and animals becoming exposed to contamination.

Guidance sheet 2 – Alternative ammunition and clay targets

Note: This guide presents alternative ammunition and clay targets as one approach of many to control contamination and does not advocate any one control over another. Shooting range operators should assess which controls are most appropriate for their risks.

EPA is an independent authority and does not endorse specific products. Shooting range operators must do their own research into alternative ammunition and clay targets to ensure that they understand and reduce contamination risks.

Description

There are alternatives available in Victoria to lead-based ammunition, and clay targets which contain polycyclic aromatic hydrocarbons (PAH).

This guidance sheet is written for all shooting ranges, but where the information is only relevant for shotgun or rifle/pistol ranges it is labelled accordingly.

Type of control

Management control.

What can it achieve?

Using non-lead ammunition at a shooting range can prevent further lead contamination from occurring. Similarly, the use of no or low PAH clay targets can significantly reduce, or eliminate, the release of PAH. This reduces the risks of people becoming exposed to contamination.

What can it not achieve?

All ammunition and clay targets create waste issues. Switching to alternatives will not replace responsibilities to manage waste.

Using alternative ammunition or clay targets at an existing shooting range will only prevent further contamination. Any existing contamination will still require management.

When would you use this?

All existing shooting ranges could consider using alternative ammunition and, if applicable, clay targets. Alternatives can be an effective way to prevent further contamination and can be used at ranges of all sizes.

Considerations

Shooting ranges considering using alternative ammunition or clay targets need to do their own research. It is not always easy to determine what alternatives are made of, or whether they will have an impact on the environment. The sections below will discuss this for the specific topics.

Costs

Low to medium.

Unlike other controls, switching to alternative ammunition or targets does not require engineering works. If a shooting range chooses to engage a consultant to inform decisions on switching to alternative ammunition or clay targets, then this may increase their costs.

It is worth noting that it is the responsibility of the shooter to provide ammunition, while providing targets and range management is generally the responsibility of the shooting range operator.

Effectiveness

High.

Not using lead in ammunition or PAH in clay targets is an effective way of reducing further impacts at shooting ranges.

Shotgun ranges

Shot

There are benefits in using non-lead ammunition at a shotgun range. As outlined in Section 4 *Shotgun ranges*, there are challenges to controlling contamination due to the dispersal of shot and its ability to oxidise and erode. Switching to a non-lead alternative may be a more effective contamination control than more complex methods, such as shot barriers. For more information on switching to non-lead shot in shooting sports, see the article by Thomas and Guitart *(2013)* which is referenced in the bibliography of this guide.

Steel shot is a common alternative to lead shot. Most of the large shotgun cartridge manufacturers produce it in the sizes and specifications required for clay target shooting in Victoria.

While steel shot is safer for human health than lead shot, introducing large amounts of steel into the environment may cause some contamination. In some cases, shooting ranges may consider engaging a suitably qualified person to assess this. Managing environmental impacts of any shot used should be considered as part of ongoing shooting range management.

Non-lead ammunition can influence ballistics. In some circumstances shooters may choose to adjust their ammunition specifications when using non-lead ammunition (*Thomas and Guitart 2013*).

Clay targets

Clay targets that contain no or low levels of PAH are available in Victoria. Using these alternatives may reduce, or eliminate, these contaminants from being introduced at a shooting range (*Lobb. 2006*).

Often alternative clay targets are branded as ‘eco’, ‘green’ or ‘PAH free’ yet it is not clear what alternative materials these are made of. These could potentially pose contamination risks. Shooting ranges considering using alternative targets should research what they’re made of and whether they’re going to reduce contamination. Manufacturers sometimes provide information on their websites about their composition and environmental impacts. Safety data sheets (SDS), formerly known as material safety data sheets (MSDS), are also sources of information which can be requested from suppliers.

There is no Australian Standard for an ‘eco-friendly’ clay target, however the International Shooting Sport Federation (ISSF) provide their own definition (*ISSF 2016*). This definition outlines the levels or concentrations of PAH compounds they consider acceptable. Organisations hosting ISSF events may have to comply with this definition, but other shooting ranges may choose to use this definition to inform their decisions when purchasing clay targets. As these are not Australian standards, EPA is not able to comment on the suitability of the ISSF definition in Victorian circumstances.

Wads

Wads may cause plastic waste issues at shooting ranges. This plastic waste can spread from a shooting range and litter other areas. Currently, most wads used in Victoria are made from non-degradable plastics such as polyethylene.

There are wads available which are claimed to be degradable. Using these wads may reduce the impact of plastic waste on the environment. A shooting range may consider using these as an alternative. Like clay targets, it is important to research what they’re made of to ensure that they don’t pose new risks.

Whether wads are degradable or not, it is better for the environment if they are collected for disposal rather than allowed to degrade.

Rifle and pistol ranges

There are non-lead ammunition sources available which can be used at rifle and pistol ranges. These alternatives can be useful in instances when contamination is not easily confined to small manageable areas like stop butts.

Non-lead ammunition can increase ricochet risk (*Kanstrup et al. 2016*). In some circumstances, Victoria Police require shooting ranges to only use lead ammunition and alternative ammunition sources may not be appropriate.

Sometimes small amounts of clay targets are used at rifle and pistol ranges. If so, there is an opportunity to consider using no or low PAH targets. For information on this, see the ‘Clay targets’ section on the previous page.

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Guidance sheet 3 – Vegetation management

Description

Ground covering vegetation can reduce the spread of contamination through dust or surface water. The most common type of ground cover is grass or pasture species, however, many options are available and what is used will depend on the situation.

Type of control

Physical control.

What can it achieve?

A reduction in the risk of lead and other pollutants spreading through:

- Water (through surface water)
- Wind (as dust).

(*US EPA 2005*).

What can it not achieve?

Vegetation cannot divert, treat, or thoroughly filter surface water runoff. For this see *Water management* (guidance Sheet 4). On its own, vegetation is not sufficient to prevent the spread of lead from a shooting range. It will need to be used with other controls.

When would you use this?

This control is especially useful at shooting ranges that:

- contain bare ground with the potential for producing dust
- experience high winds
- experience high or intense rainfall or flooding
- experience boggy conditions.

Compared to many other controls, vegetation management is an easy, accessible and relatively inexpensive strategy. All shooting ranges should consider managing the vegetation on their range to help manage risks.

Considerations

The following should be considered:

- Vegetation may inhibit lead recovery due to the need to strip the ground cover to allow collection. For more information see *Lead recovery* (guidance sheet 10).
- Vegetation usually requires some ongoing maintenance.
- Grass located in heavily contaminated areas, such as the stop butt or shot fall zone, should not be irrigated or fertilised as these processes could increase the risk of contamination.
- It is important to use the right plants for your conditions otherwise they might not be effective.
- Animals can become exposed if they interact with a contaminated area (*Braun et al. 1997; Vermun et al. 2002*). People who consume them or their products (meat, dairy, eggs, etc.) may then also become indirectly exposed. It is important to have a fence that restricts access to livestock (see *Controlling access* guidance sheet 1) and not to remove any hay or fodder from contaminated areas.
- Ground cover is most important in the highly contaminated areas. For information on identifying contaminated areas see sections 4 ‘shotgun ranges’ and 5 ‘rifle and pistol ranges’ in this guide. In areas with comparably lower levels of lead, vegetation is still important as contamination could still create risks in these areas.

Costs

Low – medium.

In many cases there will already be grass covering a portion of a shooting range, establishing grass in less vegetated areas, or applying a different ground cover solution will cost less in these instances.

Effectiveness

Medium.

Vegetation is quite effective at preventing or reducing lead from spreading from a shooting range through water or dust (*NSSF 1997*). It does not prevent contamination from occurring and does little when direct pathways are the main risk.

Ground cover

Ground cover is a very effective form of erosion control (*US EPA 2005*).

The following information outlines the different types of ground cover and what they can achieve.

Grasses

Grasses, or any other type of low growing vegetation, prevents soil erosion, dust particles being blown from top soil, and acts as a sponge to absorb surface water runoff (*US EPA 2005*). Grasses do not have to be lawn and can take a variety of forms such as hardy pasture or native grasses.

Mulch

Mulch is effective in reducing soil erosion and dust (*US EPA 2005*). It also introduces organic matter to the soil which aids in binding lead and other pollutants, making them less likely to be absorbed by people or animals. Other organic material, such as compost, may also be used for this purpose but this would require reapplication.

Hydro mulching

Hydro mulching involves spraying soil with water containing paper fibre which can be combined with seed or fertiliser. Hydro mulch can be a cost-effective way to reduce erosion in the short term in disturbed areas, such as following lead recovery while grasses regrow.

Other options
There are other ground cover products available designed to reduce or prevent soil erosion. Erosion control matting, for example, may be useful to prevent erosion in areas of high contamination and sloped areas such as the backstop immediately behind a target (*US EPA 2005*). They may be most useful to quickly cover an exposed area following lead recovery.

Trees
Trees can play a role as a wind break at a shooting range. By creating a wind break, the risk of lead contaminated dust spreading is reduced. Although they can cause issues for shooting ranges by inhibiting shooting activities and lead recovery.

Some of the trees and shrubs at heavily vegetated shooting ranges, such as Australian Simulated Field, may become contaminated directly from lead shot becoming imbedded in bark, trunks and branches. All the vegetation within the shot fall zone at a range should be treated as contaminated and not removed from site for example as firewood.

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Guidance sheet 4 – Water management

Description
Surface water runoff is one of the main pathways for lead and other contaminants to spread from shooting ranges. By managing and controlling the runoff, you can minimise the spread of contamination.

This control involves a range of practices including reducing surface water entering a range, reducing the amount of water potentially being polluted and the retention, treatment and monitoring of any surface water leaving a range (*Finnish Ministry of the Environment 2014*).

Type of control
Physical control.

What can it achieve?
The spread of lead and other contaminants can be minimised by managing surface water. It can assist in preventing groundwater and offsite surface water contamination.

What can it not achieve?
- It does not control spread by dust.
- It does not reduce the amount of contamination on site, it just reduces it from spreading.

When would you use this?
When the neighbouring land, buildings, or ecosystems are threatened by contaminated surface water flowing from the shooting range.

Costs
Low to high.

Water management systems vary and can be inexpensive, such as simple diversion drains, or expensive such as detailed flow management and treatment systems.

Effectiveness
Medium – High.

When there are significant risks of contamination spreading in water, a well-designed water management system can directly address this issue and be very effective.

Considerations
Understanding surface water runoff and designing controls is complex. A suitably qualified person or consultant with specialist water management, engineering and ecological expertise may be required. For information about how to engage a consultant see our webpage Engaging consultants.

Assessing the shooting range
As outlined in section 3 of this guide *Assessing contamination risk*, there are many factors which influence risk. It is important to thoroughly assess the shooting range to gain an understanding about which water management measures are the right control. Key things to look out for include:

- Lead from projectiles in direct contact with water, such as shooting ranges located near waterbodies or shooting over watercourses.
- Type and pH of soil that lead is in contact with.
- High and frequent rainfall.
- Any significant flora or fauna (such as rare or endangered species) nearby.
- Nearby buildings or sensitive land uses such as agriculture.
- Aquatic plants and animals in downstream waterways.
- Amount of projectiles and/or clay targets on the range.
- If runoff water from the shooting range flows towards:
    - nearby buildings
    - land that is used for farming, gardening and other sports or recreations

- any domestic or stock water supply dams
- any water used for irrigation
- significant waterway or wetlands.

Controlling surface water runoff

Vegetation

Vegetative ground cover is a low cost and easy way to help control surface water contamination. Vegetation will frequently be used in conjunction with engineering controls for water management. Guidance sheet 3 goes into further detail about vegetation management.

Diverting and treating runoff

A more complex, but effective, control is to redirect surface runoff. Surface water can either be:

- Flowing onto the shooting range.
- Flowing from the shooting range and therefore possibly contaminated.

Both forms of runoff can cause contamination to spread and can be controlled through diversion and, in some cases, treatment (*Finnish Ministry of the Environment 2014*).

Controlling surface water can include:

- Redirecting water to flow around and not encounter contamination at a range.
- Retaining contaminated water on the range were possible.
- Collecting and filtering the initial runoff during rain, this water is likely to be the most contaminated.
- Treating contaminated water to make it less hazardous.
- Reduce boggy conditions by draining water away from highly contaminated areas.
- Redirecting water so it does not flow towards a sensitive receptor, such as farmland or a wetland.

Deciding on the objectives of water management and designing controls requires a thorough understanding of the risks at a shooting range. Section 3 of this guide provides information about this but the advice from a suitably qualified person or consultant with civil engineering and water treatment expertise is recommended. For information about how to engage a consultant see the EPA webpage Engaging consultants.

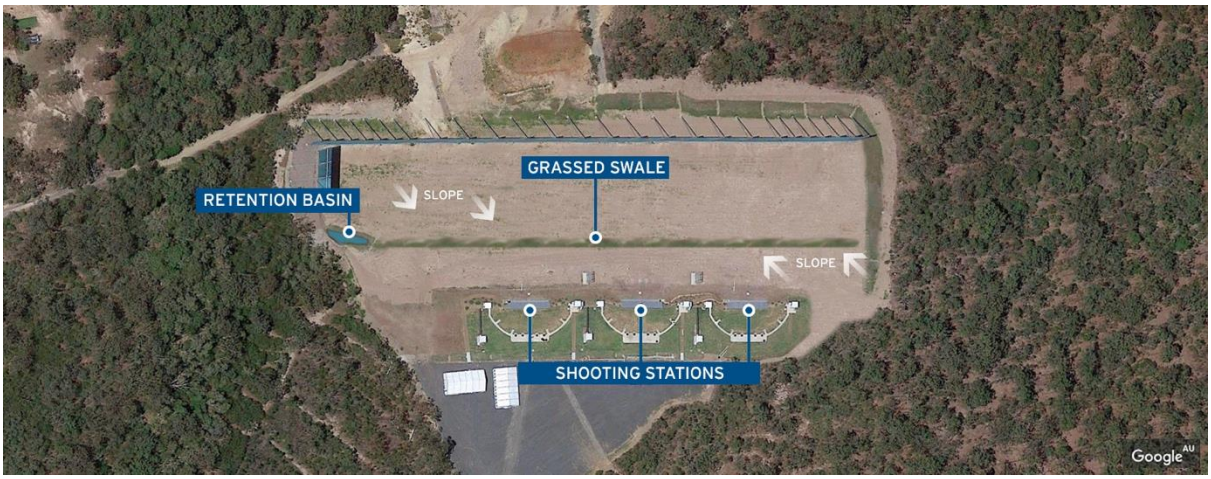

Figure 8. Water management system at Belmont Shooting Complex Queensland.

Drainage

Surface water runoff can be diverted with swales, drains and trenches. On ranges with open, rolling terrain, the slope of the land can be used to help direct surface water runoff. For shooting ranges that have flatter terrain, civil engineering designs and a system of trenches and drains could be established to direct the runoff. If the surface runoff is flowing too fast, vegetative ground cover can assist in slowing down the surface water runoff (*Finnish Ministry of the Environment 2014*). Drains can also be combined with the development of filter bed, see Figure 9 on the next page.

Filtering

Filtering is the process of removing mobilised lead. These water management techniques are effective in collecting and filtering the initial runoff during a rain event as this water contains the most contamination. This can be achieved using simple systems such as sediment traps, vegetated swales or dams, or with more advanced sub-surface filter systems.

Simple systems allow diverted surface runoff water to slow and sediments to settle out before runoff leaves a range. Settlement basins can be grassed swales or vegetated retention basins or dams. Figure 11 is an example of a vegetated retention basin at a shooting range.

More advanced systems channel water to a sub-surface filter bed system. This comprises of a:

- sand layer to screen out mobilised lead fragments
- limestone/gravel layer to alter the pH of the water to reduce the concentration of dissolved lead in the water (*EAEST 1996*; *NSSF 1997*)
- perforated pipe to drain the water away from the area of contamination possibly to a retention basin or pond dam prior to discharge (*US EPA 2005*).

(*US EPA 2005*).

More advanced systems will be most effective where lead contamination levels are high and there is lots of surface water on the range. Figure 9 on the next page illustrates this process.

Adapted from (US EPA 2005).

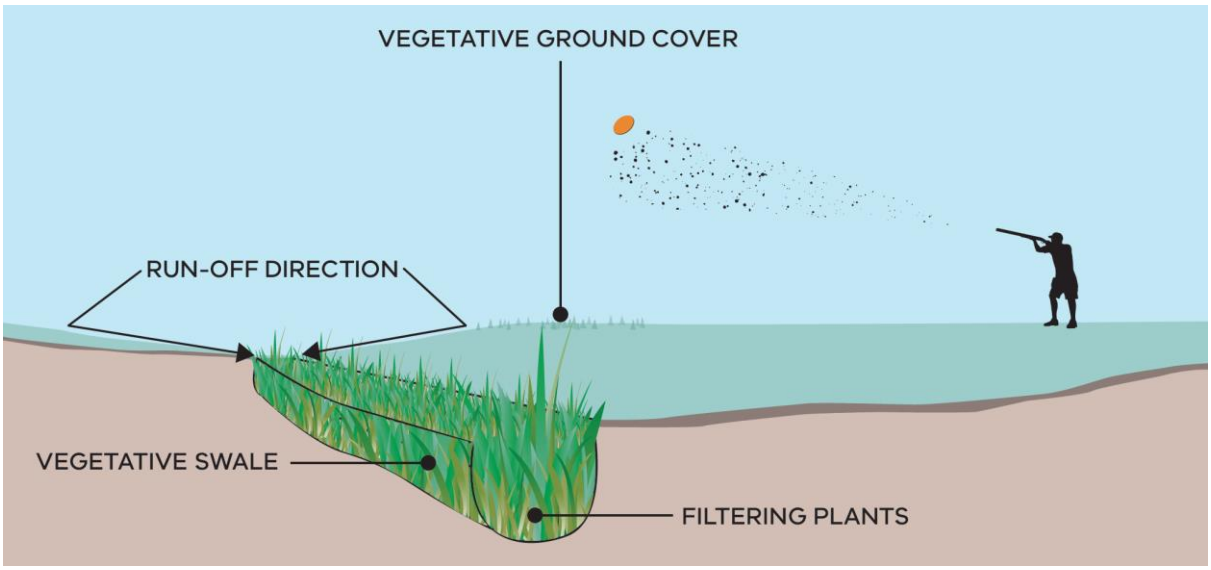

Figure 9. Simple water filtration system.

Adapted from (US EPA 2005).

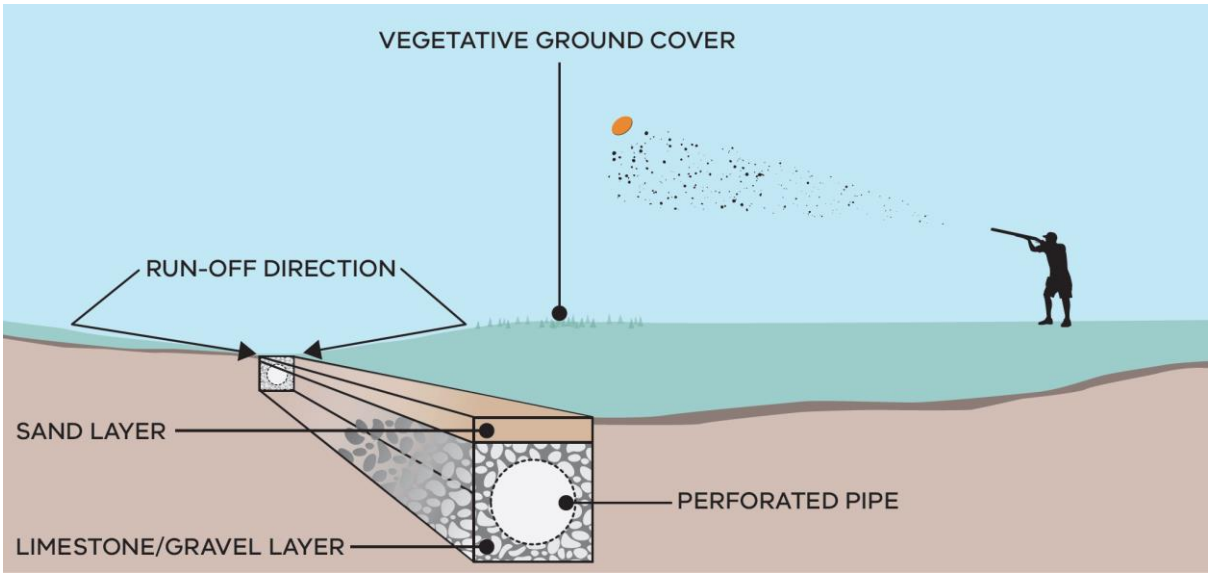

Figure 10. Advanced water filtration system.

Image of Belmont Shooting Complex courtesy of Queensland Rifle Association.

Figure 11. Retention basin at a shotgun range.

Red section – perimeter berm

A berm has been constructed around the shot fall zone to restrict surface water from flowing onto or from the shooting range. This ensures only the surface water from the controlled shot fall zone requires management.

Blue section – retention basin

Water is routed into this retention basin using a grassed swale. Here the grass and reeds absorb much of the water, the water flow is slowed down and sediment and particulate matter, which can transport lead, settle out of suspension.

Yellow section – overflow area

The raised rock bank serves as a protective barrier to reinforce the overflow area of the retention basin and prevents erosion. During rain, initial runoff from the shot fall zone will fill the retention basin, this water is the most likely to be contaminated. Excess surface water during heavy rain will overflow and move off-site into natural drainage areas.

Treatment
Treatment of lead contaminated surface runoff involves adjusting the pH of the water using alkaline pH adjustors such as limestone (*US EPA 2005*). Establishing these systems can be complicated as there are many things to consider, such as local conditions and the appropriate volume of limestone. It is advised that a suitably qualified person or consultancy with water treatment expertise is engaged. For information about how to engage a consultant see Engaging consultants.

Increasing the pH of the runoff can decrease the amount of lead that is dissolved in water. The solubility of lead decreases when the pH value increases and is at its lowest when pH is between 6-7 (*US EPA 2005; NSSF 1997*). This sort of treatment should be considered if soils, and therefore the water runoff from these soils, is acidic. The solubility of lead in water is complex and depends on factors like the concentration of organic matter and carbonates in the water. Where the risk from water runoff is high, it is advised that a suitably qualified person or consultancy with water treatment expertise is engaged.

Treatment systems need to be simple and robust. Systems where runoff passes through limestone rubble or over limestone 'rip rap' prior to discharge from a range may be all that's needed (*EAEST 1996*).

Discharge
Surface water runoff that has been diverted usually needs to be discharged from the range into existing natural drainage systems. It is important to understand the amount of contaminants present in the treated runoff water, how this water could cause harm and whether there are any associated legal obligations. This can be complex, it is advised that a suitably qualified person or consultancy with water treatment expertise is engaged. For information about how to engage a consultant see the EPA webpage Engaging consultants.

Maintenance
All surface water management systems require ongoing maintenance to maintain their effectiveness. This involves regularly checking that water flow is not impeded. This can involve tasks such as clearing the debris from drains and sediment traps and periodically replacing limestone rubble or rip rap if used.

Recovering lead and clay target fragments from the shooting range surface can complement shooting range water management. This helps reduce the pollutant load in the first place, putting less strain on the water management system, and the risk of pollution spreading. See *Lead recovery* (guidance sheet 10) for more details about lead recovery.

Guidance sheet 5 – Shotgun range design

Description

Managing lead contamination at shotgun ranges is challenging due to the large areas over which lead shot is spread. This area, known as the shot fall zone, can be contained and concentrated by optimising the location and design of trap devices and shooting grounds. This can greatly assist in managing contamination (*ITRC 2005*).

Shooting range design and layout should always prevent any impact on sensitive environments or off-range areas. Overlapping shot fall areas may also improve the efficiency of future lead recovery (see guidance sheet 10 *Lead recovery)*.

Type of control

Management control.

What can it achieve?

- The area of a range impacted by lead shot is reduced in size.
- Shot fall is contained within a known area.
- Lead recovery can be more effective and efficient.

What can it not achieve?

- Contamination is not reduced and may still be able to spread.

When would you use this?

- When sensitive land uses or environments are identified within, or close to, the shot fall zone.
- When lead recovery is being planned.
- When there are multiple shooting fields at a range.
- It is much easier to implement this control when other works are taking place. Such as when:
  - new traps are being installed
  - shooting ranges are being reconfigured or re-designed.

(*Finnish Ministry of the Environment 2014*).

Considerations

- Range design and layout should always be considered alongside other controls and are not a solution to managing contamination alone.
- Relocating trap devices and changing shooting layouts can be expensive so careful planning and consideration should be given when making decisions.
- When planning a new shot fall area it is important to consider how local conditions will influence it. Consider:
  - Local wind conditions and features that create wind breaks or wind funnels such as vegetation and shelter beds.
  - How the slope of the land could affect the size of the shot fall zone and whether this could cause contamination to spread in water.
  - Drainage in the shot fall zone to avoid waterlogging and surface water flow off the range.
- It is also important to consider whether a different shooting range layout could create new contamination risks. For information on this see section 3 of this guide *Assessing contamination risk*.
- When planning new shooting ground configurations, it is important to have detailed knowledge and understanding of the shot trajectories expected at the shooting grounds and how factors such as wind will influence these.
- Maximising shooter safety is also a critical issue.
- It is important to understand and work within the boundaries of the approved range danger area.

Costs

Medium to high.

Moving traps and associated facilities can involve significant costs.

Effectiveness

Medium.

Optimising the shooting range layout can make it much easier to effectively manage lead contamination. To be more effective, other controls such as lead recovery should also be considered.

Overlapping shot fall zones

A shooting range can be designed so that the shot fall zones from multiple shooting grounds overlap as much as possible. This can greatly reduce and concentrate the area of contamination making it easier to manage. This is demonstrated in Figures 12 and 13 below.

Adapted from NSSF (1997).

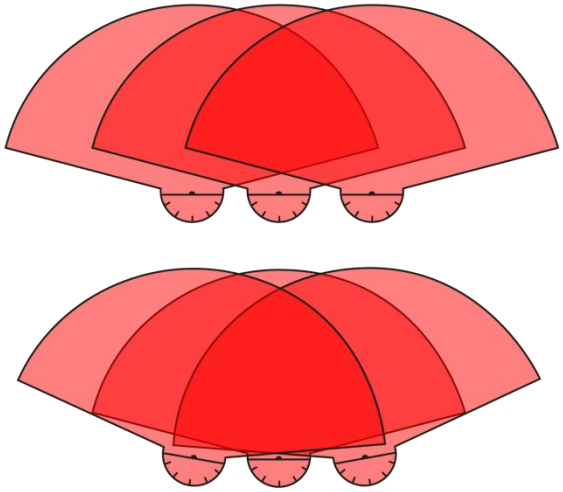

Figure 12. Using overlap to reduce shot fall zone at a Skeet Field.

Adapted from NSSF (1997).

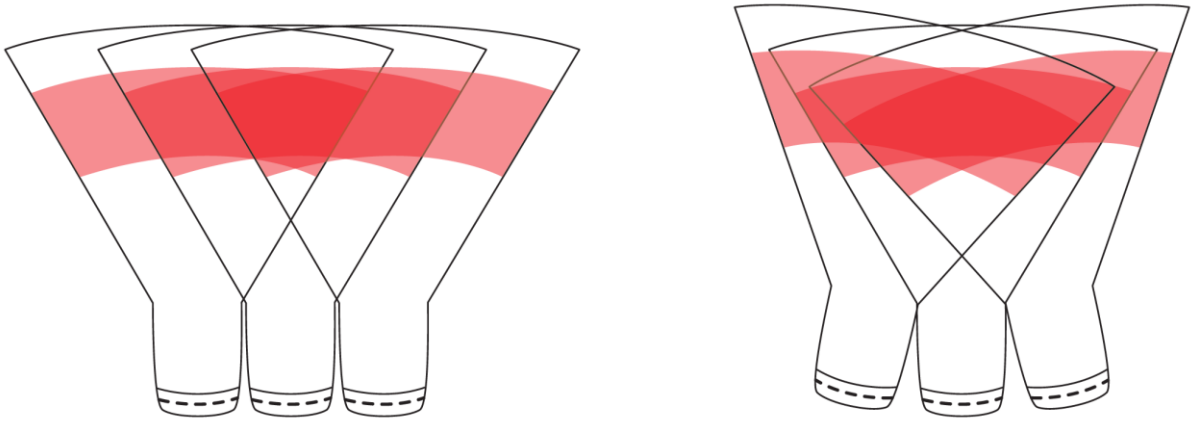

Figure 13. Using overlap to reduce shot fall area at trap field.

Shooting up hill

Another way to reduce the extent of contamination is to shoot up hill. When shooting up hill, shot will travel a shorter distance as it is restricted by gravity. This is demonstrated in Figure 14 below.

While this may reduce the size of the contaminated area, having a sloped shot fall zone can create issues. For example, there may be an increased risk of contamination spreading in surface water flowing from sloped areas.

Adapted from RCMP (2007).

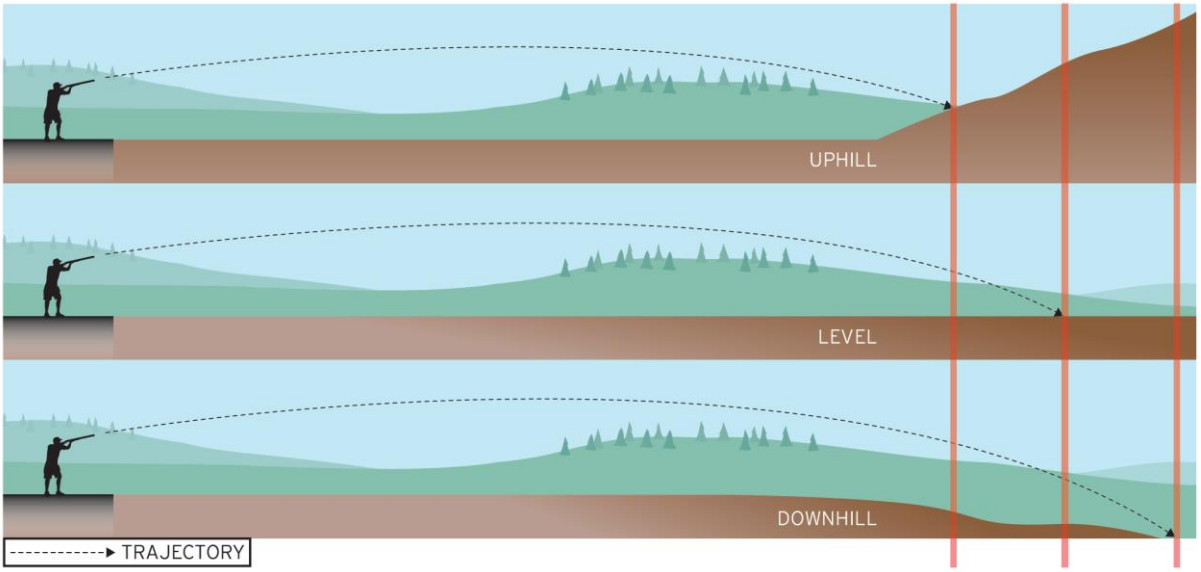

Figure 14. The effect of slope on the distance shot travels.

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Guidance sheet 6 – Shot barriers

Shot net at Belmont Shooting Centre, Queensland

Image courtesy of Queensland Rifle Association.

Description

Managing lead contamination at shotgun ranges is easier if the spread of shot is reduced. This can be achieved with earth berms and vertical barriers such as nets, screens, and curtains (*ITRC 2005*).

Type of control

Physical control.

What can it achieve?

The spread of shot can be significantly reduced and concentrated.

The shot fall area can be reduced by as much as 85% at a trap range and 30% at a skeet shooting range. This is illustrated in the diagram below.

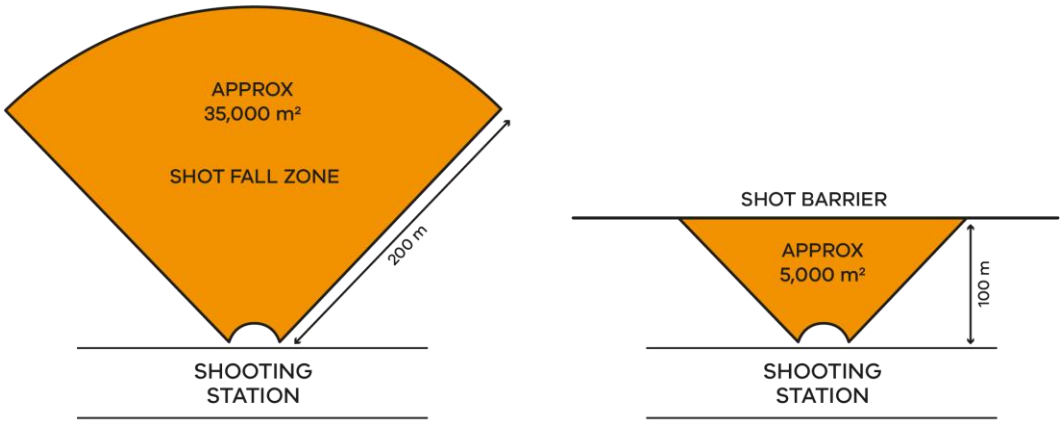

Figure 15. Reduction in the shot fall zone by using a barrier at a trap station.

The reduction in area can assist lead recovery. For information on this, see guidance sheet 10 *Lead recovery*. Nets, can be designed so that lead can be recovered directly from the base of the net rather than the soil. This helps minimise contamination.

What can it not achieve?
This physical control does not reduce the total amount of lead at a firing range. It only reduces its spread which makes other management practices more effective.

When would you use this?
Physical shot barriers should be considered if there is a risk that lead can spread outside of the range danger area and impact surrounding land. Sensitive land uses or environmental values include residential areas, parks, sports ovals, farms, residences, or waterbodies. For more information on this, see Section 3 of this guide.

Considerations
Shot barriers are expensive, but effective, controls. To assess their suitability, and make sure they work effectively, careful consideration should be given to any decisions to invest in them. Examples of things to look at include:

- A thorough understanding of the shot fall zone and how a shot barrier will reduce it.
- Areas where the shooting range might expand in the future.
- Wind conditions that may cause shot to spread over a much greater area.
- Other management practices that are being undertaken or considered such as lead recovery and how shot barriers will support other management approaches.
- Nets and barriers should be considered alongside other controls and are not a solution to contamination alone.

Costs
High.

Costs will generally be high as any barriers will involve detailed design, engineering and construction. To be effective, barriers need to be of sufficient vertical size to contain lead.

Effectiveness
High.

Barriers can be effective at significantly reducing the shot fall zone to a much smaller, more manageable, area (*Kim and Lewis 2006*).

Further detail
This section outlines the two main types of physical barriers – **berms** and **nets**. These different types of barriers can be used alone or in combination depending on the requirements and conditions at a range. For example:

- net alone
- berm alone
- net build on top of a berm
- net build behind a berm
- fence below a net.

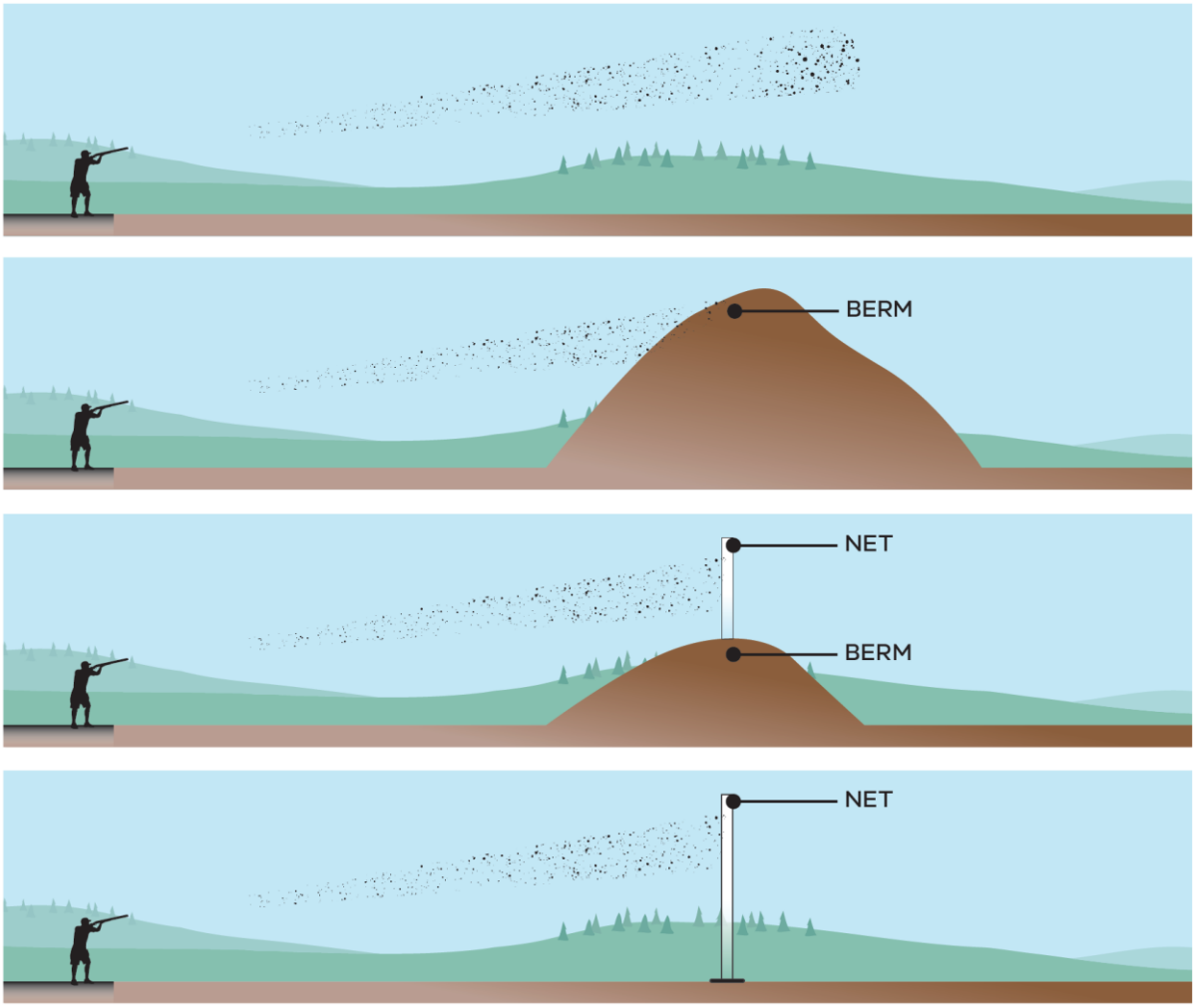

Figure 16. How berms and nets can restrict the spread of shot.

Berms

Berms are mounds of earth usually built from locally sourced material. They vary in height depending on what they are designed to achieve, cost and engineering considerations. This is different from a stop butt, as stop butts are specifically designed to capture bullets behind targets at rifle and pistol ranges. Berms are sometimes used at shotgun ranges to provide multiple benefits, including:

- prevent or restrict the spread of shot
- provide a noise barrier
- provide a visual barrier.

Berms can restrict the spread of shot by acting as a barrier. This is shown in Figure 16. They can also create sloped conditions so shooting takes place uphill which restricts the spread of shot. For more information on this see guidance sheet 5 *Shotgun range design*.

When designing a berm to restrict shot, detailed planning is required and a solid understanding of the types of shooting taking place, projectile trajectory, and local wind conditions.

Berms do not necessarily have to contain the spread of all shot to be effective. A berm that only partially intercepts shot can still be effective in reducing its spread. The total area where shot is spread may not be reduced, but more of it will be concentrated closer to the firing point.

Once established, berms have little maintenance requirement other than monitoring, vegetation management (see guidance sheet 3 *Vegetation management*) and preventing soil erosion which can occur due to their steep slopes (*RCMP 2007*). Where berms create enhanced surface water runoff, additional water management will be required (see guidance sheet 4 *Water management*).

The design and construction of berm structures will often need expert technical input to ensure that they are stable, safe and comply with all local government and landowner requirements. This may require the engagement of a suitably qualified person such as a civil engineering consultant. For information about how to engage a consultant see our webpage Engaging consultants.

Nets

A variety of vertical structures can be used to contain the spread of lead shot. These are often called 'nets', but they include both fixed and movable barriers, fences, curtains, screens and walls. Nets can be used alone but also in conjunction with berms which will reduce the amount of net material required and increase the effective height of the net. Nets can be cheaper to construct than earth berms though they have substantially greater maintenance and replacement requirements. Nets and curtain are generally not very effective in reducing noise.

The requirements of all shooting ranges are unique, and a net system will need to be specifically designed for the requirement of each range. As a general guide nets are typically placed 80-120 m in front of the firing stations and can be between 10 and 20 m tall and 100-400 m long (*Kim and Lewis 2006*).

The benefits of nets include:

- They can reduce the footprint of the firing range and shot fall zone substantially. Reductions of over 60% have been achieved using nets in Australia.
- They provide a barrier with smaller footprint than berms.
- They provide a visual backdrop from the shooters perspective which can enhance the visibility of targets.
- They can enhance lead recovery which can reduce contamination and help offset net construction and maintenance costs through the sale of recovered lead. For more on this see guidance sheet 10 *Lead recovery*.
- Some movable barriers can be in place only during actual shooting times and otherwise be lowered or 'drawn' which can reduce the impact of strong winds, maintenance costs, and visual impact (*Kim and Lewis 2006*).

Guidance sheet 7 – Stop butt design

Description

A stop butt (also known as a backstop) is a barrier behind the target area at an outdoor rifle or pistol range. There are two types of stop butts:

- Constructed – usually constructed using locally sourced earth but can also be made from timber or steel.
- Natural – use a natural rise in ground levels such as a steep hill side or slope.

All stop buts are designed to capture and contain projectiles and bullets. By capturing the projectiles, lead impacts can be controlled.

This guidance sheet outlines some of the different stop butt designs and how they assist in controlling pollution and prevent it from spreading in water or wind.

Type of control

Physical Control.

What can it achieve?

Stop butts capture the majority of bullets in a confined area. This restricts the area of contamination greatly and significantly improves safety.

By concentrating the lead contamination, it is much easier to manage and prevent people from being exposed through direct contact, or stop it spreading in water or wind. The primary area of lead contamination is restricted to several square metres of the stop butt immediately behind each target.

What can it not achieve?

Stop butts only capture projectiles allowing for contamination to be managed, they do not treat or reduce contamination levels.

When would you use this?

The designs outlined in this guidance sheet are relevant to all ranges using stop butts. It is standard practice for a rifle or pistol range to have a stop butt or bullet trap of some type, so all of these ranges should consider them.

Costs
Low to medium.

If a range has a stop butt, or is investing in one, the additional costs of incorporating the more advanced designs outlined in this guidance sheet are relatively low.

Effectiveness
Medium.

Stop butts are very effective at reducing contamination to a small and manageable area. The designs proposed in this guidance sheet have additional benefits of preventing the spread of lead. The effectiveness of these additional benefits varies considerably, depending on circumstances.

Considerations
There are several issues (listed below) that operators of outdoor shooting ranges should consider before implementing this control.

- Victoria Police has specific requirements for stop butts which are outlined in *Firearms ranges – standards for approval*.
- The health and safety of people in contact with the stop butt should always be front of mind. By design, stop butts concentrate lead, so lead can easily build up to very high levels. People who are maintaining stop butts or recovering lead should receive appropriate OHS training and use appropriate personal protective equipment. For more information consult the WorkSafe Victoria Code of Practice for Lead.
- It is important to allow for sufficient space for machinery to access the stop butts for lead recovery and for its maintenance.
- A suitably qualified person, such as a civil engineer or earthworks specialist, may be required for the design and construction of stop butts to ensure their physical stability. For information about how to engage a consultant see our webpage Engaging consultants.

Ground cover
Lead is at risk of spreading through erosion, surface water and dust from stop butts. Vegetation can be used to reduce this risk.

Ground cover at the stop butts can consist of low growing vegetation or mulches that require minimal maintenance. One thing to consider with ground cover is that it may inhibit lead recovery as the ground cover will need to be removed prior to lead recovery from stop butts. For information about vegetation see guidance sheet 3 *Vegetation management*.

Roof structure
Covering the stop butt with a roof structure can be an effective way to prevent or reduce the spread of contamination. Lead and other contaminants can spread in surface and groundwater, constructing a roof over the stop butt will keep the area dry and prevent this.

When designing stop butt roof, things to consider include:

- The roof should extend over the target area to cover any bullets that fall in this area.
- Design and construction will need to minimise ricochet risk.
- There are many technical considerations which may require the engagement of a suitably qualified person. For information about how to engage a consultant see the EPA webpage Engaging consultants.
- If a roof keeps a stop butt too dry, then the stop butt could crack and erode. This can increase the risk of contamination spreading through wind as dust. This risk should be considered during the design phase and managed appropriately. For example, vegetation on a stop butt may require ongoing watering.
- Care should be taken to make sure that water runoff from the roof is diverted away from the stop butt with suitable guttering and/or drainage. For more information about controlling surface water runoff, see guidance sheet 4 *Water management*.

A roof can be adapted to different ranges and situations. Any construction material can be chosen depending on availability, cost, suitability and durability and the design can be tailored to the unique size and conditions at a range. Due to this, the costs of constructing a roof vary significantly.

A major consideration of a roof is the need for ongoing maintenance. Misses, ricochet and stray bullets can damage the roof, requiring maintenance. Another issue is that a roof might make maintenance work on the stop butt more difficult. For example, the roof might prevent machinery access which would make removing and replacing contaminated soil or sand difficult.

For more information on stop butt roofs, see *Finnish Ministry of the Environment (2014)*.

Adapted from NSSF (1997).

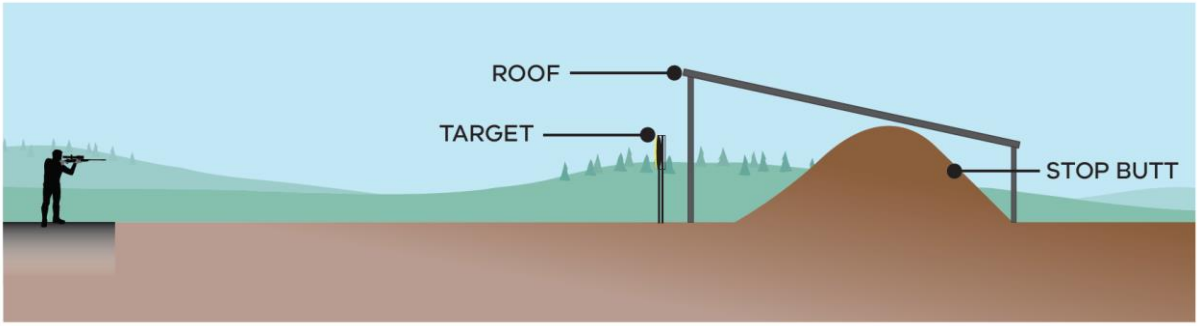

Figure 17. Roof covering stop butt.

Stop butts with sand traps

With this system, ballistic-grade sand can be used on the surface of the stop butt behind the targets, to capture and contain projectiles (*Larson et al. 2007*). An impermeable layer beneath the sand would allow contaminated surface water to easily and predictably flow to where it can be managed. For information about water management see guidance sheet 4.

Figure 18 demonstrates a stop butt with a sand trap.

This stop butt design has several advantages:

- lead can be efficiently recovered from the sand trap
- contaminated surface water can be managed
- sand traps can be used in conjunction with other controls such as bullet traps.

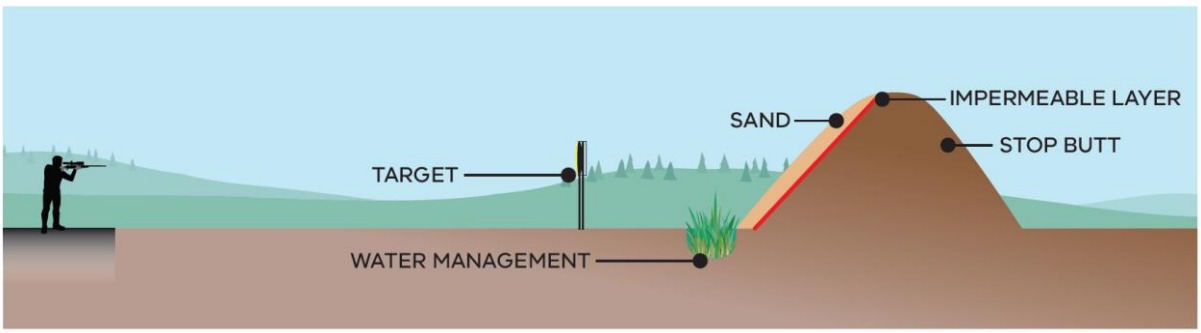

Figure 18. Water management at the stop butt.

Debris-free and uniform sand

In a sand-trap, it is important to use high-quality sand. It should be debris-free (for example free from stones, organic material and metals) and uniform (sieved to a uniform grain size and washed to remove smaller particles). This reduces projectile fragmentation and often allows for simple sifting to be sufficient for stop butt maintenance and lead recovery. Another advantage of debris-free and uniform sand is that water flows through it easily and predictably allowing drainage to be managed. Due to the specific nature of the sand, it might come at a higher cost.

Impermeable liner
A variety of materials can be used to construct water barriers, what is important is that it is strong and impermeable. Bitumen, concrete and clay are strong but not necessarily impermeable so may need to be used along with a plastic membrane or other impermeable material. The design of the barrier is important to ensure its strength and durability as it will have a lot of weight on it and could be pierced by projectiles.

For more information about sand traps see (*Finnish Ministry of the Environment 2014; Struck 2011; and Larson et al. 2007*).

Maintenance of stop butts

Stop butts will eventually become heavily contaminated with lead bullets and fragments. Once this happens, the surface of the stop butt should be de-leaded. This involves physically removing the contaminated sand/soil and sieving it to remove projectiles and projectile fragments. The contaminated soil on the front face of the stop butt can be relocated to the rear face for storage and future lead recovery. Continued use of the stop butts without de- leading may result in an increased risk of ricochet, spreading lead further and posing a safety hazard. Consideration should be given to de-leading stop butts on a regular basis to manage contamination risks, this is a recommendation in Victoria Police *Firearms Ranges – Standards for Approval*.

For more information on recovering lead see guidance sheet 10 – *Lead recovery*.

Guidance sheet 8 – Bullet traps

Image supplied by Meggitt.

Description

Bullet traps capture and contain projectiles fired at rifle and pistol ranges. They can be used in conjunction with stop butts to capture bullets, and the lead they contain.

Type of control

Physical control.

What can it achieve?

Bullet traps capture and contain almost all projectiles at a rifle or pistol range. This will manage contamination as well as safety at a shooting range.

Capturing bullets also enhances lead recovery. Traps are designed so that the projectiles can be easily removed at periodic intervals and there is a reduction in the amount of lead that needs to be recovered from the shot butt. For more information see guidance sheet 10 *Lead recovery*.

What can it not achieve?

Bullet traps cannot contain all lead contamination at a rifle or pistol range. Some bullets may miss the bullet trap and small amounts of lead are also released during firing (*Laidlaw et al. 2017*).

When would you use this?

Bullet traps are useful at medium to large firing ranges, with high numbers of shooters, as the benefits of installing them is much greater than for ranges that are used less.

Shooting ranges should consider bullet traps when there is a high level of risk that contamination could cause harm.

Costs

Medium to high.

Bullets traps can be expensive as they must be durable, robust, and engineered to stop and contain projectiles travelling at high speed. Bullet traps also need significant maintenance including a regular schedule of inspection and removal of projectiles.

Effectiveness

High.

Bullet traps are very effective at reducing risks from contamination. They capture lead before it enters the soil, enabling it to be removed from the shooting range.

Considerations

Deciding which type of bullet trap is appropriate for a specific range depends on:

- the type of firearms and ammunition used at the range
- the amount of firing, and
- the need for containment of lead.

This Guidance Sheet will not detail individual bullet traps that are available as these can vary greatly in their design and availability. For specific information about what is available in Victoria, talk to your shooting association or commercial bullet trap suppliers.

Kinds of bullet traps

Bullet traps are located behind the target area, usually in front of the stop butt.

There are three basic types of bullet traps:

- bullet traps with a filler material such as sand or rubber which makes a bullet lose its energy, slowing, stopping and containing it upon impact
- bullet traps containing no filler material, reducing the kinetic energy of the bullet by redirecting it with, for example, a metal plate; and
- a combination of the above, where the bullet is redirected into the filler material with, for example, a metal plate.

Issues to consider with bullet traps

Maintenance – bullet traps generally require a high level of inspection and maintenance to remove captured projectiles.

Safety – any hard surface at a rifle or pistol range could contribute to ricochet. Ranges should always ensure that this has been carefully considered and that a suitably qualified person has been engaged. For information about how to engage a consultant see our webpage Engaging consultants. Ranges should also ensure their operations are consistent with Victoria Police requirements.

Bullet fragmentation – to minimise the spread of lead, the design of bullet traps should always seek to keep the projectile as intact as possible.

Lead contact – removing lead projectiles from bullets traps, maintenance work and the storage and transport of lead greatly increases the chance of people being exposed to airborne lead dust and fine particles. Precautions, such as appropriate personal protective equipment, are crucial to minimise a person's exposure. For information on this see the WorkSafe Victoria *Code of practice for lead*.

Further information

For more information on bullet traps see *Finnish Ministry of the Environment (2014)*.

Guidance sheet 9 – Environmental management plans

Description
An environmental management plan (EMP) is a site-specific plan that ensures appropriate actions are undertaken to avoid, minimise, or manage contamination. An EMP can also cover a wide variety of environmental and waste management activities such as vegetation management.

Type of control
Management system.

What can they achieve?
An EMP provides a site-specific framework for managing risks, setting out which controls will be used, what actions must take place, and who is responsible. A comprehensive EMP also sets roles and responsibilities as well as standard procedures for different parties (shooting range operators, contractors, shooters etc.) to follow.

An EMP is a place where information about environmental management at a shooting range can be recorded and managed. This information can provide confidence to shooting range operators that contamination risks are being identified, avoided, minimised and managed.

What can they not achieve?
EMPs do not control contamination, they provide a framework for shooting ranges to work within. Pollution can only be controlled if the systems or processes outlined in the EMP are followed and actions implemented.

When would you use this?
EMPs could benefit many shooting ranges; however, they would benefit larger, or higher risk shooting ranges the most. For information about assessing contamination risk, see section 3 of this guide.

Considerations
Although EMPs are useful tools to help manage risks of lead and other contaminants, there are some things to consider before implementing this control.

- EMPs are only effective when used and adhered to, simply having a plan in place will not ensure lead impacts and waste is controlled.
- EMPs should be considered 'living' documents and be revised and updated regularly.

An EMP can be simple or comprehensive:

- EMPs can simply list actions for environmental management. These should also include key information such as relevant laws and a list of people with responsibilities and what these are. The input of a consultant may not be required. EMPs can be created by the shooting range. They can be easy to implement and very effective.
- Comprehensive EMPs could include technical information and address more advanced aspects. This could include topics such as soil and water sampling, water management system design and engineering solutions. These EMPs can give a shooting range confidence that risks are being appropriately managed. Comprehensive EMPs may require the input of a consultant or suitably qualified person. For information about how to engage a consultant see the EPA webpage Engaging Consultants.

If a shooting range is considering creating their own EMP, the South Australian EPA have useful information in their guide *Small business environmental management solutions (2002)*.

Costs
Low to medium.

If an EMP is created without the input of a consultant, the costs can be low. If a consultant is engaged, costs can vary but can be considerable.

Effectiveness

Low – medium.

An EMP is only as effective as the amount of effort that is put into implementing its content. Because of this, it can range from low to medium.

What an EMP should include

An EMP should cover the following topics.

Detailed background

The EMP should start by scoping the situation at the range, this will include:

- What the general environmental roles, responsibilities and obligations are for the shooting range operator and/or the land holder or owner.
- A list of regulatory bodies and legislative requirements relevant for the different environmental and human health issues found at a range.
- A thorough description of the site's history, surrounding land uses, other users of the site, and its associated values and risks.
- What contaminants may be present at the range.
- An assessment of the risk that the shooting range poses from contamination.
- Who has access to what parts of the shooting range, when and why.

Contamination controls

An EMP should include a list of the controls recommended for a specific shooting range and its assessed risk. It should also contain information on why these controls have been chosen, how these controls work, what they will do, and how to maintain them.

Further to this, a good EMP should provide a 'conceptual site model' (CSM) depicting a shooting range with the controls in place. This can aid in understanding how, when implemented correctly, the recommended pollution control methods will be implemented at a range. Figures 2, 3 and 4 in Section 3 of this Guide are examples of CSMs at shooting ranges.

Implementation

Alongside information about the recommended controls, an EMP should include a detailed plan for implementing the controls to ensure their safe and timely application or installation.

It is good practice to also have a schedule identifying who is responsible for implementing a control, their role and other information such as instructions for their maintenance.

It is also important to have instructions on what documentation and record keeping will be needed.

Review schedule

It is important to periodically review an EMP to make sure it is still relevant. An EMP should outline when it will need to be reviewed. Reviewing an EMP can often be done by a shooting range and doesn't always need the input of a consultant.

Guidance sheet 10 – Lead recovery

Description
Lead recovery involves collecting and removing formed metal projectiles and fragments from shooting ranges for recycling. Lead recovery is not remediation and does not clean up soil or significantly reduce existing contamination.

Type of control
Management control.

What can it achieve?
Lead recovery reduces the potential for future contamination. The total volume of lead at a shooting range, which is always increasing, is reduced. By reducing the volume of lead, there is less potential for it to cause future contamination.

For lead recovery to be most effective, it must be undertaken frequently enough that the lead doesn't have time to weather and impact soil (*Cao et al. 2003*).

What can it not achieve?
While lead recovery can prevent future contamination, it does little to reduce the existing level of contamination at a shooting range.

Recovery can remove much of the intact lead shot at a shotgun range, and larger projectile fragments at rifle and pistol ranges, but many smaller fragments will remain after recovery. Also, if lead is left to weather it can impact soil and create lead compounds including lead oxides, carbonates and sulphites. This will also not be removed by lead recovery. As a result, there may be little change in the amount of contamination at a shooting range following lead recovery.

When would you use this?
Lead recovery and removal should be considered by all shooting ranges which use lead ammunition. It is a key control for preventing future contamination.

Considerations

- Lead recovery should be undertaken as frequently as possible. This lessens the length of time that lead spends in the soil and reduces the chance that it could become mobile.
- The mechanical process of lead recovery may make lead impacted soil more likely to spread through water or wind. Shooting ranges should carefully choose their provider to ensure that the operation doesn't create additional risks and their methods are effective (ITRC 2005).
- Mechanised lead recovery is most effective when there is good access to contaminated areas and soils are easy to process.
- Any vegetation or grass on the range will also influence lead recovery. It is ideal for vegetation to consist of grasses and pasture plants that can easily be removed but then re-established after recovery. It is also necessary to allow sufficient access for machinery.
- Lead recovery should always be considered alongside other controls and is not a solution to contamination alone.

Costs

Low to medium.

The costs of lead recovery vary depending on many factors. These include ease of access, the volume of lead available, the quality of lead and if there is anything which could practically make the recovery more difficult.

Effectiveness

Medium.

Recovery is the only control which manages the volume of lead at a shooting range and can prevent contamination from getting worse over time. However, it is not effective at totally removing lead contamination and, in some cases, it can spread through dust and erosion if not undertaken appropriately.

Further detail

This section gives more detailed consideration of lead recovery with the different contexts of rifle/pistol ranges and shotgun ranges. The frequency of lead recovery must be based on consideration of the risks at each shooting range. For information about this, see section 3 of this Guide *Assessing contamination risk*.

Planning and undertaking lead recovery

Lead recovery is not a management approach that can be considered in isolation. Recovery must be planned and undertaken alongside:

- reducing the total area of lead contamination through reducing the area of the impact zone at rifle or pistol ranges or the area of the shot fall zone at shotgun ranges.
- concentration of lead in a reduced area through design and management of the shooting field and stations.
- vegetation management that will accommodate recovery of lead from stop butts and range soils while also preventing any wind or water erosion. This will mean that vegetation cover should be easy to remove during lead recovery but then easily re-established. (see guidance sheet 3 Vegetation management).
- the location, layout and design of the shooting range.
- availability of the required machinery and suitably qualified people or contractors.
- timing of recovery. Depending on their individual circumstances some ranges may choose to postpone any lead recovery for some years while others may undertake it on a regular or semi-regular basis.
- OHS risk management.
- consideration of financial costs and benefits.

It is recommended that a trial of lead recovery is undertaken to determine if the practice will be effective for an individual shooting range.

Hazards of lead recovery

Lead recovery can create conditions where lead can easily spread. Following recovery, soil can be left loose and friable with no or limited surface cover. When soil is dry, and there are high winds, there is a risk that significant amounts of dust could be generated and spread lead impacted soil (*ITRC 2005*).

There is also a risk of water erosion transporting lead into water courses and water bodies. It is important to consider this during the planning phase and take necessary precautions.

When recovering lead, ensure that all contact with lead and lead contaminated soil is minimised and, were this is not possible, appropriate PPE should be used. For information about safety when handling lead, see the WorkSafe Victoria *Code of practice for lead (2000)*.

The risk of lead dispersal should be minimised wherever possible by:

- detailed planning prior to recovery starting to ensure all hazards are identified and controlled.
- minimising areas of soil disturbance as much as possible.
- minimising the time bare soil is exposed. This is especially important when there is increased risk of soil erosion through wind or water. This can be achieved by only removing any vegetation immediately prior to lead recovery and replacing cover through vegetation or temporary cover, such as mulch, as soon as possible following lead recovery. For more information see guidance sheet 3 *Vegetation management*.
- not recovering lead when conditions such as wind could cause dust to be generated and spread.
- not storing any recovered lead on site at a range.
- requesting information from lead removal contractors detailing their dust mitigation controls.

Soil management

Any soil containing lead at a range should be treated as contaminated during and after lead recovery. This is because lead recovery cannot remove 100% of the lead. Small lead pieces and particles, and any lead that has corroded and dissolved, will remain in the soil after recovery.

Due to residual lead contamination remaining in the soil, after lead recovery soil should be replaced where it was collected from rather than spread around other parts of the range or removed from the range.

- At a rifle/pistol range, soil should be returned to the shot butt. The treated soil may be placed on the rear face of the stop butt, if clean soil/sand is used in the impact zone.
- At a shotgun range, soil should be returned to where it was removed in the shot fall zone. Soil should not be stored on site at another location as this can spread potential contamination.

It is important that contaminated soil is not removed from a shooting range during lead recovery. This soil is considered prescribed industrial waste (PIW), and removing it is costly and regulated. If contaminated soil is required to be removed for any reason, this should be done in compliance with the EPA Industrial Waste Resource Guidelines (IWRG621). For more information about PIW, see *Prescribed industrial waste classifications*.

Recovered lead management

When concentrated lead in the form of projectiles, projectile fragment or shot is removed from a range, its storage and transport will need to need to meet appropriate guidelines and regulations. For this, see the WorkSafe Victoria *Code of Practice for Lead* and *Occupational Health and Safety (Hazardous Substances) Regulations* 1999 and the EPA *Industrial Waste Resource Regulations* 2009. Any sale of recovered lead should be arranged beforehand so that storage of lead at the range is avoided.

Recovery at rifle and pistol ranges

At rifle and pistol ranges, projectiles are captured in the stop butt or bullet trap. Lead recovery usually takes place in this area. The driver for lead recovery at a stop butt is often reducing ricochet risk, however the process has many advantages for reducing the potential for contamination to spread from the stop butt.

Stop butt

Lead recovery at a stop butt involves the removal of the outer layer of the impact area behind the targets and processing this on-site to remove and recover the lead (*Finnish Ministry of the Environment 2014*).

Lead recovery can be incorporated into a regular stop butt maintenance routine. The face of a stop butt can require periodic maintenance, such as applying a new layer of earth or sand (*ITRC 2005*). Lead recovery, sometimes referred to as ‘de-leading’, can fit into this maintenance process easily. However, as with all lead recovery, to get the best results for reducing contamination it should be done frequently so the lead has less time to degrade and contaminate soil or water. For more information see guidance sheet 7 *Stop butt designs.*

Bullet trap
Bullet traps are designed to capture projectiles, and lead recovery is required as part of their ongoing management. Because the projectiles do not need to be separated from soil, the issues with impacted soil dust discussed on page 69 in *Hazards of lead recovery* usually do not apply. However, other considerations discussed in this guidance sheet do. For more information about bullet traps, see guidance sheet 8 *Bullet traps*.

Recovery at shotgun ranges
At shotgun ranges, lead can be recovered by extracting it from the topsoil within the shot fall zone. The area with highest lead concentrations will be between 70 m and 120 m from the firing position, however shot will also fall both closer and further away than this and contamination will extend across the entire shot fall zone (*Finnish Ministry of the Environment 2014*). Testing of the soil to understand lead loads may be necessary in the planning phase of lead recovery.

For information about estimating a shot fallout zone, see section 4 *Shotgun ranges*.

To allow for lead recovery the shot fall zone should be kept clear of permanent vegetation, such as trees and shrubs. Outside of lead recovery operations, there should always be total vegetative ground cover from other plants such as grasses or mulch. This reduces the risk of dust spreading contamination. For information on this see guidance sheet 3 *Vegetation management*.

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Environment and planning websites

The following publicly available information sources may assist to determine what are sensitive environmental values and other receptors are located on, adjacent to, or close to a range.

EPBC protected matters search tool.

The Australian government's Department of the Environment and Energy, Protected Matters search tool is a useful resource. This can help to determine whether matters of national environmental significance or other matters protected by the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* are likely to occur in your area.

http://www.environment.gov.au/epbc/protected-matters-search-tool

GeoVic

GeoVic is a free web mapping application which allows users to search geospatial databases and to display the results as maps or tables.

http://earthresources.vic.gov.au/earth-resources/maps-reports-and-data/geovic

Nature Kit

Nature Kit is a biodiversity web mapping and reporting tool produced by the Department of Environment, Land, Water and Planning.

https://www.environment.vic.gov.au/biodiversity/natureprint

Planning maps online

http://services.land.vic.gov.au/landchannel/jsp/map/PlanningMapsIntro.jsp

Planning online

http://planning-schemes.delwp.vic.gov.au/

Understanding groundwater

The Department of Environment, Land, Water and Planning (DELWP) website provides general information about groundwater as well as specific information about local areas.
https://www.water.vic.gov.au/groundwater/understanding-groundwater

Vic plan

http://mapshare.maps.vic.gov.au/vicplan/

Victorian biodiversity atlas

https://vba.dse.vic.gov.au/vba/#/

Visualising Victoria's groundwater

Online database can provide information regarding groundwater usage in the local area.

http://www.vvg.org.au

Health

Those wishing to learn more about the health impacts from exposure to contaminants such as lead and PAH could consult the following resources.

Better Health Channel. *Lead exposure and your health***.**

https://www.betterhealth.vic.gov.au/health/healthyliving/Lead-exposure-and-your-health

Department of Health & Human Services. *Information for gun shooters - Managing exposure to lead*.

https://www2.health.vic.gov.au/about/publications/policiesandguidelines/information-for-gun-shooters

TOXNET database

The United States National Library of Medicine TOXNET Toxicology Data Network has a great deal of scientific information about contaminants discussed in this guide such as lead and PAH compounds.

TOXNET provides information on toxicology, environmental health, hazardous chemicals, toxic releases, chemical nomenclature, poisoning, risk assessment and regulations, and occupational safety and health.

https://toxnet.nlm.nih.gov/

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Appendix 1 – Relevant laws

The legislation listed in this appendix may be relevant in relation to contamination at Victorian outdoor shooting ranges.

It is the responsibility of a shooting range operator to ensure it is meeting its legal obligations. The legislation and guidelines listed below are focused on contamination at shooting ranges. This is not a complete or comprehensive list of all the relevant obligations an operator may have. A shooting range may choose to seek legal advice to ensure it meets its obligations.

Relevant legislation

Environment Protection Act 1970
Under the *Environment Protection Act 1970*, it is an offence to pollute land, air and water (including groundwater). Under the Act, entities that manage land and water resources are responsible for environment protection. The State Environment Protection Policy (Prevention and Management of Contamination of Land) 2002 is made under the Act and details the requirements for the prevention, management and remediation of contamination in Victoria.

Firearms Act 1996
All shooting ranges in Victoria need to be approved by Victoria Police, via the Chief Commissioner, under the *Firearms Act 1996*.

National Environment Protection (Assessment of Site Contamination) Measure [NEPM] (1999). Amended 2013.
NEPMs are a special set of national objectives designed to assist in protecting or managing particular aspects of the environment. This NEPM provides adequate protection of human health and the environment, where site contamination has occurred, through the development of an efficient and effective national approach to the assessment of site contamination.

Commonwealth National Environment Protection Council Act 1994
The *Commonwealth National Environment Protection Council Act 1994*, and complementary State and Territory legislation allow the National Environment Protection Council to make National Environment Protection Measures (NEPMs).

Planning and Environment Act 1987
The purpose of this Act is to establish a framework for planning the use, development and protection of land in Victoria. It sets procedures for preparing and amending the Victoria planning provisions and planning schemes. It also sets out the process for obtaining permits under schemes, settling disputes and enforcing compliance with planning schemes and permits.

Occupational Health and Safety Act 2004
Shooting range operators have responsibilities for workers (including volunteers), visitors and guests.

Other legislation
Aboriginal Heritage Act 2006
Catchment and Land Protection Act 1994
Commonwealth Environment Protection and Biodiversity Conservation Act 1999
EPA Industrial Waste Resource Regulations 2009
Occupational Health and Safety (Hazardous Substances) Regulations 1999
State Environment Protection Policy (Prevention and Management of Contamination of Land) 2002
State Environment Protection Policy (Waters) 2018
Water Act 1989

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