

Best Available Techniques (BAT)

Management of the Environmental Impact of Shooting Ranges

Sara Kajander and Asko Parri (ed.)



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FOREWORD

The concept of Best Available Techniques (BAT) plays a very important role in the assessment of the requirement level of environmental protection during permit proceedings in accordance with the Environmental Protection Act. Shooting ranges are not covered by the scope of the Industrial Emissions Directive, so there is no joint European steering for the Best Available Techniques. Over the last years, a high-level national environmental protection guideline has been prepared by the so-called AMPY project involving, for example, the environmental administration. Regardless of this, both the shooting range operators and the representatives of the public administration saw fit to collect the technical and procedural solutions of environmental protection at shooting ranges and assess them in more detail. A BAT study can further improve the level of environmental protection, develop the cost-effectiveness of environmental protection at shooting ranges, harmonise the requirement levels of environmental permits, establish better means for taking case-specific conditions into account, and reduce unnecessary or incorrect investments.

The BAT study for shooting ranges encountered the challenge that although a shooting range as a facility subject to the issuance of a permit would seem to be a reasonable simple structure, in reality, shooting ranges have been built for quite a large variety of purposes and numbers of users. Furthermore, the environmental conditions have a significant effect on the level of environmental impact or risks caused by the shooting range. The study was different from most other national BAT studies in the sense that only a limited amount of domestic or international user experience is available for the various technical solutions for environmental protection at shooting ranges. Indeed, this resulting BAT report for shooting ranges places increased emphasis on *emerging technologies* and *best practices* related to operations. This should be taken into consideration when applying the contents of this report. The technical solutions compiled during the project have been piloted in practice during the preparation work, and structural design has improved further with experience.

The national BAT report for shooting ranges was prepared in broad-based co-operation, the participants including representatives from several administrative branches, other users of shooting ranges, structural designers of shooting ranges, and experts in the management of environmental impacts. The project comprised two working groups (soil and water protection, and environmental noise) and a steering group. The working groups included representatives from permit and supervisory authorities from both the state and municipal administration, and the top experts in the field from the Finnish Environment Institute, the Finnish Defence Forces, the Construction Establishment of Defence Administration, shooting enthusiasts, and consulting firms. Preliminary studies were commissioned from the Aalto University, the University of Helsinki, and consulting firms. I would like to extend my warmest thanks to all parties who participated in the work of the steering group and the working groups and, in particular, the experts and authors of the preliminary studies who welcomed the challenge with open arms. Thank you to the Finnish Environment Institute (SYKE) for acting as the coordinating representative of the environmental administration and the party responsible for producing the publication. Support from the SYKE experts and the reviews required by the publishing process have allowed this report to achieve a high level of quality. Major thanks to the Finnish Defence Forces and the Ministry of Education and Culture for funding the project.

I would like to give special thanks to Sara Kajander (Construction Establishment of Defence Administration), who directed the project execution, and Asko Parri (Army Command Finland), who was responsible for the section on environmental noise, for their countless working hours and in-depth delving into the subject.

Matias Warsta
Chair of the Project Steering Group

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ABSTRACT

Goals and limitations

The goal of the analysis of the Best Available Techniques for environmental protection at shooting ranges was to determine **the technical and practical methods for reducing the environmental impact of shooting ranges and to assess their effectiveness, availability and costs** in Finland. As the outcome of the work, we present the best available practices and practices for the management of pollutants and noise emissions at shooting ranges. Sample specifications and structural drawings that are indicative in nature or show the principles have been prepared of the techniques assessed to be the best.

This report has been prepared in the same way as earlier so-called national BAT reports: in co-operation between different operators, authorities and experts. This report should be considered to be a guideline, and it is intended for shooting range operators, permit and supervisory authorities, and shooting range designers.

The report covers rifle, pistol and shotgun ranges located outside. The work does not discuss the remediation of contaminated soil and groundwater, or the procedures for closing down a shooting range. In many ways, environmental protection techniques for shooting ranges are still at the prototype stage, and the experiences of the effectiveness of the various technical solutions are mainly based on short usage experience or applications in other fields. This work takes into consideration the safety aspects of the solutions, but separate structures solely intended for operational safety are not discussed by this work.

Applying the definitions of Best Available Techniques (BAT) and Best Environmental Practice to shooting range operations

Best Available Techniques refer to methods of production and treatment that are as efficient and advanced as possible and technologically and economically feasible, and to methods of designing, constructing, maintenance and operation with which the pollution caused by activities can be prevented or most efficiently reduced.

As a rule, Best Available Techniques reports have been prepared for industrial operations, the environmental protection techniques of which are already rather advanced. The controlled circumstances of industrial processes and the long-term monitoring results enable the description of the minimum and maximum emission levels and the techniques required to achieved them. The basic premises of the specification of best available techniques for shooting ranges with regard to pollutant emissions are exceptional in the sense that instead of determining minimum and maximum emission levels, the goal was to determine the need the operations have for environmental risk management, and to assess management methods some of which are still experimental. With regard to noise, we examined the existing techniques and practices and recommended a procedure for assessing the need for noise abatement and targeting it in the most purposeful way possible from the perspective of BAT.

In accordance with the **Best Environmental Practice**, operations must comply with purposeful and cost-effective combinations of different methods such as working methods and the choice of raw materials and fuel in order to prevent environmental contamination. With regard to shooting ranges, this has been particularly taken into consideration when examining the procedures and raw material choices. In the case of shooting ranges, the best environmental practices fit naturally together with the assessment of the sufficiency of technical solutions.

The environmental impact of shooting ranges

Pollutant emissions

Shooting range operations burden the environment mainly through the shot and bullets containing metals that are harmful to the environment. The main pollutants in bullets are **lead, copper, antimony, and zinc**. The main pollutants in shot are lead and antimony. The gunpowders used in the cartridges and their additives, such as nitroglycerin, may also be harmful to the environment. In shotgun shooting, you must also take into consideration the littering caused by the clay pigeons used as targets.

Shooting range pollutants do not cause acute or short-term environmental risks; instead, pollutant migration may occur over a time period of dozens or hundreds of years. When bullets and shots embedded in the range structure get into contact with the soil and water, they are exposed to physical and chemical reactions. Pollutants may migrate to surface waters along rainwater, or deeper into the soil layers and groundwater along the percolating water absorbed by the soil. Environmental conditions such as the type, water permeability and pH of the soil, and the amount of rainfall have a significant impact on the erosion of bullets and shot and the migration of pollutants. Erosion is particularly promoted by acidic and humid conditions.

At both rifle and pistol ranges and shotgun ranges, elevated pollutant concentrations are primarily detected only in the surface layer of the range area.

Noise

Shooting generates noise that may be damaging or harmful to its hearer. According to the Environmental Protection Act, noise is a physical harm that may cause pollution of the environment. In the case of environmental noise from shooting ranges, the harm is primarily based on the annoyance caused by the noise. This report discusses the best techniques and practices related to the abatement of shooting range noise.

Guideline values have been set for environmental noise from shooting ranges in Government Decision 53/1997. The guideline values are specified as A- and I-weighted maximum sound levels L_{AImax} . When applying the Decision, one must take into consideration the nature of shooting range operations, such as shooting times, numbers of shots and the shooting sports, as well as the actual or planned use and importance of the area. This report presents the working group's views on the issues mentioned above.

In 2011, it was estimated that around 3,000 people live within the noise areas of civilian shooting ranges and around 2,400 people within the noise areas of the shooting ranges of the Finnish Defence Forces. With regard to the FDF, the shooting ranges are mostly used during the day, while the civilian shooting ranges are usually used during the evenings and weekends. Shooting range noise thus only occurs during the day, i.e., shooting noise does not disturb sleep during the night.

Noise assessment and the planning of measures must always stem from reliable and sufficiently extensive noise surveys and data on range-specific numbers of shots fired.

Best available techniques and practices in the management of the environmental impact of shooting ranges

Management of pollutant emissions

For pistol and rifle ranges, suitable methods that are both practical and based on the reduction of the pollutant load include the renovation of the impact areas in the backstop berm through screening or mass replacement, and the use of various bullet traps. Pollutant migration to the environment can be prevented by, for example, covering the backstop berm or placing a lining structure inside the berm. As pollutants

primarily migrate to the environment along water, emissions can also be managed through the collection and, if necessary, treatment of water containing pollutants.

The remediation of impact areas using either the screening or mass replacement technique is, in principle, suitable for use at all ranges where shooting is targeted at a backstop berm. The method is particularly suited to new shooting ranges, where the accumulation of easily soluble metal dust from fragmented and eroded bullets in the impact areas can be prevented through the regular removal of the bullets.

Bullet traps with a filler material that makes a bullet lose its energy and stop upon impact are suitable for use at most shooting ranges. Rubber grindings are often used as the filler material, and the structure can be, for example, a layer lined with a rubber membrane and installed on the surface of the backstop berm, or a wall or box structure. The solution is effective for pollutant management.

Metal bullet traps, where the bullet's kinetic energy is reduced by redirecting it, for example with metal plates, are particularly recommended for use with smallest calibre firearms; there are various reasonably simple implementations. Bullet fragmentation often causes metal dust that must be taken into consideration when planning environmental protection. There is no experience in Finland in the use of metal bullet traps with rifle calibre firearms (and equivalent) but in the USA, for example, commercial metal traps are used in rifle-calibre shooting with good results.

Covering the backstop berm and the target area prevents the formation of water with pollutant content and the migration of metals effectively. Covering is particularly well suited for biathlon, where the risk caused by bullets fragmented in front of the targets is otherwise difficult to manage.

Lining installed within the backstop berm (bentonite, film or asphalt) or a sand trap prevents water with pollutant content from migrating to the soil. The benefit of this structure is that the usage and safety characteristics of the shooting range do not differ from a normal backstop berm structure. The structure is suitable for use at all shooting range where firing is directed at a backstop berm. In connection with the sand trap structure, infiltration water must be collected from the top of the lining via underground drains and treated if necessary.

If the structural solution of the shooting range causes pollutant content in water, the **polluted water can be collected** depending on the water permeability and structure of the soil either with ditches or with lining and underground drains. Water with pollutant content can be **cleaned** in a treatment well by filtration or in basins or ditch systems by sedimentation.

Management of pollutant emissions at shotgun ranges is more challenging due to the larger target area, and more expensive than at pistol and rifle ranges. The spreading area of **pollutants can be limited and reduced** by landscaping or other physical obstacles. In practice, this means building extensive earthen berms or mesh or wall structures, or their combinations, in the firing sector. This solution does not eliminate the possibility of pollutant migration, but focuses the risk and need for measures to a smaller area. Pollutant migration can be prevented by surfacing the primary shot fall areas **and shot removal**, or **by managing water with pollutant content in the same way** as on pistol and rifle ranges.

The pollutant management need and the site-specific best available techniques for shooting range operations are determined based on the long-term environmental risk caused by the operations. The BAT report includes instructions for the assessment of the need for pollutant management **at a shooting range**. The assessment procedure of the environmental risk management need involves the investigation and description of the site's operating history, soil, groundwater and other environmental conditions, and the emissions caused by the operations and their possible long-term impact. The goal is to determine how the operations burden the environment and what effects they have. The emission level acceptable with regard to the environmental conditions

is determined and the environmental risk caused by the operations assessed site-specifically. Depending on the site's characteristics and the already available source data, the survey can be carried out either as a desk study, or it can include terrain surveys and environmental sampling, if necessary.

Based on the results of the risk management need assessment procedure, the site's risk management goals are determined. In the survey, shooting ranges are divided into four **categories** according to risk level:

- Level 1 – low environmental risk
- Level 2a – elevated surface water contamination risk, impact wider than local
- Level 2b – elevated groundwater contamination risk that is targeted at a classified groundwater area or an aquifer used for household water supply.
- Level 3 – high environmental risk or detected environmental impact.

An indicative **risk management requirement level** has been defined for each risk level. Techniques or practices to be used have not been separately defined for the different requirement levels or shooting range types; risk management can usually be implemented in several different ways. The operator plans and presents the site-specifically most suitable and feasible solution that meets the requirements for the risk level in question to the authorities for assessment. The choice of best available techniques and practices are also guided by their suitability for the site, cost-effectiveness, and implementation schedule. Should there not be any particular reason for urgent measures, the operator can be granted a sufficient amount of time to complete the implementation, if this facilitates, for instance, arranging financing.

At sites with a low environmental risk, we consider that **monitoring the burden** caused by the operations through monitoring of shots fired and the possible **observation of the impact** are sufficient risk management measures.

Noise management

The management of shooting noise is divided into noise abatement and the reduction of the harmful impacts. Noise abatement is commonly divided into reduction of the source emission, reduction of transmission, and receiver protection. In the case of shooting range noise, receiver protection is not used as a means of abatement. Most commonly, noise is abated with noise barriers and other noise control structures. Planning the operations and the usage times of the range aim at reducing the harmful impact.

During the **designing stage** of the shooting range, the noise caused by the shooting range can be influenced effectively and the generation of harm prevented. The design should pay attention to the range's location, elevation, range structures, and changes in the terrain and stands of trees. The arrangements of the range area, the positioning of the ranges and the direction of firing can affect the noise spreading to the environment. Early in the design stage, we recommend contacting the municipal land use planner and the building and environmental protection authority in order to determine the prerequisites for range placement. With regard to noise, the distance between the shooting range and the areas subjected to the noise should be sufficient. Usually, 3.5 km or template review is enough. At ranges where only .22 calibre firearms are used, the sufficient distance is clearly shorter. If the above-mentioned condition is not met, the design must be more detailed, using a prediction method for shooting range noise.

Techniques for reducing noise emission include reducing the calibre and using silencers, taking into consideration the limitations set by competition rules, etc.

The best techniques for controlling the propagation of noise include correctly designed and dimensioned **firing line enclosure structures** and **noise berms and screens**.

In the rear directions, the best available technique is considered to be a noise-attenuating, tight **enclosure**. The ventilation of the firing line enclosure must be planned to attenuate the noise. At shotgun ranges, an enclosure can be used only at a trap range.

An earthen berm is often the most natural choice for a noise barrier at shooting ranges. The noise berm, constructed from natural soil, is affordable, does not allow noise to be transmitted through it, nor does it reflect it. **A noise barrier** in its basic form has a hard surface, reflecting sound to the opposite direction. If this direction is also problematic, the barrier's surface on the side of the noise source must be sound-absorbing.

In the firing direction and the frontal sector, a sufficiently high backstop berm should be used as noise protection. At a pistol and rifle range, noise obliquely and directly to the sides, is abated using a noise berm, noise barrier, or a combination of the two. The barriers should be dimensioned so that the noise level at the receiver to be protected does not exceed the guideline or limit values, however so that the barrier attenuation is at least 5 dB. At a shotgun range, side barriers or berms can only be used with certain limitations, for example, taking the clay pigeon's flight trajectory into consideration. The barriers should always be placed as close to the firing stands as possible for performing the sports.

If other means are insufficient, overhead baffles can be used, if their noise attenuation can be reliably anticipated.

The ground in front of the firing line enclosure or the firing stand should be soft to reduce ground reflection.

Retaining **vegetation** in the vicinity of the shooting range is important, particularly if the vegetation is dense and high between the shooting range and the area subjected to noise. Particularly, the zone closest to the range, to a distance of around 100 m, is important.

Planning of the usage times of the shooting range can reduce the disturbance caused by noise. The usage times of the shooting range should be planned specifically for the ranges of all different sports in co-operation with the shooters, authorities, residents in the area, and other operators. The planning should take into consideration the special characteristics, operational requirements and noise emissions of the different shooting sports. For instance, the environmental permit limits the use of the shooting range in the evenings of certain weekdays at the shotgun and rifle ranges, while the usage of small .22-calibre firearms that have low noise emissions is allowed without limitations.

Procedures related to the use of the shooting range can affect the effectiveness of the implemented noise abatement measures. At rifle and pistol ranges, for instance, shooting should be carried out from the firing points located closest to the side berm; this allows the berm to best attenuate the propagation of noise. Such procedures should be put into writing, all range users made aware of them, and effective practices established to monitor compliance.

Communications form an important part of noise abatement measures at shooting ranges. The better the residents in the vicinity are aware of the usage times of the shooting range, the easier it is for them to prepare for and feel positive about the operations. In addition to communications, other stakeholder activities also increase acceptance to the operations, therefore reducing the experienced harm. For example, the residents in the vicinity could be offered a visit to the shooting range in order to familiarise themselves with the operations; they could also be informed of the operations at the shooting range being responsible and goal-oriented.

Monitoring ensures that the operations follow the rules; it can also have an effect on how the noise caused by the operations is experienced. It will be good for the residents to know that the operations at the range are pre-approved, in compliance

with the regulations, and monitored. The range usage times must be monitored and off-hours usage prevented, if necessary.

The range structures and their condition must be monitored and reviewed regularly. The operations at the shooting range must be monitored systematically.

Assessment of the viability of the implementation

The assessment of the benefits of environmental protection measures at shooting ranges is based on the assumption that the benefits at a minimum level can be considered to be sufficient, when the **acceptable emission or maximum risk level** is not exceeded using the chosen solution. Acceptable level can be considered to be, for instance, noise or pollutant emissions that even in the long term do not cause health hazards; contamination of the environment or the risk thereof; deterioration of special natural conditions; endangering of water supply or other use important of groundwater in the impact area of operations; or undue burden to the neighbours referred to in the Adjoining Properties Act.

The environmental protection legislation also requires that the operations strive to **minimise the harmful environmental impact and prevent any harm**. During the selection of the best available techniques, one must thus also assess the degree of additional benefit relative to cost of measures exceeding the minimum level the implementation for which requires investments that can be considered reasonable. If the benefit achievable by further measures is assessed to be significant while the overall cost remains at a level deemed reasonable, the application of a requirement level higher than minimum can be considered justified.

Economical viability considerations are based on the premise that it must be possible to continue operations on a **hobby basis** in such a manner that the end users' costs are comparable to the costs of other corresponding hobbies. The assessment of the operating costs should include the planning and implementation of the measures, maintenance of the structures, and the measures related to the termination of the operations. The analysis may also take into consideration the possibilities of receiving various subsidies and the effect of the schedule on the viability.



1 Introduction

The estimated number of shooting ranges in operation in Finland varies from six hundred to about one thousand. A shooting range facility typically includes ranges for several different shooting sports. A majority of the shooting ranges are maintained by shooting and hunting clubs. The largest individual operator is the Finnish Defence Forces that operates around 50 shooting ranges. Other authorities also operate shooting ranges, such as the Police, the Finnish Border Guard, and the Customs. Shooting ranges are necessary for supervised shooting in a location fit for the purpose. See Appendix A for basic information on shooting activities and shooting ranges.

There are an estimated 700,000 holders of a firearm possession permit in Finland, with a total of around two million permits (Government Proposal 106/2009). According to the Finnish Wildlife Agency, there are around 300,000 hunters in Finland. The Hunting Act stipulates that a big game hunter must have passed a shooting test. Police officers must also take a regulated shooting test twice a year. The statutory tasks of the Finnish Defence Forces include providing military training based on general conscription, and shooting instruction is one of the key aspects of the training. Shooting as a hobby is also the most popular reservist activity.

Outdoor shooting ranges require an environmental permit. The issued permits generally require using the best available techniques (BAT) in the management of emissions caused by the operations in accordance with the Environmental Protection Act. However, the best available techniques for shooting ranges have not been specifically defined. The environmental permits require the varying use of different methods and techniques for the management of pollutant and noise emissions. There are differing views on the necessity, effectiveness and cost-effectiveness of the required measures among both the authorities and the operators. Overzealous requirements cause unnecessary investments to the operators and limit the development of the operations. On the other hand, insufficient or incorrectly targeted measures may lead to the deterioration of the environment, its contamination, or a health hazard or reduced living comfort. Insufficient level of environmental protection may increase the costs of terminating the operations due to the incurred liabilities, and is therefore not in the best interests of the operator, per se.

Work on the national report on the best available techniques (BAT) and best environmental practices (BEP) began in 2010. The report was prepared in the same way as earlier so-called national BAT reports: in co-operation between different operators, authorities and experts. The following parties took part in the preparation of the report: the Finnish Defence Forces, the umbrella organisations of shooting enthusiasts the Finnish Shooting Sport Federation and the forum for shooting hobbyists *Ampumaharrastusfoorumi*, the Ministry of the Environment, the Finnish Environment Institute, and representatives from permit and supervisory authorities.

To direct the work, a steering group was established, composed of the following members:

Matias Warsta (chair)	Finnish Defence Forces / Logistics Division of Defence Command until 31 Oct 2012, thereafter the Ministry of Defence
Elise Sahivirta	Ministry of the Environment, until 28 Feb 2013
Oili Rahnasto	Ministry of the Environment, from 1 Mar 2013
Ari Saarinen	Ministry of the Environment
Kaija Savelainen	The ELY Centre for Uusimaa
Juha Aho	The ELY Centre for Northern Karelia
Mika Seppälä	The Regional State Administrative Agency for Southern Finland, until 30 Jun 2011 (launch and planning stages)
Katariina Serenius	Environmental Centre for Central Uusimaa
Outi Pyy	The Finnish Environment Institute
Irina Hakala	The Finnish Environment Institute, until 30 Sep 2011
Timo Jouttijärvi	The Finnish Environment Institute, from 1 Oct 2011
Risto Aarrekiivi	Ampumaharrastusfoorumi
Markku Lainevirta	Ampumaharrastusfoorumi
Kari Pesonen	Ampumaharrastusfoorumi
Olli Ohrankämmen	Finnish Defence Forces / Personnel Division of Defence Command, until 31 Dec 2012
Kari Melanen	Finnish Defence Forces / Personnel Division of Defence Command, from 1 Jan 2013
Vesa Valpasvuo	Association of Finnish Local and Regional Authorities

Sara Kajander, Construction Establishment of Defence Administrator, acted as the secretary for the steering group. The steering group informed the Ministry of Education and Culture (Risto Järvelä) and the Ministry of the Interior (Mika Lehtonen) of the contents and progress of the project; the development of shooting ranges falls under the administrative branches of these two ministries.

Two expert groups worked under the steering group (the soil and groundwater working group, and the noise working group). The task of the working groups was to prepare materials for discussion by the steering group, and to compile a final report with the help of project secretaries. All members of the working groups have participated in the preparation of the final report. The contribution of the project secretaries has been significant, particularly with regard to the sections concerning pollutants and their management.

The noise working group was composed of the following members:

Asko Parri (chair)	FDF / Army Command
Tapio Lahti	TL Akustiikka
Larri Liikonen	The ELY Centre for Uusimaa
Rauno Pääkkönen	Finnish Institute for Occupational Health
Jari Hosiokangas	Ramboll Finland Oy

Asko Parri acted as the secretary for the noise working group.

The soil and groundwater working group was composed of the following members:

Sara Kajander (chair)	Construction Establishment of Defence Administration
Esa Kuitunen	The ELY Centre for Central Finland
Ilkka Närhi	The ELY Centre for Southern Ostrobothnia
Jussi Reinikainen	The Finnish Environment Institute
Jorma Riissanen	Ampumaharrastusfoorumi

Jenni Haapaniemi and Jenni Takala from Ramboll Finland Oy acted as the secretaries for the soil and groundwater working group and the project secretaries for the overall project.

Simultaneously with the BAT report work, the Ministry of the Environment launched the AMPY project, aiming at the development of the environmental permit process for shooting ranges, involving the definition and harmonisation of the contents of permit applications and permit decisions. The working groups have partially used the same experts, and the contents of the projects have been jointly coordinated. As the outcome, the AMPY working group published the "Permit for a shooting range: a guide for operators and environmental permit and supervisory authorities" (Ministry of the Environment, 2012), that acts as a guideline for applicants for an environmental permit, and the authorities processing the permit applications. The goal of the BAT report is to define the best available techniques and the best environmental practices for shooting range operations in accordance with the Environmental Protection Act to support case-specific deliberation. The purpose is that the environmental permit guide and this BAT report form one integral whole that provides a sufficient basis for the planning of the technical and functional solutions of a shooting range and the related decision-making in the environmental permit process.

This BAT report is intended for shooting range operators, permit and supervisory authorities, and environmental consultants to act as a guideline for the assessment of the environmental protection needs and requirement level of shooting ranges, and the planning of the technical and functional environmental protection measures.

2 Background, goals and limitations of the work

2.1

Background

The report on the best available techniques for shooting ranges aims to clarify and harmonise the permit and land use planning practices, and to promote the availability of information on the environmental impacts of shooting ranges and their management. The lack of sufficient information has made it difficult for both the environmental permit authority and the permit applicant to determine what kinds of alternative techniques and practices could be considered to be sufficient, reasonable and purposeful from the environmental protection perspective at different shooting ranges.

The best available techniques do not mean the most advanced and demanding technical solutions; they are techniques that are effective in the management of the impact of operations, economically viable, and commonly available. On the other hand, using the best available techniques does not guarantee a sufficient level of environmental protection in all conditions. According to the Environmental Protection Act, an environmental permit cannot be granted, if the operations cause soil or groundwater contamination, a risk of groundwater contamination, or an undue burden to the neighbours. For example, establishing a shooting range in a population centre or in the vicinity of a water abstraction facility may require environmental protection measures more extensive than the definition of the best available techniques.

2.2

Goals and limitations

The goal of this work was to determine the technical measures for the reduction of the environmental impact of shooting ranges, and to assess their effectiveness, availability, and costs in Finland. As the outcome of the work, we present the best available practices and practices for the management of pollutant and noise emissions at shooting ranges.

The report covers rifle, pistol and shotgun ranges. The assessment of the methods takes into consideration shooting ranges of different scales and environments. Pistol and rifle ranges have been separated from shotgun ranges into their own sections in this work, as their impact and therefore the relevant solutions are significantly different from each other.

The assessment of the best available techniques focuses on the prevention of the environmental impact and the minimisation of emissions. The work does not discuss the remediation of contaminated soil and groundwater, or the procedures for closing down a shooting range. The work examines only those solutions for which some kind of usage experience exists, either in Finland or abroad. However, the environmental protection techniques for shooting ranges are in many ways still at the prototype stage, and the experiences of the effectiveness of the various technical solutions are mainly based on short usage experience, particularly considering that the environ-

mental impact of shooting ranges does not usually become evident until decades later. In addition to the collection and assessment of data that is a normal part of a BAT report, this work has also attempted to develop new overall solutions for the management of the environmental impact of shooting ranges by utilising, for instance, technical solutions for which there is sufficient usage experience from other fields. Several pilot sites have been implemented during the project, allowing the testing of the technical solutions in a shooting range environment. When this report is utilised in the assessment of applicable technical solution, it should be considered that to be precise, some of the solutions defined as best available techniques are in the final stages of the *emerging technologies* phase and have only been pilot tested. This work takes into consideration the safety aspects of the solutions, but separate structures solely intended for operational safety are not discussed by this work.

2.3

Instructions and plans produced as part of the project

Sample specifications (Appendices D, E) and structural drawings (Appendix J) that are indicative in nature or show the principles have been prepared of the techniques assessed to be the best. They have helped in making the assessment of the costs incurred by the measures more precise. These indicative sample designs can be applied site-specifically to help in the planning of the management of the environmental impact of shooting ranges.

Furthermore, we have drawn up a guideline for the assessment of the need for pollutant management at shooting ranges (Appendix F). The guideline is intended to be applied, for example, when determining the information to be presented in an environmental permit application for a shooting range, planning the environmental protection measures, and planning the monitoring. We have also prepared separate instructions concerning the environmental monitoring at a shooting range (Appendix G).

3 Applicable law

3.1

Acts and decrees applied in the environmental protection at shooting ranges

- The Environmental Protection Act (527/2014) and the Environmental Protection Decree (new decree issued on 4 September 2014, repeals the previous decree 169/2000)
- The Land Use and Building Act (132/99) and the Land Use and Building Decree (895/99)

- The Waste Act (646/2011)
- The Adjoining Properties Act (26/1920)
- The Government Decree on Water Resources Management (VNa 342/2009)
- The Government Decree on Substances Dangerous and Harmful to the Aquatic Environment (1022/2006)
- The Government Decree on the Assessment of Soil Contamination and Remediation Needs (214/2007)
- The Government Decision on the Guideline Noise Levels Caused by Shooting Ranges (53/1997).

According to Section 27 and Table 2 of Annex 1 of the Environmental Protection Act (EPA) is a site that requires an environmental permit. According to Section 7 of the EPA, the operator must arrange its operations in such a manner as to be able to prevent the contamination of the environment, or if the prevention is not entirely possible, limit the contamination to the minimum possible. According to Section 8.1, item 1 of the EPA, the operator must ensure that the best available techniques are used. Sections 16 and 17 of the EPA lay down prohibitions on contaminating soil and groundwater; these prohibitions are absolute. This means that the effects of soil contamination may not extend to outside the shooting range. According to Section 48.2 of the EPA, an environmental permit shall be granted, if the operations meet the requirements of the EPA and the Waste Act, and the decrees issued based on them. Section 49 of the EPA lays down provisions on the conditions for granting the permit. The condition for being granted an environmental permit is, therefore, that the best available techniques are used to prevent prohibited consequences, such as the undue burden referred to in Section 20 of the Adjoining Properties Act, or the contamination of soil and groundwater, and to limit the environmental impact as effectively as possible, taking into account the relativity considerations of the BAT principle. In this regard, it must also be noted that the prohibited consequences are absolute with regard to being granted an environmental permit, i.e., using the best available techniques will not necessarily be enough for fulfilling the requirements of the law in all conditions.

According to Section 52.3 of the EPA *"When issuing permit requirements, one must take into account the nature of the operations, the properties of the impact area, the effects of the operations on the environment as a whole, the significance of the measures intended to prevent environmental contamination with regard to the environment as a whole, and the technical and economical possibilities of implementing the said measures. The permit requirements concerning emission limit values and the prevention and limitation of emissions must be based on best available techniques. The permit requirements must not, however, compel the use of only a specific technique. Furthermore, where necessary, the efficiency of the use of energy and materials, and preparation for the prevention of accidents and the limitation of their consequences must be taken into consideration."* This provision means that the case-specific assessment of best available techniques is influenced by many factors, including the environmental conditions in the area and the economical reasonableness for the sector. Furthermore, the starting point is that the operator presents a technical solution, and the authority assesses its acceptability, unless specifically otherwise required by the nature of the operations. When the suitability of the technical solutions is assessed, their effectiveness in exceptional situations such as accidents must also be taken into consideration.

According to Section 133.1 of the EPA, the party whose operations have caused the contamination of soil or groundwater is obligated to remediate the soil and groundwater to a state that can not cause a health hazard or harm or danger to the environment. The liability in accordance with the so-called polluter pays principle means that regardless of whether there was a permit for the operations or not, the operator will always bear the ultimate responsibility for restoring the area into a state

that will not cause harm or danger to the environment. The Government Decree on the Assessment of Soil Contamination and Remediation Needs (the so-called PIMA decree, VNa 214/2007) was issued to support the assessment of the level of contamination. The starting point of the PIMA decree is the assessment of the danger of health or environmental risk caused by pollutants. For instance, the pollutant content in the surface structures of shooting ranges is typically high, but managing the migration risk of the pollutants is central to contamination management. The Government Decree on Substances Dangerous and Harmful to the Aquatic Environment, among others, is applied in the assessment of water contamination.

During the preparation of this report, reforms of the environmental protection legislation and the legislation concerning the establishment and management of shooting ranges are under way. This report has been prepared based on the currently valid legislation, but the work has attempted to take into consideration issues that have arisen during the preparations for the reforms that have or may have significance with regard to the report.

With regard to noise, environmental contamination is assessed to the undue burden as referred to in Section 20 of the Adjoining Properties Act. The Government Decision on the Guideline Noise Levels Caused by Shooting Ranges can be utilised to support the assessment of the burden. The guideline noise levels have been designed for land use planning, and they should not be directly applied in the assessment of the acceptability of the noise levels of existing shooting ranges during permit proceedings. The guideline values do, however, provide a reasonably good tool that supports the dimensioning of the noise abatement structures.

3.2

Best Available Techniques (BAT)

According to Section 3 of the Environmental Protection Act (86/2000), Best Available Techniques refer to methods of production and treatment that are as efficient and advanced as possible and technologically and economically feasible, and to methods of designing, constructing, maintenance and operation with which the pollution caused by activities can be prevented or most efficiently reduced. According to the Environmental Protection Act, a technique is technologically and economically feasible when it is generally available and may be applied in the relevant field at a reasonable cost. Section 37 of the Environmental Protection Decree (169/2000) defines the factors to be taken into consideration in the assessment of the best available techniques.

The so-called IPPC Directive (2008/1/EC, later replaced by the Directive on Industrial Emissions 2010/75/EU), issued for the harmonisation of the prevention and control of environmental pollution that is primarily applied to industrial production lies on the background of the definition of BAT. Shooting range operations are, however, materially different from industrial production, and all factors listed in Section 37 of the Environmental Protection Decree cannot be considered to be significant in the definition of the BAT for shooting range operations. For this reason, the following factors to be taken into consideration in the assessment of best available techniques are discussed in this work:

- reduction of the amount and harmfulness of waste;
- the hazardousness of the substances used, and the possibilities of using less hazardous substances;
- the possibility of reusing and utilising substances used and the waste generated in the operations;
- the quality, amount and impact of the generated emissions;

- the prevention of risks and accident hazards related to the operations and the prevention of further consequences from accidents;
- the time required to adopt the best available techniques, the significance of the planned starting time of the operations, and the costs and benefits of preventing and limiting emissions;
- emission management methods that are in use or available; and
- the development of technology and scientific knowledge.

As a rule, Best Available Techniques reports have been prepared for industrial operations, the environmental protection techniques of which are already rather advanced. The controlled circumstances of industrial processes and the long-term monitoring results enable the description of the minimum and maximum emission levels and the techniques required to achieve them. The basic premises of the specification of best available techniques for shooting ranges with regard to pollutant emissions differ from the norm in the sense that instead of determining minimum and maximum emission levels, the goal was to determine the acceptable level of the environmental impact caused by the operations, provide instructions for the assessment process, and assess management methods some of which are still experimental.

The European IPPC Bureau organises information exchange between the industry and the authorities regarding best available techniques. The results of this information exchange are published as BAT Reference Documents (BREF) and as BAT Conclusions that are binding to the member states. In Finland, the Finnish Environment Institute (SYKE) acts as the national focal point for the exchange of BAT information. If necessary, a national BAT study may be carried out for activities that are not included in the scope of the Industrial Emissions Directive (IED, 2010/75/EU). The studies are carried out under the direction of the Finnish Environment Institute. The legal status of the reports published as a result of the national BAT studies (this BAT report is one such) is guiding.

3.3

Best Environmental Practice (BEP)

Section 4 of the Environmental Protection Act lays down the principle of best environmental practice. In accordance with the principle, the activities will comply with purposeful and cost-effective combinations of different methods such as working methods and the choice of raw materials and fuel in order to prevent environmental contamination. In the case of shooting ranges, this has been particularly taken into consideration when examining the procedures and raw material choices. In the case of shooting ranges, the best environmental practices fit naturally together with the assessment of the sufficiency of technical solutions. In the case of noise impacts, for instance, the need for noise abatement structures can be affected by limitations to the usage times and amounts.

Best environmental practices offer environmental impact management options for consideration by the operator through operational changes. On a case-specific basis, the best practices can be used to complement or replace other technical solutions, and find solutions for situations where other environmental impact management methods are insufficient or too expensive. Implementing operational changes may, however, change the nature of the operations to such a great degree that they cannot always be considered feasible, and they cannot therefore be unequivocally required.



4 The impact of shooting range operations on the soil and the surface and groundwaters

4.1

Environmental contamination at shooting ranges

Shooting range operations burden the environment mainly through the shot and bullets containing metals that are harmful to the environment. The main pollutants in the bullets most commonly used in Finland are lead, copper, antimony, and zinc. The main pollutants in shot are lead and antimony. The gunpowders used in the cartridges and their additives, such as nitroglycerin, may also be harmful to the environment. In shotgun shooting, you must also take into consideration the littering caused by the clay pigeons used as targets, and the pollutants possibly discharged into the environment from the clay pigeons.

The cartridges used in rifle and pistol sports comprise four parts: the case, bullet, primer, and propellant. The case forms the body of the cartridge into which the bullet and primer are attached. The most common raw material used for cases is brass, which contains 72% copper and 28% zinc. The bullets can be divided into lead bullets, full metal jacket bullets, soft-point bullets (semi-jacketed bullets), and special bullets. The jacket partially protects the lead core from getting into contact with the surrounding soil. Today, the bullet jacket is manufactured from an alloy of copper (90...95%) and zinc (5...10%) (tombak). The bullet core is mainly lead (97...99%) with small amounts (1...3%) of antimony in the mix. Of the total mass of the bullet, roughly 89% is lead and roughly 9% copper. Antimony and zinc both amount to around 1% of the total mass of the bullet. Bullet weights vary between 2.9 g and 15.6 g depending on the sport. Bullets with a nickel jacket were still used after the wars. Their use ended in the 1950s. This means that old shooting ranges may still contain nickel from bullets. (Naumanen 2002.)

A shotgun shell contains several shot that exit the gun barrel in a single mass but quickly disperse. Shot usually contain around 97% of lead, around 1...3% of antimony, and 0.1...0.5% of arsenic. The shot may also contain trace amounts of copper, zinc, and nickel. The maximum allowed load is 24 grams in most shotgun shooting sports, while a 28-gram load is allowed in Compak Sporting and Sporting Clays. The clay pigeons used in shotgun shooting weigh 110 g and are 110 mm in diameter. The clay pigeons are usually painted orange in order to increase their visibility. The most commonly used clay pigeons consist of calcite (around 70%) and coal tar (20...40%). (Naumanen 2002.)

The lead used in bullets and shot is not pure; it is largely melted down from lead batteries and contains many impurities. Pure lead corrodes extremely slowly; for instance, the lead used in the buildings and structures from the Antique and the Middle Ages is largely non-corroded. Other substances purposefully added to lead, such as antimony, increase the solubility of the lead (Hurley 2013).

Shooting range activities do not cause immediate or short-term environmental impacts; the migration of pollutants to the environment is typically slow. When the

bullets and shot left in the range structures get into contact with the environment (air, water and soil), they are subjected to physical and chemical reactions. As a result, metals may in time dissolve into rain and melt water, precipitate in the varying conditions of the soil layers into different minerals, and bond with the small particles in the soil. Metals may migrate to surface waters along rainwater, or deeper into the soil layers and even to groundwater along the percolating water absorbed by the soil. Environmental conditions such as the type, water permeability and pH of the soil, and the amount of rainfall have a significant impact on the speed and amount of bullet and shot erosion takes place, and the resulting migration of the released pollutants to the environment. In a dry environment with a neutral acidity, such as in sandy soil, erosion is typically very slow. On the other hand, in sandy and gravelly soils that are very water-permeable, the migration of pollutants dissolved as a result of erosion may be rapid with low retention. A layer of secondary minerals forms on the surface of bullets and shot, mainly comprising metal oxides and hydroxides, that slows down erosion and the dissolving of metals. In acidic or humid soil conditions, erosion is more rapid and the formed secondary minerals dissolve easily. The humus and micro-organisms in the soil plants speed up the erosion of metals, but on the other hand, they can also bind the metals that have dissolved into the soil. The permanent negative surface charge and ion exchange capacity of clay minerals and fines also enable the bonding of metals dissolved into the soil, thus slowing down their migration.

The effect of soil conditions on the dissolving of different metals is illustrated in Table 4.1.

Sites where bullets and shot get into direct and continuous contact with water are particularly problematic for the environment. Such a situation may occur in, for example, wetlands, when shooting into a body of water, or in areas where the groundwater level is close to the surface.

A rather large number of environmental studies have been carried out on shooting ranges in Finland. During the preparation of this report, the results of 36 shooting range studies were compiled and analysed in order to obtain a better idea of the actual environmental impacts of shooting ranges. There were a total of 97 separate shooting sport ranges in the studied shooting range facilities. The usage amounts and positioning in groundwater areas of the ranges is presented in Table 4.2.

The results of the study summary are presented in Sections 4.2–4.5. Generally speaking, it can be stated that making reliable conclusions was made more difficult by the significant differences in the content and quality of the studies. The metal contents in the soil were studied at almost all ranges, but the migration of pollutants or the contributing factors were studied less often. The quality of ditch or other surface waters had been studied at 18 sites, sediment quality at 6 sites, and groundwater quality at 24 sites. At some of the sites, soluble metals were analysed from the water

Table 4.1. Effect of soil characteristics on the solubility of heavy metals (Smolander et al 2010).

As the characteristic increases	Lead (Pb) solubility		Copper (Cu) solubility		Antimony (Sb) solubility	
	increases	decreases	increases	decreases	increases	decreases
Humidity	X		X		X	
Temperature	X		X		X	
Clay content		X		X	X	
Humus content		X		X		X
pH value		X*		X	X	

* With regard to lead, the effect of the pH value is not unambiguous. The solubility of lead is at its lowest when pH is neutral or close to neutral. The solubility increases when the pH value decreases, but also strongly alkaline conditions cause an increase in solubility.

Table 4.2. The numbers, usage, and location in a groundwater area of the ranges examined in the shooting range study summary.

Number of sites	36
Tot. no. of ranges for different shooting sports	97
No. of pistol and rifle ranges	68
No. of shotgun ranges	29
Annual no. of shots	
<10,000	17
10,000–100,000	15
>100,000	13
unknown	52
In a groundwater area	
Class I	60
Class II	6
partially	8
no	19
unknown	4

samples, at others, the total concentration, at some sites, both. One significant conclusion drawn from the study summary was the need for instructions on performing environmental studies at shooting ranges.

4.2

Emissions of pollutants and their migration at pistol and rifle ranges

The structures of pistol and rifle ranges can be divided into five segments based on the pollutant load:

- impact area in the backstop berm; high pollutant content;
- target area and the backstop berm (comprising the target area, front berm and the front side of the top of the backstop berm above the impact areas); high pollutant content as a rule;
- front of the shooting stands; moderate pollutant content;
- intermediate area (comprising the intermediate berms at rifle ranges); low to moderate pollutant content; and
- side berms and the rear of the backstop berm; clean as a rule.

Powdery lead is produced during shooting to the front of the firing stand from the lead trispartite contained by the primer of the cartridge and the unjacketed rear of the bullet, released by the pressure resulting from powder combustion. Powder combustion releases carbon dioxide, carbon monoxide, nitrogen oxides, hydrocarbons, and minute amounts of antimony and arsenic (Lindfors & Lyly 2004). Shooting also releases powder and other propellants, such as nitroglycerin. Furthermore, fine-grained copper and zinc land to the front of the firing stand, originating from the bullet jacket rubbing against the barrel.

The pollutants in the front of the firing line are in a fine-grained form that migrates more easily than those in the bullets in the target area. Metal dust and the powder

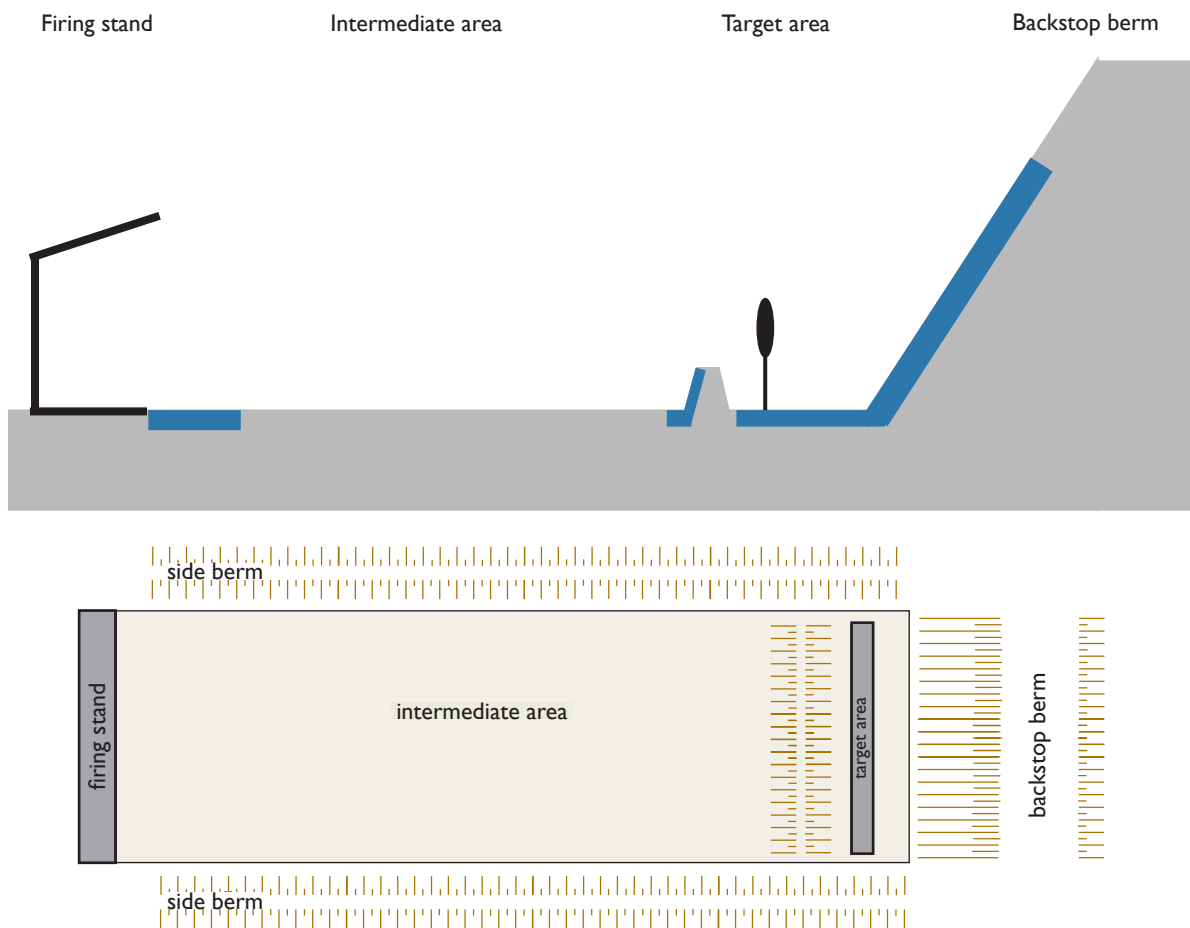


Figure 4.1. Simplified representation of the accumulation of pollutants in the structures of a rifle range (blue colour).

and propellant residues can migrate along water and melt water, making it possible for small amounts of pollutants getting into surface or groundwater. (Smolander et al 2010)

Bullets primarily accumulate in the impact area in the backstop berm behind the targets, bullet traps, or other bullet collection structures. As a result of missed shots or ricochets, a small number of bullets end up in the intermediate area, other parts of the backstop berm, or even outside the range area, if the backstop berm is not sufficiently high or wide. At ranges with moving targets and modifiable ranges (practical, SRA), the impact areas are not clearly defined as at traditional rifle ranges; the metal distribution in the backstop berm is more even. In sports where metal targets are shot, such as in biathlon and silhouette shooting, the bullet fragments against the target, and fine metal fragments spread to the surface layer of the range in the area surrounding the targets. Metal dust is also generated and accumulates in the surface layer of the target area when certain metal bullet traps are used. At silhouette ranges, the soil contamination spreads more evenly throughout the entire shooting range area, as there are several targets and low intermediate berms in the intermediate area. Figure 4.1 presents a simplified depiction of the accumulation of pollutants in the structures of a rifle range.

Based on the study summary carried out during this study, the elevated pollutant concentrations in the backstop berms of pistol and rifle ranges are primarily limited to the surface layer (0...0.5 m). Concentrations higher than the background concentration were also often detected at a depth of around 1...2 metres, which may be caused by old impact or runoff areas being covered during berm heightening, etc., or the precipitation of dissolved metals.

Emissions of pollutants and their migration at shotgun ranges

At shotgun ranges, shot and metal originating from them appear in almost the entire surface layer of the range area due to the nature of the shooting activity. The flight distance of shot is directly proportional to their size. At a rough estimate, shot fly as many hundreds of metres as their diameter is in millimetres. Thus, at skeet ranges, shot spread over the firing sector to distance of around 200 metres from the firing stand, and around 250 metres at trap ranges. If larger shot are used at the ranges during practice, the shot may spread as far as over 300 metres from the firing stand. (Naumanen et al 2002.) Terrain contours and trees have a significant effect on the spread of the shot. Wind conditions also have a large effect on the spread of the shot. Figures 4.2 and 4.3 present the areas into which a majority of shot falls at skeet and trap ranges. The highest metal concentrations occur in these areas. Shot and elevated pollutant concentrations in the surface layer can, however, be detected very close to the firing stands.

At shotgun ranges, broken clay pigeons typically fall down at a distance of 20...80 metres from the firing stand. Missed clay pigeons fly to a maximum distance of around 90 metres, depending on the sport. (Baer K 1995.) Clay pigeons mainly comprise calcium and coal tar that contains high PAH compound concentrations. According to a study carried out during the preparation of this report, around 0.2...2.5% of the mass of the clay pigeons commonly used in Finland is PAH compounds. However, their solubility is poor, which means that the compounds mostly remain bonded with the material of the clay pigeon. However, elevated PAH compound concentrations have been detected in the topsoil (<10 cm) at some sites in the areas where clay pigeons fall. The migration of PAH compounds in the soil is minor, and their spreading outside the range structures is unlikely. The concentrations and solubility of the PAH compounds in clay pigeons are described in more detail in Section 5.3.2. Due to the poor solubility and migration of PAH compounds, clay pigeon debris has no significant environmental impact with the exception of littering. There

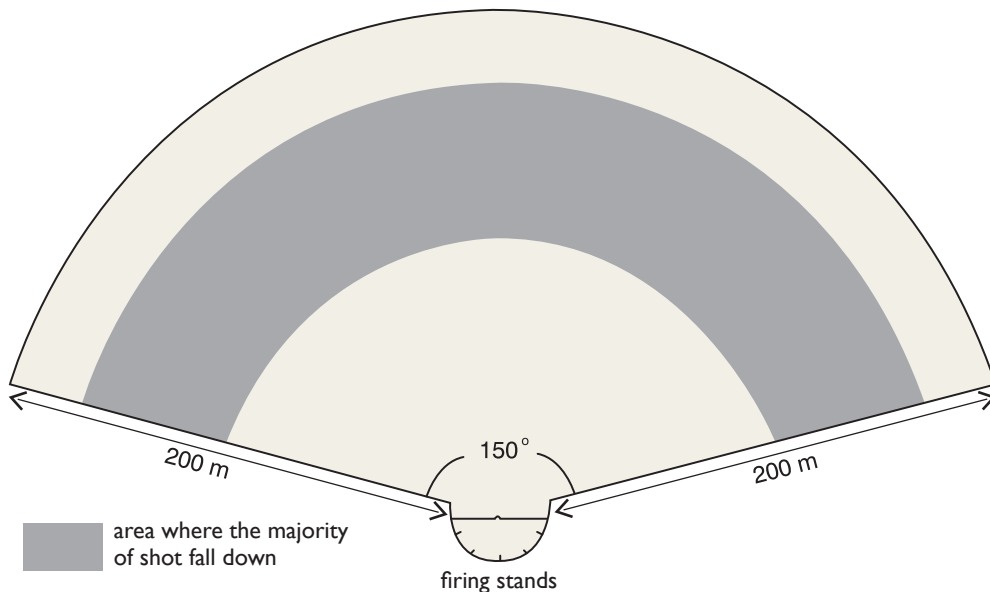


Figure 4.2. The primary spreading area of shot at a skeet range (grey colour). The length of the shooting sector radius is around 200 m, and a majority of the shot falls down at a distance of 100...150 m from the firing stand.

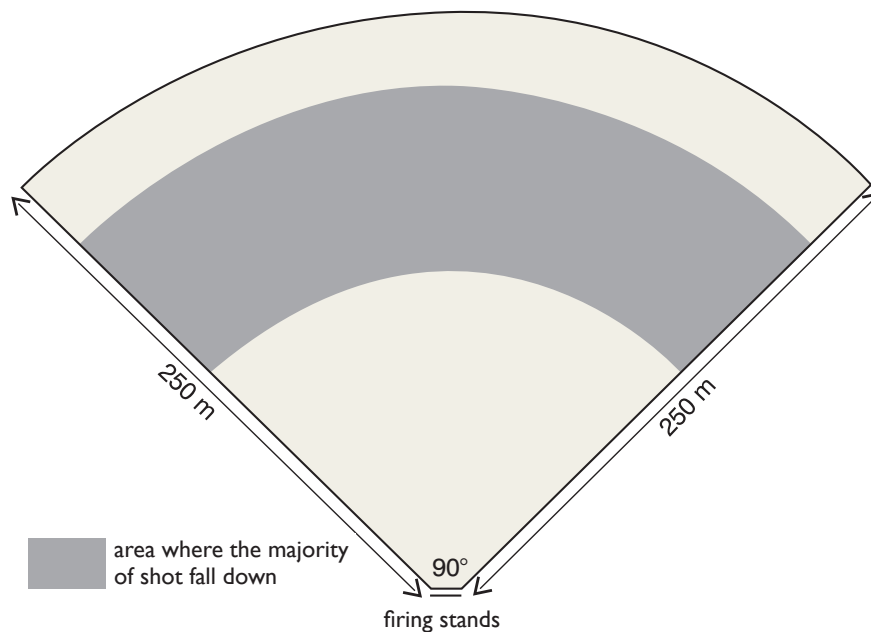


Figure 4.3. The spreading area of shot at a trap range (grey colour). The length of the shooting sector radius is around 250 m, and a majority of the shot falls down at a distance of 100...200 m from the firing stand.

is therefore no need for the removal of the fragments during the shooting range's service life due to pollutants.

Based on the study summary carried out during this study, the elevated pollutant concentrations in the firing sector of shotgun ranges are primarily limited to the topsoil (0...0.1 m). At some ranges, however, metal concentrations higher than the background concentration were detected at a depth of around 1 metre from the surface. Based on the results, it can be stated that in acidic, swampy and constantly humid peatland, shot erode more rapidly than in dry mineral soil, due to which metal concentrations are detected at a greater depth. In the studies, PAH compounds were not found to have migrated deeper than the topsoil.

4.4

Migration of pollutants into groundwater

Pollutants can migrate from the structures of pistol, rifle and shotgun ranges to the groundwater along percolating water, i.e., rain water absorbed into the soil. Pollutant migration is affected by the characteristics of both the soil and the pollutants. With regard to groundwater, lead and antimony are the most problematic substances. The migration of lead in the soil is usually relatively poor, but, for example, acidic and humid conditions, short distance between groundwater level and the surface, and a large lead content in the soil can facilitate its migration into groundwater. The solubility and migration of antimony are often clearly higher than lead's, but the concentrations and total contents of the substance in the soil are lower than lead (Lewis et al 2010).

The quality of percolating waters at shooting ranges has not been studied a lot in Finland. As a result of the recent development work in environmental protection and technical solutions, water management and monitoring systems have been installed at some shooting ranges, providing monitoring data in the future. Individual studies have found that the percolating waters of the backstop berms at pistol and rifle ranges contain metals originating from bullets in dissolved form, with concentrations

varying from a few micrograms per litre ($\mu\text{g/l}$) to a few hundreds of micrograms per litre ($\mu\text{g/l}$) (Ramboll Finland Oy 2013, client Construction Establishment of Defence Administration, Lysimeter analysis at the Hälvälä shooting range, work ongoing). International sources support these findings. However, the amount of percolating water formed in the part of the backstop berm with a high metal load is very small; even at a large range, no more than a few hundreds of cubic metres per year, which means that the total load to which groundwater could possibly be subjected to remains small (for example, observations made during the monitoring at the FDF's Parolannummi shooting range following the installation of protective structures). The quality of percolating water at shotgun ranges has been studied only minimally.

The migration of pollutants into groundwater is, as a rule, likelier at shotgun ranges than pistol and rifle ranges, as the pollutant load per round caused by shotgun shooting is larger and the area subjected to pollutant load is wide. At pistol and rifle ranges, there are also usually range structures reducing the risks, such as a backstop berm constructed from neutral sandy soil. Furthermore, the erosion of shot is more rapid than that of bullets because of their smaller size. The migration of PAH compounds from clay pigeons and their fragments into groundwater in significant amounts is unlikely due to the poor solubility of the compounds.

According to studies carried out at Finnish shooting ranges, metals may migrate into groundwater from shooting ranges, but concentrations clearly elevated from the background level and significant regard to environmental impact are uncommon. Tables 4.3, 4.4, and 4.5 present the distributions of the detected metal concentrations and the reference values used.

Table 4.3. The distribution of dissolved lead concentration and the total concentrations of lead and arsenic in the analysed groundwater samples in the study summary of the 36 shooting range studies.

Concentrations in groundwater	Total Pb	Soluble Pb	Total As
Household water limit value $\mu\text{g/l}$	10	-	10
Groundwater environmental quality norm $\mu\text{g/l}$	5	-	5
Background concentration (1000 kaivoa study, 98th percentile) $\mu\text{g/l}$	2	-	3
Distribution No. of observations			
<5 $\mu\text{g/l}$	17	12	10
5–10 $\mu\text{g/l}$	2	1	4
>10 $\mu\text{g/l}$	5	0	5
n	24	13	19

Table 4.4. The distribution of total copper, nickel and zinc concentrations in the analysed groundwater samples in the study summary of the 36 shooting range studies.

Concentrations in groundwater	Total Cu	Total Ni	Total Zn
Household water limit value $\mu\text{g/l}$	2000	20	-
Groundwater environmental quality norm $\mu\text{g/l}$	20	10	60
Background concentration (1000 Wells study, 98th percentile) $\mu\text{g/l}$	200	15	400
Distribution No. of observations			
<10 $\mu\text{g/l}$	13	10	12
10–20 $\mu\text{g/l}$	0	1	3
20–60 $\mu\text{g/l}$	4	7	6
60–100 $\mu\text{g/l}$	0	0	0
>100 $\mu\text{g/l}$	5	3	1
n	22	21	22

At around one third of the pistol and rifle ranges where groundwater was analysed, lead concentrations were detected exceeding the value categorised as background concentration, 2 µg/l. In this context, the background concentration was determined in accordance with the 98th percentile (numerical value that is greater than 98% of the results) of the lead concentration in the study of 1,000 Finnish wells (Lahermo, et al 2002) used as reference data. Antimony concentrations in the groundwater in excess of the 98th percentile (0.2 µg/l) were also found at around one third of the analysed ranges. For copper, concentrations in excess of the 98th percentile (200 µg/l) were found only at around one sixth of the analysed ranges. Nickel and zinc were found in the groundwater at almost all analysed ranges, and the 98th percentile for nickel (15 µg/l) was exceeded at half of the analysed ranges. The 98th percentile for zinc (400 µg/l) was not exceeded at the analysed ranges.

At shotgun ranges, corresponding values in excess of the 98th percentile were found for lead, at half of the ranges; for antimony, at three quarters of the ranges; for copper, at one seventh; and for arsenic (3 µg/l), at over half of the analysed ranges. The link of arsenic to shooting activities is not unambiguous, as there are significant regional variances in arsenic concentrations. For zinc, no values in excess of the 98th percentile were found.

The highest found total lead concentration in the groundwater exceeded the quality requirement for household water (10 µg/l) by around ten times. The share of soluble lead was not analysed from the sample. The total lead concentration was in excess of the quality requirement for household water in three samples from pistol and rifle ranges and in two samples from shotgun ranges. Of these, one sample was the same for a pistol and rifle range and a shotgun range.. The concentration of soluble lead was not in excess of the quality requirement for household water in any of the samples from which it was analysed.

Table 4.5. Distribution of the total concentration of antimony in the analysed groundwater samples in the study summary of the 36 shooting range studies.

Concentrations in groundwater	Total Sb
Household water limit value µg/l	5
Groundwater environmental quality norm µg/l	2.5
Background concentration (1000 Wells study, 98th percentile) µg/l	0.2
Distribution No. of observations	
<1 µg/l	20
1-2.5 µg/l	0
2.5-5 µg/l	3
>5 µg/l	1
n	24

The groundwater studies involve some uncertainties due to which the results from the different studies are not directly comparable, and the conclusions on pollutant migration are therefore not unambiguous. In several cases, the description of sampling is lacking certain details, for example with regard to the sampling method (pumping/sampler) and the representativeness of the sample (turbidity). There is also variance in the analyses. In some of the studies, both soluble and total metal concentrations were analysed, in some only one, and in some, there is no mention of the matter. The results may have significant differences, particularly when the sample is turbid. The concentrations of substances in groundwater may also vary rather narrowly, both chronologically and geographically, so it is impossible to get a reliable idea of the actual condition of the groundwater from a single sample.

For instructions on assessing the environmental risk at shooting ranges, see Appendix F, Assessment of the need for pollutant management at a shooting range.

4.5

Migration of pollutants into surface waters

At shooting ranges, pollutants generally migrate from the soil into surface waters along surface runoff in both a soluble form and bonded with soil particles. Pollutants may also migrate into surface waters along groundwater discharged into surface waters, mainly in soluble form. Pollutants migrating from shooting ranges into surface waters mainly comprise metals, of which the most significant for the aquatic environment are lead and copper, when the observed concentration levels of the substances are also taken into consideration.

Just as for groundwater, the contamination risk of surface water is generally higher at shotgun ranges than at pistol and rifle ranges. Migration is particularly affected by the amount of surface runoff formed in the range area and coming from outside the area, determined by the inclination of the top soil, amount of rainfall, soil types, and vegetation.

Pollutants also migrate from shooting ranges into the bottom sediments of water bodies. Pollutants in soluble form can in suitable conditions precipitate at the bottom, and pollutants in particle form settle down at the bottom as the flow rate of the water slows down.

Surface water quality has been analysed rather seldom in Finnish studies of shooting ranges. In fewer than one third of the studies compiled for the summary was the sediment quality of the surface water, or drainage ditch, etc. from the range area analysed. However, at almost all sites where the analyses were carried out, lead, antimony, copper and zinc and/or arsenic were found to migrate from the shooting range via surface waters (Heinonen 2013). The surface water concentrations were compared with the background concentrations of Nordic lakes (Verta et al 2010). The 80th percentiles of the metal concentrations in lakes representing average humus content (water colour 30–90 mg/l Pt) were selected from the background concentration data. Tables 4.6, 4.7, and 4.8 present the distributions of the detected metal concentrations and the reference values used.

Pollutants were also found in the sediments of waterways flowing from the shooting ranges. The sediments were found to have accumulated lead, antimony, copper, zinc, and arsenic. Very high lead concentrations were found in the sediment in the vicinity of shotgun ranges (as high as 12,000 mg/kg). The variance was great in the

Table 4.6. The distribution of dissolved lead concentration and the total concentrations of lead and arsenic in the analysed surface water samples in the study summary of the 36 shooting range studies.

Concentrations in surface water	Total Pb	Soluble Pb	Total As
Household water limit value µg/l	10	10	10
Surface water environmental quality norm µg/l	-	7.2	-
Background concentration (Verta et al 2010, 80th percentile) µg/l	0.23	-	-
Distribution No. of observations			
<7.2 µg/l	6	2	9
7.2–10 µg/l	1	0	0
10–50 µg/l	4	3	2
>50 µg/l	7	3	0
n	18	8	11

sediment samples from pistol and rifle ranges, <10...1,100 mg/kg. A high antimony concentration was found only in a single sediment sample taken from a pond next to an old shotgun range, where the above-mentioned high lead concentration was also found; furthermore, the sample had a high arsenic concentration. There were only eight sediment samples in the summary study, two of which were from shotgun ranges and six from pistol and rifle ranges.

Table 4.7. The distribution of total copper, nickel and zinc concentrations in the analysed surface water samples in the study summary of the 36 shooting range studies.

Concentrations in surface water	Total Cu	Total Ni	Total Zn
Household water limit value µg/l	2000	20	-
Surface water environmental quality norm µg/l	-	20 (soluble)	-
Background concentration (Verta et al 2010, 80th percentile) µg/l	-	0.77	-
Distribution No. of observations			
<10 µg/l	11	15	1
10-100 µg/l	4	0	13
>100 µg/l	0	0	1
n	15	15	15

Table 4.8. Distribution of the total concentration of antimony in the analysed surface water samples in the study summary of the 36 shooting range studies.

Concentrations in surface water	Total Sb
Household water limit value µg/l	5
Surface water environmental quality norm µg/l	-
Background concentration (Verta et al 2010, 80th percentile) µg/l	-
Distribution No. of observations	
<1 µg/l	8
1-5 µg/l	7
>5 µg/l	0
n	15

Summary of the impact of shooting range operations on the soil and the surface and groundwaters

- The main pollutants from shooting range operations are heavy metals: at pistol and rifle ranges, particularly lead, copper, antimony, and zinc; at shotgun ranges, lead and antimony. The gunpowders used in the cartridges and their additives, such as nitroglycerin, may also be harmful to the environment.
- The erosion and migration of bullets and shot in the soil is slow as a rule. Shooting range pollutants do not usually cause immediate or short-term environmental impacts.
- The effect of the surrounding conditions on the erosion of bullets and shot and the dissolving of pollutants is significant. Erosion is accelerated by, in particular, the acidity and humidity of the soil.
- At pistol and rifle ranges, the pollutant load is mainly concentrated in the lower part of the backstop berm behind the target equipment (impact areas, 0...0.5 m), the target area, and the fronts of the firing stands, where the pollutants are in fine-grained form. The load in the range area is minor.
- At ranges with moving targets and modifiable ranges (practical, SRA), the load of the backstop berm is more evenly spread. In sports where metal targets are shot, such as in biathlon and silhouette shooting, the bullet fragments against the target, and fine metal fragments spread to the area surrounding the targets.
- At shotgun ranges, the heavy metal load spreads to the topsoil (0...0.1 m) of the entire range area, although it concentrates in certain sections.
- The clay pigeons used in shotgun shooting do not cause a significant risk of environmental contamination due to their pollutants.
- As a rule, the migration of pollutants into surface and groundwaters and the sedimentation of ditches and water bodies is likelier at shotgun ranges than on pistol and rifle ranges.
- During the preparation of this report, a summary and analysis was performed of the results of 36 studies carried out on Finnish shooting ranges, finding metal concentrations elevated from the background concentration in the surface and groundwaters of the shooting ranges. Concentrations exceeding the household water limit values were, however, relatively rare. The reliability and comparability of the study results are reduced by deficiencies in the planning of the studies, study methodologies, and reporting.
- One significant conclusion drawn from the above-mentioned summary analysis was the need for instructions on performing environmental studies at shooting ranges. See Appendix F for instructions on the assessment of the need for pollutant management at shooting ranges.

5 Possibilities for the management and reduction of pollutant emissions

Metal emissions from shooting ranges can be reduced or prevented with numerous different methods. This section presents technical solutions for the reduction of shooting range pollutant emissions that are in use or have been assessed to be effective but are often still at the development and testing stage. The presentation of the techniques does not attempt to describe all variations of the different methods; it focuses on the description of their functional principles and the solutions that are most commonly used or have been assessed to have the most potential. In addition to the presentation of the techniques, we assess their functional effectiveness and environmental impact, suitability and safety, and costs (2012 cost level). There is a short summary of each technique at the end of each subsection, while Section 6 presents a more extensive summary of the feasibility and suitability of the different techniques, and recommendations for the solutions required for different conditions.

In addition to the presented techniques, there are technical solutions in use and under development for which an insufficient amount of data was available at the time this report was being written, or to the use of which such uncertainties are linked that their use cannot be recommended without reservations. Such techniques include the use of alternative bullet and shot materials, and the reduction of the solubility of pollutants with the help of additives mixed into the range structures, described in Section 5.3.

5.1

Pistol and rifle ranges

The pollutant management methods suitable for pistol and rifle ranges can be divided into three main categories:

- Reduction of pollutant load
 - renovation of the backstop berm
 - bullet traps
- Prevention of pollutant migration
 - covering the backstop berm
 - liners placed inside the backstop berm, or sand trap
- Water management and, if necessary, treatment.

5.1.1

Reduction of pollutant load

Preventing or reducing the accumulation of pollutants in the structures of the shooting range can be used to reduce the risk of the substances migrating into the soil and further to surface or groundwater. The pollutant load can be reduced either by regularly removing the bullets embedded in the backstop berm or by using various types of bullet traps. Bullet traps collect the bullets behind the targets and enable their recovery without having to handle the soil in the backstop berm.

Renovation of the backstop berm

Screening or mass replacement of the impact areas

The spread of pollutants from earthen backstop berms can be reduced by regularly removing the bullets, which reduces the amount of pollutants released from them through erosion. Bullet removal affects both the total amount of bullet scrap and the increase in the reaction surface caused by bullet fragmentation. The required bullet removal frequency depends on, for instance, the amount of shooting, the bullets used, and the dissolution of lead in the prevailing conditions. Bullet removal can be implemented either by screening the soil in the impact areas or by replacing it completely.

In addition to bullet removal, the amount of dissolving pollutants can be reduced by regularly removing the surface layer of the backstop berm into which pollutants released from the bullets have accumulated.

A majority of the metal accumulated in the backstop berm can be removed by screening the soil in the impact areas forming behind the targets. Screens of different sizes can be used in the screening process. First, the larger pieces are removed from the soil using a coarser screen, after which the bullets can be screened out using a finer screen. The costs of screening depends on the desired effectiveness, soil type, size of bullet scrap, and the screening method used. Depending on the amount of soil, screening can be done manually or mechanically. The objective is that the screened soil can be returned to the backstop berm structure.

Screening gives the best result, when the grain size of the soil in the backstop berm is smaller than the bullets, and the soil does not contain organic materials. Screening can be carried out mechanically, for example, using a vibrating screen or a screening bucket. At small ranges, the screening can be done manually. Bullets can also be separated from the soil in other ways, such as methods based on the the different specific gravities or electromagnetic properties of different substances.

During the replacement of the soil in the impact areas, the impact areas should be removed as thoroughly as is possible considering the excavation technology available. Sand collapsed by erosion or bullet impacts should be lifted back to the impact areas, with clean sand added as necessary.

The bullet screening interval or the impact area removal interval depend on the annual number of rounds shot and the geochemical properties of the backstop berm. When the backstop berm is made of sand and the conditions are dry, around 10,000 rounds per firing stand or three to five years could be considered a suitable renovation interval. We also recommend carrying out bullet removal during any renovation of the impact areas for other reasons.

Screening equipment is portable, allowing the screening to be carried out on the site. There is not much experience in the use of a screening bucket in treating soil at shooting ranges in Finland, but in Belgium, for example, the method is used at the shooting ranges of the defence forces.

The use of screening as an environmental impact management method is described in the environmental permit application as part of the maintenance of the range structures. The screened soil is returned to the backstop berm, with clean soil added to the impact areas if necessary.

Treatment and final disposal of bullet scrap and soils

The following fractions are generated during the screening of soil containing bullets and replacing the soil in the impact areas:

- pure bullet scrap that can be recycled;
- contaminated soil containing bullets; and
- uncontaminated or contaminated soil not containing bullets.

A compilation of the categorisation and treatment information for waste generated in shooting range operations is presented in Section 15 (Part V).

Berm sand from which bullets have been removed and that is returned to the berm structure as part of the planned maintenance of the structure is not considered to be waste. If the sand cannot be returned into the berm structure, it is treated as clean or contaminated soil waste depending on its pollutant content.

If the bullets are not separated from the soil by screening, but the soil containing bullet scraps is removed from the shooting range as is, waste treatment must be planned separately. The final disposal of the soil masses in a landfill or its stabilisation and utilisation in the landfill structures is usually possible within the limitations of the properties of the waste, but final disposal in a landfill is in the last place of the treatment options listed in the Waste Act in order of priority. Provisions on the eligibility of waste to be disposed in a landfill and proving the said eligibility are laid down in the legislation (Government Decree on Waste 179/2012). Waste is delivered to a landfill or a consignee with a permit to receive the waste in question. The consignee may require a more specific determination of the waste quality (for instance, landfill eligibility testing).

Bullet separation is waste sorting and utilisation as referred to in the Waste Act. Clean bullet scrap separated from soil can be delivered to be recycled as metal waste. Bullet scrap separated from soil or collected in bullet traps is accepted at least by some metal recycling companies.

Bullet scrap containing soil is usually categorised as contaminated soil. Due to the solubility of lead, the waste batches may have to be treated as hazardous waste. A shipping document must be drawn up for the transport of soil waste, contaminated soil and hazardous waste, handed over to the waste transporter to be then handed over to the consignee of the waste. The shipping document is drawn up in two copies, and after the signature of the consignee, one copy is returned to the producer/possessor of the waste. The producer/holder of the waste must retain the shipping document or a copy of it for a period of three years.

With certain limitations, contaminated soil may be utilised in structures, such as noise berms. Utilisation requires a separate plan and an environmental permit. The utilisation can also be permitted as part of the environmental permit process for the shooting range operations.

Functional effectiveness and environmental impact

When correctly used, screening is an effective method of reducing the metal load in the range area and therefore the risk of spreading. However, there are some uncertainties inherent in the use of the method. Screening cannot remove pollutants bonded with fine soil particles or small pieces and dust separated from bullets, that are the most problematic with regard to the solubility of the pollutants. At old ranges, the mechanical handling of soil may even increase the solubility of pollutants through the metals bonded to soil particles and oxidation layers slowing down dissolution coming loose. The effect screening has on the solubility of pollutants has not been studied enough, yet. The method is best suited to be used at new or quite new shooting ranges when carried out at sufficiently regular intervals. At shooting ranges that have been in use for a long time and are located in groundwater areas, the use of screening as the only pollutant management method should be considered until the effects of screening on the migration of pollutants has been studied in more detail.

The reuse of screened soil in the impact areas reduces the consumption of natural materials and transport, and allows the recycling of bullet scrap as material.

The recycling of bullet scrap as material constitutes the utilisation of waste as a material, which is as a rule recommendable from the perspective of environmental considerations.

The delivery of bullet scrap and soil containing bullets to proper treatment reduces the environmental load at the shooting range. However, according to the order of priority laid down in the Waste Act, final disposal in a landfill is the last alternative. The separation of bullets from the soil going to final disposal and their recycling is recommended.

Utilisation of the contaminated soil complies with the waste treatment order of priority. The location and structures of the utilisation site must be carefully planned and the follow-up monitoring taken care of. The environmental impact of the utilisation depends on the site, structures, and environmental conditions. In the main, utilisation can be considered to be preferable for the environment, as it reduces the need for transport and virgin materials.

The on-site intermediate storage of the bullet scrap is not considered to cause any significant harm to the environment, if the bullet scrap is properly stored, preventing water from getting into contact with the bullet scrap. Waste storage should be discussed in the environmental permit.

Suitability and safety

Mass replacement and screening of the impact areas are technically suitable for use at most pistol and rifle ranges. At ranges with moving targets, the bullets are spread in a larger area of the berm instead of individual impact areas. In practice, bullet removal requires processing the soil in a larger area. At silhouette shooting, biathlon and other ranges where the pollutants are spread over a wide area – practically everywhere else but the backstop berm – the method is poorly suitable.

Replacement of impact areas can reduce the risk of ricochets caused by the bullet scrap.

Costs

When the structure of the backstop berm at the shooting range remains unchanged, the use of the method does not incur investment costs. The delivery of bullet scrap or soil to treatment and, when necessary, adding soil into the impact areas will incur operating costs.

The costs of impact area replacement is estimated at around EUR 10,000 at a 20-stand range (including earthworks, transports, reception of the contaminated soil, and refill materials carried out as work contracted out). At a corresponding range, the renovation costs of the entire berm is estimated at EUR 30,000...100,000, depending on how contaminated the soil is and how thick the contaminated layer is.

When soil is reused in the berm structure, the overall costs are smaller compared to the replacement of the impact areas. Screening saves the transport and reception costs for contaminated soil and the price of the replacement material. The mechanical screening of the material in the impact areas of the backstop berm at a 20-stand range is around EUR 2,000...5,000. At small ranges, screening is often more expensive than at large ranges when examined relatively, as the general work site costs are in the same ballpark regardless of the size of the range.

The reception costs for the final disposal of soil containing bullets or contaminated by metals depend on the soil's eligibility for a landfill. If the soil can be delivered to a regular waste landfill, its price is around EUR 0...20 per ton. At hazardous waste landfills, the reception price is around EUR 100 per ton. Costs are increased by excavation and transports, and the landfill eligibility testing. The price of a landfill eligibility test is around EUR 1,500 per sample. The total price of the renovation depends on the amount of soil, reception place and transport distance.

Bullet recycling is not currently economically profitable in Finland. Although the brass jacket and lead core of the bullet both contain metals that are valuable as such, their recyclability is low when combined. Bullet scrap does not therefore currently have a large monetary value. Bullets must be transported to Central Europe for

Summary of backstop berm renovation

Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Mass replacement at impact areas	The soil in the impact areas containing the most bullet scrap is removed regularly. The removal interval depends on the number of shots, recommended 3...5 years.	Significantly reduces the load on the range structures. Particularly effective at new ranges when used regularly, allowing the removal of the most significant part of the bullets. At old ranges, some of the load is often deeper in the backstop berm and not affected by the technique.	Good. Mass replacement of the entire impact area may be difficult with regard to excavation technology and requires planning.	Suitable for pistol and rifle ranges where the bullets accumulate in the impact areas. Often expensive on the long term.
Screening of the impact areas	The soil in the impact areas containing the most bullet scrap is removed regularly. The screening interval depends on the number of shots, recommended 3...5 years. The bullets are screened out of the soil that can then be returned to the structure or disposed of as waste. The bullets can be recycled.	Effective at new ranges when used regularly, allowing the removal of the most significant part of the bullets. Questionably effectiveness at old ranges. Fine-grained metal remains in the berm, and disturbing the soil may increase the solubility of the metals. The spread of dust with metal content must be controlled.	Good. Can be carried out mechanically using different techniques, or manually. Screening of the entire impact area may be difficult with regard to excavation technology and requires planning.	Limited suitability for pistol and rifle ranges where the bullets accumulate in the impact areas. At old ranges, there is the risk of the metal particles attached to the soil become mobile. Most usable at new ranges at sites where the reduction of load is considered to be a sufficient measure.
Removal of bullet scrap and soil in their entirety	The contaminated soil containing bullet scrap is removed and transported away from the area. Requires quite extensive earthmoving work. The soil and bullet scrap can be separated by screening.	Effective management of pollutants. Eliminates the need of water management when carried out regularly. The mass replacement work causes some dust generation. Regularly causes the contamination of clean soil brought to the site.	Good/moderate. Requires a plan made by an expert. Mass replacement requires quite extensive earthmoving work.	As a risk management method, effective in principle, but an expensive solution that has poor eco-efficiency.

recycling, and the price received will likely not cover the transport costs, unless the transport batches contain a large quantity of bullets.

Bullet traps

The purpose of bullet traps is to try to collect the bullets during firing as a fraction that is as pure as possible, and prevent the migration of the pollutants contained by the bullets. The traps can be used as additions to the backstop berm, or in some case, they can replace the backstop berm entirely. There are different kinds of bullet traps, and they can be divided into three categories based on their operating principle:

- bullet traps with a filler material that makes a bullet lose its energy and stop 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.

Bullet trap structures usually require a backstop berm or protective wall behind them in case of missed shots.

Metal bullet traps

Plate and Pit

The bullet trap comprises a steel plate installed at an angle of at least 25 degrees relative to the bottom of the trap. When a bullet hits the plate, it fragments into small pieces that are directed into sand below the plate (Figure 5.1.) (Action target academy). This type of bullet trap requires relatively lot of maintenance. The steel plate must be replaced due to wear. Lead must also be removed from the sand, or the sand replaced at certain intervals, which incurs costs. (Navy Environmental Health Center)

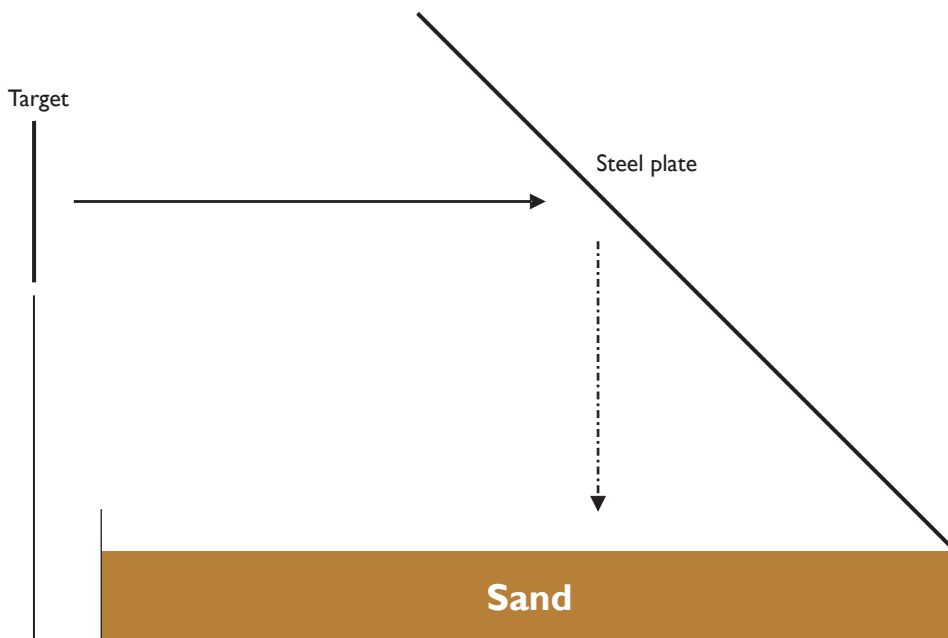


Figure 5.1. Pit and Plate bullet trap.

Venetian Blind

The bullet trap comprises several steel plates installed behind the target that are at an angle of around 35 degrees down from horizontal in relation to the direction from where the bullets come (Figure 5.2.) (Nikula et al 2005). The bullets are redirected into horizontal chambers with the steel plates. The problem of this bullet trap is the resulting ricochets and the generated lead dust. (Partridge 2000)

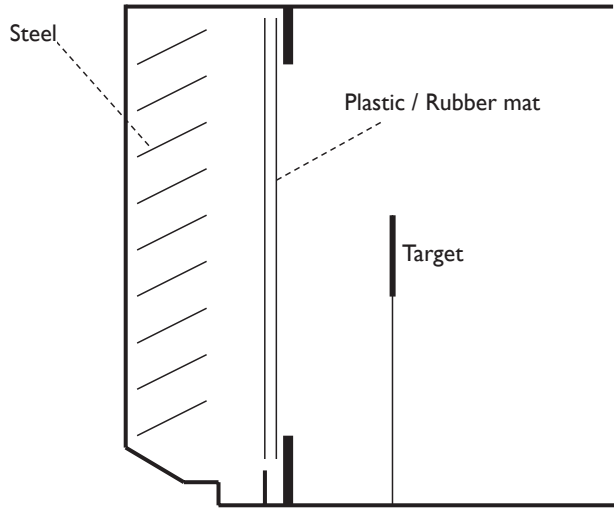


Figure 5.2. Venetian Blind bullet trap.

Escalator bullet trap

In the escalator trap, bullets hit a steel plate that has been installed at an angle of around 30 degrees. The steel plate redirects the fragmented bullets into an open collection container. Some manufacturers recommend oiling the steel plate in order to reduce fragmentation.

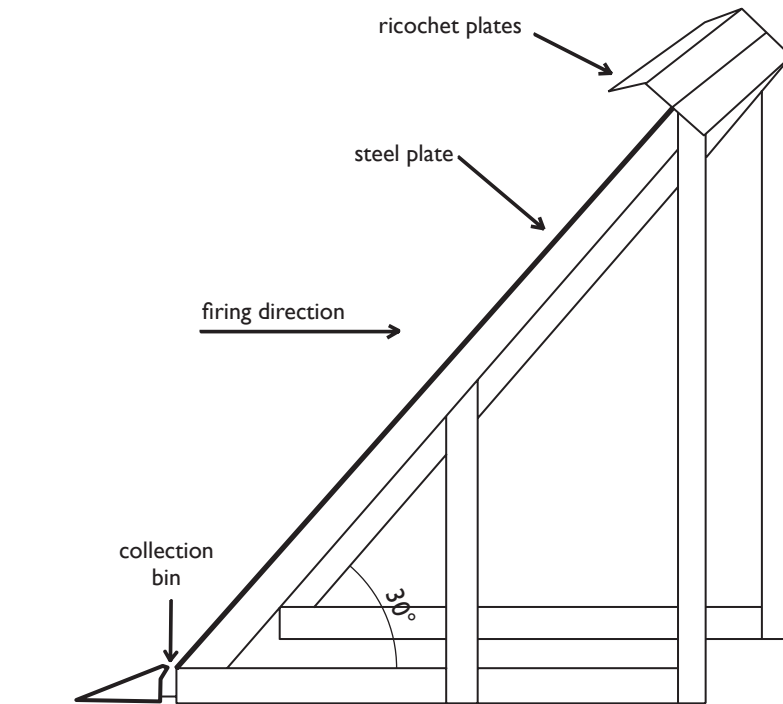


Figure 5.3. Escalator bullet trap.

Snail Trap

Snail Trap (a trademark) is a steel bullet trap comprising two slanted steel ramps that redirect the bullets into a circular deceleration chamber (Figure 5.4. and Figure 5.5.). The bullet revolves in the chamber until it falls down into a bullet collection container. The bullets collected into the container are banged up but mostly whole, and no lead dust can spread into the air. (Proact Cross Talk 2003)

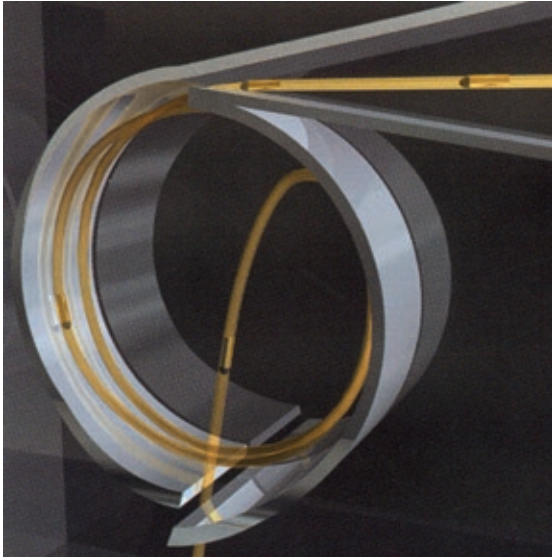


Figure 5.4. Snail deceleration chamber (Savage Range Systems 2010).

The steel structures used to redirect the bullets into the bullet collection chamber are at an angle less than 12 degrees to the ground/floor level. (Proact Cross Talk 2003)

Snail bullet traps are available in both wet and dry versions. The dry versions are mainly used at outdoor ranges, particularly in cold climates where the fluid might freeze. (Nikula et al 2005).

Maintaining the steel bullet trap structure is rather simple, and is mainly based on monitoring the condition of the chamber, emptying out the collection containers, and oiling the moving parts. The metal parts of, for example, the bullet collection chamber must be eventually replaced. According to the manufacturer, the replacement interval is over 10 years. (Nikula et al 2005).

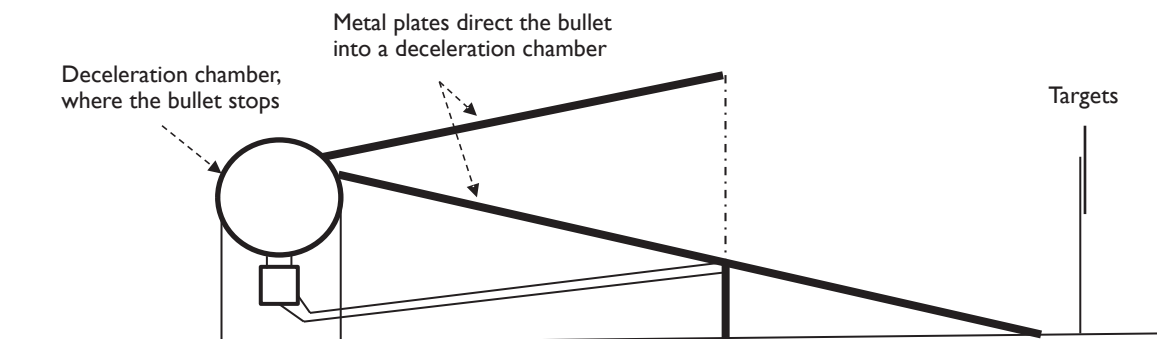


Figure 5.5. Snail deceleration chamber.

Total Containment Trap

The operational principle of the Total Containment Trap-TCTTM by Action Target (Figure 5.6.) is similar to the Snail bullet trap. The bullets travel along steel plates into the "throat" of the bullet trap and further into the deceleration chamber, where they revolve, losing their kinetic energy and falling down on the bottom of the chamber. A conveyor can be installed at the bottom of the chamber that conveys the bullets into a collection container. The TCT trap also includes an exhaust air suction system that prevents dust emissions. (Action Target 2011)

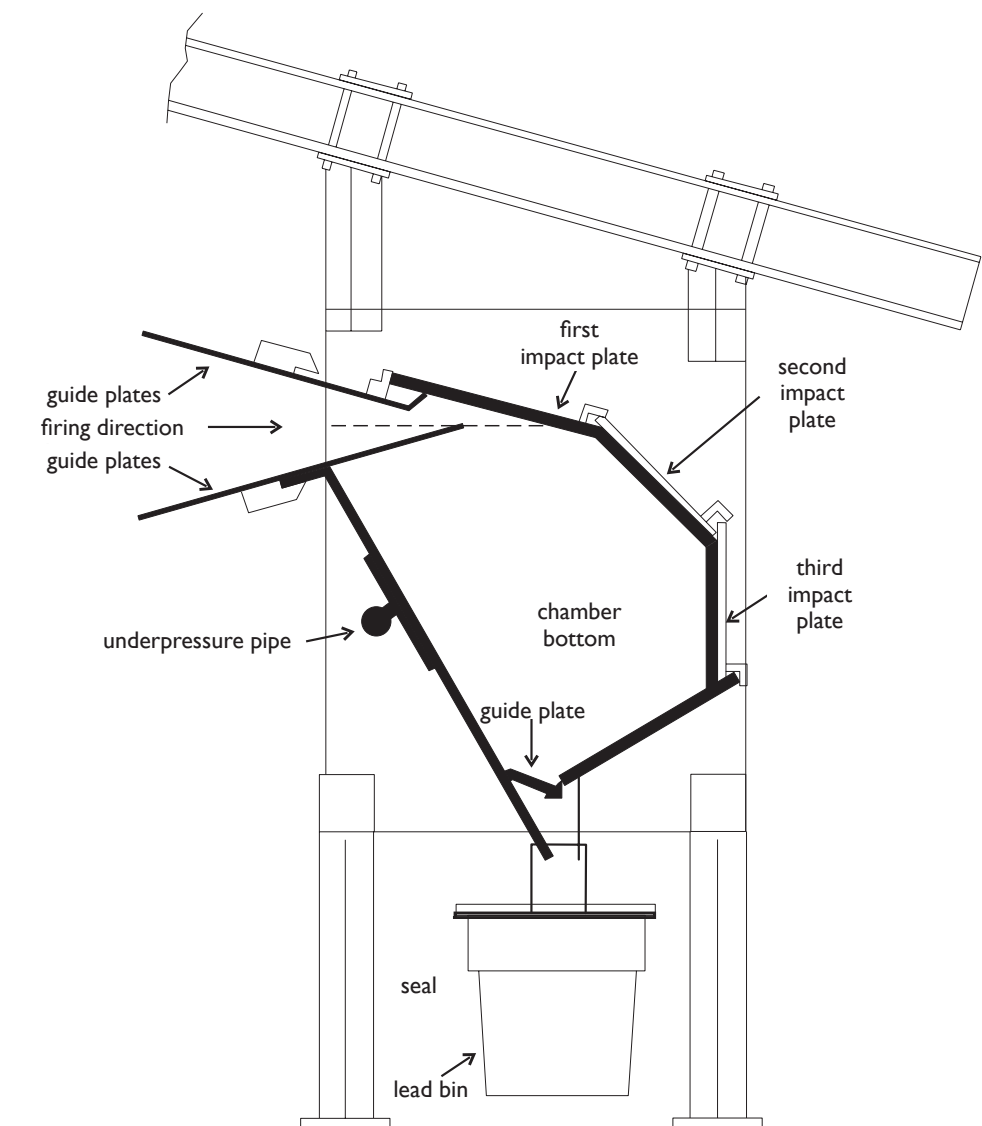


Figure 5.6. TCT bullet trap.

Simple steel and other bullet traps

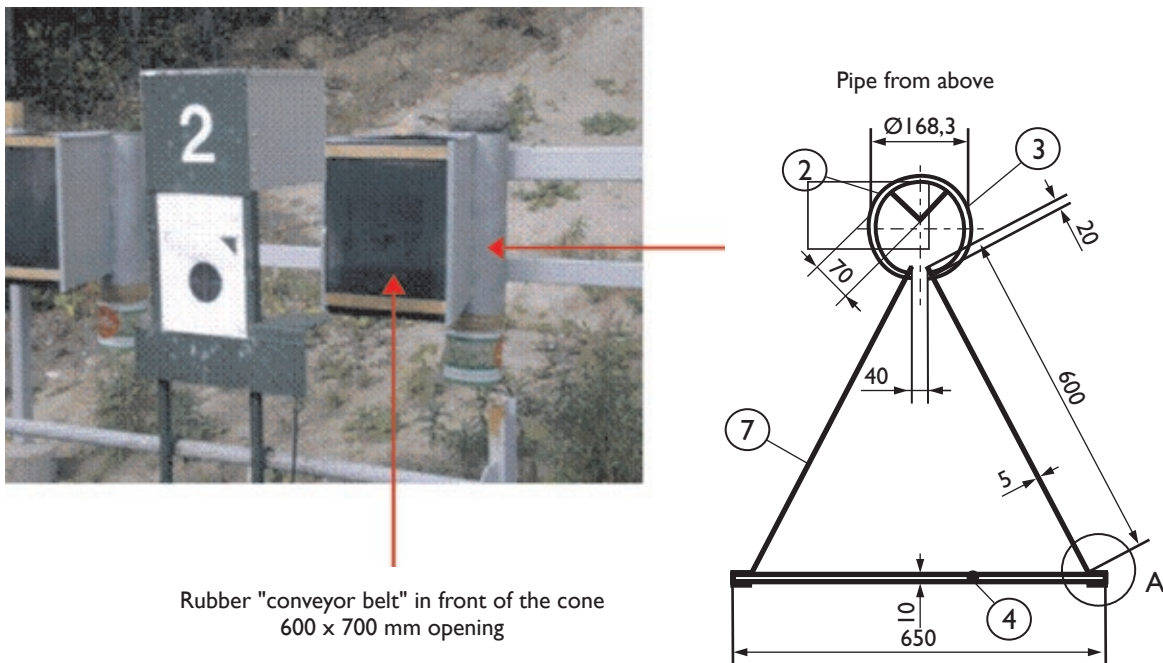
Shooting clubs have designed and commissioned various bullet traps for, in particular, pistol and .22 LR rifle ranges, that have been found to be relatively effective in practice. In 2002, for example, Nokian Seudun Ampujat ry installed bullet traps at all of its pistol and rifle ranges (Figure 5.7.). The bullet traps are manufactured from 5 mm steel plate based on the club's own design. The bullet trap's structure is conical, directing the bullets into a vertical pipe with a diameter of 200 mm. One side of the pipe has a 50-mm opening from which the bullets can enter the pipe. The bullets do not revolve inside the pipe for a long time: a steel angle bar stops the bullets, after which they fall down to the bottom of the pipe. The bullet trap is manufactured from hot galvanised steel. (Nikula et al 2005). By 2011, the steel plates do not show significant wear, but wear is evident in the metal brackets at the front of the bullet trap. Wear is caused by missed shots and shooting with firearms with a calibre larger than .22. Wear causes an estimated maintenance need of the brackets every 5...10 years. (Ilkka 2011)

There is a rubber mat in front of the cone, made from an old conveyor belt. Its purpose is to prevent dust from bullets entering the cone and ricochets from exiting the bullet trap. The rubber mat has been repaired by gluing patches when necessary (around twice a year). (Nikula et al 2005). Instead of a rubber mat, also cardboard sheets are used in front of the bullet traps. (Ilkka 2011)

Bullets are removed from the traps twice a year. Bullets collected in the traps (Figure 5.8) are delivered to recycling annually. (Nikula et al 2005.) In the future, the intention is to collect lead from the bullet traps more often, allowing more effective separation of bullets/bullet jackets made from different materials from each other. (Ilkka 2011)

Steel bullet traps similar to those in Nokia are used by shooting clubs also elsewhere in Finland. Another type of a simple steel bullet trap model is used at, for example, the Jurva shooting range. In the model in question, there is a metal box behind the target. The bullets hit its back wall and fall down on the bottom of the box

Bullet trap at Nokia.



Rubber "conveyor belt" in front of the cone
600 x 700 mm opening

Figure 5.7. Steel bullet trap at the Nokia shooting range.

(Figure 5.9). The rubber/neoprene mat over the trap opening slows down the bullets and prevents dust from spreading.

In Koivujärvi, at the 25-metre pistol range of the Finnish Defence Forces, bullet traps called pipe traps have been used since 2002. The bullet traps at the pistol range are horizontal plastic pies filled with sand (Figure 5.10.), which allow the bullets hitting the target to be managed. (Nikula et al 2005).

During their service life between 2002 and 2013, a total of around 42,000 shots have been fired into the five pipe traps at the Koivujärvi pistol range. The traps have not been renovated, and the sand in them has not yet been replaced. A majority of the bullets hit the traps and are captured by them. (Kralik 2014).

At the Koivujärvi pistol range, the bullet traps have worked well, but based on the current usage experience, it is difficult to estimate whether bullet traps of this type would work at rifle ranges.



Figure 5.8. Fragmented bullets from steel bullet traps.



Figure 5.9. Jurva bullet trap from front and back.



Figure 5.10. Bullet traps at the Koivujärvi pistol shooting range (photo: Finnish Defence Forces).

During the preparation of this report, there is a solution for .22-calibre firearms under development in Finland, where the target devices and the filler material used to stop the bullet – such as rubber grindings – are, in practice, enclosed within a metal case. The technique is at prototype stage and is being used in biathlon that is particularly challenging with regard to pollutant management.

Targets, such as the biathlon targets presented in Figure 5.11, are placed in a metal container (for example, a shipping container). A container filled with rubber grindings is placed behind the cardboard targets to collect the bullets. When bullets hit the metal targets during biathlon competitions, they fragment, but the fragments remain in the container and do not spread into the environment. The metal fragments and dust can be removed from the container, for example, by hoovering. Optimally, the bullets can be recovered almost completely with the help of the container.

The container is placed in front of a traditional backstop berm that acts as a safety structure. With heightening, the containers could possibly also be utilised as, for instance, noise barriers.

Figure 5.11 presents an implementation of the container solution.

One benefit of the container solution is the weather protection it provides to the target devices. Furthermore, the lockable container protects the devices from vandalism and prevents unauthorised shooting.

Concrete bullet traps

SACON™ (Shock-Absorbing Concrete) is a low-density, fibre-reinforced, "foamed" concrete developed by the U.S. Army Engineer Research and Development Center (ERDC). SACON is a fire-proof material that can be fabricated in any shape whatever, which enables its use in a variety of applications. SACON was developed for use during combat shooting to minimise ricochets. Its shock-absorbing effect also acts as a bullet trap collecting small-calibre bullets. In a well-designed SACON™ structure, the bullet becomes embedded in the concrete structure upon impact. (US Army Environmental Center 1999)



Figure 5.11. Biathlon target equipment and bullet traps installed in a shipping container, prototype (photo: Pauli Harjula).

A SACON™ structure could possibly be used instead of a backstop berm, and as a protective barrier in front of the targets. A SACON™ structure is portable, and no fixed firing stand is required with its use. The technical characteristics of the structure could thus be suitable for tactical and combat ranges, etc., and temporary shooting ranges.

Rubber grinding bullet traps

A product by the Swedish Stapp AB, Bullet Catcher, was tested by the Swedish Defence Forces, following which the method was approved for the shooting ranges of the SDF in 1998. As a rule, Stapp AB's bullet trap is suited to 12-calibre firearms and smaller. There are also similar products by other manufacturers in the market. (Nikula et al 2005).

The bullet trap is installed in an earthen embankment over support structures. The structure contains a watertight film, drain pipe, rubber grindings for the filler, and a rubber surface layer. The surface layer limits moisture and dirt from getting into the structure. An example of a rubber grinding bullet trap is presented in Figure 5.13.

Another bullet trap structure based on rubber grindings is the model used by the German Army, where the rubber grindings are inside a box covered with HMPE film (Figure 5.14.). In Germany, the bullet trap in question has been used since 1993 at a total of over 150 shooting ranges. The film used in the structure withstands around 15,000...20,000 shots, after which the bullet trap can be turned around and the same number of shots can be fired. The rubber grindings can be removed from the box by hoovering, and the bullets can be separated from the rubber grindings. (Nikula et al 2005).



Figure 5.12. Sacon bullet trap during construction phase (Terran Corporation 2011).

Functional effectiveness and environmental impact

With regard to bullet recovery, the solutions presented above can be considered to be rather equal. Almost all bullets fired can be recovered in the bullet traps with the exception of misses. In Nokia, for example, lead loss has been under 1% when the number of shots fired and the mass of the recovered bullets has been compared (Nikula et al 2005). The SACON™ structure has been studied in the United States at a 25-metre shooting range, where 87% of the bullets could be recovered into the structure. A majority of the remaining bullets were in a pile in front of the SACON™ structure (US Army Environmental Center 1999). In studies performed by the U.S. Army Environmental Center, the recovery efficiency of a steel bullet trap with a deceleration chamber was determined to be 79% (Fabian 2000). Snail Trap and TCT are bullet traps with a deceleration chamber.

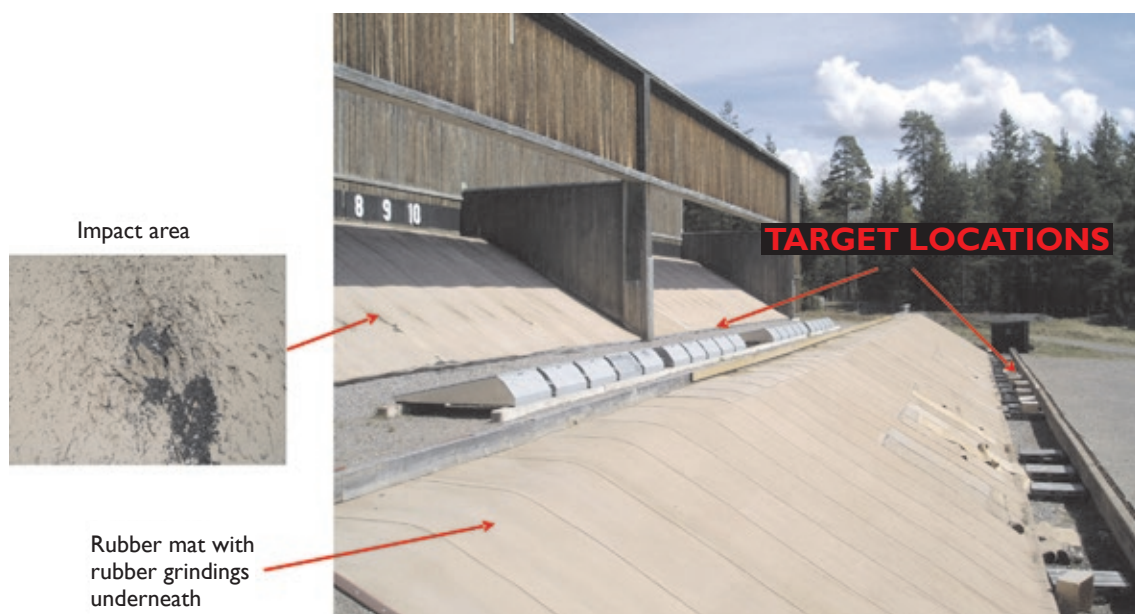


Figure 5.13. Rubber grinding structure (Stapp AB) at a 300/150 m rifle range in Sweden (Nikula et al 2005).

Recycling of bullet scrap works best with solutions where the bullets can be recovered as such without filler material that becomes contaminated. Bullet scrap can be recovered in pure form from metal bullet traps (with the exception of a Pit and Plate bullet trap). In bullet traps filled with rubber grindings, the bullets need to be separated from the rubber grindings, and foamed concrete crumbles from the SACON™ structure and gets mixed in with the bullet scrap. In a Pit and Plate bullet trap and a pipe bullet trap, metals get mixed up in the sand in the structure, and all of it cannot be separated. In container solutions, some of the bullet materials can be removed from



Figure 5.14. Rubber grinding box used in Coesfeld, Germany (Nikula et al 2005).

the bottom of the container by hoovering, while some needs to be separated from the rubber grindings. The amount of grindings is, however, small in this solution.

Rainwater getting into contact with the bullet scrap increases the contamination risks of surface and groundwater. For this reason, water getting into the bullet scrap must be prevented, for example by covering the open collection containers. According to the Swedish experiences, water does not accumulate inside a Stapp rubber grinding structure, as the temperature inside the rubber grindings is so high that water evaporates (Nikula et al 2005). Rainwater can get into the SACON™ structure and the bullet scrap mixed up with foam concrete in front of it. However, the structure's water permeability is low, and its alkalinity reduces the solubility of lead (US Army Environmental Center 1999). No data is available for the solubility of other substances, such as antimony, in the structure. In the container solution, the target devices and the filler material used to stop the bullets are covered, and water cannot get into contact with pollutants. The solution is also suitable for use in groundwater areas..

Bullet fragmentation in a bullet trap generates metal dust that can migrate into the soil and the surface and groundwater. Fragmentation takes place in almost all metal bullet traps. According to the manufacturers of the Snail Trap and TCT, bullets remain intact in these traps; TCT also includes a dust management system. In studies made by the U.S. Army Environmental Center, lead concentration was measured in five spots around a steel bullet trap with a deceleration chamber, and the lead concentrations

in the air exceeded the intervention limit (0.03 mg/m³) on both sides of the bullet trap and in the exhaust air of the bullet trap's ventilation (Fabian 2000). In rubber grinding bullet traps, the bullets remain rather intact, and dusting is minor. In pipe bullet traps with sand used as filler material, the bullets remain more intact than in metal bullet traps. In the container solution, fragments and dust remain inside the container, and there is no migration of pollutants.

In 2011, soil samples were taken at the Nokia shooting range from the target area and underneath the bullet traps. High lead concentrations (4,000...30,000 mg/kg) and elevated concentrations of antimony, copper, and zinc were detected in the surface layer of the range, but there were no bullets or bullet fragments visible to the naked eye. This suggests that the metals are present in fine-grained form. Simple bullet traps of the type used at the Nokia range thus do not fully prevent pollutants from getting into the range structures, although they significantly reduce the pollutant load. Covering the target area, as has been done in Nokia, prevents the pollutants from sprading into the environment (Ramboll Finland Oy 2011).

Bullets hitting metal bullet traps generate noise, unlike shooting into rubber grindings (Nikula et al 2005). However, the noise from the bullet traps is rather insignificant compared to the noise from shooting.

Suitability and safety

Metal bullet traps where the bullets hit a steel plate in a steep angle (Pit and Plate, Venetian Blind, Escalator Trap) may cause a ricochet hazard. Because of the ricochet hazard, the front of the bullet traps should be covered with a rubber mat or other suitable covering. In a Pit and Plate bullet trap, bullets hitting the old bullets at the bottom of the structure may also cause a ricochet hazard. For this reason, the structure should be maintained sufficiently often. Rubber mats used in the front of the bullet traps may cause a ricochet hazard when certain low-powered firearms and cartridges are used, and the bullet hits the rubber mat with a low velocity (Nikula et al 2005).

The TCT and Snail bullet traps are different from the other bullet traps based on steel plates; their steel plates are at a shallow angle in relation to the bullet's entry vector instead of a steep angle. The steel plates at a shallow angle do not fragment the bullets or cause ricochets. There are no vertical parts in the structure that might cause ricochets. For this reason, shooting does not have to be perpendicular to the bullet trap structure. (Action Target 2011)

In metal bullet traps, other structures than the actual bullet-catching plate may also cause a ricochet hazard. For example, the external steel structures of bullet traps of the type used at the Nokia shooting range may cause a ricochet hazard into the target pits. Due to the ricochet hazard, bullet traps cannot be recommended for use with firearms of a calibre larger than .22 without further study. For smaller-calibre firearms, most bullet traps are considered to be suitable at short firing distances.

Bullets will not ricochet from the structure surrounding the rubber grindings of the Stapp structure even in cold weather conditions or at short firing distances. The other sample structure, or a box filled with rubber grindings, is also a safe solution. The materials withstand shooting at a temperature of -28°C, and their cold endurance is -40°C (Nikula et al 2005). In hot and warm weather, the rubber grinding constructions may cause a risk of fire (Fabian 2000). The rubber grindings are usually treated with chemicals the purpose of which is to prevent it from catching fire due to shooting (Nikula et al 2005).

In pipe traps, the risk of ricochets is lower compared to metal bullet traps, as they are made from plastic. The risk of ricochets is, however, higher than with the backstop berm solution.

Due to the ricochet hazard and the size of the bullet trap, a majority of the bullet traps cannot be used when shooting at moving targets. Solutions suitable for shooting

at moving targets are the Stapp structure and, possibly also TCT. Neither are a majority of bullet traps suitable for practical or SRA shooting, where the range construction and the locations of firing stands and targets are different each time. For such modifiable ranges, the rubber grinding wall could be the only suitable bullet trap structure.

Costs

Commercially available trademarked bullet traps (Stapp, SACON™, Snail, TCT) are significantly more expensive compared to the other bullet trap solutions.

The rubber mat used as surface material on the Stapp rubber grinding bullet trap wears in use and requires patching after each 5,000...10,000 rounds. The rubber grindings are screened or replaced every 7...8 years. Taking into consideration the investment costs and operating costs, the estimated costs at a 20-stand rifle range over 20 years are around EUR 415,000 (Smolander et al 2010). Estimated per firing stand, the costs are around EUR 20,000.

SACON™ needs refurbishment after around 7,000 rounds. In practice, the refurbishment means the rebuilding of the entire structure. Taking into consideration the investment costs and operating costs, the estimated costs at a 20-stand rifle range over 20 years are around EUR 875,000 (Smolander et al 2010). Estimated per firing stand, the costs are around EUR 44,000. The waste management costs incurred by the dismantled structures must be added on top of that.

The estimated investment costs of the Snail bullet trap at a 20-stand rifle range are around EUR 260,000 (Smolander et al 2010). According to the manufacturer (Action Target), the estimated investment costs of the TCT solution at a 200-metre, 10-stand rifle range around EUR 250,000 including installation. The price does not include shipping costs. Steel bullet traps require relatively little maintenance. Calculated per firing stand, the estimated investment costs of the Snail bullet trap are around EUR 13,000 and of the TCT, around EUR 25,000.

The costs of simple steel and pipe bullet traps commissioned for the site vary, but compared to commercial bullet traps, the solutions are affordable. The safety and durability of these structures has not, however, usually been tested.

A used shipping container used as the shell for the container solution costs around EUR 1,000...2,000. The construction also requires, for instance, building a front wall that can be opened, installing rubber grindings behind the targets, and the installation of the target devices.

Summary of the bullet trap structures

Table 5.1. compares bullet trap structures with the traditional backstop berm and gives them a + if a feature is in favour of implementation, a - if a feature is not in favour of implementation, and a 0 if there is no significant difference between the solutions.

5.1.2

Prevention of pollutant migration

Pollutants migrate from the backstop berm into the environment along water. For this reason, pollutant migration can be prevented either by preventing water from getting into the backstop berm or by preventing the uncontrolled discharge of water from the backstop berm into the environment.

Covering the backstop berm

The backstop berm can be covered, preventing rainwater from leaching the soil of the backstop berm. Redirecting water to the outside of the backstop berm reduces erosion and the water-borne migration of pollutants in the structures deeper into the soil and groundwater.

Table 5.1. Comparison of bullet trap structures and a backstop berm.

	Dusting	Recycling	Noise	Ricochet hazard	Costs
Plate and pit	–	+	–	–	–
Venetian Blind	–	+	–	–	–
Escalator bullet trap	–	+	–	–	–
Snail trap	+	+	–	0	–
Total Containment trap	+	+	–	0	–
Simple steel bullet traps	–	+	–	–	+
Pipe trap	+	+	0	–	+
Container solution	+	+	+	–	+
Concrete bullet traps	+	–	+	+	–
Rubber grinding bullet traps	+	0	+	+	–

+ feature in favour of implementation compared to backstop berm
 – feature not in favour of implementation compared to backstop berm
 0 no significant difference

Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Metal bullet traps	Bullets are stopped and collected with metal bullet traps installed behind the target devices. The bullets are stopped by a deceleration chamber, plate, or other obstacle.	Pollutants can be mostly managed. Bullets are fragmented in some of the bullet traps, generating metal dust. May be a problem, particularly with non-commercial, self-designed implementations. A rubber/neoprene sheet can be used with them in front of the mouth of the trap to slow down the bullet and prevent the spreading of dust. Dust management with suction equipment is recommended for some of the bullet traps; they are best suited to indoor ranges. At other ranges, possible solutions include covering the spreading area of dust. Minor load from missed bullets. Water must be prevented from getting into contact with the bullet scrap, which eliminates the generation of water with pollutant concentration to a large extent.	Good. Commercial solutions are available; own implementations have also been designed at many ranges.	Well suited to .22-calibre firearms, with several alternative solutions available. Models suitable for rifle ranges have not been tested in Finland, but they are in use elsewhere. As a rule, are not suitable for ranges that have moving targets or can be modified (e.g. practical), or silhouette shooting and biathlon ranges.
Rubber grinding bullet traps	The bullets are stopped by a layer of rubber grindings covered by a rubber mat in the surface of the backstop berm. Alternatively, the rubber grinding trap can be, for instance, of a box type.	Effective management of pollutants. Bullets remain in the rubber grindings, and the surface layer prevents water from getting into contact with the bullets, thus eliminating the generation of water with pollutant content.	Moderate, commercial applications available in, for example, Sweden and Germany	Suitable for most pistol and rifle ranges. Not for silhouette shooting or biathlon ranges.

The cover can be constructed from steel, concrete or wood. See Figure 5.15 for a drawing in principle of a backstop berm cover structure. In front of the berm, the cover should reach over the target area so that the bullets accumulated in the vicinity of the targets and at the base of the berm are protected. The structure should cover the impact areas detectable in the berm in a sufficient manner; extending the cover over

the backstop berm in the manner depicted in Figure 5.15 is, however, not required, although it may be purposeful for structural reasons.

The cover requires continuous maintenance in order to prevent holes.

Sand trap

A sand trap refers to a structure akin to an earthen berm, where the spreading of lead deeper into the soil and the groundwater is prevented by liners. The liner can be made from, for example, bentonite matting, watertight membrane, asphalt or concrete, or a combination of these. Water percolating into the backstop berm is collected from the surface of the liner into underground drainage.

The quality of water collected from a sand trap is easy to monitor. If the percolated water is found to contain elevated pollutant concentrations, the surface layer of the sand trap can be replaced or the percolated water can be treated. Water treatment methods are presented in Section 5.1.3.

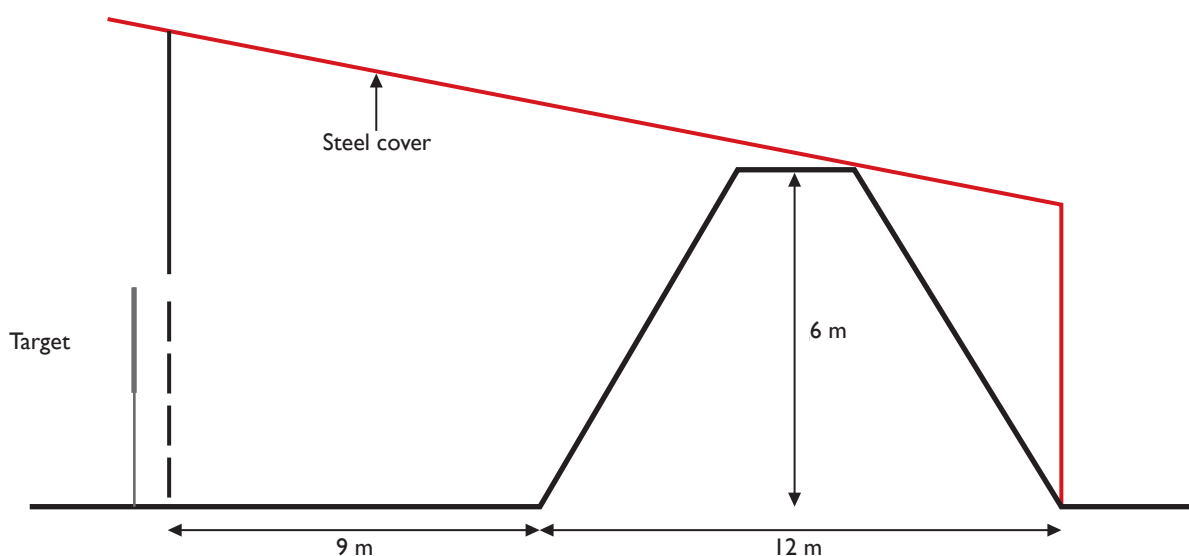


Figure 5.15. Drawing in principle of the backstop berm cover structure (Smolander et al 2010).

In order to function, the sand trap must be a watertight structure. When bentonite matting and membrane is used, the storage and installation of the materials requires professional skills, suitable equipment, and supervision of the installation work. A sufficiently wide working area for the machines should be left between the sand trap and the targets, and the structure must withstand mechanical sand replacement. A layer protecting the liner can be installed on top of the sealing layer, separated from the topsoil with a strainer so that the protective layer is easy to identify during maintenance work.

Materials reducing the solubility of pollutants presented in Section 5.3.1 can be used in connection with a sand trap structure. Data on them is currently insufficient for us being able to recommend the method, but the solution is being studied, particularly by the Norwegian Defence Administration.

During the preparation of this report, indicative sample designs have been drawn up for three different types of sand trap structures. The sample designs are included as Appendix D1 (bentonite mat), D2 (plastic membrane) and D3 (asphalt liner).

Sand traps have also been implemented as covered versions; in Norway, for instance, a structure has been tested where a concrete basin filled with sand has been covered with a wooden cover. Shipping containers and other box structures have also been filled with sand and placed behind the targets. Covering eliminates the need for

percolating water management, as there will be none. The structures may, however, cause a ricochet risk and make maintenance more difficult.

Functional effectiveness and environmental impact

Covering the backstop berm may cause the soil to generate dust, as the soil is dryer than without the cover. Dust may spread to the vicinity of the berm, but wider spreading is unlikely. People may be exposed to dust mainly in the target pit, if one is in use.

Rainwater is unable to leach the polluted soil of a covered backstop berm, due to which the migration of pollutants from the backstop berm into surface and groundwater is prevented. Missed shots and ricochets make holes into the cover, requiring regular maintenance.

A sand trap structure can be used to recover any water-borne pollutants percolating through the backstop berm. If necessary, the percolating water can be treated in a centralised location, resulting in an effective reduction of pollutant load on surface and groundwater.

Suitability and safety

A protective barrier above the targets may be necessary in order to protect the cover (avoiding holes) and reduce the number of ricochets.

Installing a cover and a liner structure (sand trap) for the backstop berm is suitable for most pistol and rifle ranges, also those with moving targets as well as practical and SRA ranges. However, the solutions as described are not suitable for biathlon or silhouette shooting ranges.

Costs and maintenance

The costs of the cover structure vary a lot depending on the selected material and the size of the cover. According to an analysis by the Aalto University, the investment costs of a steel-framed cover (length 50 metres, width 21 metres, column interval 5 metres) are around EUR 260,000 (Smolander et al 2010). The cover requires constant maintenance, but the maintenance costs are relatively low.

The costs of a sand trap structure with a bentonite, plastic membrane, or asphalt liner for a 20-stand shooting range come to around EUR 40,000...50,000. This kind of structures have been implemented at the shooting ranges of the Finnish Defence Forces in 2012–2013.

The mass containing most bullets can be replaced from the impact areas of a covered backstop berm and a sand trap at suitable intervals, for example, every ten years. The replacement time is determined by the increase in ricochet hazard caused by the bullets accumulating in the impact areas. In the case of a sand trap, mass replacement may also be needed if the pollutant concentrations of the percolating water increase to harmful levels, and the operator either does not wish to treat the water, or water treatment does not achieve good enough results.

Covering the backstop berm may make the repair and maintenance work on the backstop berm more difficult, if sufficient working space for the machines is not left underneath the cover. In the case of a liner solution, sufficient movement space for machines should also be left between the targets and the sand trap.

Summary of the prevention of pollutant migration at pistol and rifle shooting ranges

Table 5.2. presents a summary of the features of structures intended for the prevention of pollutant migration and gives them a + if a feature is in favour of implementation, a - if a feature is not in favour of implementation when compared with a traditional, uncovered backstop berm. If there is no difference between the solutions, the feature is given a 0.

Indicative sample designs have been drawn up for three different types of liner structures installed inside a backstop berm, see Appendices D1–D3.

5.1.3

Water management and treatment

Water management at a shooting range means the minimisation of the amount of water getting into contact with pollutants, the controlled collection of water with pollutant content, and its redirection into monitoring and, if necessary, treatment. At pistol and rifle ranges, this particularly refers to the redirection of waters outside the range area past the range area, and the collection of water from the backstop berm and, in some cases, also the intermediate area and the firing stands. In practice, water collection can be implemented in many different ways. The principle is that, depending on the conditions of the area, water from the backstop berm is directed either to a monitoring well or, via open or underground drains, into a collection basin from which water samples can be taken for monitoring the pollutant concentrations. If necessary, water treatment can be combined with water management, removing pollutants. Water with pollutant concentrations within acceptable levels are directed to the terrain or absorbed into the ground.

Table 5.2. Features of structures preventing pollutant migration compared with an uncovered backstop berm.

	Dusting	Water body impact	Ricochets	Maintenance	Costs
Covering the backstop berm	–	+	–	–	–
Sand trap	0	+	0	0	–

+ feature in favour of implementation

– feature not in favour of implementation

0 no significant difference

Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Covering the backstop berm	Rainwater is prevented from getting into the backstop berm and/or the topsoil in the target area with a covering structure.	Effective management of pollutant migration. Water with pollutant content is not generated, eliminating migration. Dusting is somewhat increased. Requires maintenance of the structure in order to manage the holes from missed shots and ricochets.	Good. Possibility for voluntary work. Requires maintenance.	Suitable for most pistol and rifle ranges. At biathlon ranges, emission management in the target areas must also be taken into consideration.
Sandtrap structure	The migration of pollutants deeper into the soil and groundwater is prevented with a liner structure, for example, concrete, asphalt, bentonite, or plastic membrane. The percolating water is collected from the surface of the liner with underground drains.	Effective management of pollutants. Water with pollutant content is collected; there is also the possibility of monitoring the water quality and, if necessary, treatment. Replacement of sand from the top of the structure is possible.	Good. Requires a plan made by an expert. Construction at an old range requires rather extensive earthmoving and likely some remediation of contaminated soil.	Suitable for most pistol and rifle ranges, also modifiable ranges (e.g. practical). Not suitable for silhouette shooting ranges or biathlon.

Water collection

The need for collecting water from the target area depends to a large extent from the water collection system selected. In terrain with low water permeability, water can be collected from around a traditional backstop berm in a controlled manner with open ditches and underground drainage, and directed to monitoring and, if necessary, treatment. In terrain with high water permeability, collecting water from around a traditional backstop berm with open ditches is practically impossible, as the water is absorbed into the soil. If water traps are used, or the backstop berm is covered, water collection is usually unnecessary. The collection of percolating water requires that a sand trap has been constructed into the backstop berm, allowing the water to be directed into underground drainage from its watertight surface. The water is directed from the underground drainage into monitoring and, if necessary, treatment in a controlled manner.

Pollutant concentrations are usually low or moderate in the front of firing stands, but on the other hand, the pollutants are present in a fine-grained form. The need for water management in these areas is assessed on a case-by-case basis. If necessary, the water can be collected with well-designed ditches or underground drainage, or the firing line enclosure can be extended to cover the area. As a rule, water management is not required in the intermediate area of the range.

Water treatment by filtration

The collected water can be treated by filtration in, for example, a well. There are several brands of metal filtration materials in the market. Products from two manufacturers have been tested in practice at Finnish shooting ranges. Kemira has developed a treatment method for water with metal content, based on the water flowing through a granular mass (CFH 12). The mass adsorbs metals, also eliminating dissolved pollutants from the water. In order for the purification method to be as effective as possible, the water should flow through the granules from the bottom to the top. The granular size of the adsorption material is 1...2 mm and its water permeability is around 0.05 l/min/cm² (Kettunen 2010).

See Figure 5.16 for a drawing in principle of a water treatment system. See Appendix D5 for a more detailed sample design of a water treatment system where the CFH 12 granules or equivalent are used for water treatment. Dimensioning of the system is based on the capacity of the adsorption mass and the amount of water to be treated, and must be checked on a case-by-case basis.

A well made from concrete rings and a prefabricated plastic well are examples of suitable treatment wells. All joints and pass-throughs must be built to be watertight. This method is in use at two Finnish shooting ranges, at least.

Envitop Oy has also developed a filtration-based treatment method for water with metal content (EnviSHOT) using the TOP-15J1 material that is specific to heavy metals as the filtration material.

In principle, active carbon could also be used in filtering, but the water would then usually require pretreatment in order to remove organics and iron, for instance, through sand filtration. Otherwise, the filter will become clogged.

After filtration, the water can be discharged into the environment as surface water or absorbed into the soil, depending on the soil conditions in the area. Assessment of the acceptable quality level of water discharged into the soil or a body of water is discussed in Appendix F, Instructions for the assessment of the need for pollutant management at shooting ranges. The environmental authority accepts the quality level of the discharged water.

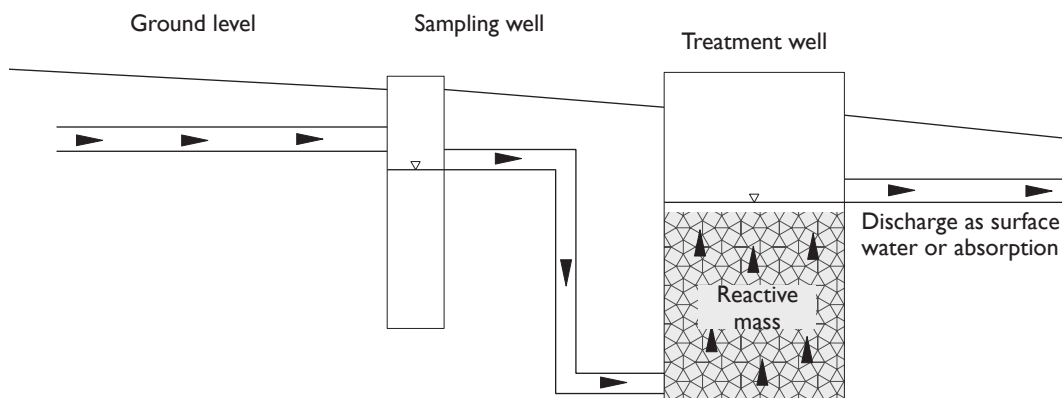


Figure 5.16. Drawing in principle of a filtration well.

Water treatment by sedimentation

The studies performed have indicated that a significant amount of the migrating pollutant emissions in the surface waters from shooting ranges is bonded with fine matter. Their spread can be effectively limited by sedimentation. Sedimentation is not considered to have a significant effect on pollutants that are in soluble form or bonded with organic matter.

Sedimentation can be implemented in a well, basin or a system of ditches. The well can be, for example, a two-part concrete ring well, its volume dimensioned according to the amount of water generated. The first part acts as the sedimentation basin, where the suspended fine matter settles. The second part acts as the clarifier, from which the monitoring samples are taken. The water is removed as overflow, if the terrain contours are suitable; otherwise, the water is pumped out.

The sedimentation basin can be an excavated basin or a natural depression, where the water flow slows down and solid particles settle down at the bottom of the basin. There is experience on the use of sedimentation basins in the treatment of water from shooting ranges in at least Finland and Norway. In Finland, elevated lead concentrations have been detected in the bottom sediments of ditches and sedimentation basins at shooting ranges, which indicates that some of the lead settles down at the bottom of the basin. In order to improve the results, several sedimentation basins could be placed in a sequence. In practice, it is usually easiest to expand the outflow point of the water from the shooting range into a basin, or to dig a basin at the start of the drainage ditch. The basin design (dimensioning, shape of the bottom) is under development.

A zig-zagging ditch system in which the water flow slows down can also be used for sedimentation. In order to boost water purification, the ditch system can be planted with vegetation or root systems that bind pollutants. These kinds of wetland or root system water treatment facilities have been used for quite some time with good results in, for example, the treatment of surface runoff from road areas, but they have not been tested at shooting ranges, yet. The method must, however, be considered to have quite a lot of potential, as wetland plants and root systems are able to bind pollutants in dissolved or particle form, or bonded with organic matter. Appendix D4 is a presentation of the principle of a water sedimentation system based on wetland water treatment.

Functional effectiveness and environmental impact

According to the manufacturer, the CFH 12 granule filtration method has achieved a lead reduction of over 98% at a pistol and rifle range (Kettunen 2010). According to analyses performed in 2010, the CFH 12 granule also effectively reduces antimony (reduction 90...98%), and is also reasonably good at reducing the amount of copper (reduction 66...70%) (Kemira 2010). The method is effective in reducing the pollutant

content in waters from shooting ranges, and thus also reduces the environmental impact on surface waters. The effectiveness of the CFH granule in eliminating metal content from water has also been studied in other contexts. According to Backman et al (2007), the method works well in arsenic removal.

Sufficient data could not be obtained of the EnviShot method during the preparation of this report for it to be possible for us to reliably assess the effectiveness of the method.

Reliable research data is not available on the functional effectiveness of sedimentation basins, wells and ditch systems at shooting ranges. The amounts of surface runoff from the ranges, and their pollutant concentrations, vary significantly over the year. A particularly large amount of pollutants bonded with solid matter migrates with the springtime meltwater pulses and during heavy rain in the autumn. This must be taken into consideration when designing the basins. The sediment in the basins and ditches slowly becomes contaminated, as the solids with metal content settle down at the bottom. If necessary, the sediment can be remediated.

No data is available on the effectiveness of active carbon filtering at shooting ranges, but it can be assumed to be effective at removing metals. In practice, however, the method requires the pretreatment of the water (removal of iron and organic matter).

Suitability

Sedimentation and filtration are well suited to the water treatment at shooting ranges. The water treatment systems by Kemira and EnviShot or easy to use.

Costs and maintenance

The price of CFH 12 granules is around EUR 3,000...4,000/t. The amount of filtration mass required depends on the amount of water in the area, but one ton is usually enough for shooting ranges. The replacement interval of the filtration mass depends on the quality of the percolating water and the conditions. At two pilot sites (Oulunsalo and Kiiminki), replacing the granules had not yet become necessary after four years of use, as the purification results have remained at a good level (Kemira 2010). The mass must be replaced once it becomes clogged or the purification results deteriorate. The replacement interval is affected by, for instance, the concentrations of pollutants, solids and organic matter, and the amount of water to be treated. With high concentrations and large amounts of water, the granule mass becomes clogged more rapidly. In addition to the price of the CFH 12 granules, there will be a one-time investment cost of building the monitoring and treatment wells and the pipelines. We estimate the investment cost of the water treatment system (without the granules) at around EUR 5,000, including the materials and earthworks, excluding the possible remediation of contaminated soil. The price depends on the depth of the well, the length of the pipelines, and the materials chosen.

The EnviShot water treatment system includes the filtration mass and treatment well. According to the manufacturer, the price of the treatment well is around EUR 4,500, and the price of the filtration mass is EUR 600 per tonne. The mass is delivered in 500 kg batches, and one tonne is required at a time. According to the manufacturer, the replacement interval of the EnviShot mass is 2...5 years (Envitop 2010). The investment costs for the method, taking earthworks and pipelines into consideration, is in the ballpark of EUR 7,000...10,000 (excluding the filtration mass).

The price estimates do not include any water pumping systems or pumping operating costs, as the water treatment systems should be built without pumps whenever possible.

According to the manufacturer, the EnviShot mass can be disposed of as regular waste (Envitop 2010). The CFH-12 granule's eligibility for landfill disposal has not been studied, but presumably it can also be disposed of as regular waste (Kettunen 2011).

Summary of water management and treatment at pistol and rifle ranges

Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Water management	The water from the vicinity of the shooting range is directed away from the range area. In the range area segment with the highest pollutant load, the percolating water generated is collected with ditches or underground drainage and directed into a basin or collection wells in a controlled manner. The water quality is monitored and, if necessary, the water is treated. If the soil is water permeable, requires a watertight bottom structure underneath the drainage layer.	Effective, enables the monitoring of the quality of water with pollutant content and, if necessary, its treatment.	Good. Requires a plan made by an expert.	Suitable for all shooting ranges.
Treatment of water with pollutant content	Water with pollutant content is treated by sedimentation or filtration. Water quality is monitored both before and after treatment.	Effective management of pollutants, metal migration outside the shooting range area is significantly reduced, or prevented entirely. The water filtration system is more effective than sedimentation, but sedimentation allows the easier treatment of large amounts of water.	Good/moderate. Requires a plan made by an expert.	Well suited to all pistol and rifle ranges, combined with a technique for water collection. This technique is still being developed.

See Appendix D5 for a presentation of a principal plan for a water treatment system where the CFH 12 granules or equivalent are used for water treatment. Appendix D4 is a presentation of the principle of a water sedimentation system based on wetland water treatment.

5.2

Shotgun ranges

The pollutant management methods suitable for shotgun ranges can be divided into three main categories:

- Reduction of the spreading area of pollutants
- terrain contouring
- nets and barriers
- Prevention of pollutant migration
- soil covering and shot collection
- Water management.

Reduction of the spreading area of pollutants

At shotgun ranges, the greatest challenges of pollutant management are connected to the large size of the spreading area of the shot. By making the spreading area smaller, you can limit the size of the area loaded by metals, thus reducing the need and extent of other measures. However, the amount of pollutant load remains unchanged. For this reason, in addition to reducing the spreading area of the shot, other methods are usually also needed in order to improve the management of pollutants.

The spreading area can be reduced by terrain contouring or structures such as curtains, nets and barriers. In practice, terrain contouring refers to a berm that interrupts the flight trajectory of the shot, or lowering the ground level at the firing stands so that the shot fly uphill, thus flying for a shorter distance, or a combination of these. Structural solutions could include an independent barrier or net, or a structure combined with terrain contouring, such as an elevation barrier or net. The essential part is that the structures are located as close to the firing stand as possible and that they are high enough.

An indicative sample design has been prepared for the reduction of the spreading area of shot with the help of a barrier and an elevation structure; see Appendix E2.

Terrain contouring

If the terrain is level with no trees, pollutants may spread in the form of shot from a single sket or trap range to an area of around five hectares (50,000 m²). The spreading area of pollutants at shotgun ranges can be reduced by terrain contouring.

In Finland, terrain contouring at a shotgun range has been used at several shooting ranges, such as the shooting range of the Nokian seudun ampujat shooting club in Nokia, and the Hälvälä shooting range.



Figure 5.17. Backstop berm at the Nokia shotgun range (photo: Ramboll Finland Oy).

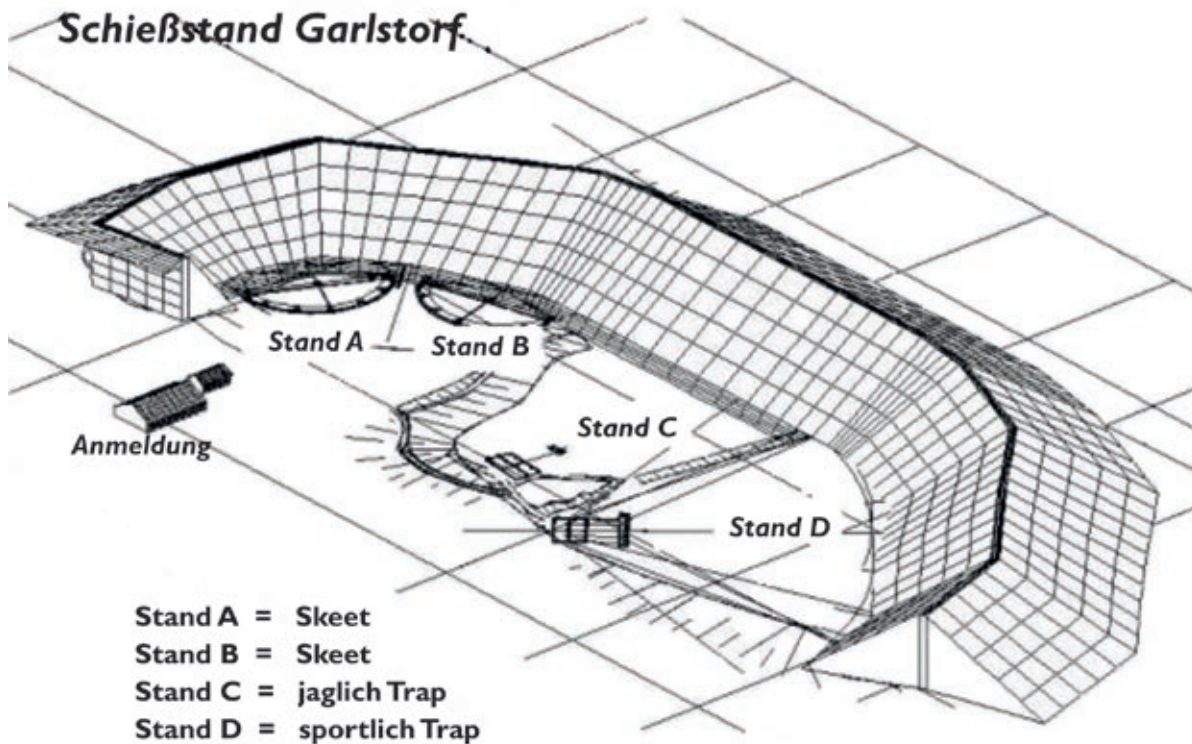


Figure 5.18. Drawing in principle of the backstop berms at the Garlstorf shooting range (Schießstand Garlstorf gGmbH 2011).

The earthen berm at the Nokia shooting range was constructed in 2005, and it is covered with the decommissioned wire of a paper machine for shot collection (Figure 5.16.). The backstop berm is located at a distance of around 150 metres from the firing stand, and its height is 4.5 metres measured from the shooting height (Väyrynen 2011).

At the Garlstorf shooting range in Germany, massive berm structures were built in 2000 for skeet and trap shooting. See Figure 5.18 for a drawing in principle of the berms.

Mesh-covered earthen berms have been constructed at the Lonato shooting range in Italy to stop the shot (Figure 5.19.). In Lonato, the bottom edge of the berm is at a distance of around 90 metres from the firing stands. The height of the berm is around 23 metres. There is a net in the front edge of the berm with PVC plastic underneath to ensure that the shot are stopped and recovered. There is also PVC plastic at the bottom edge of the berm, preventing vegetation from growing and allowing the collection of the shot. The shot are collected from the bottom edges of the berms every six months. There is a low berm in front of the bottom edge, but it is mainly for landscaping purposes (Aarrekiivi 2011) (Bufi et al 2007).

There are corresponding berms in Italy at the Bonate Sopra and Belvedere shotgun ranges. In Bonate Sopra, the berm height (12 metres) is insufficient, and in Belvedere, the shot have partially broken the fabric on the surface of the berm. Both ranges have problems with shot collection, as the gutters at the foot of the berms become quickly clogged with clay pigeon fragments (Bufi et al 2007).

The sufficient height of the berm structure depends on the existing terrain contours in the area and the berm's distance from the firing stands. At the Garlstorf shooting range, the berms are 18...24 metres high (Schießstand Garlstorf gGmbH 2011). The amount of earth required is extremely large; at the Garlstorf shooting range, 120,000 m³ of earth was required to build the continuous berm structure for four ranges.



Figure 5.19. Berm structure at the Lonato shooting range in Italy (A.S. Trap Concaverde, Gallery).

Nets and barriers

Nets or barriers that stop the shot can also be used instead of berms, or together with them. Using nets and barriers in addition to berms significantly reduces the amount of earth required.

The Bettolino shooting range in Trenzano, Italy has readiness for the installation of nets that would stop the shot. The nets can be attached to steel cables fastened to pylons 14 metres tall. The distance of the pylons from the firing stands varies from 80 metres to 142 metres. However, the nets are not high enough to stop the shot at that distance from the firing stands. A gutter has been built in front of the pylons for shot collection, allowing the automatic collection of shot falling into it in the future (Bufi et al 2007).

At the Fagano shooting range in Valle Olona, Italy, there are nets (height 5 m) installed on top of the berms (height 6 m). There are also corresponding structures in Italy at the Il Campanille, Arlunese and Madonna Del Bosco shooting ranges, where the berms are also covered with polyethylene. The total height of the structure is not sufficient at any of the above-mentioned ranges, and the net material is not durable or there are gaps between the nets (Bufi et al 2007).

Sample designs of combinations of berms and woven screens have been proposed in Italy, comprising improvements to the current solutions. In the first solution type (two model designs), the shot are stopped once they have passed their apex and are falling down. The total height of the structure, comprising a berm and a net, is 19 (23) metres, and its distance from the firing stands is 120 (125) metres. In the second Italian sample design, the shot are stopped at their apex, at a distance of around 95 metres from the firing stands, using the same type of structure described above with a height of around 23 metres (Bufi et al 2007).

The German company O. Luntz GmbH & Co has developed a patented shot collection system called ShotNet that is based on a multi-layer net that is supported by

pylons and can be automatically raised and lowered. According to the manufacturer, the shot penetrate the surface layer of the net structure and fall into a fold in the net from where they are easy to recover. The solution allows reducing the spreading area of the shot by 80%. The height of the net is 16 m (Shotnet 2013).

Functional effectiveness and environmental impact

If the firing stand is lower than the rest of the terrain, or the firing stands are surrounded by high earthen berms, barriers, nets, or their combinations, the pollutant spreading area can be significantly reduced. The best-case scenario is a spreading area that is around one tenth of the area without the protective structures. See Figure 5.20 for a drawing in principle of the reduction of the spreading area of the shot at skeet and trap ranges.

Earthen berms that are sufficiently high enable a very effective recovery of the shot. At the Lonato shooting range in Italy, 96% of the fired shot can be recovered. Some of the shot still fly over the berm structure (Aarrekiivi 2011).

In order for rainwater not to leach the shot, its collection from the fronts of the berms and nets must be arranged effectively, or the absorption of the water prevented by covering the berm. Water management must also be seen to.

At the Nokia shooting range, the shot-stopping berm has been found to abate the noise reaching the vicinity (Väyrynen 2011).

In its current state, the rather low earthen berm at the Nokia shooting range is estimated to stop around 55% of all fired shot. The shot have been found to bounce from the surface of the structure, due to which a collection gutter will be built at the bottom part of the berm.

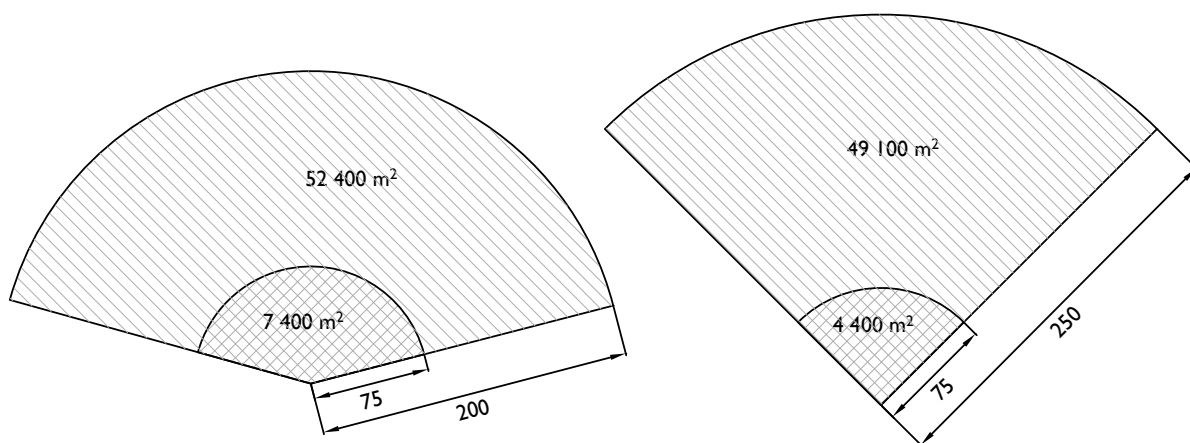


Figure 5.20. The reduction of the spreading area of shot at skeet and trap ranges (barrier distance 75 metres from the firing stand).

Suitability

Terrain contouring can be used to effectively reduce the spreading area of the shot, particularly at new shooting range, where terrain contouring can be taken into consideration in the design of the entire area. Curtain, net, and combined berm and net solutions are suitable for use at all shotgun ranges.

Erecting curtain, net and barrier structures that are high and withstand changes in weather is technically problematic, due to which the implementation of a combined earthen berm and a net or curtain structure is recommended.

Costs

The length of the earthen berm required for one shotgun range is around 100 metres, if it can be located at a distance of around 75 metres from the firing stands. A theoretical volume of around 60,000 m³ of earth (around 3,000 lorries with trailers) is then required to build a berm 20 metres high. Even if the earth could be had for free transported to the site as surplus suitable for construction, the earthworks would still incur significant costs. For instance, with a unit price of EUR 1.5 per theoretical volume, the cost of earthworks would come up to around EUR 90,000. If suitable surplus earth is not available in the vicinity, the cost of the earthworks may rise to hundreds of thousands of euros.

The costs of a berm and net combination 23 metres high, as presented in the sample design of Appendix E2, are around EUR 300,000...600,000 depending on the relative heights of the earthen berm and the net, and the cost of the earth.

There is no price information in Finland for a solution using just a net, such as the ShotNet system.

Summary of the prevention of pollutant migration at shotgun ranges

Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Terrain contouring, berm structures	Terrain contouring (with berm structures) reduces the spreading area of the shot. The berm can be surfaced, facilitating the accumulation of the shot at the foot of the berm.	The area subjected to pollutant load is reduced, but the total load remains unchanged unless the shot are regularly removed from the foot of the berm.	Requires a large amount of soil. Requires a plan made by an expert.	Well suited. Possible to implement as a combined earthen berm and net or barrier structure.
Nets and barriers	The spreading area of the shot is reduced with vertical nets or barriers. The shot can be collected from underneath the net or barrier. The collection can be made easier by surfacing the ground.	The area subjected to pollutant load is reduced, but the total load remains unchanged unless the shot are regularly removed from the foot of the berm.	Quite poor so far, existing solutions have mainly been designed site-specifically and have variable effectiveness. Requires a plan made by an expert.	Suitable, but as there are no commercial solutions in the domestic market, the solution is not easy to implement.

Appendix E2 presents an indicative sample design for the reduction of the spreading area of shot with a combination of the berm and net solutions.

5.2.2

Prevention of pollutant migration

Soil surfacing and shot collection

The migration of pollutants from the area subjected to pollutant load into the soil and further into the groundwater can be managed through soil surfacing that prevents water from being absorbed into the ground. Asphalt or a suitable membranous material can be used as surfacing material. To our knowledge, there is no experience on the large-scale surfacing of soil at shotgun ranges in Finland.

Surfacing a shotgun range with asphalt is discussed in the indicative sample design of Appendix E3.

Functional effectiveness and environmental impact

When the spreading area of the shot is surfaced, the water accumulated in the area can be collected in a controlled manner from the watertight surface and treated if necessary. Water management allows a significant reduction of the risk of pollutant migration into the environment.

Shot and clay pigeon fragments can be collected from the surfaced area, for example, with a sweeping machine. Surfacing and the regular removal of shot prevent soil contamination effectively, also when the surfacing material is water permeable.

Surfacing the area requires the removal of trees and other vegetation. The removal of trees can result in increased shooting noise emissions into the environment. Furthermore, an acoustically hard surface, such as asphalt, may increase the shooting noise spreading into the environment. If surfacing the area is considered, you must first analyse what effect the solution would have on noise, and whether noise management measures are needed in the area.

Suitability

Soil surfacing can effectively prevent soil contamination, particularly at new shooting ranges. At new shooting ranges, the need to surface the soil can be taken into consideration during the design process, combining the surfacing to other emission management methods such as terrain contouring or net or barrier solutions, which can result in a significant reduction of the area that needs to be surfaced.

Costs and maintenance

The costs depend essentially on the size of the area to be surfaced, the water collection method, the groundwork required before surfacing, and the selected surfacing method.

If the entire shot spreading area at one shotgun range is surfaced with asphalt, the costs of just the asphalt amount to around EUR 150,000. Then there are the groundwork and water redirection, raising the overall cost to several hundreds of thousands of euros. If the size of the area to be surface can be reduced by limiting the flight trajectories of the shot, the costs are reduced approximately in relation to the reduction in the surfaced area. Asphalt can be considered to be a rather maintenance-free structure. Cost information for soil surfacing is not available for other materials.

Summary of the prevention of pollutant migration at shotgun ranges

Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Ground surfacing	The spreading area of the shot is surfaced. The ground can be surfaced with, for example, asphalt, membrane, or plastic. The shot can be collected from the surfaced area by, for example, brushing manually or with a machine.	The surfacing and shot collection prevents pollutant load and migration. Water can also be collected from the surfaced area for treatment, which entirely prevents pollutant migration.	Good. Surfacing can be limited by terrain shapes and trees or rocks. Surfacing can be combined with the berm or net/barrier solution, reducing the area that needs to be surfaced and improves the viability of the solution.	The effectiveness of surfacing depends on the topology of the terrain. Not recommended for large areas, but may be suitable when combined with the reduction of the spreading area of the shot. Water management in a large, surfaced area may be challenging. The possible noise impact surfacing may have must be determined during the design stage.

The surfacing structure used can be, for example, asphalt, for which an indicative sample design has been drawn up; see Appendix E3.

Water management and treatment

Water management at shotgun ranges can be implemented mostly using the same methods as on pistol and rifle ranges. Due to the larger surface area requiring management, the systems must be designed for clearly larger amounts of water, which is also reflected in the costs.

Water collection

The controlled collection of water at shotgun ranges is an effective method for reducing the environmental load caused by pollutants. Water collection can be implemented through ditches, underground drainage, and terrain contouring, when the soil has poor water permeability. In soil with high water permeability, water collection is extremely challenging due to the large surface area. In practice, measures such as a membrane below the underground drainage layer would be required to prevent water from being absorbed into the soil.

Water treatment by filtration

Once water collection has been implemented at the shotgun range, water treatment is similar to that used at pistol and rifle ranges. Water treatment by filtration is discussed in Section 5.1.3. At a shotgun range, the large amount of water to be treated increases the challenge; this must be taken into consideration when dimensioning the systems.

Water treatment by sedimentation

Water treatment by sedimentation is discussed in Section 5.1.3. At a shotgun range, the large amount of water to be treated increase the challenge.

Functional effectiveness and environmental impact

The effectiveness of these methods and their environmental impact correspond to those of a pistol and rifle range, if the system has been designed for the amount of water from a shotgun range. This issue is discussed in Section 5.1.3.

Suitability

Water collection is best suited to ranges where the soil has poor water permeability, allowing the effective collection of water via ditches without watertight structures.

If the soil has high water permeability, water is quickly absorbed into the soil, and ditches alone without watertight structures will not give good results.

Costs

Cost information for a water collection and treatment system covering an entire shotgun range is not available. The costs of a collection system using ditches are reasonably low, as are the costs of a water treatment system based on sedimentation. The costs of a chemical water treatment system will be significantly higher than for a pistol and rifle range. A water collection system based on underground drainage pipes installed on top of a watertight membrane and a water treatment system based on CFH 12 filtration have been implemented at the Oulunsalo shotgun range. The costs, excluding design costs, amounted to around EUR 9,000, with the implementation area covering around 2,000 m². This is just a fraction of the surface area of the entire range, but it gives indications on the feasibility of the system, for example, in the subareas with the highest pollutant load, or combined with the reduction of the shot fall area.

Summary of water management and treatment at shotgun ranges

Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Water management and the treatment of water with pollutant content	The water from the vicinity of the shooting range is directed away from the range area. Rainwater is collected from the section of the range area exposed to pollutant load with ditches, terrain contouring and underground drainage into a basin or another collection location. The water quality is monitored and, if necessary, the water is treated. If the soil is water permeable, requires a watertight bottom structure underneath the drainage layer.	Water collection prevents migration. The large area makes collection more difficult and reduces effectiveness. The large amount of water makes dimensioning and treatment more difficult.	Water collection from a large area is difficult, can mainly be done with ditches. A membrane or other liner structure can be constructed in the primary shot fall area. Requires a plan made by an expert.	Suitability for the entire range area is rather poor, but the solution is very suitable for use in a limited section of the range. Treatment methods are the same as described above for pistol and rifle ranges, but the larger amount of water must be taken into consideration during the design stage.

5.3

Methods being developed

5.3.1

Reducing the solubility of the pollutants

The solubility of lead can be reduced by adjusting the pH of the backstop berm to between 6.5 and 8.5, and increasing its fines content or the amount of organic matter. At neutral and slightly alkaloid pH, lead bonds with the fines and organic matter in the soil more strongly. Lime can be used in the adjustment of soil pH (U.S. Army Environmental Center 1998).

The lead-binding capacity of the backstop berm can be improved by, for example, adding clay into sandy soil. Bentonite, for example, is a clay type suitable for shooting ranges (U.S. Army Environmental Center 1998).

You can try to bind the pollutants more strongly into the backstop berm by adding reactive materials in the impact areas and the surface layer of the backstop berm's front side. Reactive materials tested by the Norwegian Defence Forces include iron powder, olivine, alginate, and bone powder (Nikula et al 2005), and apatite and CFH 12 granules. The most promising materials have proven to be iron powder and the CFH 12 granules.

Phosphate can also be used to bind lead. There are large differences between different phosphate compounds with regard to their pollutant binding capacity, and all phosphates are not suited to binding lead.

PIMS (Phosphate-induced metal stabilization) is a method utilising phosphate additives that has been developed for the in situ treatment of pollutants in the soil. The PIMS method uses Apatite IITM (U.S. patent no. 6,217,775). Apatite II can bind an amount of lead equalling 17% of its weight, at which point the lead precipitates into pyromorphite (Wright et al 2004). Apatite II is also rather effective in binding antimony, copper and zinc, and a reasonable amount of nickel (Stevenson et al 2003).

In Finland, apatite is mined in the Siilinjärvi mine. Apatite is used as a fertiliser. The suitability of tailings from the apatite mine for reducing the solubility of lead has been studied by the University of Helsinki. The untreated tailings reduced the concentration of water soluble lead (Venäläinen 2011).

A laboratory-scale test simulating the effect of rain on soils treated with phosphate additives has been performed in the United States. Tests were performed with two different pH values: neutral and acidic. Furthermore, different dosages were tested on the soils: 1% and 5% of potassium phosphate, and 1% and 5% hydroxylapatite. During the simulation, the lead concentrations of both surface waters and the percolating water were analysed. The tests proved that binding lead with phosphates was not effective (Larson et al 2004). Studies by the Norwegian Defence Administration have indicated that apatite increases the solubility of antimony.

A reactive layer can also be constructed inside the backstop berm. Water is filtered through it, and the metals the water contains get attached to the reactive layer (sorption). There may be several layers, where metals are tightly attached to the structures with chemical bonds.

At shotgun ranges, changing the soil conditions by, for instance, adjusting the pH is possible just like at pistol and rifle ranges.

Changing the soil conditions can be combined with other methods, such as the sand trap.

Functional effectiveness and environmental impact

In groundwater areas, the possible effects of the reactive materials on groundwater quality must be thoroughly studied before the method is used.

Although increasing the pH of the soil to neutral reduces lead migration, it can significantly increase the dissolution of antimony from the soil, as antimony compounds are usually bonded with soil in acidic conditions and dissolve when the pH increases to neutral or alkaloid (Johansson et al 2005). Adding fines increases surface runoff, possibly increasing the impact on surface waters.

Adding reactive materials to soil containing bullets or shot involves risks, as the reaction mechanisms of the different metals are not known well enough. According to some studies, the solubility of the bullets even increases when iron is added (Hurley 2013).

The use of phosphate compounds may cause surface water eutrophication and groundwater contamination risks, as the amount of soluble phosphates has been found to increase significantly in the water percolating through the soil after the addition of phosphate compounds (Larson et al 2004) (Dermatas et al 2008).

Furthermore, the reactions of lead with phosphate compounds depend on pH to a great degree and may require acidic conditions to occur. In acidic conditions, the solubility of lead is higher, due to which the lead concentrations could not be decreased sufficiently in the studies, although some of the soluble lead did bond with phosphates (Dermatas et al 2008).

Apatite IITM is manufactured from fish cleaning remains, due to which its use can be considered to be reuse of waste material, saving natural resources. The utilisation of tailings from the Finnish Siilinjärvi apatite mine would constitute the reuse of materials. However, the effectiveness of apatite in binding metals other than lead is questionable.

The effectiveness of phosphate compounds depends on several factors, and the solution alone is thus not suitable for the protection of surface and groundwaters.

The surface area of the area needing treatment at shotgun ranges would be significantly larger than at pistol and rifle ranges. At a single range, around 50,000 m² of ground would need to be treated (breaking the surface and mixing the additives into the topsoil). Soil treatment in such a large area and its surroundings may have a

significant negative impact, for instance, due to the increasing solubility of antimony or the increase in phosphorus load.

Modifying the chemical state of the humus layer at old shooting ranges may release pollutants bonded to the humus. At old shooting ranges, the removal or modification of the humus layer during pH adjustment may have a negative impact on natural bonding.

Suitability and safety

The use of these methods requires additional study.

Mixing clay with sand reduces the mechanical characteristics of the material, reducing its permanence on a steep slope without additional measures (e.g. reinforcement) (Nikula et al 2005). When reactive materials are added into sand, its elasticity characteristics may change, possibly increasing the risk of ricochets. Mixed with sand, clay may make it more difficult to separate bullets from the soil (Nikula et al 2005).

At shotgun ranges, soil treatment is not considered to have a harmful impact on the shooting activity or safety in the area.

Costs and maintenance

In 2002, a shooting range was renovated in the United States using the PIMS method (Apatite IITM). Mixing the Apatite IITM and other groundwork took two weeks. The amount of renovated soil was around 2,300 m³. The total price of the renovation was around USD 64,000. The treated soil was spread to the shooting range area and covered with uncontaminated soil. The price did not include the transport or screening of soil, or the reshaping of the backstop berm. The amount of Apatite IITM reagent used in the renovation was 80 tonnes, and it cost USD 18,000. The freight price of the Apatite IITM reagent (within the United States) was USD 24,000 (Wright et al 2004). Today, the minimum price of Apatite IITM (for a 20 tonne batch) is USD 13,500 (c. EUR 9,900). The price varies by season and does not include the costs of freight or handling (Inc. PIMS NW). The freight costs can be assumed to be significant, as the reagent is manufactured in the United States.

Using the tailings from an apatite mine would be relatively cheap compared to the commercial Apatite II reagent. The price of powdery fertiliser apatite is around EUR 150 per tonne, and the tailings could be obtained at an even lower price directly from the mine, depending on the transport distance.

Adjusting soil pH with lime is cheap. Lime is easily available and its price in small batches is around EUR 250 per tonne. At shotgun ranges, spreading the lime incurs costs due to the large surface area that needs to be treated, if the spreading is done by machine or contracted out. However, the spreading can be performed, for example, as voluntary work.

The price of bentonite powder delivered in small batches is around EUR 350 per tonne (Hopponen J.).

The amount of required lime or phosphate has not been reliably estimated for shooting ranges; the estimates are very rough ballpark figures.

5.3.2

Using substitute materials

The pollutant emissions from shooting ranges and their environmental impact can be limited by substituting the traditional materials of bullets, shot and clay pigeons with materials that contain less pollutants than usual, or materials that are less harmful to the environment than traditional materials. At shotgun ranges in particular, where shot recovery is difficult, choosing harmless materials could significantly reduce the environmental load.

In bullets, lead can be substituted with other metals, including steel, copper, aluminium, and tungsten. Tungsten bullets, for instance, have been considered to be one possible substitute for the lead bullets currently in use. Tungsten bullets contain 91% tungsten, 6% nickel, and 3% cobalt (Qvarfort et al 2006) (Kalinich et al 2005).

The lead in shot, just like in bullets, can be substituted with other metals, such as steel, bismuth, tungsten, tin, and zinc, and their alloys. Shotgun shells with no lead are commonly sold in Finland for hunting use. Steel shot are used in clay pigeon shooting in some European countries (AFEMS 2002).

The PAH content of the clay pigeons used in shotgun sports vary a lot, with clay pigeons made from bitumen containing less PAH than in clay pigeons using pitch or tar as binder. The use of clay pigeons containing no pollutants or less pollutants than traditional clay pigeons will likely increase in the future; in some European countries, the use of clay pigeons with high PAH content have already been prohibited. In addition to traditional clay pigeon materials, entirely new clay pigeon materials have also been developed in the United States and Europe (AFEMS 2002).

The concentrations and distribution of the PAH compounds vary significantly depending on the material and manufacturing method of the clay pigeon. There are also large differences in the PAH compound concentrations of different batches from the same clay pigeon manufacturer. The composition of the Nasta clay pigeons manufactured in Finland is presented in Table 5.3. Ecological clay pigeons are not currently manufactured in Finland. The first three result columns of the table list the results from the analyses commissioned by Nasta-kiekko, while the last three result columns contain the results of the analyses of the Nasta clay pigeons commissioned in 2010 during the preparation of this report. The analysis reports can be found in Appendix B to this report.

Table 5.3. PAH compounds in the clay pigeons of a Finnish manufacturer (source: Nasta-kiekko Oy), and the 2010 analysis results of the most commonly used clay pigeon (Nasta, manufactured in Finland), clay pigeon waste, and ecological clay pigeon (Nasta, manufactured in Latvia).

	The most commonly used clay pigeon (Nasta) mg/kg	Ecological clay pigeon (Nasta) mg/kg	Paint used on the clay pigeons (Nasta) mg/kg	Clay pigeon waste in the soil (2010) mg/kg	The most commonly used clay pigeon (2010) mg/kg	Ecological clay pigeon (2010) mg/kg
anthracene	30	1.9	0.04	280	250	<1
acenaphthene	12	2.5	0.02	310	350	<1
acenaphthylene				0.5	0.50	<1
benzo(a)anthracene	171	4.4	0.05	810	2100	<0.5
benzo(a)pyrene	241	4.7	0.09	1200	3300	0.2
benzo(b)fluoranthene	159	3.8	0.07	1500	4100	<0.3
benzo(g,h,i)perylene	27	0.4	0.01	890	2300	0.2
benzo(k)fluoranthene	93	1.1	0.04	620	1600	<0.2
dibenzo(a,h)anthracene	117	2.9	0.05	150	350	<0.1
phenanthrene	84	11	0.15	670	880	<1
fluoranthene	175	4	0.35	1300	2500	<0.2
indeno(1,2,3-cd)pyrene	132	2.1	0.05	870	2500	0.1
chrysene	102	4.8	0.10	810	1900	<0.2
naphthalene	4.40	0.76	0.19	44	39	0.4
pyrene	163	6.6	0.02	1200	2300	<0.2
TOTAL (EPA 16)	1420	51	1.2	11000	25000	<10

According to the analyses, around 0.2...2.5% of the mass of commonly used clay pigeons are PAH compounds. The PAH compound concentration of ecological clay pigeons is significantly lower, less than 0.001%. The paint used in the clay pigeons contain small amounts of PAH compounds.

Functional effectiveness and environmental impact

When choosing substitute materials, one must ensure that they will not cause new environmental problems at the shooting ranges. Only a small amount of data is available of the environmental performance and harmfulness of many proposed substitute materials.

Iron is most commonly proposed as a substitute material for lead. Plain iron cannot be used as bullet material; it must be mixed with other metals and carbon, making it steel. Steel as such has no known harmful impact on the environment. The environmental impact of steel is mostly related to steel manufacturing (Qvarfort et al 2006).

A study of the impacts of lead-free steel bullets has been made in Norway. The study has shown that the steel bullets reduced the solubility of the lead and antimony in the backstop berm. The decrease in solubility also reduces the migration of pollutants into the groundwater. Another benefit is that transition to steel bullets would reduce the use of metals categorised as harmful by around 70%. According to the study, the use of lead-free steel bullets could be beneficial at both new and old shooting ranges (Qvarfort et al 2006) (Strømseng et al 2002). The study was, however, from a short time span. According to some views, adding iron into soil containing bullets and shot will, instead, accelerate the erosion of the bullets and shot (Hurley, 2013).

Relatively little data is available on the environmental impact and toxicity of tungsten, and with regard to migration and toxicity, the data is partially conflicting. Until 2001, tungsten was considered to be a poorly soluble metal, due to which it was considered to be well suited for use as a lead substitute in bullets, but it has later been found to dissolve into water (Clausen et al 2007). Until the 2000s, tungsten was considered to be only slightly toxic, but it has later been found to be possibly carcinogenic (Doust et al 2007). In one study, bullets made from a tungsten alloy were found to cause cancer and tumors in rats; however, the study could not link the carcinogenic effect directly to tungsten, as the tungsten alloy also contained small amounts of nickel and cobalt (Kalinich et al 2005). Tungsten exposure has also been suspected to be linked to leukaemia (Begley 2007).

At the Camp Edwards military shooting range in the United States, tungsten bullets have been used from 1999 to 2006. The bullets were nylon-coated, their cores compressed from fine tungsten powder. Tungsten concentrations of over 2,000 mg/kg have been measured in the soil of the shooting range. According to the studies, tungsten migrated deeper into the soil from the impact areas, up to a depth of 1.5 metres. At the shooting range, tungsten concentrations of up to 400 mg/l were measured in the water of lysimeters installed in the soil layer not saturated with water. The studies found the tungsten in the water to likely be in dissolved form. Tungsten was also found to have migrated into the groundwater, the level of which is at a depth of around 36 metres from the ground. The soluble tungsten was estimated to occur in oxide form (Clausen et al 2007).

Tin forms both inorganic and organic compounds in the environment. Organotin compounds, in particular, have been found to be toxic to organisms. Inorganic tin compounds may cause lung diseases in their particle forms (Qvarfort et al 2006).

Bismuth has been used for a long time, for example in medicinal drugs, and the studies have not found it to be environmentally harmful. Bismuth has been found to be less toxic than lead. Bismuth has been found to affect the gonads and sex hormones (Qvarfort et al 2006).

In small doses, copper is a vital trace element for humans, animals and plants. However, copper is extremely toxic to aquatic organisms (Reinikainen 2007).

Aluminium is the third most common element in the crust of the Earth, and it is also common in bodies of water. Low pH increases the solubility of aluminium, and as the pH level decreases, the share of the most toxic aluminium compounds of the total aluminium also increases. Aluminium bonds easily with organic matter (Doust et al 2007). In the human body, aluminium accumulates particularly in the bones, and can also migrate to the brain, placenta, and foetus (Begley 2007).

In shotgun shooting, the environmental and health impacts of the shot substitute materials are as presented above. Because the shot spread over a wide area, lead substitute materials may cause significant harm, if they turn out to be easily migrating and environmentally harmful.

In 2010, during the preparation of this report, the water solubility of pollutants in Nasta clay pigeons was analysed in addition to their total pollutant concentrations, using a one-stage shaking test. According to the analyses, substances that dissolve from clay pigeon fragments in the soil and regular unused clay pigeons comprise anthracene, acenaphthene, benz(a)anthracene, phenanthrene, fluoranthene, fluorene, chrysene, naphthalene, and pyrene. Additionally, benzo(a)pyrene, benzo(b)fluoranthene and indeno(1,2,3-c,d)pyrene dissolve from regular clay pigeons. However, the solubility of the PAH compounds was minor. Around 0.01% of the PAH compounds in the clay pigeon waste dissolved into water, and around 0.004% of the compounds in regular, unused clay pigeons. PAH compound concentrations exceeding the detection limit were not found to dissolve from ecological clay pigeons. See Appendix B to the report for the analysis reports. According to the study, both types of clay pigeon can be disposed of as mixed waste. The regular removal of clay pigeon fragments is not necessary, although at the latest, they should be removed after the shooting range is decommissioned.

Suitability and safety

In addition to environmental considerations and price, material selections are affected by the properties of the materials during firing, and their safety aspects.

The ballistic properties of steel and lead bullets are rather similar, although a lead bullet is more powerful when shooting at long ranges (US EPA 2005). The Swiss Defence Forces use bullets with a steel core in their assault rifles. The hard core that resists deformation causes higher stress on the jacket during firing, which means, in practice, more copper emissions at the firing stand. The bullet also causes more wear to the rifling of the barrel than a lead bullet. Steel bullets are not suited to all older firearms. Using steel bullets also increases the risk of ricochets, as steel as a material is not as plastic as lead. Steel bullets will thus increase the size of the safety zone and reduce the safety of shooting. The current bullet trap structures and target equipment are not suitable for use with steel bullets (Nikula et al 2005). Some steel bullets may have armour-penetrating characteristics, which means that they can be considered to be specially dangerous projectiles referred to in the Firearms Act (1/1998). As a consequence, a permit for their possession (ammunition permit) can be granted only for a special reason.

Aluminium-cored bullets (with a brass jacket) are used in Finland to some extent, at least in the life-firing combat exercises of the Finnish Defence Forces. The bullet's weight and safety zone are around one half of a lead bullet's. Its ballistic properties are equivalent to those of a lead bullet at short ranges (under 300 m).

The specific weights of copper and iron are lower than lead, due to which a bullet of the same weight must be made longer than a lead bullet, which causes instability during firing. Copper fouls the gun barrel. In order to prevent fouling, the bullet can be coated with molybdenum sulphide (Qvarfort et al 2006).

In shotgun shooting sports, the international clay pigeon shooting rules require the use of lead shot. Due to the difference between the specific weights of lead and iron, practitioners of these sports cannot practise using steel shot shells, as they require a different amount of leading the target and have different trajectories when compared to lead shot (Qvarfort et al 2006). Furthermore, shotgun shooting enthusiasts are concerned on the effect steel shot have on their firearms and the firing experience (AFEMS 2002). The hardness of steel shot increases their ricochet properties, causing related safety problems (AFEMS 2002). Embedded into wood, steel shot may damage saws and cause safety hazards to forestry workers. Steel shot becoming embedded in trees cannot, however, be considered to be a significant problem in range shooting.

There are no significant differences between the appearance and functioning of ecological and regular clay pigeons. Ecological clay pigeons are harder and break down into larger pieces, while regular clay pigeons break down into small fragments. The use of ecological clay pigeons can be recommended.

Costs

Today, bullets made from substitute materials are as a rule more expensive than lead bullets, as they are manufactured in smaller quantities. Copper bullets, for instance, are significantly more expensive than lead bullets (Kemikalinspektionen 2008), although copper is a metal commonly used by the metal industry. As demand grows, however, the prices will presumably fall. In addition to demand and the manufacturing quantities, the market price of the material affects the price of the bullets. In January 2011, the price of tungsten was almost 16 times that of lead, and the price of copper almost four times that of lead (London Metal Exchange Limited 2003–2011 and Ltd, Fastmarkets), while the price of steel is around one fifth of that of lead (London Metal Exchange Limited 2003–2011).

Correspondingly, shot manufactured from substitute materials are, as a rule, more expensive than lead shot. Table 5.4 presents the 2005 comparison of the prices of different materials by US EPA.

Table 5.4. Prices of cartridges made from lead substitutes in 2005 (US EPA 2005).

Material	Price USD/cartridge	Price compared to lead
Lead	0.2	
Bismuth (97% bismuth, 3% tin)	1.5–2.5	7.5–12.5 times
Steel	0.3-0.5	1.5-2.5 times
Tungsten 40%, iron 60%	2.5	12.5 times

Aluminium core bullets intended for civilian use are not currently sold in Finland. The Finnish Defence Forces, however, use around 1.5 million aluminium core bullets annually. Their price is roughly the same as that of lead bullets.

The price difference between regular clay pigeons and ecological clay pigeons is not large. Ecological clay pigeons are around 15% more expensive than regular ones. Ecological clay pigeons are thus far not manufactured in Finland, but they are available through Nasta-kiekko. Manufacturing can be started if there is sufficient demand.

5.3.3

Water treatment by precipitation

Metals can be precipitated from water using various precipitation chemicals. The pollutants will then settle down at the bottom of the precipitation basin or well. There are no experiences of water treatment by precipitation from shooting ranges.

As a rule, precipitation techniques are not considered to be particularly suitable for shooting ranges, as they require industrial know-how and equipment.

5.3.4

Collecting the shot

A solution has been presented in Italy, where shot are collected from a shotgun range with the help of a surfaced and inclined ground. Another solution would be to collect shot from the ground surfaced with PVC plastic that would operate like a conveyor belt with the help of rollers, collecting the shot into a collection chute. See Figure 5.21 for a drawing in principle of the collection solution.

Shot can also be collected with horizontal nets hanging above the ground (Ceccarelli et al 2004). Water can penetrate the nets, but shot and clay pigeon fragments would be caught by them. The shot should be collected from the nets before they start to erode in order to prevent water-borne migration of pollutants. In the Finnish conditions, the freezing temperatures and snow during the winter must be also taken into consideration, as they reduce the durability of the nets.

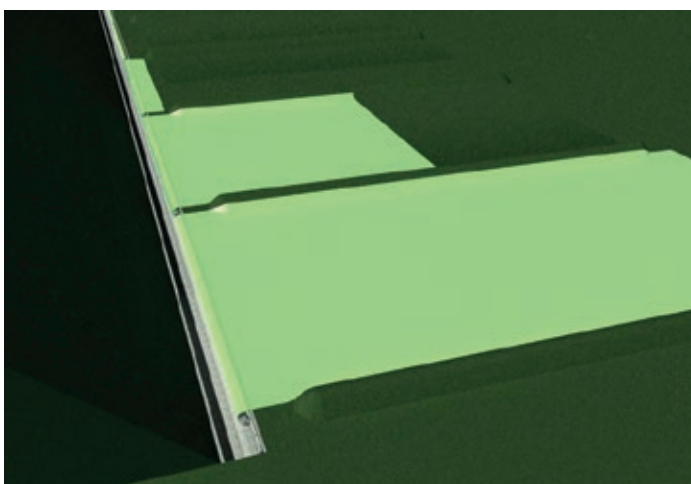


Figure 5.21. "Conveyor belts" used in the collection of shot from level ground into a collection gutter (Bubi et al 2007).

Summary of the developing techniques

- Techniques under development that are estimated to have the most potential are the use of lead substitutes in bullets and shot, and the reduction of the solubility of the pollutants by adding various reactive materials into the structures of the shooting range.
- An indisputably harmless substance or compound suited to the manufacturing of bullets and shot has not been found thus far. Steel and aluminium have been estimated to be the most suitable.
- The chemical effects of substitute bullet and shot materials on the solubility of lead shot and bullets found at old shooting ranges is not known well enough.
- The use of reactive materials in the reduction of the solubility of pollutant is made more difficult by the differences in the environmental behaviour of the metals contained in bullets and shot.
- Clay pigeons used in shotgun sports can also be manufactured as so-called ecological versions that contain practically no PAH compounds. Their usage characteristics are identical to those of normal clay pigeons. The use of ecological clay pigeons can be recommended, although the solubility of PAH compounds is minor from normal clay pigeons as well.

6 Best Available Techniques and Best Environmental Practice in the management of pollutant emissions

6.1

Planning the management of pollutant emissions

The starting point of the correct and cost-effective planning of pollutant management measures for shooting ranges is that the environmental impact and risks caused by the operations, and their magnitude and targeting, are known. Because there is significant variance in the types of shooting activities and the locations and environmental conditions of the ranges, the identification and quantification of the impact and risks usually require site-specific studies and assessments of the environmental conditions, emissions, and the long-term significance of the emissions.

One single best available technique cannot be unambiguously specified to apply all shooting range operations; the technical requirements of pollutant management should, first and foremost, be determined by the site-specific environmental protection needs. For this reason, four different risk levels have been defined for the application of BAT. The risk level can be determined site-specifically using the procedure for the assessment of the need for pollutant management at a shooting range, based on environmental risk assessment, presented in Appendix F. Depending on the site's characteristics and the already available source data, the survey can be carried out either based on the existing source data, or it can include terrain surveys and environmental sampling. The procedure is only indicative in nature, and it can be applied at your discretion.

The goal of pollutant management is that the operations do not cause environmental contamination or other prohibited or harmful impacts. With regard to shooting ranges, the possible impact of the pollutants is mainly targeted to the surface and groundwaters. The significance of the impacts can be assessed based on the changes in the pollutant concentrations in the surface and groundwaters. They are affected not only by the total emission volume (pollutant concentration and water volume), but also the mixing occurring in the surface and groundwater at the discharge location of the emissions. The determination of an acceptable emission level based on the maximum concentrations in surface and groundwaters is described below in Section 6.1.1.

The acceptable emission level can be utilised in setting the goals for and planning the risk management, and in the monitoring of the actual values, for instance, as a long-term reference value of the monitoring of surface water or the monitoring of the quality of water absorbed into the ground. The acceptable emission level is not intended to be used as a monitoring limit value in such a manner that a detected value in excess of it would trigger an immediate need for action.

The pollutant management planning process and its contact points with the environmental permit process are illustrated in Figure 6.1. The pollutant management requirements at different environmental risk levels are described in more detail in Section 6.4, Table 6.3. For an assessment of the effectiveness, feasibility and suitability of the different emission control methods, see Tables 6.1 and 6.2.

The same principles apply to both pistol and rifle ranges, and shotgun ranges.

Determining the acceptable emission level

Surface waters

According to the Government Decree 1022/2006, pollutant concentration in surface waters may not exceed the environmental quality norm set for it. In this context, surface waters refer to a body of water as defined in the Water Act (587/2011), or a pond, river, brook, or other natural waterway, and a reservoir, channel or other corresponding artificial waterway. A rivulet is not considered to be a body of water; it refers to a watercourse that is smaller than a brook, has a drainage basin that is less than ten square kilometres in size, and in which water does not constantly flow and fish passage is not possible to any significant extent, or a ditch.

According to the Government Decree 1022/2006, the environmental quality norm set for the lead concentration of surface waters is 7.2 µg/l as an annual average (= the arithmetic mean of the measured results of each individual, representative monitoring point over one year). Should the operator request, the environmental permit may also specifically lay down provisions on a mixing zone, where the pollutant concentration(s) may exceed the environmental quality norm defined in the section in question, if the rest of the surface water body conforms to the norms in question. The size of the mixing zone is limited in the environmental permit to the vicinity of the emission source so that it is in correct ratio with regard to the pollutant concentrations at the emission source, and that the general principles laid down in Section 4 of the Environmental Protection Act applied to operations causing an environmental contamination hazard are followed.

If no mixing zone has been defined, the primary goal of the risk management can be considered to be that the lead concentration of the surface water discharged from the shooting range area into the receiving body of water at the point of discharge does not exceed the environmental quality norm (7.2 µg/l as an annual average at the sampling points of the body of water). According to the Government Decree 1022/2006, compliance with the environmental quality norm is monitored in the body of water only after a sufficient amount of mixing, which means that discharging water that meets the environmental quality norm into the body of water cannot significantly deteriorate its state.

The maximum acceptable lead concentration in the water discharged from the shooting range can then be estimated, for example, by dividing the environmental quality norm by the ratio of the surface areas of the shooting range area and the drainage basin of the ditch leading from the range to the body of water (mixing factor).

Example:

The drainage basin of a ditch leading from the shooting range to the body of water is 10 ha, or 100,000 m². The total surface area of the shooting ranges is 20,000 m². The mixing factor is then 0.2 and the acceptable emission level from the range area comes to 36 µg/l (= 7.2 µg/l /0.2). Due to the mixing taking place in the ditch, the average concentration in the ditch water discharging from the range area to the body of water will not exceed the environmental quality norm for lead at the discharge point.

Lead acts as the primary indicator for the pollutant emissions from shooting ranges. With regard to other metals, the acceptable emission level can be determined, if necessary, based on a risk assessment during a more detailed analysis. An environmental quality norm has been defined for nickel (20 µg/l as an annual average), but limit values have not been set for other metals present at shooting ranges. Nickel may be present at old shooting ranges.

Groundwaters

The primary goal of groundwater quality protection in accordance with the groundwater contamination prohibition laid down in the Environmental Protection Act is to safeguard the use of the groundwater as a household water supply. Based on this goal, it is justifiable to use the quality requirements for household water as the goal for groundwater quality (Government Decree 461/2000; Pb 10 µg/l, Ni 20 µg/l, and Cu 2 mg/l).

Environmental quality norms have also been defined for groundwater under an EU Directive, presented in Decree 1040/2006 (Pb 5 µg/l, Sb 2.5 µg/l, Cu 20 µg/l, Ni 10 µg/l, and As 5 µg/l). With regard to metals present at shooting ranges, the quality norms are stricter than the quality requirements for household water. The quality norm has been primarily drafted to direct the work of the authorities, but on the other hand, these norms can also be applied on a case-by-case basis when estimating the acceptable pollutant concentration of groundwater. Indeed, before performing the analyses, we recommend agreeing with the local ELY Centre on what quality criteria shall be applied to the groundwater. One option could be that household water limit values are applied at the range area, while the environmental quality norms are applied outside the range area. The site-specific conditions such as groundwater utilisation and the cycle period of the aquifer can also steer the selection of the quality criteria so that, as a rule, the household water quality requirements are applied, but at particularly sensitive sites, stricter environmental protection measures may be required.

The acceptable pollutant load on groundwater can be determined using the mixing factor as follows:

The site-specific mixing factor can be determined based on the conditions at the shooting range. The most important variables in the determination of the mixing factor are the length of the area in the direction of groundwater flow, and the amount of water absorbed from the precipitation. The mixing factor is calculated based on the following formula:

$$DF = \frac{L_{gw} \times I}{v_{gw} \times d_{mix} + (L_{gw} + x) \times I}$$

where

- DF is the mixing factor
- L_{gw} is the length of the area with pollutant concentration in the direction of groundwater flow in metres (m)
- I is the amount of water infiltrating into the groundwater in metres per year (m/a) (generally 0.2–0.3 m/a)
- v_{gw} is the groundwater flow; 1 m/d or 365 m/a is usually used as the value if there is no measurement data from the site
- d_{mix} is the mixing layer at the surface part of the groundwater; 1 m is always used as this value
- x is the distance to the monitoring point; 0 m is usually used as this value.

When the predefined values are entered into the formula, it can be presented as follows:

$$DF = \frac{L_{gw} \times I}{365 + L_{gw} \times I}$$

If no data is available to perform the calculation, you can use the value 0.1 as the mixing factor, which is a conservative value.

The acceptable concentration in the percolating water at the range area, or the pollutant concentration in the water percolating into the groundwater, can be obtained by dividing the safe groundwater concentration for the substance in question (usually the household water limit value or the environmental quality norm) by the mixing factor. The result can be used as a reference value, for example, during risk management planning, when estimating the quality of water that can be safely absorbed into the ground. The acceptable pollutant concentrations in percolating water are not intended to be used as limit values in such a manner that a measurement above the limit value would trigger an immediate need for remediation.

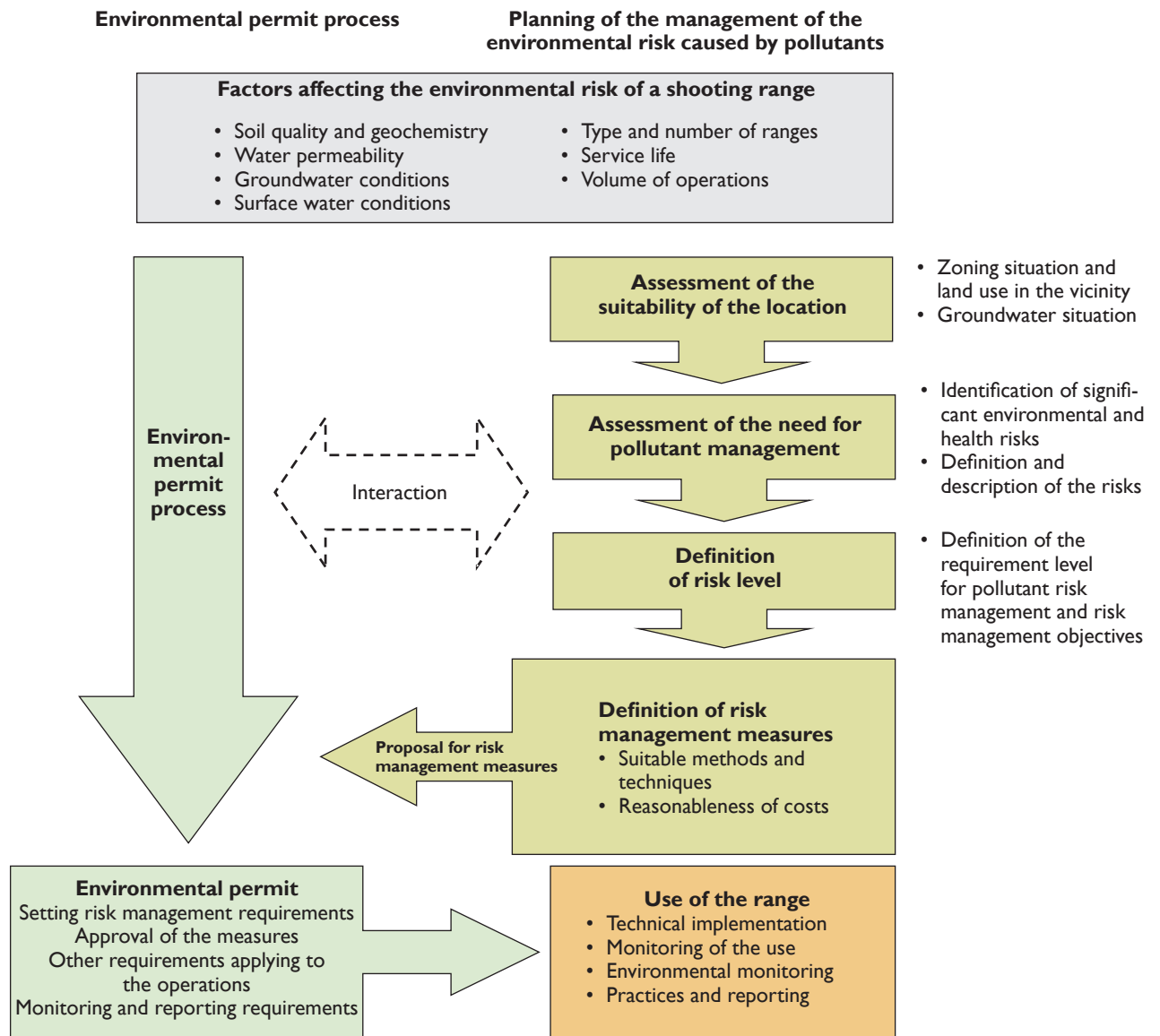


Figure 6.1. Pollutant management planning process and its connections to the environmental permit process.

6.1.2

Planning of measures at a new range

The choice of location is the primary risk management measure when establishing a new range. The shooting range should be located in such a manner that its operations do not cause contamination or its risk, and contamination can be prevented. You should avoid locating new shooting ranges, particularly those that are larger than minor, in an important groundwater area or other groundwater area suitable for water supply, wetland, swamp, or other such area where the migration of projectiles or pollutants into the water body cannot be prevented. Locating a shooting range in such an area should always be based on a case-by-case consideration, and any alternative locations should have been determined and compared when the decision is made. When locating a shooting range in environmental conditions that are more challenging than usual, the requirement level for environmental protection may be set higher than usual.

The environmental risks caused by the pollutant load from the planned new range area, and the need for their management, should be assessed by applying for instance the instructions in Appendix F in such a manner that the analysis focuses on the study of the conditions and the possible migration routes, and the assessment of the risks of the operations. The soil, groundwater and surface water conditions of the site, and their quality prior to the commencement of operations, should be determined and described. Based on the results, and the type and volume of the planned operations, the factors affecting the erosion of bullets and shot, and the accumulation and migration of pollutants in the area are assessed. Performing these analyses and assessments requires sufficient expertise in the field and experience in similar projects. Based on the assessment procedure for the need for pollutant management, the risk management targets and the level of risk at the site are determined, and the required risk management measures planned.

At new shooting ranges, the requirements primarily comprise the collection of water with pollutant content and, if necessary, its treatment, or the prevention of water accumulation and/or limiting the pollutant load. The suitability of different pollutant management methods for different types of shooting ranges is depicted in the technique selection table in Section 6.3.

The effectiveness of pollutant management must be regularly monitored. The results from the assessment of the need for pollutant management are used as help when planning the monitoring programme. See Appendix G for instruction on how to implement the monitoring.

6.1.3

Planning of measures at an existing range

The purposeful planning of pollutant management at existing shooting ranges requires that there is sufficient initial data on the site, its emissions and their migration, and the environmental risk caused by the operations. If there is not enough initial data, we recommend assessing the need for pollutant management at the shooting range in accordance with the instructions in Appendix F. The assessment procedure involves the study and description of the history of the operations, the soil, groundwater and surface water conditions, the emissions caused by the operations, and their impact in the current situation. The goal is to determine how the operations cause an environmental load (e.g., have pollutants migrated into surface waters, or on what timescale is it possible for the pollutants to migrate into the groundwater), and what impact this will have on the environment (e.g. impact on the aquatic ecosystem or changes to groundwater quality).

Performing these analyses and assessments requires sufficient expertise in the field and experience in similar projects. Based on the results of the assessment of the need for pollutant management, the risk management requirement level and objectives are determined, and the required risk management measures planned. The risk levels and the starting points for planning the measures are described in Section 6.4.

The effectiveness of pollutant management should be followed up through regular environmental monitoring. The results from the assessment of the need for pollutant management are used as help when planning the monitoring programme. See Appendix G for instruction on how to implement the monitoring.

If the studies or monitoring related to the assessment of the need for pollutant management show indications of environmental contamination or a significant contamination risk, the site's contamination level and remediation needs must be separately assessed.

6.2

Assessment criteria for the suitability of the techniques and practices

The assessment criteria used for the suitability of the measures and techniques for protecting the soil, and surface and groundwater are

- the environmental impact;
- safety; and
- availability.

The assessment of the environmental impact of the different solutions considers the reduction of the pollutant load, the effectiveness and reliability of its management, the generation of water with pollutant content, the generation of dust with pollutant content, the collection of recycling possibilities of bullet scrap, and the possible noise impact.

Safety has been assessed from the perspectives of ricochet risk and dust generation causing a possible health hazard.

6.3

Assessment of the suitability of the techniques and practices

The results of the assessment of the pollutant emission management techniques presented in Chapter 5 are compiled in Table 6.1. Table 6.2 presents the availability and suitability per shooting sport.

Table 6.1. Suitability of pollutant emission management techniques, summary of the results in Section 5.

Type of shooting range	Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)
Pistol and rifle ranges			
	Mass replacement at impact areas	The soil in the impact areas containing the most bullet scrap is removed regularly. The removal interval depends on the number of shots, recommended 3...5 years.	Significantly reduces the load on the range structures. Particularly effective at new ranges when used regularly, allowing the removal of the most significant part of the bullets. At old ranges, some of the load is often deeper in the backstop berm and not affected by the technique.
	Screening of the impact areas	The soil in the impact areas containing the most bullet scrap is removed regularly. The screening interval depends on the number of shots, recommended 3...5 years. The bullets are screened out of the soil that can then be returned to the structure or disposed of as waste. The bullets can be recycled.	Effective at new ranges when used regularly, allowing the removal of the most significant part of the bullets. Questionable effectiveness at old ranges. Fine-grained metal remains in the berm, and disturbing the soil may increase the solubility of the metals. The spread of dust with metal content must be controlled.
	Metal bullet traps	Bullets are stopped and collected with metal bullet traps installed behind the target devices. The bullets are stopped by a deceleration chamber, plate, or other obstacle.	Pollutants can be mostly managed. Bullets are fragmented in some of the bullet traps, generating metal dust. May be a problem, particularly with non-commercial, self-designed implementations. A rubber/neoprene sheet can be used with them in front of the mouth of the trap to slow down the bullet and prevent the spreading of dust. Dust management with suction equipment is recommended for some of the bullet traps; they are best suited to indoor ranges. At other ranges, possible solutions include covering the spreading area of dust. Minor load from missed bullets. Water must be prevented from getting into contact with the bullet scrap, which eliminates the generation of water with pollutant concentration to a large extent.
	Rubber grinding bullet traps	The bullets are stopped by a layer of rubber grindings covered by a rubber mat in the surface of the backstop berm. Alternatively, the rubber grinding trap can be, for instance, of a box type.	Effective management of pollutants. Bullets remain in the rubber grindings, and the surface layer prevents water from getting into contact with the bullets, thus eliminating the generation of water with pollutant content.
	Covering the backstop berm	Rainwater is prevented from getting into the backstop berm and/or the topsoil in the target area with a covering structure.	Effective management of pollutant migration. Water with pollutant content is not generated, eliminating migration. Dusting is somewhat increased. Requires maintenance of the structure in order to manage the holes from missed shots and ricochets.
	Sand trap structure	The migration of pollutants deeper into the soil and groundwater is prevented with a liner structure, for example, concrete, asphalt, bentonite, or plastic membrane. The percolating water is collected from the surface of the liner with underground drains.	Effective management of pollutants. Water with pollutant content is collected; there is also the possibility of monitoring the water quality and, if necessary, treatment. Replacement of sand from the top of the structure is possible.
	Water management	The water from the vicinity of the shooting range is directed away from the range area. In the range area segment with the highest pollutant load, the percolating water generated is collected with ditches or underground drainage and directed into a basin or collection wells in a controlled manner. The water quality is monitored and, if necessary, the water is treated. If the soil is water permeable, requires a watertight bottom structure underneath the drainage layer.	Effective, enables the monitoring of the quality of water with pollutant content and, if necessary, its treatment.

Possibility of recycling bullet scrap	Possible noise impact	Safety	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Like the current situation, bullet scrap mixed with sand.	No impact during operations. Mass replacement work may cause some noise.	Removal of bullet scrap reduces the risk of ricochets. Dust generation during excavation is possible.	Good. Mass replacement of the entire impact area may be difficult with regard to excavation technology and requires planning.	Suitable for pistol and rifle ranges where the bullets accumulate in the impact areas. Often expensive on the long term.
Good	No impact during operations. Excavation and screening work may cause some noise.	Removal of bullet scrap reduces the risk of ricochets. Dust generation during excavation and screening work must be taken into account.	Good. Can be carried out mechanically using different techniques, or manually. Screening of the entire impact area may be difficult with regard to excavation technology and requires planning.	Limited suitability for pistol and rifle ranges where the bullets accumulate in the impact areas. At old ranges, there is the risk of the metal particles attached to the soil become mobile. Most usable at new ranges at sites where the reduction of load is considered to be a sufficient measure.
Good	No significant impact	Risk of ricochets with some models. Dust generation concentrated in the target area, does not usually cause a health hazard.	Good. Commercial solutions are available; own implementations have also been designed at many ranges.	Well suited to .22-calibre firearms, with several alternative solutions available. Models suitable for rifle ranges have not been tested in Finland, but they are in use elsewhere. As a rule, are not suitable for ranges that have moving targets or can be modified (e.g. practical), or silhouette shooting and biathlon ranges.
Good, in connection with the replacement of the rubber grindings. Bullets can be separated from the grindings, for example, using gravity, and they are mainly intact.	No impact	No risk of ricochets, bullets stay in the filler material. Theoretical fire safety risk, although the filler material is treated with a fire retardant.	Moderate, commercial applications available in, for example, Sweden and Germany	Suitable for most pistol and rifle ranges. Not for silhouette shooting or biathlon ranges.
Like the current situation, bullet scrap mixed with sand.	No significant impact	Possible risk of ricochets, must be taken into consideration during the design stage and material selection.	Good. Possibility for voluntary work. Requires maintenance.	Suitable for most pistol and rifle ranges. At biathlon ranges, emission management in the target areas must also be taken into consideration.
Like the current situation, bullet scrap mixed with sand.	No impact	In practice, corresponds to a normal earthen berm structure. Risk of sliding surfaces if the berm is built too steep, with a slope of over 35 degrees, which requires geotechnical reinforcement	Good. Requires a plan made by an expert. Construction at an old range requires rather extensive earthmoving and likely some remediation of contaminated soil.	Suitable for most pistol and rifle ranges, also modifiable ranges (e.g. practical). Not suitable for silhouette shooting ranges or biathlon.
No impact	No impact	No impact	Good. Requires a plan made by an expert.	Suitable for all shooting ranges.

Table 6.1 continued on the next page...

...Table 6.1 continued

Type of shooting range	Technique	Description	Pollutant management (effectiveness and reliability, generation of water with pollutant content, generation of dust with pollutant content)
Shotgun ranges			
	Terrain contouring	Terrain contouring (with berm structures) reduces the spreading area of the shot. The berm can be surfaced, facilitating the accumulation of the shot at the foot of the berm.	The area subjected to pollutant load is reduced, but the total load remains unchanged unless the shot are regularly removed from the foot of the berm.
	Nets and barriers	The spreading area of the shot is reduced with vertical nets or barriers. The shot can be collected from underneath the net or barrier. The collection can be made easier by surfacing the ground.	The area subjected to pollutant load is reduced, but the total load remains unchanged unless the shot are regularly removed from the foot of the berm.
	Ground surfacing	The spreading area of the shot is surfaced. The ground can be surfaced with, for example, asphalt, membrane, or plastic. The shot can be collected from the surfaced area by, for example, brushing manually or with a machine.	The surfacing and shot collection prevents pollutant load and migration. Water can also be collected from the surfaced area for treatment, which entirely prevents pollutant migration.
	Water management	The water from the vicinity of the shooting range is directed away from the range area. Rainwater is collected from the section of the range area exposed to pollutant load with ditches, terrain contouring and underground drainage into a basin or another collection location. The water quality is monitored and, if necessary, the water is treated. If the soil is water permeable, requires a watertight bottom structure underneath the drainage layer.	Water collection prevents pollutant migration. The large area makes collection more difficult and reduces effectiveness. The large amount of water makes dimensioning and treatment more difficult.
All range types			
	Treatment of water with pollutant content	Water with pollutant content is treated by sedimentation or filtration. Water quality is monitored both before and after treatment.	Effective management of pollutants, metal migration outside the shooting range area is significantly reduced, or prevented entirely. The water filtration system is more effective than sedimentation, but sedimentation allows the easier treatment of large amounts of water.
	Removal of bullet scrap and soil in their entirety	The contaminated soil containing bullet scrap is removed and transported away from the area. Requires quite extensive earthmoving work. The soil and bullet scrap can be separated by screening.	Effective management of pollutants. Eliminates the need of water management when carried out regularly. The mass replacement work causes some dust generation. Regularly causes the contamination of clean soil brought to the site.

Possibility of recycling bullet scrap	Possible noise impact	Safety	Availability / viability	Assessment on the method's suitability in the management of the environmental impact of shooting ranges
Possible, if the shot can be collected.	The berm can act as a structure limiting the propagation of noise.	No risk of ricochets, if the berm is at a sufficient distance from the firing stand. The berm surfacing material can reduce the risk of ricochets, if necessary.	Requires a large amount of soil. Requires a plan made by an expert.	Well suited. Possible to implement as a combined earthen berm and net or barrier structure.
Possible, if the shot can be collected.	Net has no significant impact. The barriers can act as structures limiting the propagation of noise.	The material of the nets and barriers must be chosen so that they do not introduce a risk of ricochets.	Quite poor so far, existing solutions have mainly been designed site-specifically and have variable effectiveness. Requires a plan made by an expert.	Suitable, but as there are no commercial solutions in the domestic market, the solution is not easy to implement.
Gathering and collection of shot are possible	Surfaced ground must be open, which increases noise propagation. Hard surfacing material may increase the propagation of noise.	No impact	Good. Surfacing can be limited by terrain shapes and trees or rocks. Surfacing can be combined with the berm or net/ barrier solution, reducing the area that needs to be surfaced and improves the viability of the solution.	The effectiveness of surfacing depends on the topology of the terrain. Not recommended for large areas, but may be suitable when combined with the reduction of the spreading area of the shot. Water management in a large, surfaced area may be challenging. The possible noise impact surfacing may have must be determined during the design stage.
No impact	No impact	No impact	Water collection from a large area is difficult, can mainly be done with ditches. A membrane or other liner structure can be constructed in the primary shot fall area. Requires a plan made by an expert.	Suitability for the entire range area is rather poor, but the solution is very suitable for use in a limited section of the range. Treatment methods are the same as described above for pistol and rifle ranges, but the larger amount of water must be taken into consideration during the design stage.
No impact	No impact	No impact	Good/moderate. Requires a plan made by an expert.	Well suited to all pistol and rifle ranges, combined with a technique for water collection. This technique is still being developed.
Like the current situation, bullet scrap mixed with sand.	No impact	Removal of bullet scrap reduces the risk of ricochets. Dust generation during excavation is possible.	Good/moderate. Requires a plan made by an expert. Mass replacement requires quite extensive earthmoving work.	As a risk management method, effective in principle, but an expensive solution that has poor eco-efficiency.

Table 6.2. Suitability of the pollutant management techniques for different shooting sports.

Type of firearm	Shooting sport	Suitable pollutant management techniques
Rifle	Standard and free rifle shooting .22LR rifle shooting Bench rest shooting	Metal bullet traps Rubber grinding bullet traps Sand traps (liner in backstop berm and water collection) Covering the backstop berm Removal of impact areas (screening/mass replacement) Backstop berm water management and, if necessary, treatment.
	Silhouette shooting	Water management and, if necessary, treatment in the sections of the range area where bullets accumulate
	Game shooting	Rubber grinding bullet traps Sand traps (liner in backstop berm and water collection) Covering the backstop berm Removal of impact areas (screening/mass replacement) Backstop berm water management and, if necessary, treatment.
	Game target	Rubber grinding bullet traps Sand traps (liner in backstop berm and water collection) Covering the backstop berm Backstop berm water management and, if necessary, treatment.
	Biathlon	Covering the backstop berm and the target area, or a container solution Backstop berm water management and, if necessary, treatment
Shotgun	Skeet Trap Game shooting	Reduction of the spreading area of the shot through terrain contouring, berm structures, nets, or barriers; water management and, if necessary, treatment, or ground surfacing and shot removal Water management and, if necessary, treatment Ground surfacing and shot removal
	Sporting Game trail shooting	Site-specific discretion
	Compak-sporting	Reduction of the spreading area of the shot through terrain contouring, berm structures, nets, or barriers; water management and, if necessary, treatment, or ground surfacing and shot removal Water management and, if necessary, treatment Ground surfacing and shot removal
Pistol	Centre-fire pistol, standard pistol, .22 pistol 25 m pistol and 50 m pistol	Metal bullet traps Rubber grinding bullet traps Sand traps (liner in backstop berm and water collection) Covering the backstop berm Removal of impact areas (screening/mass replacement) Backstop berm water management and, if necessary, treatment.
	Silhouette shooting	Water management and, if necessary, treatment in the sections of the range area where bullets accumulate
Rifle, shotgun and pistol	SRA-shooting Practical shooting	Rubber grinding bullet traps Sand traps (liner in backstop berm and water collection) Covering the backstop berm Backstop berm water management and, if necessary, treatment.
Shooting practice of the Finnish Defence Forces	Basic shooting; assault rifle, rifle, and pistol shooting with small-calibre pistols according to the shooting programme	Metal bullet traps (pistol) Rubber grinding bullet traps Sand traps (liner in backstop berm and water collection) Covering the backstop berm Removal of impact areas (screening/mass replacement) Backstop berm water management and, if necessary, treatment.

Pollutant risk level and choosing the risk management technique

The need and method of pollutant emission management is determined site-specifically based on the operations and conditions, and the resulting environmental risk. In this report, shooting ranges are divided into four categories according to risk level:

- Level 1 – low environmental risk
- Level 2a – elevated surface water contamination risk, impact wider than local
- Level 2b – elevated groundwater contamination risk that is targeted at a classified groundwater area or an aquifer used for household water supply
- Level 3 – high environmental risk or detected environmental impact.

The risk levels are described in more detail in Table 6.3. The risk level is determined site-specifically following the instructions in Appendix F, for example, or in another manner agreed with the authorities. A risk management requirement level has been specified for each risk level, described in Table 6.3. These requirement levels are guidelines only, and the specifications are intended to act as starting points for the planning of risk management. Techniques or practices to be used have not been separately defined for the different requirement levels or shooting range types; risk management can usually be implemented in several different ways. The operator plans and presents the site-specifically most suitable and feasible solution that meets the requirements to the authorities for assessment. Risk management also includes the monitoring of emissions and impacts, and the monitoring of the volume of operations, or the use of the shooting range, due to which they have been included in the requirements. See Appendix G for instructions on the planning of the monitoring. The implementation schedule of the measures may have a significant impact on their economical viability, due to which the urgency of the risk management must be taken into consideration as one of the factors. Should there not be any particular reason for urgent measures, the operator can be granted a sufficient amount of time to complete the implementation, if this facilitates, for instance, arranging financing. The assessment of the economical viability of the measures is discussed in Section 12.

Table 6.3. Risk levels of the pollutants and the starting points of risk management planning at the different levels.

	LEVEL 1	LEVEL 2a	LEVEL 2b	LEVEL 3	No suitable technical solutions
	Basic level	Demanding / surface water	Demanding / groundwater	Extremely demanding	
Significance of the pollutant risk (In accordance with Appendix F)	Low emission potential or Moderate emission potential and low surface/groundwater risk	Moderate or high emission potential and moderate surface water risk	Moderate or high emission potential and moderate groundwater risk	Moderate or high emission potential and high surface/groundwater risk	
Risk description	Pollutant migration from the range area into the environment insignificant or minor. Impact local and minor.	Significant pollutant migration outside the range area via surface waters possible on the long term. Impact wider than local or more severe than minor. New shooting range larger than minor, not located in a groundwater area.	Significant pollutant migration into groundwater in a classified groundwater area or an aquifer used for household water supply is possible or likely on the long term.	Pollutant migration into groundwater or a water body is likely, and the emission may have a significant impact, for example through the use of household water, or clearly elevated pollutant concentrations have already been detected in the groundwater or water body. Establishment of a new shooting range larger than minor in a groundwater area or the immediate vicinity of a sensitive water body.	<i>New range, shooting into a wetland or a water body, or Groundwater level at the level of the range structures, or Location in the protected area around a water abstraction facility, or Location in an area with particular conservation value on which the operations are assessed to have a significant impact</i>
Requirements, pistol and rifle ranges	Monitoring and reporting of use. Management of external water systems. Remediation after the termination of the operations.	Monitoring and reporting of use. Collection of water with pollutant content and, if necessary, treatment, or prevention of the formation of polluted water, or limiting the pollutant load. Remediation after the termination of the operations.	Monitoring and reporting of use. Collection of water with pollutant content and, if necessary, treatment, or prevention of the formation of polluted water, or limiting the pollutant load. Remediation after the termination of the operations.	Monitoring and reporting of use. Collection and treatment of water with pollutant content, or prevention of its formation, and also limiting the pollutant load. Remediation after the termination of the operations, or if significant pollutant migration or impact is detected.	<i>Operations cannot be implemented in accordance with the BAT principles</i>
Requirements, shotgun ranges	Monitoring and reporting of use. Management of external water systems. Remediation after the termination of the operations.	Monitoring and reporting of use. Management of surface waters, and the collection of water with pollutant content from the range area and, if necessary, treatment. Remediation after the termination of the operations.	Monitoring and reporting of use. Reduction of the size of the spreading area of the shot, and limiting the pollutant load, or collection of water from the most critical area and, if necessary, treatment. Remediation after the termination of the operations.	Monitoring and reporting of use. Reduction of the spreading area of the shot, combined with limiting the pollutant load or management of the water in the range area. Remediation after the termination of the operations, or if significant pollutant migration or impact is detected.	<i>Operations cannot be implemented in accordance with the BAT principles</i>
Technical solutions	Directing external waters around the range area with ditches.	A case-specifically suitable solution	A case-specifically suitable solution	A case-specifically suitable solution	
Monitoring of the use	Numbers of shots per range and firearm type, and opening hours	Numbers of shots per range and firearm type, and opening hours	Numbers of shots per range and firearm type, and opening hours	Numbers of shots per range and firearm type, and opening hours	
Monitoring of the emissions and impacts	Not required as a rule. Case-specifically limited monitoring, targeted according to impact, every 3 to 6 years	Monitoring of the surface runoff and surface water in the range area, every 3 to 6 years. Groundwater monitoring when separately justified.	Monitoring of the percolating water of the backstop berm and/or groundwater every 1 to 3 years. Surface water monitoring when separately justified.	Targeted according to impact every 1 to 3 years	
Schedule	-	0–10 years or based on discretion. No immediate need for technical risk management measures, possibility for the operator to prepare financially. Assessment of the need for pollutant management must be made, and monitoring started immediately.	0–10 years or based on discretion. No immediate need for technical risk management measures, possibility for the operator to prepare financially. Assessment of the need for pollutant management must be made, and monitoring started immediately.	0–5 years. Measures must be implemented as soon as possible.	

Summary of the best available techniques and environmental best practices in pollutant management

- The pollutant management need and the site-specific best available techniques for shooting range operations are determined based on the long-term environmental risk caused by the operations.
- Four different requirement levels have been defined for the best available techniques. These so-called risk levels and starting points for risk management planning are presented in Table 6.3.
- The pollutant management requirements can be determined using the procedure for the assessment of the need for pollutant management at a shooting range, based on environmental risk assessment, presented in Appendix F.
- The assessment procedure of the need for pollutant management involves the investigation and description of the site's operating history, soil, groundwater and other environmental conditions, and the emissions caused by the operations and their impact in the current situation. The goal is to determine how the operations burden the environment and what effects they have.
- Depending on the site's characteristics and the already available source data, the survey can be carried out either based on the existing source data, or it can include terrain surveys and environmental sampling.
- Based on the results of the assessment of the need for pollutant management, the risk level and risk management objectives for the site are determined, and the required risk management measures planned. The selection of methods and techniques is also influenced by their technical suitability for the site, their cost-effectiveness, and the implementation schedule.
- At new shooting ranges, the requirements primarily comprise the collection of water with pollutant content and, if necessary, its treatment, or the prevention of water accumulation and/or limiting the pollutant load.
- The effectiveness of pollutant management must be regularly monitored. The results from the assessment of the need for pollutant management are used as help when planning the monitoring programme. See Appendix G for instruction on how to implement the monitoring.
- The assessment criteria for the suitability of the methods and techniques were the environmental impact, safety, and availability. The results of the suitability assessment are presented in Tables 6.1 and 6.2.

7 Development needs of the management of pollutant emissions

The usage experience of a majority of the presented technical measures for pollutant management is limited. For this reason it can be assumed that the designs and the related solutions, such as dimensioning and material selection, will develop further. The systematic development of the technical measures for pollutant management on the national level requires the collection and analysis of usage experiences and new, improved designs, and the updating of this report based on the result after a period of, for example, five years.

Alternative materials for lead bullets and shot should be studied more. Aluminium is one promising material that is already in use in certain live-fire combat exercises of the Finnish Defence Forces. The possibilities of changing certain factors limiting the use of alternative materials, such as the requirements on bullets and shot used in competitions, should be studied.

With regard to remediation methods, the use of tailings from an apatite mine as a lead-binding material requires further study, for example. A Finnish study by the University of Helsinki gave indications that in certain conditions, the tailings would be suitable for reducing the solubility of lead. The use of tailings in remediation would also benefit the mining industry, as significant amounts of unutilised tailings are generated.

Water treatment methods should be developed. Water collection from wide areas results in a lot of water that needs to be treated, which is a deal breaker for most current treatment methods. The use of equalisation basins is possible in certain areas, but there is a need to also develop other solutions for the treatment of the water volumes from expansive shotgun ranges or large pistol and rifle ranges.

The recycling possibilities for bullet and shot scrap remain poor. The materials are not processed for reuse in Finland; the scrap to be recycled is transported abroad. The compensation received from the scrap is minimal. The recycling operations are not organised, and some of the scrap is disposed of as hazardous waste or among contaminated soil. The recycling system should be developed on a nationwide basis to provide incentive to recycle the bullet and shot scrap.

Although the BAT report does not directly discuss the remediation of shooting ranges from the perspective of contaminated soil, it clearly became evident during the study that there exists a need to study, assess, and develop the processes related to the procedure for the assessment of the need for remediation, remediation techniques, and the utilisation and final disposal of contaminated soil.



8 Shooting range noise

Shooting generates noise. Noise refers to a sound that is damaging (e.g. hearing damage) or harmful (e.g. annoyance) to its hearer. According to the Environmental Protection Act, noise is a physical harm that may cause pollution of the environment. In the case of environmental noise from shooting ranges, the harm is primarily based on the annoyance caused by the noise. This Section discusses the best techniques and practices related to the management of shooting range noise.

Guideline values have been set for environmental noise from shooting ranges in Government Decision 53/1997. The guideline values are specified as A-frequency and I-time weighted maximum sound levels L_{Amax} . The guideline values are presented in Table 8.1.

Section 3 of the Government Decision 53/1997 states that when applying the Decision, one must take into consideration the nature of shooting range operations, such as shooting times, numbers of shots and the shooting sports, as well as the actual or planned use and importance of the area referred to in Section 2. There are no more detailed application instructions. This report contains the working group's views on the majority of the above-mentioned issues.

Table 8.1. Guideline values for the maximum sound level L_{Amax} to be used as design values

Land use	Sound level [dB]
Residential areas	65
Areas in service of educational institutions	
Recreational areas in population centres or in the immediate vicinity of population centres	60
Areas in service of healthcare institutions	
Areas used for holiday homes	
Nature conservation areas	

8.1

Significance of shooting range noise

In 2011, it was estimated that around 3,000 people live in the noise areas of civilian shooting ranges (Saarinen A 2013). The number of people exposed to noise has reduced to less than half from the 1998 figure. The reduction is largely a result of one shooting range located in the middle of densely populated area (Viikki, Helsinki) being closed down.

In 2012, the Finnish Defence Forces had 48 shooting ranges, with a majority of them also seeing civilian use. According to a study on these, 2,400 residents are exposed to an AI maximum sound level of over 65 dB, while 630 holiday homes are located in the area of the AI maximum sound level area of over 60 dB. The study is based on noise areas determined based on the noise surveys performed, and the 2011 data of the Population Register Centre's Building and Dwelling Register (BDR). Of the shoot-

ing ranges, 24, or half, were located in an area with no people exposed to noise over 60 dB. Six ranges had over 100 exposed residents. Hiukkavaara was the only range with over 1,000 exposed people (Hosiokangas & Kumpula 2011).

With regard to the FDF, the shooting ranges are mostly used during the day, while the civilian shooting ranges are used during the evenings and weekends. Shooting ranges are used during the night only very seldom, for example, when the Finnish Defence Forces arranges night-firing training. This being the case, noise is also generally generated only during the day when it is light out, and the shooting range noise does not cause disturbance during sleeping hours.

According to estimates, 285,000 people live in the noise areas of public highways, and 500,000...600,000 in the noise areas of city streets. In total, around 1,000,000 people are estimated to be exposed to noise exceeding the guideline values (Saarinen A 2013). The number of people exposed to shooting range noise is less than 1% of this.

The harmful effects of shooting range noise are related to the comfort of the living environment. Studies have been unable to identify any other possible health-related effects. There are not many restrictions on land use and construction due to shooting range noise, as the noise area practice has not yet become established. The effect of shooting range noise on the value of real estate has not been studied in Finland. Based on the locations of the shooting ranges and the number of people exposed, the effect can be assumed to be minor.

8.2

Generation of shooting range noise

Shooting range noise usually has two different sound generation mechanisms, meaning that the noise comprises two different components: the firing noise, or muzzle blast, and the bullet's flight noise, or supersonic boom. They usually occur so close in time to each other that they cannot be told apart by listening or in regular measurements.

The firing noise, or muzzle blast, is caused by the combustion gas expelled from the barrel of the firearm, caused by the combustion of the powder. It expands rapidly and causes a pressure, or sound wave. The flying bullet generates a second, separate noise, the supersonic boom, if the bullet's velocity is higher than the speed of sound (around 330–340 m/s, depending on temperature).

In some special cases, the bullet impact to a hard target generates a third noise, the impact noise, which is louder than usual. Impact noise is usually insignificant when compared to the other noise components. Bullet traps with hard surfaces may increase the impact noise somewhat.

8.3

Propagation of shooting range noise

The same acoustic phenomena apply to the propagation of shooting range noise as to other environmental noise (Lahti 2003). Unlike previously suggested in some occasions in Finland, the very short duration of shooting noise compared to other, slowly varying or constant environmental noises has no effect whatsoever on the fundamental rules of acoustics controlling its propagation.

A sound source radiates an expanding sound wave, where the sound energy is spread over a larger surface area as the distance increases. The sound pressure decreases correspondingly. This attenuation due to distance always takes place, regardless of terrain and other factors.

Acoustically, the muzzle blast component of shooting noise is generated in a single point. The type of the sound source is thus a point source, and the sound wave it creates is a spherical wave. The wave follows the normal propagation rules of a spherical wave.

The generation of the flight noise and the type of the sound wave are complex phenomena due to the supersonic speed of the bullet. The attenuation of the sound wave that propagates as a conical wave in a certain angle follows its own special form. To simplify, the conical wave attenuates clearly slower than a spherical wave in the vicinity of the bullet's flight trajectory.

8.4

Assessment, measurement and calculation of the noise

The assessment, measurement, and calculation of noise are not strictly speaking best available techniques, but they are necessary for determining and dimensioning the techniques. The results of the measurements and the calculations should be congruent. The results have a rather large effect on the dimensioning of the noise abatement need, and the scope and costs of the measures.

8.4.1

Assessment of shooting range noise

The harmfulness of shooting range noise is assessed in Finland in accordance with the Government Decision 53/1997. The Decision defines the sound level quantity used in the assessment, the maximum value of the A-frequency weighted and I-time weighted sound pressure level, or AI maximum sound level L_{AImax} in short, and specifies guideline values for the quantity.

Thus far, the only official method of assessing shooting range noise in Finland and comparing it with the guideline value is to measure the noise in accordance with the relevant instructions (Ministry of the Environment 1999).

There are no official instructions on the use of the shooting range noise prediction method. Neither has a common practice become established via other sources thus far for the prediction method being considered to be as valid or even the primary assessment method. The situation is therefore the opposite to, for instance, the assessment of traffic or industrial noise, where the prediction method is considered to be more reliable than measurements, and usually sufficient as the only method used.

8.4.2

Measurement of shooting range noise

Shooting range noise is measured in accordance with the measurement instructions of the Ministry of the Environment (Ministry of the Environment 1999). The measured sound level quantity is the AI-maximum sound level L_{AImax} of the guideline values. According to the instructions, the measurements are carried out in the place exposed to the noise, or the site of the possible disturbance, separately for each shooting sport and each range. The maximum sound level is ordered to be measured "as an average value of a minimum of five shots". The justification for this is that at greater distances, the maximum sound levels of individual shots may vary significantly, primarily due to momentary changes in weather conditions (e.g. changes in wind speed and gusts of wind).

The representativeness of a single series of measurements carried out during a single day is relatively low, even if the weather conditions during the measurements

meet the recommendations of the measurement instructions. It is usually necessary to carry out measurements on more than one day. Even an extensive series of measurements at typical distances and weather conditions meeting the recommendations of the instructions may still give a rather large range of results; the difference between the lowest and highest sound levels can often be 5...10 dB, sometimes even more (Parri 2009).

8.4.3

Calculation of shooting range noise

The measurement results always represent only themselves, i.e., the situation and prevailing conditions during precisely the day and time of measurement. Only the statistical result of a long series of measurements can be considered to represent a longer time period with some modicum of reliability. The principal purpose of the model calculation is, instead, to directly generate a result representing the long-term noise situation that corresponds as well as possible with the overall results of numerous different measurements performed over a long period of time and in the specified weather and other measurement conditions.

The established calculation method for shooting range noise in Finland is the joint Nordic shooting range noise prediction method. The method is based on the joint Nordic environmental noise prediction method (so-called industrial noise prediction method) (Kragh et al 1982). The prediction method is used to calculate in principle the AI maximum sound level $L_{A\text{Imax}}$ at the point of calculation, based on the noise emission data of the firearms. The calculation is performed as a function of frequency, i.e., in octave bands.

The method has been formulated in such a manner that it produces results that correspond with weather conditions favourable to noise propagation; in practice, this means a moderate tailwind. In the method, there is "fair wind in all directions", always from the noise source to each calculation point. The moderately favourable weather conditions have a large significance in principle. They also mean that the calculation results correspond to a measurement result that could be obtained by performing a very long-term series of measurements and calculating the long-term energy average of the measurement results.

With the exception of the bullet noise, the calculation can be performed using common calculation software (such as SoundPlan and Cadna/A), using their general calculation models. For a more detailed description on how to use the prediction method and the software, see Sections H5.2 and H5.3 of Appendix H. The calculation of the bullet noise is discussed in Section H5.4 of the Appendix.

8.4.4

Noise zones and noise area

In practice, the measurement of the noise level of shooting range noise is only possible at a limited number of measurement points, usually located near the sites exposed to the noise. If you wish to create a noise level map of the area surrounding the shooting range, you must use model calculation.

The results of the model calculations, or the areas delimited by the noise level curves of the noise map, are called noise zones. The map presents, for example, the 55–60 dB, 60–65 dB, and 65–70 dB noise zones of the AI maximum sound level $L_{A\text{Imax}}$. The noise zones and the exposed sites within them can be used in the immediate assessment of the harmfulness of the noise by comparing the zones with the guideline or limit values. Furthermore, using the shot number data in the assessment is recommended (see Table 10.1).

The concept of noise area, not the same as a noise zone, is required in land use planning and town planning. A noise area is an area where restrictions are set for construction, for example, during town planning, etc.

Table 8.2. Total noise emissions of small-calibre firearms: A-w. sound energy level L_{OA} [dB]. Source data: Ministry of the Environment (Saario 1985) and the Finnish Defence Forces (Markula 2006), Miljøstyrelsen 1995.

Ministry of the Environment 1985		
rifle	.338 magnum	140
rifle	7.0 Remington magnum	138
rifle	8.2 x 53 R	138
rifle	30-06	138
semi-automatic rifle	.308 Winchester	138
rifle	.308 Winchester	137
shotgun (elev 0°)	cal 12 skeet 2 mm	137
shotgun (elev 45°)	cal 12 skeet 2 mm	137
shotgun	cal 12 trap 2 mm	135
revolver	.44 magnum	136
rifle	.222 Remington	136
rifle	7.62 x 53 R	136
.22 LR rifle	.22 LR high vel. (wild boar)	126
revolver	.357 magnum	125
revolver	.38 special	124
free pistol	.22 LR	121
.22 pistol	.22 LR	120
revolver	.22 LR	118
revolver	.32 SW long	117
rapid fire pistol	.22 LR	120
.22 LR rifle	.22 LR	113
Finnish Defence Forces 2006		
assault rifle	7.62 Rk 62	138
assault rifle	7.62 Rk 95	137
military rifle	7.62 Sotkiv 85	137
military pistol	9.00 Pist	137
Miljøstyrelsen 1995		
hunting rifle	6.5 Norma, 9 g Vulkan	137
Otterup rifle	6.5 Norma	135
shotgun	cal 12 Italian, lead shot no. 9 (2 mm)	136
shotgun	cal 12 Italian, lead shot no. 7 (2.5 mm)	134
shotgun	cal 12 Dan-Arms, lead shot no. 9 (2 mm)	132
shotgun	cal 12 Dan-Arms, lead shot no. 7 (2.5 mm)	131
shotgun	cal 12 Dan-Arms, steel shot no. 7 (2.5 mm)	134
revolver	.357 Norma Magnum	133
revolver	.38 Remington special	125
pistol	.32 Norma	124
pistol Walther	.22 Norma	124
pistol Agner	.22 Eley blue	121
Otterup rifle	.22 Norma	111

The noise area or areas is/are created based on the noise zones generated by the model calculation using certain rules. For instance, in a varying terrain, the shapes of the noise zones may be non-continuous, comprising several different areas that may be very small in size. The noise area or areas should comprise clearer and preferably continuous areas. One rule could be considered to be that a noise area is an area surrounded by a smooth, closed curve that encloses the curves of a certain noise zone.

8.4.5

Noise emission data for firearms

The strength of sound of the shooting noise from a firearm with regard to the environment can be compared with the help of noise emission data. Table 8.2 contains calculated total noise emissions for firearms as A-weighted sound energy levels, compiled from various sources. The concept of firearm noise emission is described in more detail in Appendix H, Section H-1.1.1, Sound energy level.

The hearing damage risk caused by firearms is not assessed using the firearm's noise emission, or energy level. Instead, the hearing damage risk is assessed based on the C-weighted peak sound level (L_{Cpeak}) occurring near the ear. The peak sound level of the shooting noise of all firearms exceeds the 140 dB C peak sound level limit value for hearing damage risk at the shooter's ear.

The quality of emission measurements varies greatly. Concerning the Finnish measurements from 1985, it is now known that at that time, the researchers did not realise that they should separate the bullet noise component from the muzzle blast emission. It is also possible that the Danish data in the table has the same deficiency. The significance of the noise emission data is assessed in Appendix H, Section H-1.1.

Summary of shooting range noise

- Guideline values have been set for environmental noise from shooting ranges in Government Decision 53/1997. The guideline values are specified as A-frequency and I-time weighted maximum sound levels L_{AImax} .
- Shooting noise usually comprises two different components: the firing noise, or muzzle blast, and the bullet's flight noise, or supersonic boom.
- Shooting range noise is assessed through measurements and calculations
- The propagation of shooting range noise is depicted as noise zones and noise areas
- The sound strength of the muzzle blast from a firearm can be compared with the help of noise emission data
- From a nation-wide perspective, the number of people exposed to shooting range noise is minor

9 Management and reduction of shooting range noise

Noise management is divided into noise abatement and the reduction of the harmful impacts. Noise abatement is commonly divided into reduction of the source emission, reduction of transmission, and receiver protection. In the case of shooting range noise, receiver protection is not used as a means of abatement. Most commonly, noise is abated with noise barriers and noise control structures. Planning the usage times of the range aim at reducing the harmful impact.

9.1

Design

During the designing stage of the shooting range, the noise caused by the shooting range can be influenced effectively and the generation of harm prevented. In Finland, only a rather small number of new shooting ranges are designed, only a few ranges each year. The design should aim at reducing the noise emissions and reducing the noise propagation, by paying attention to, for example, the location of the range, range structures, changes to the terrain and trees, and noise barriers. The arrangements of the range area, the positioning of the ranges and the direction of firing can affect the noise spreading to the environment.

Early in the design stage, contacting the municipal land use planner and the building and environmental protection authority is recommended in order to determine the prerequisites for range placement. With regard to noise, the location of the shooting range should be selected so that the distance to the exposed sites is as large as possible. A distance of 3.5 km is usually enough for noise abatement purposes. At ranges where only .22 calibre firearms are used, the distance is shorter. The locations of residential buildings, holiday homes, and healthcare and educational institutes in the surroundings of the planned location of the range must be determined to a distance of 3.5 km. The locations of various nature conservation areas and recreational areas must also be determined.

Once the locations of these sites are known, the noise zone templates (see Appendix) are positioned on a map over the ranges of each shooting sport. If no sites are located within the noise zones, a more detailed noise prevention plan is not required. If there are sites within the noise zones, a noise survey must be prepared and the need for noise abatement assessed using sufficient expertise.

The orientation of the range can affect the location of the noise area, as the noise radiates most effectively in the direction of firing. When planning the range orientation, you can utilise the noise zones of the template (Appendix I). The terrain contours in the surroundings of the range can be utilised as obstacles to noise propagation. The elevation of the range can be used to affect noise propagation. With regard to noise, it is beneficial to design the range to a place with as low elevation as possible, or excavate a location for the range so that it is below the surrounding terrain. If the orientation, elevation or terrain contours of the range do not give sufficient results, structural noise control solutions such as noise berms or noise barriers will also be needed.

Land use and zoning

Land use planning is the primary noise management measure in the design of new shooting ranges. In land use planning and zoning, shooting ranges and their noise areas must be marked in the plans (Figure 9.1). This secures the position of the shooting range so that no residential buildings or other sites or activities sensitive to noise are planned inside the noise areas.

Noise areas must also be determined for existing shooting ranges. The land use in the area surrounding these ranges is also planned taking the noise from the shooting range into consideration. The goal must be that the number of exposed people does not increase, and decreases on the long term.

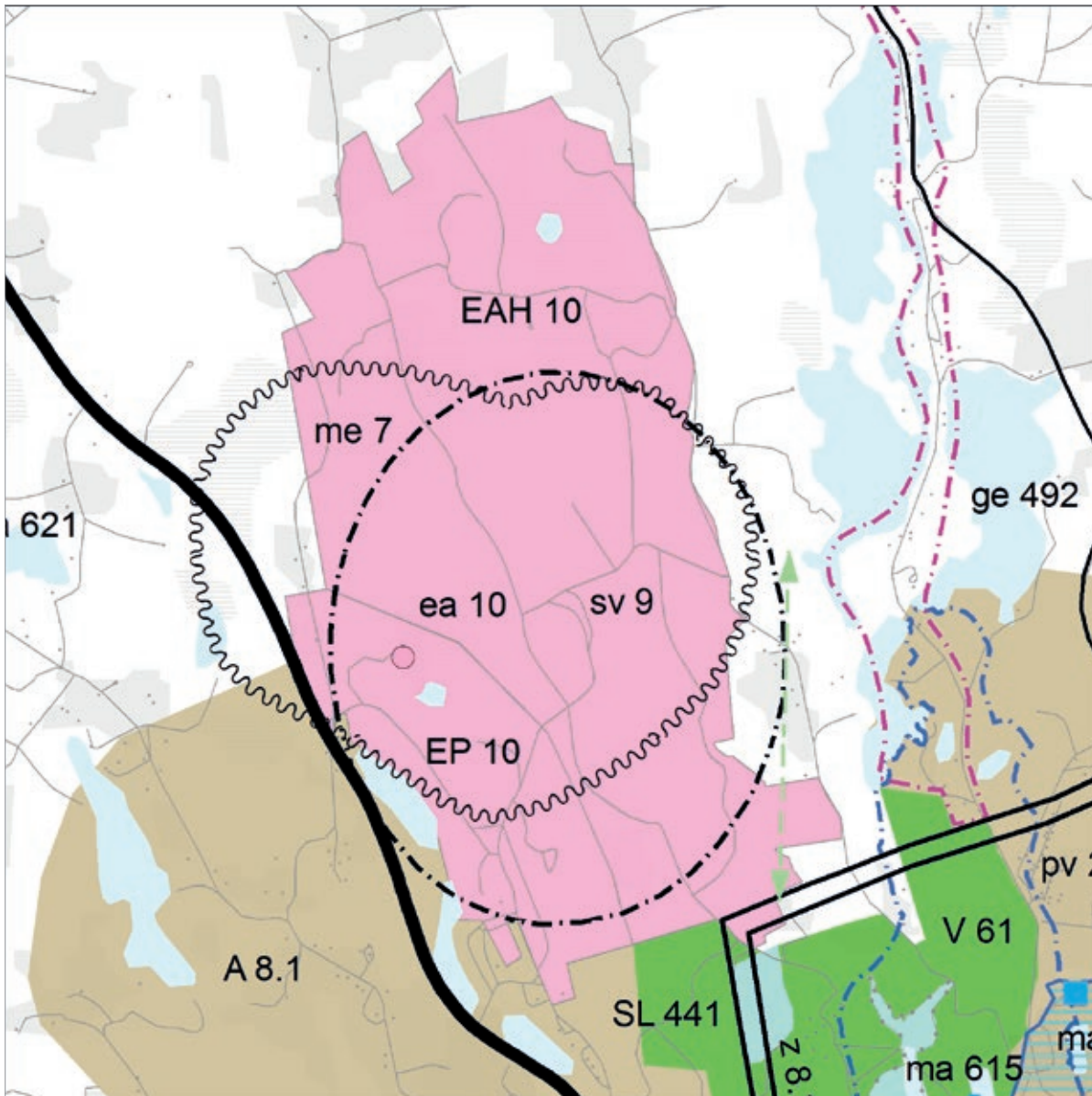


Figure 9.1. An example of the designation of a shooting range and the noise area and a planning regulation in a provincial land use plan (Plan: Regional Council of South Savo; Base map: National Land Survey of Finland).

9.1.2

Sport shooting ranges

There are sport shooting ranges at shooting range facilities, where different firearms are used. When designing a new shooting range, you must consider what sport shooting ranges can be placed in the area, and how. With regard to existing shooting ranges, this consideration must also be extended to the sufficiency of the noise abatement. Noise control measures are targeted at the sport shooting ranges, beginning with the noisiest. In some cases, an individual sport shooting range must be closed in order to reduce the total noise load.

There have been cases, where shotgun ranges, for instance, have had to be closed due to residential buildings built nearby, while rifle, pistol and .22LR ranges could continue operations. Similarly, in some cases, large-calibre hunting training ranges have had to be closed, while biathlon, pistol and .22LR ranges could continue operations. This means that the measures do not require the immediate closing down of the entire shooting range; the most important firearms and ranges, and their noise prevention measures, just need to be reviewed.

9.2

Reduction of the noise emission of the firearm

9.2.1

Calibres and cartridges

The calibre and the cartridge load have a significant impact on the noise emission of a firearm. Cartridges can be loaded with very different amounts of powder and different bullets. For example, there are several dozens of alternative loads for the common hunting rifle calibre .308. When the shooters' own loads are added to this number, there are hundreds of alternatives for a single calibre. In pistols and rifles, the relation of the calibre to the noise emission can be generalised so that the larger the calibre (inner diameter of the barrel), the greater the noise emission.

Table 8.2 shows that the total noise emission, or A-weighted sound energy level, of small-calibre firearms used in Finland varies between 113 dB and 140 dB. The lowest sound energy can be found in .22-calibre pistols and rifles, while high-powered rifles have the highest sound energy. If the noise emission data of the firearms is compared as a function of calibre, the result for .22LR pistols and rifles is 113–121 dB, for other rifles 135–140 dB, for shotguns 135–137 dB, and for pistols 124–137 dB. To simplify, the values in Table 9.1 can be presented as the average total noise emissions.

Over the years, the Finnish Defence Forces and cartridge manufacturers have carried out tests in order to reduce the amount of powder in the cartridge, modify the bullet and reduce the noise, but the results have mostly been meagre. Noise is

Table 9.1. Average overall noise emissions of firearms, or A-weighted sound energy levels by firearm group.

	A-weighted sound energy level, dB
Rifles	138
Shotguns	136
Pistols	130
.22LR rifles	120
.22 calibre pistols	120

reduced when the amount of powder is reduced, but the firearm's operation, soiling, accuracy, bullet flight, sensitivity to wind, and many other factors are deteriorated to such an extent that these measures cannot be implemented in practice. For these reasons, cartridge manufacturers have optimised the amount and type of powder and the bullets used in their cartridges in order to achieve the best possible performance, and there have not been any new innovations in this field over the last years.

The choice of shotgun shells does not have a large impact on the resulting noise emission. At shotgun ranges, competition shells are most commonly used. Their shot diameter is 2.0 or 2.5 mm, and the shot load is 24 g. Shotgun hunting shells have a larger load and greater noise emission, but their use is often prohibited at shotgun ranges.

9.2.2

Muzzle brakes

Firearms may have muzzle brakes developed to reduce recoil, thus improving the shooting characteristics of the firearm. A muzzle brake slightly increases the amount of noise in the shooter's direction, but not in the frontal sector. A muzzle brake has only a minor effect on environmental noise.

With regard to its structure, a muzzle brake is integrated into the barrel of the firearm or it is a separate part mounted at the end of the barrel (Figure 9.2). The most common structure comprises drilled or machined holes at the front part of the barrel pointing directly upwards, upwards at an angle, or to the sides. This results in the muzzle pressure being directed to the sides or upwards.

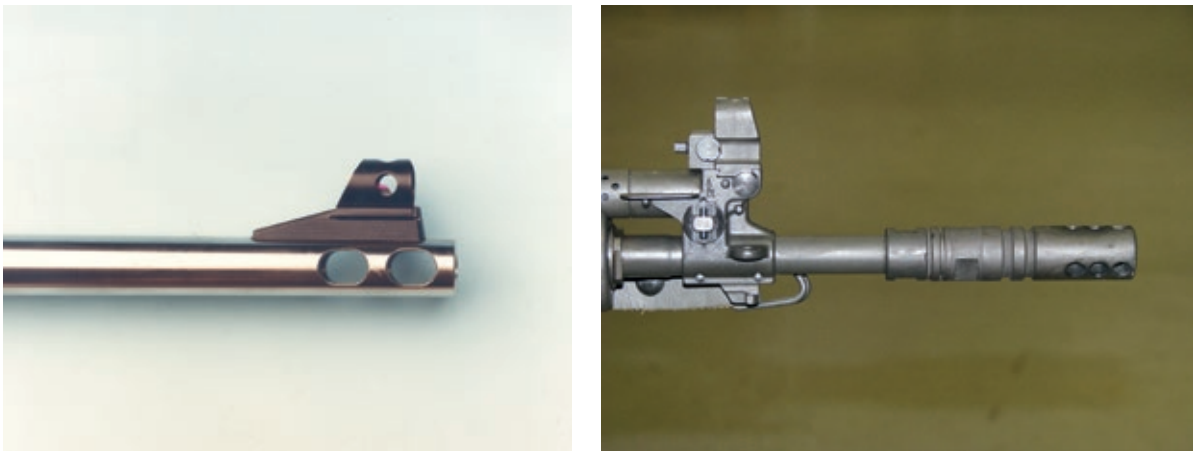


Figure 9.2. On the left, an integrated muzzle brake (Photo: Löppö Production), and on the right, a muzzle brake manufactured and installed as a separate component (Photo: SA kuva).

9.2.3

Silencers

Silencers are used in order to reduce the shooter's exposure to noise and reduce the recoil of the firearm (Figure 9.3). However, silencers also attenuate the noise emissions to the environment. Their use is limited by most competition rules prohibiting the use of silencers. The Finnish Defence Forces does not use silencers in the assault rifles when it trains conscripts and reservists. The purchase and installation of a silencer costs around EUR 200–500.

Other effects of a silencer include a change in the firearm's impact point and the safety risk caused by the use of the silencer. A silencer's effect on environmental noise is presented in Figures 9.4 and 9.5.



Figure 9.3. Assault rifle silencers (Photo: Finnish Defence Forces).

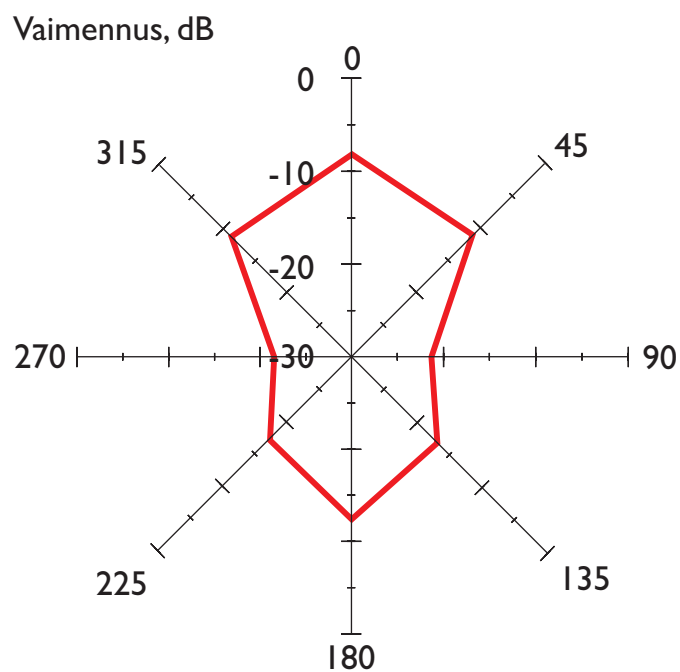


Figure 9.4. An assault rifle silencer's effect on the muzzle blast, directional dependence.

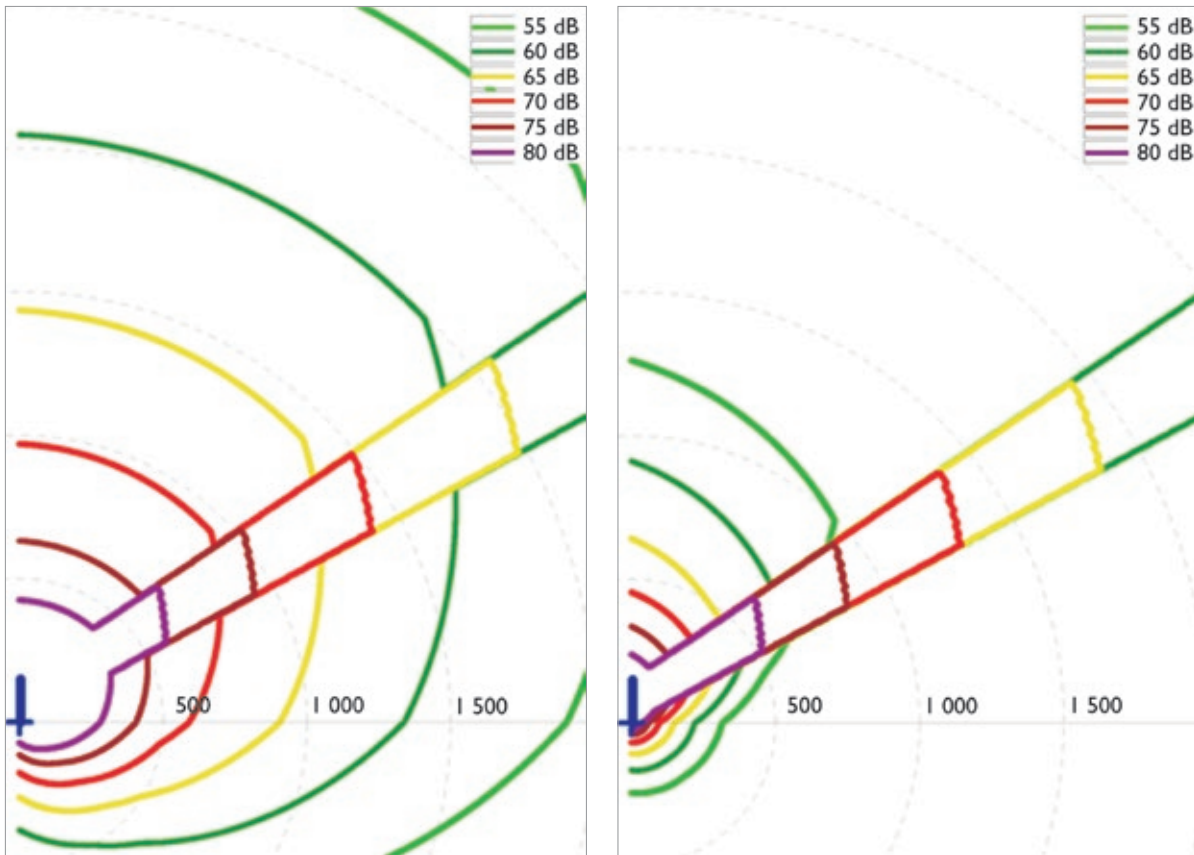


Figure 9.5. Silencer's effect on the total noise (muzzle blast + bullet noise) of a 7.62 Rk 62 assault rifle on open, level ground: (left) no silencer (right) = silencer. The silencer reduces the muzzle blast but does not affect the generation of the bullet noise.

9.3

Management of noise propagation

9.3.1

Enclosures

The firing stands at a shooting range are often located in an enclosure. The enclosure usually significantly attenuates the noise propagating to the sides and the rear sector, compared to a situation without the enclosure. If the enclosure is a sturdy structure, closed from the sides and the rear, the noise propagating directly through the walls will be attenuated by around 15–20 dB, depending on the structure, at best as much as by 25 dB. If the wall has windows, the sound insulation is poorer, and if it has ventilation holes or gaps, the insulation may be practically non-existent. At worst, a combination where the roof slope rises towards the rear and the rear wall is not solid may even slightly increase the noise towards the rear.

In addition to the path directly through the walls of the enclosure, sound can get behind the enclosure via another route: the directivity of the sound radiating upwards from the muzzle of the firearm is the same as that of sound radiating directly to the sides; the sound is thus usually clearly louder than directly to the rear. The sound radiating upwards diffracts around the front edge of the roof to the rear over the roof. Sound travelling via this path strengthens the total sound audible to the rear, which means that the total attenuation towards the rear is clearly lower than just the sound insulation of the sound going through the back wall compared to a situation

with no enclosure. Furthermore, reflections from range structures may in some cases propagate to the side and the rear of the firing cover or enclosure, increasing the noise in those locations.

With regard to environmental noise, an acoustically good enclosure is sturdy, and solid and tight from both the sides and the rear. Ventilation for the extraction of powder smoke, for example, should preferably be arranged via a well insulated passage at the bottom of the back edge of the enclosure. A well-designed roof is slanted, ascending from the back to the front, although the front part of the roof may have the opposite slant, descending towards the front, which reduces the above-mentioned diffraction towards the rear around the edge of the roof. The further forward and down the roof reaches, the better it is with regard to abating noise propagating over the roof to the rear. It must be noted that the roof has no effect whatsoever to noise radiating to the frontal sector ($\pm 90^\circ$). The noise radiating to the frontal sector emanates entirely directly from the muzzle of the firearm.

The ceiling surface should be covered with sound-absorbing cladding, particularly above the locations of the shooters. 50 mm of mineral wool constitutes suitable and fully sufficient cladding. It has a beneficial effect not only on the environmental noise, but naturally also the noise heard by the shooters themselves inside the enclosure. Cladding the rear wall of the enclosure does not have much effect on the environmental noise, however. Even if the wall is hard, the sound reflected back forward and out originally radiated backward from the firearm, and a firearm's noise emission to the rear is, in practice, always much lower than directly to the front. However, the absorptive cladding of the rear wall does provide some additional benefit inside the enclosure.

Noise attenuation can be achieved in the frontal sector towards the sides (c. $90^\circ \dots 45^\circ$ perhaps even $\dots 30^\circ$) by installing partitioning walls, made from a hard material covered in an absorbent material, between the firing stands of the enclosure so that

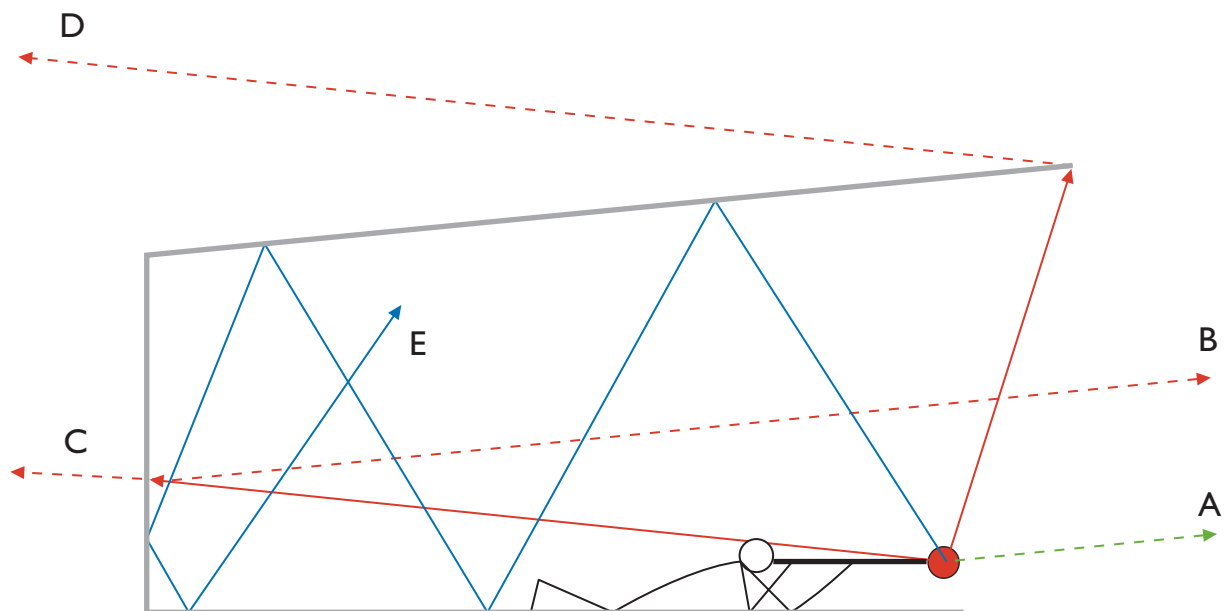


Figure 9.6. Cross section of a firing line enclosure, and travel paths of the sound radiation from the muzzle blast:

- A: direct sound to the frontal sector
- B: sound reflected from the rear wall of the enclosure (insignificant compared to A)
- C: sound travelling through the rear wall of the enclosure
- D: sound diffracting or bending around the front edge of the enclosure's roof towards the back (significance same magnitude as C)
- E: sound reflecting inside the enclosure (significant only inside the enclosure, meaningless with regard to the environment).

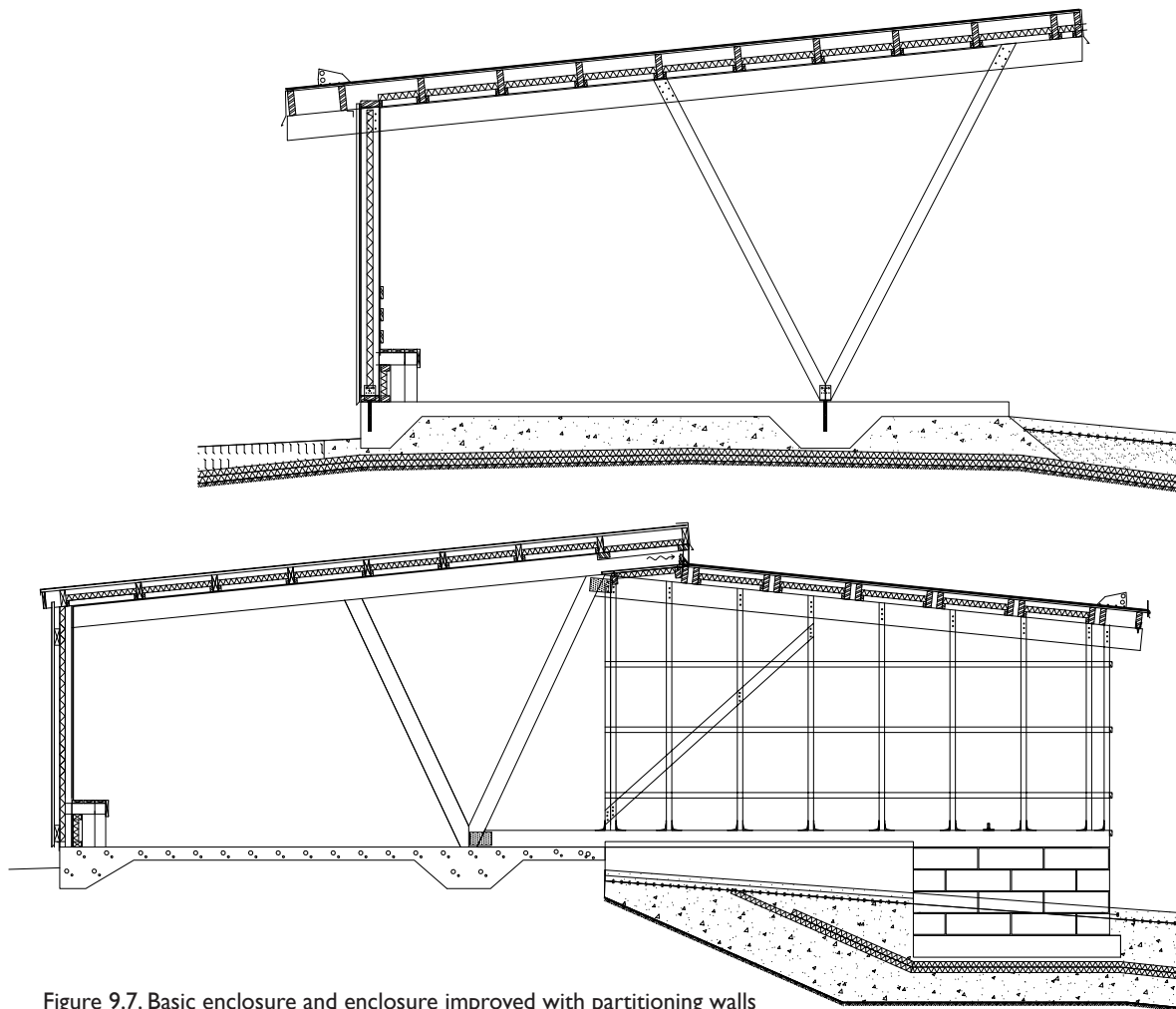


Figure 9.7. Basic enclosure and enclosure improved with partitioning walls



Figure 9.8. Enclosure with 4.6 m long noise-attenuating partitioning walls.



Figure 9.9. Photo from the enclosure of an elk target shooting range, Krääkkiö range, Vesilahti. Drawings in principle in OM publication 39/93.



Figure 9.10. The open enclosure at the Nokia pistol range without noise prevention structures.

their front edges reach clearly past the barrel of the firearm (Appendix J1.2). Noise abatement can be achieved in the directions towards the sides where the front edge of the partitioning wall blocks the line of sight when looking from where the muzzle of the firearm is located.

The walls and the roof of the enclosure can be made from wood. The most important thing is the tightness of the structure. A structure that is more robust and insulates more than a wall made of wooden boards does not usually have additional acoustic benefit, as some of the sound will in any case radiate out from the front and turn towards the rear around the front edges of the roof or the side walls.

9.3.2

Noise barriers

The environmental noise from shooting ranges is usually a larger problem to the front than to the rear, or in the sector covering -90° ... 0° ... $+90^{\circ}$. To the front and obliquely towards the sides, the berms at the range are most important factor affecting the propagation of noise. There are usually at least some kind of berms at the sides and the end of the range for safety reasons. However, berms designed for safety purposes only may, in some cases, be too low with regard to noise.

This is explained by two factors. Some of the sound diffracts over the top of the berm and to its other side. In general, the sound shadow produced by a noise barrier, berm, or screen is not as sharp and deep as the shadow produced by an obstacle in the way of light. The higher the berm is, i.e., the larger the angle the sound diffracting over the top of the berm must turn downwards, the higher the attenuation of the sound.

Weather conditions affecting the propagation paths of the sound are the second factor. When the weather is favourable to noise propagation, or mainly when the wind blows in the same direction as the sound travels, the sound will bend downwards. Sound that started out at a slightly upwards slanted angle goes over the berm or another barrier, and bends downwards farther away back to the ground.

For these reasons, the sufficiency of berm height for noise attenuation cannot be determined just by the berm blocking the line of sight from the barrel of the firearm to the receiver.

An earthen berm is often the most natural choice for a noise barrier at a shooting range. Noise barriers of the berm and screen type that are of the same height are, however, acoustically entirely identical, if the structure of the screen is rigid and solid. This means that no sound will go through the screen, in practice only over it.

Unlike in the instructions of the previous section, no general verbal instructions cannot be provided for the sufficient height of the berm. Precise dimensions and numbers are required to express what is sufficient. Figures 9.12 and 9.13 present the relationships between berm (or screen-type barrier) heights and distances, and the desired barrier attenuation. The curves in the figures are based on the Nordic shooting range noise prediction method (NT ACOU 099 2002).

An earthen noise berm is always made from a suitable material that is also the best possible. It does not let sound through or reflect sound; this means that sound hitting the slope of the berm is absorbed into the berm. The most significant downside of the berm is its width, i.e., its crest being farther away than the front edge of its foot. If there is a need to bring the ridge of the noise barrier as close to the firearm, or the noise source, a screen-type barrier is better than a berm. A noise screen in its basic form has a hard surface, reflecting sound to the opposite direction (Figure 9.11). If also this direction is problematic, the surface of the screen-type noise barrier on the side of the noise source must be made sound-absorbing, i.e., covered with sound-attenuating cladding.



Figure 9.11. Sound-reflecting noise screen constructed at an elk target shooting range.

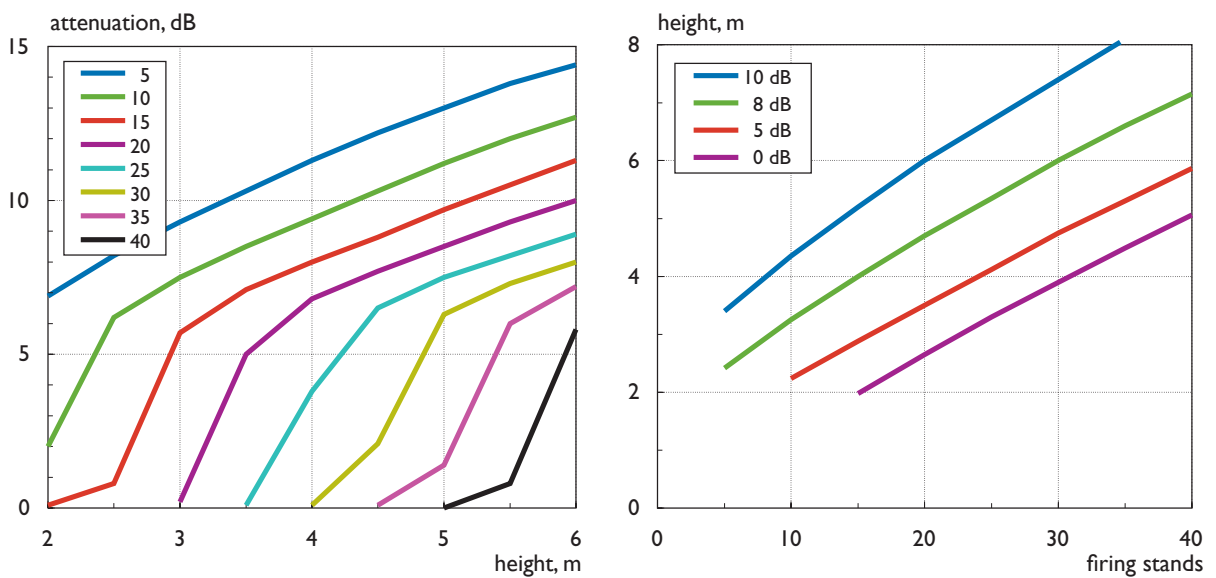


Figure 9.12. Effect of side berm height on noise attenuation presented in two different ways: (left) berm attenuation [dB] as a function of height, with range width as a parameter presented as number of firing stands; (right) required height of the berm as a function of range width, or number of firing stands, with the noise attenuation desired of the berm as a parameter [dB].

Other parameters:

- shooting from the most unfavourable firing stand, or the one farthest from the berm
- calculation direction 60° to the side from the firing direction
- berm height from the firing enclosure's floor surface
- noise attenuation calculated at a distance of 1,000 m
- shooter in a prone position
- level terrain outside the shooting range.

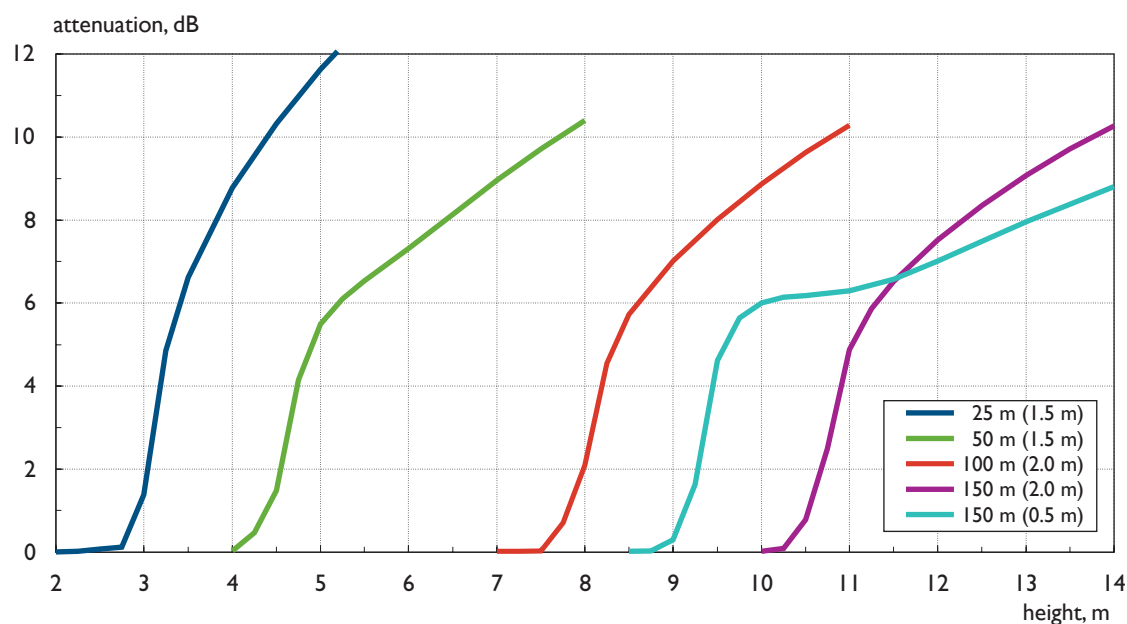


Figure 9.13. Barrier attenuation of the backstop berm [dB] as a function of berm height with five firing stands. Shooting distance or distance to the foot of the berm as a parameter; the height of the firearm's muzzle from the floor in parentheses (first two e.g. standing pistol, next two shotgun, and the last one prone rifle).

- calculation direction straight forward
- berm height from the floor of the firing stand
- noise attenuation calculated for a distance of 1,000 metres
- level terrain outside the berm.

Table 9.2. Price estimates for barriers, when the required additional noise attenuation is 8 dB.

Barrier	Range, shooting	Barrier height/length	Price, EUR
Side berm	rifle, prone	3.5 m / 150 m	50,000
Side barrier	rifle, prone	3.5 m / 150 m	90,000
Backstop berm	rifle, prone	13 m / 20 m	40,000
Backstop berm	pistol, standing	4 m / 20 m	20,000
Backstop berm	shotgun	12.5 m / 250 m	500,000

Table 9.2 lists examples of rough price estimates for certain barriers. The barrier heights were chosen (from Figures 9.12 and 9.13) in such a manner that they all achieve the same noise attenuation. The estimates have been calculated for a 10-stand pistol and rifle range, and a trap shotgun range.

9.3.3

Shotgun

The shooting direction and sector cannot be influenced at existing ranges, so structural means must be used to achieve the required noise reduction. See Appendix K2 to this report for a drawing in principle for skeet and trap ranges, and possible structural noise reduction measures. For noise abatement in the direction of firing, a noise berm or a combination of a noise berm and screen is suitable; you can use noise screens or berms in the side and rear directions. Furthermore, a firing line enclosure can be used for noise abatement at trap ranges; however, at skeet ranges, an enclosure cannot be used.

For examples on the effects of noise control on noise levels at trap and skeet ranges, see Appendix K2.



Figure 9.14. A trap shooting enclosure at the shooting range of Sipoon SSG, attenuating noise to the rear sector. The window openings have airtight glazing.

The firing stands for Sporting Clays and similar sports are often built in the woods in varying conditions. The firing directions at the different stands may also be clearly different from each other, meaning that the noise propagation areas can also be clearly different. One can therefore influence noise propagation by planning the positioning of the firing stands. Noise to the side and rear directions can be reduced with berm and screen solutions.

Positioning alternatives for noise control solutions at shotgun ranges are presented in the type drawing (Appendix J2).

A noise-reducing firing enclosure can only be used for the firing stand of a trap range (Figure 9.14), in which case the side and rear walls of the enclosure are solid structures. At a range that is in competition use, the rear wall of the enclosure must be sufficiently transparent to enable the judges to have a visual contact with the shooters. An attenuation of around 10 dB can be achieved in the rear sector with a transparent enclosure with a lot of windows.

As a rule, only noise barriers, or screens, berms, and their combinations, are suitable for the prevention of noise propagation at shotgun ranges. The fence between ranges can be constructed as a noise screen. Its construction must then be solid and sturdy. A similar screen structure can also be used in the rear direction. Noise screens are not usually used in the front direction.

As the height of the screen increases, the requirements for its foundation increase in order for the structure to remain standing during storms. Figure 9.15 shows the 5-metre-high noise screen at the Hälvälä shotgun range as an example.

Noise berms can be used at shotgun ranges to prevent noise propagation in all directions. In the front sector, or the firing direction, barriers are the only possible



Figure 9.15. Noise barrier at the Hälvälä shotgun range.



Figure 9.16. 15 metres high noise berm at the shotgun range of Sipoon SSG.

noise prevention solution (Figure 9.16). The barrier must be located at a distance required by the rules from the firing stand. At a skeet range, the barrier can be located closer to the firing stand than at a trap range, or a combined skeet and trap range. The barrier's height requirement is lower or its effectiveness higher, the closer it can be located to the firing stand.

9.3.4

Baffles

Some shooting ranges use crosswise overhead baffles, primarily due to safety reasons (Figure 9.17). They may also affect the propagation of noise.

A baffle dimensioned with safety in mind may have insufficient acoustical dimensions and have only a minor noise abatement effect. The sound wave of a muzzle blast may advance from beneath the baffle via its bottom edge to the ridge of the end or side berm so that the two diffractions occurring during the travel of the sound are only relatively minor. The resulting attenuation from the barrier is then small. If the baffle is supposed to also have a significant noise-attenuating effect, its design and dimensioning require acoustic expertise.

If a cross-wise baffle has an acoustically hard surface, it usually significantly worsens the noise situation in the rear directions, as it produces a back reflection. Both the muzzle blast and the bullet's flight noise are reflected. If there are more than one baffle, the sound may reflect twice or more between the baffles, rising above the baffles this way. In order to prevent these phenomena, at least the enclosure-facing surfaces of the baffles must be sound-absorbing.

In principle, a lengthwise structure can also be used for noise control; either partition walls covering the entire length of the range's shooting area, or just actual lengthwise baffles located higher up. Such barriers could be considered as the last, complementary noise control measure; in practice, they should only be used at



Figure 9.17. A baffle constructed to improve the safety at a shooting range.

existing ranges with very large noise problems. In principle, lengthwise barriers could also abate the bullet noise in addition to the muzzle blast. Designing and dimensioning partitioning walls or lengthwise baffles is very demanding.

9.3.5

Ground quality and vegetation

Most regular ground surfaces are about equal with regard to noise, and equally suitable. Water surface and asphalt are clearly unfavourable. Hard-padded gravel and wide, continuous and clear open rock are also approximately acoustically hard, or unfavourable, surfaces. The same rules apply both at the range itself and in its surroundings. For instance, hard surface such as asphalt in front of the firing enclosure is a poor alternative with regard to noise propagation.

Vegetation does not significantly attenuate shooting noise until the wooded zone is very dense and at least 100...200 m in width. In addition to the trees, also the undergrowth must be dense. With regard to coniferous trees, spruce is clearly more effective than pine. Deciduous forest provides no abatement during the leafless time of the year. Woods provide 0...4 dB of attenuation, optimally even slightly more.

9.4

Range usage

In addition to controlling the propagation of the noise emission (structural noise control) and reducing the noise emission, the harm caused by the noise can be reduced through means related to the operations and procedures, or Best Environmental Practices (BEP). In the case of shooting ranges, these have to do with the procedures, operating hours, planning them, informing the public of them, and other cooperation with the stakeholders. The procedures must be clearly written down, and all of the range users must be made aware of them. Furthermore, effective practices must be planned for their monitoring.

The planning of and instructions on shooting range usage can have a significant effect on the harm caused by the noise in its surroundings.

Measures related to range usage for reducing the disruptiveness and harm from noise include:

- The usage order of the firing stands
- Usage times during the day, week, month, year, summer, quiet times
- Communications, interaction with stakeholders
- Monitoring.

9.4.1

The usage order of the firing stands

In some cases, the procedures can also influence the effectiveness of the implemented noise control measures. Because the effectiveness of the noise barriers depends on, for example, how close to the noise source the noise control structures are, the best possible benefit can be obtained from the noise barriers through the prioritisation of the firing stands. At rifle and pistol ranges, for instance, shooting should always be carried out from the firing stands located closest to the noise berm; this allows the berm to best screen the noise from propagating. For this reason, the ranges should establish a clear practice of primarily using the firing stands located closest to the side berms on the side of the protected areas.

Open hours

One problem with shooting range operations and the resulting disruption is that the best times for recreation and outdoor activities for non-shooters – spring and summer, weekends and weekday evenings – are also the best times for shooting sports enthusiasts. For this reason, planning the opening hours of the shooting range can be used in the reduction of disturbance caused by noise in addition to structural noise control measures. Well-planned opening hours can reduce the disturbance caused by the noise, and allow the residents and other people in the area of effect time without shooting noise for recreational and hobby purposes.

It is important to those who find the noise annoying to know when shooting will take place at the range. For this reason, communications form an important part of noise control measures at shooting ranges. The better the residents in the vicinity are aware of the usage times of the shooting range, the easier it is for them to prepare for and feel positive about the operations. With the addition of predictable, regular operations, the disturbance caused by shooting activities can be reduced.

On the annual level, summertime (June to August) is the most sensitive period with regard to the disturbance caused by the noise. During that period, people spend a lot of time in recreational areas, the yards of their homes, and at holiday homes. For this reason, stricter and shorter opening hours can be demanded of shooting ranges during summer time.

On the weekly level, particularly in the areas with a lot of holiday homes in the vicinity, weekends are particularly sensitive with regard to noise. The weekend can be considered to begin already during Friday evening. On Saturdays and Sundays, shooting activities are usually restricted into a shorter time than on other days in the environmental permit decision.

On the daily level, the most problem-free hours with regard to disturbance caused by the shooting noise are the daytime hours until early evening from Monday to Friday. Noise is considered to be more disturbing during the evening than during the day, and shooting late in the evening is, as a rule, not possible at ranges with noise-sensitive sites in the vicinity. On Saturdays and Sundays, it is justifiable to follow stricter opening hours, particularly during the morning and already during the early evening, as these hours are important recreationally and, on the other hand, the shooting enthusiasts have better opportunities to go shooting during the day when the noise disturbance is not as problematic.

Limiting the opening hours should arise from the shooting range operator's own planning. When they themselves propose the most suitable opening hours for their operations and justify them well, it is more likely that they are closer to what was desired than just the opening hours stipulated by the permit authority.

Planning of the shooting range usage can reduce the disturbance caused by the noise and improve predictability. Means for this include:

- Regular shooting times
- Concentrating sessions with only a little shooting to few days and hours
- Taking firearms and shooting sessions with different noise emissions into consideration in the opening hours
- Targeting noise-free periods to whole days in addition to evenings and weekends
- There should be one or more weekly day on which there are no shooting activities causing noise at the range
- A longer quiet period, for instance, the entire summer vacation period.

9.4.3

Communications and co-operation

From the perspective of the residents in the vicinity, the predictability of the operations can also play a significant role in how much disturbance the noise causes. For this reason, planning the operations and informing the residents are important. Communications are particularly important when shooting activities differing from the regular times and the number of shots are arranged at the range; competitions, for instance.

In order to increase the positive attitude of the residents living in the vicinity of the shooting range, it would be a good idea to arrange them a chance to familiarise themselves with the activities of the shooting club, and tell them who practice the sport and why.

For any contacts and inquiries, the shooting club should have clear contact information and contact persons who the residents living in the vicinity can contact, if necessary. Any contacts should also be answered within a reasonable time period.

For successful communications, it is also important that the communicating is done well in advance and reliably. For example, the season's schedule and information on planned training camps, shooting competitions, etc., should be given to the residents living in the vicinity already during the early spring. If necessary, the communications should be repeated before the event.

The shooting club should also prepare to be flexible in its operations, for example due to events that are sensitive to noise arranged in the vicinity of the range.

9.4.4

Monitoring

The monitoring of the shooting range arranged by the shooting club can also affect how people experience the noise caused by the operations. It may be important to the residents that they know that all operations at the range have been approved in advance, take place in accordance with the rules, and is supervised.

It should also be possible to control the use of the range so that shooting activities are possible and approved only during the allowed opening hours; for example, by preventing access to the shooting range and the use of the range equipment and firing enclosures outside the opening hours.

9.5

On the costs of noise abatement

The costs of noise abatement vary greatly depending on the required measures and their extent. The costs of noise abatement are sometimes included in the costs of other structures at the range, such as the construction of a firing enclosure. The costs are also greatly affected by whether the construction work is done using voluntary work or with otherwise cheap labour costs. Materials may sometimes be available at a lower price than usual, such as surplus earth.

Table 9.3 presents the costs of the most common noise control structures when commissioned from an external contractor and purchasing the materials as new. With regard to the noise berms and noise screens, the costs are at the 2012 level. These costs do not include the design of the structures or any soil and groundwater protection structures. Figure 9.18 presents the noise control structures at one shooting range, and Table 9.4 presents their total costs.

Table 9.3. Noise abatement costs 2012.

Measure/structure	Cost
Noise screen (Appendix J2), height 7 m	EUR 1,000 per metre (EUR 143 per m ²)
Noise screen, height 3 metres	EUR 600 per metre (EUR 200 per m ²)
Noise screen (Appendix J2), 4.8 m high	EUR 900 per metre (EUR 188 per m ²)
Noise screen, height 2 m	EUR 550 per metre (EUR 275 per m ²)
Noise berm h=10 m	EUR 2,300–3,200 per metre (EUR 16–23 per m ³) + soil protection
Noise berm h=7 m + noise barrier h=3 m	berm: EUR 1,300–1,700 per metre (EUR 18–23 per m ³) barrier: EUR 600 per metre (EUR 200 per m ²) total: EUR 1,900–2,300 per metre
Noise-attenuating firing line enclosure at a pistol or rifle range	EUR 5,000 per firing stand
Noise-attenuating firing line enclosure at an elk target shooting range	EUR 10,000–20,000 per enclosure
Silencer	EUR 100–500 per piece

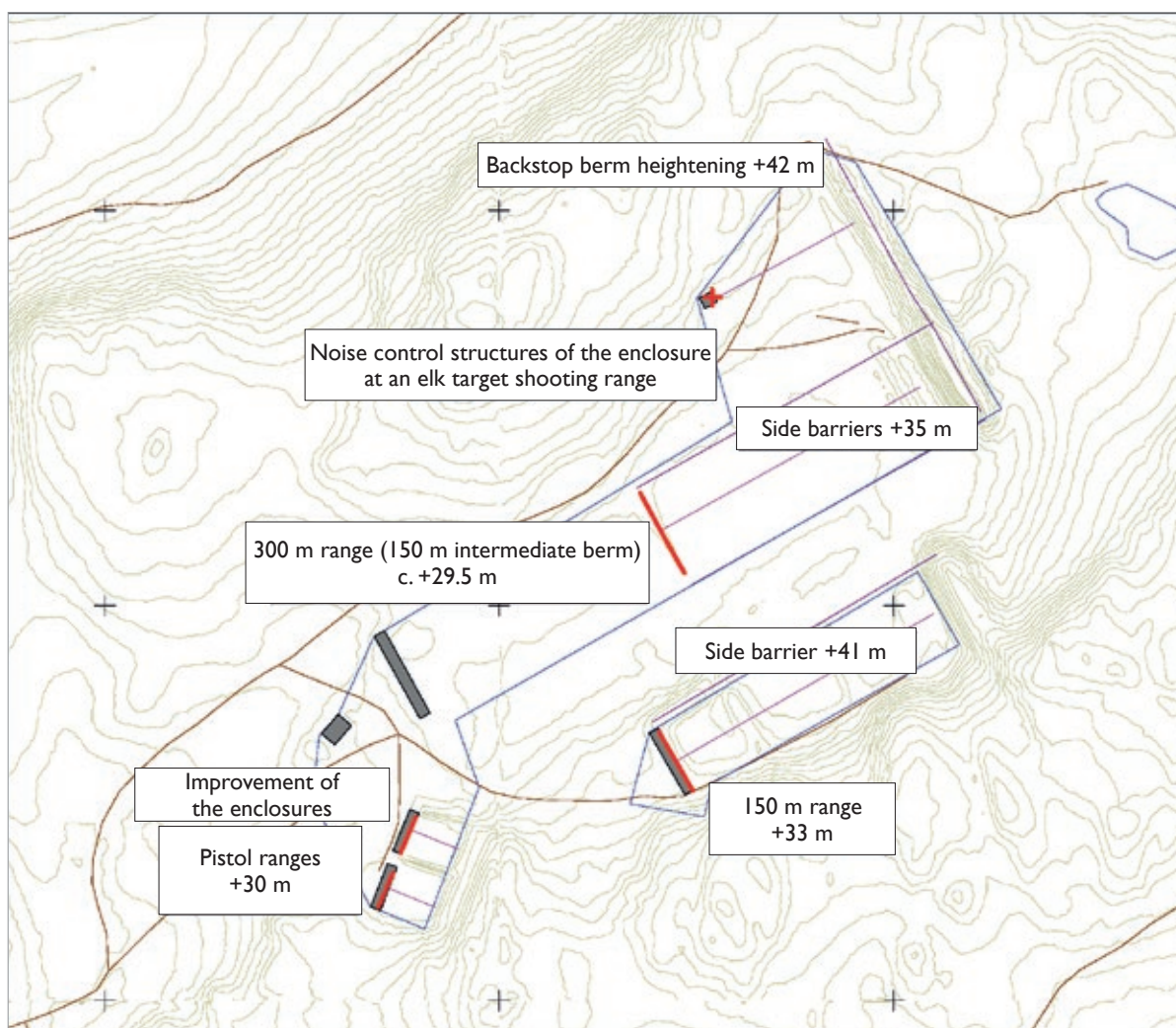


Figure 9.18. Examples of noise control measures at a shooting range.

Noise surveys for shooting ranges are performed by consulting firms specialising in shooting noise. The prices are in the same category as for other work performed by consulting firms. The hourly rate is EUR 60–120 per hour (VAT 0%), depending on the expert's experience, + travel and equipment costs. Table 9.5 lists some examples of noise survey services at the 2012 price level.

See Appendix I

Table 9.4. Sample calculation of the costs of the noise control measures depicted in Figure 9.18.

Long side barriers 150 m 2 pcs à EUR 140,000	EUR 280,000
Pistol range enclosure	EUR 200,000
Noise control structures of the enclosure at an elk target shooting range	EUR 20,000
Backstop berm heightening 2 m	EUR 50,000
Total	EUR 550,000

Table 9.5. Examples of the prices of noise surveys commissioned as expert service.

Work	Amount of work	Price	Contents
Follow-up measurement	2 man-days	EUR 1,500	includes measurements at one site and report, additional sites EUR 500 each
Light total service	4 man-days	EUR 3,000	includes template modelling* or model calculation for a couple of sites and a report for one shooting sport range
(Comprehensive) total service	15 man-days	EUR 10,000	includes model calculations, measurements and environmental permit consultation

* Cf. Appendix I

Summary of the management and reduction of shooting range noise

- Noise from a shooting range can be reduced by reducing the noise emission of the firearms and preventing the propagation of the noise. The harmful impacts are reduced through the planning of the usage times.
- Noise from a shooting range can be managed through good design and planned use.
- The most affordable way of solving the noise problems of a shooting range is to choose its location well and using a professional designer.
- Land use planning and zoning will secure the operations of the shooting range in the future
- Noise propagation is controlled with enclosure structures, noise screens and noise berms
- Planning of the usage times of the shooting range reduces the disturbance caused by the noise
- Communications improve the neighbours' awareness and approval of the shooting range's operations
- Supervision ensures that the operations follow the regulations
- Noise control costs can be covered with usage fees and investment subsidies, and they can be reduced by voluntary work.
- Noise emission can sometimes be reduced by shooting with .22-calibre firearms and using silencers

10 Best Available Techniques and Best Environmental Practice for noise abatement (BAT and BEP)

10.1

On the prerequisites of BAT and BEP

10.1.1

Assessing the disturbance and need

Studies on shooting range noise have found that the disturbance depends not only the sound level but also the number of shots (Jokitulppo et al 2007). The scope of the required noise abatement also depends on the number of people exposed.

Section 3 of the Government Decision 53/1997 states that during application, number of shots, the use of the area, etc., must be taken into consideration. The guide of the AMPY working group (Ministry of the Environment 2012, p. 81) presents when the guideline values could be deviated from. A small number of shots and the timing of the shooting activities so that they cause only minor disturbance in the vicinity could be considered to be justifiable reasons for deviating from the guideline values; on the

Table 10.1. Recommendation for the assessment procedure for the need of noise abatement at a shooting range.

Area usage 1 [L _{Almax}]	Area usage 2 [L _{Almax}]	Annual number of shots *				
		less than 10,000 shots/a	10,000–100,000 shots/a		over 100,000 shots/a	
Noise zone			Number of people exposed within the noise zone			
			1-10	over 10	1-10	over 10
Over 75 dB	Over 70 dB					
70–75 dB	65-70 dB					
65-70 dB	60-65 dB					
60-65 dB	55-60 dB					
under 60 dB	under 55 dB					
Situation unacceptable. Extensive noise control measures are required.						
The noise control structures are designed in such a manner that the sound level does not exceed the target or limit value specified in the environmental permit and/or the noise load is reduced with the help of usage times **						
Noise disturbance is minor, usually no need for noise prevention measures. Special usage time limits in exceptional cases only						
Area usage 1: Residential areas, areas in service of educational institutions						
Area usage 2: Recreational areas in population centres or in the immediate vicinity of population centres, areas in service of healthcare institutions, holiday home areas, natural conservation areas						

* Shots from .22-calibre firearms are taken into consideration only in cases where the exposed site is very close to the shooting range.

** Noise abatement at small shooting ranges (less than 10,000 shots/a) is implemented mainly through usage times; noise control structures would be required in exceptional cases only. See Section 10.1.2.

other hand, a large number of people exposed and extensive range operations could be considered as reasons to deviate from the guideline values to the other direction.

Based on the above, this report recommends that the need for noise reduction at an existing shooting range could be assessed, and the noise control measures targeted, in the most purposeful way from the perspective of BAT. The assessment is carried out in accordance with Table 10.1 based on the noise zones and the numbers of shots and people exposed. The measures are divided into three categories marked in different colours. The number of exposed people includes people living in a residential building and a building location used as a holiday home.

10.1.2

Starting points and principles

This report proposes an assessment procedure, where the numbers of shots and exposed people act as the basis for deviating from the guideline value in certain situations. A noise level greater than the guideline values would be allowed only when the number of shots is low. An annual number of shots that would meet this criterion could be considered to be 10,000 shots, in which case the noise is not considered to cause health hazards or a significant disturbance. A noise level lower than the guideline value would be required when the number of shots is large and there are many people exposed.

Human ability to register changes in the loudness of shooting noise is limited. A one-decibel change is not noticeable; a change of three is noticeable; five is clearly noticeable; and ten decibels is a significant change. The interpretation is also affected by the time between the observations (Jokitulppo et al 2007). When examining the noise abatement measures as sound levels, the abatement goals can be limited between 5 and 15 dB. We recommend considering the implementation of even minor measures, although verifying changes below five decibels is uncertain. Even a couple of decibels can reduce the disturbance caused. Noise control measures resulting in an abatement of over 15 dB are very massive and expensive. Need for such extensive measures is usually an indication of the shooting range being in an unsuitable location. On the other hand, when the noise levels are clearly below the guideline values (10 dB), one can state that noise abatement measures are not required, and the range operations do not cause noise disturbance.

The possibilities for noise prevention at a shooting range depend on what the starting situation is like. If one starts implementing noise control measures from a situation where the shooting range does not have firing enclosures, noise berms or any other structures intended for noise abatement, one can achieve clear noise abatement results with enclosures and berms to the sides and the rear, for instance, from 5 to as much as 15 dB. However, if the starting situation is that the range already has relatively good enclosures, side berms and possibly other noise control measures implemented as well, it may be difficult to achieve an additional noise abatement of just 5 dB at the site.

Example on the funding of noise abatement

The assessment of financial reasonableness examines the costs of the noise prevention measures and considers the financing options. See Section 9.5 for a discussion on the costs of the different noise prevention alternatives. Their financing is discussed here.

In the following example, the total costs are based on a number of shots, where the annual number of shots is multiplied by a price determined for one shot and divided by the "amortisation period". Financing can be collected afterwards, for example, with usage or entry fees tied to the number of shots.

Noise control structures costing EUR 100,000 are required.

Assumptions

- 100,000 shots per year
- Amortisation period 10 years
- EUR 10,000 per year
- One visit averages 100 shots.
- The club has 50 members.

Result

- Visits at the range: 1,000 per year
- One visiting fee EUR 10, or the price of one shot, EUR 0.1
- The total annual cost per shooter is EUR 200.

10.1.3

Design and implementation of the shooting range

The following lists the steps of the design and implementation of noise abatement for a new and an existing shooting ranges. The specifics of the measures and practices are discussed above in Section 9.1. The measures below enable the sustainable construction and operation of the shooting range.

New range

A new shooting range must be designed so that the guideline values are not exceeded. Noise issues must be taken into consideration in the design process of a new shooting range right from the beginning of the project.

1. Selection of the location First, use the template (see Appendix I) to examine the noise with the objective of avoiding noise exposure at noise-sensitive sites: residential buildings, holiday homes, recreational areas, other sensitive sites, and nature conservation areas. Take into account the zoning in the vicinity and have preliminary discussions on the suitability of the area for shooting range operations with the town planner for the area.
2. Drafting a layout drawing. The drawing must include the ranges for the different sports, the positioning of the ranges, and the elevations of the terrain and the structures.
3. If, during the first step, sites are found to be exposed to noise within the preliminary noise zone, a noise survey must be performed and, if necessary, noise control measures planned. The noise prediction method is used to calculate the noise zones more precisely (performing a noise survey, see Section 8.4.4). Steps 2 and 3 must be completed simultaneously, in parallel and in interaction with each other.
4. Preparing the permit applications. The environmental permit application is submitted with the municipality or the Regional State Administrative Agency, the establishment permit application with the Regional State Administrative Agency, and the building permit application with the municipality.
5. Proposal to the town planners. A good practice is that a shooting range designation is made and the noise area marked in the town plan map, and presenting the noise area planning and building regulations in the plan description. The shooting range operator must monitor the development of the zoning process and give the necessary statements for the participation and assessment plan at both the draft and proposal stages of the plan.
6. Range construction is carried out in accordance with the designs and the requirements of the environmental permit. The designer of the noise prevention measures should be involved, supervising the implementation of the measures.

7. Verification of the noise from the completed shooting range, if necessary, through measurements and modelling. Taking measurements primarily from near the shooting range is recommended, modelling the noise propagation based on the results.

Existing range

The designing of noise control measures for an existing shooting range usually begins at the request of an authority or due to the obligations of an environmental permit decision. The noise reduction design process is usually as follows.

1. Noise analysis using templates.
2. If, during the first step, sites that will be exposed to noise are found within the noise zones, an environmental noise survey must be carried out for the shooting range (Ministry of the Environment 2006, p. 28), including the determination of the noise zones and the planning of noise control measures. The goal is to not have noise-sensitive sites within the noise zones.
3. Proposals to the town planners. A good practice is that a shooting range designation is made and the noise area marked in the town plan map, and presenting the noise area planning and building regulations in the plan description. The shooting range operator must monitor the development of the zoning process and give the necessary statements for the participation and assessment plan at both the draft and proposal stages of the plan.
4. Range construction is carried out in accordance with the designs and the requirements of the environmental permit. The designer of the noise control measures should be involved, supervising the implementation of the measures.
5. The verification of the effects of the implemented noise control measures through measurements and by updating the model calculations and noise areas.

10.2

Best Available Techniques

Shooting range noise can be reduced by reducing the noise emission or by controlling the propagation of the noise. The following describes the noise control techniques for shooting ranges considered to be the best and economically viable at the moment.

10.2.1

Reduction of the noise emission of a firearm

There are only a few methods available for reducing the noise emission of a firearm. They mainly comprise silencers and reducing the calibre when possible due to other reasons, see Table 10.7.

The silencer only affects the muzzle blast. It is most effective to the side directions, but notable also in the other directions. The silencer does not, however, affect the bullet noise that propagates obliquely forward. Silencers can be used with rifles and pistols. At a shooting range, silencers give the most benefit when all shooters use them. Silencers are commercially available from different manufacturers. Their effectiveness varies depending on the purpose of use. The use of silencers is limited by competition rules, limitations of military weapons, and shotgun technology.

With regard to reducing the noise emission of firearms, significant gains are achieved when pistol and rifle shooting takes place with .22-calibre firearms to the greatest possible extent. Calibre reduction is better suited to pistol shooting sports than rifle shooting sports. The calibre cannot be reduced in, for example, shotgun

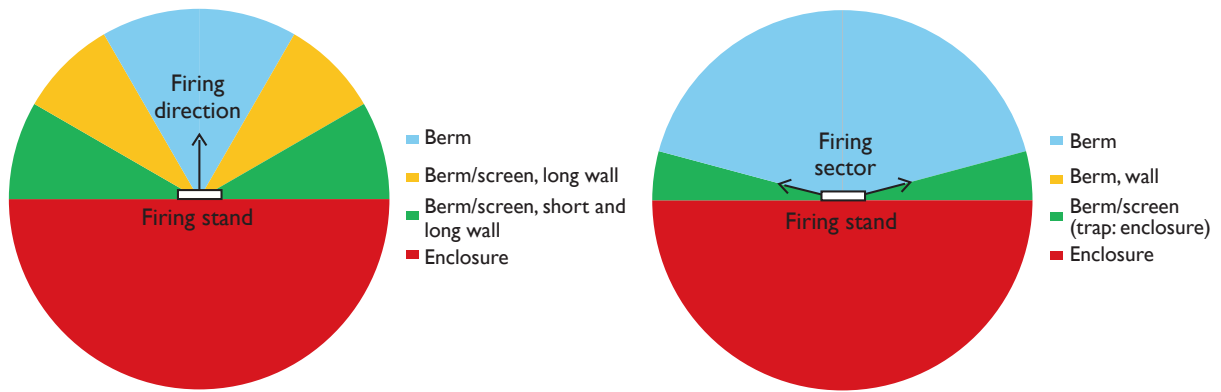


Figure 10.1. Primary noise control measures for shooting ranges. Pistol and rifle ranges on the left, shotgun range on the right.

sports or elk hunting tests. Calibre reductions can be used together with limited opening hours. For instance, only allowing shooting with .22-calibre firearms on certain evenings could be considered.

10.2.2

Management of noise propagation

Preventing or limiting noise propagation is the main method of reducing shooting range noise. Depending on the direction, BAT measures comprise noise barriers and enclosures. The direction of the noise can also be influenced with changes to the locations of the ranges and the firing direction.

Awareness of how much the noise level needs to be reduced is paramount when choosing noise control measures. The solutions can then be chosen, taking into consideration the direction into which noise abatement is required (Figure 10.1).

Protecting the sites with a sufficiently high end berm is the BAT for noise control in the firing direction and the adjacent frontal sector. To the sides and obliquely to the front, a noise berm, noise screen, or a combination of a noise berm and screen is the BAT for pistol and rifle ranges. The barrier should be dimensioned so that the noise level at the protected site does not exceed the guideline or limit values, however so that the barrier suppression is at least 5 dB. If the protected site is situated in the bullet noise sector, it is necessary to extend the barrier to cover the entire length of the range. At a shotgun range, side screens or berms can only be used with certain limitations, for example, taking the clay pigeon's flight trajectory into consideration.

Sample BAT structures are presented in Appendices J1 and J2. The essential features of the barrier structures are solidity (no gaps or holes) and mass (mass per unit area at least 10 kg/m²). Both types of barrier must be sufficiently high and long. The dimensions vary between different ranges, and they must always be determined case-specifically through noise prediction calculations. An effective barrier typically provides a 5–10 dB reduction to the noise level.

In larger angles obliquely toward the sides (from the bullet noise sector towards the sides), the following measures are BATs. The noise abatement of the side berm or screen can be increased by building extended side walls, partition walls, and a roof overhang to the firing enclosure (Figure 9.7) to have the shooting take place from a "tunnel". If there are only a few firing stands at the shooting range, such extensions alone might be sufficient. Sometimes, the protection can be implemented by continuing the side wall as a noise screen, for example, at the firing stands of elk target shooting ranges.

Table 10.2. Best available shooting noise control techniques.

	Impact on sound level			Justification for choice from noise abatement perspective	Notes
	front	sides	rear		
Emission reduction					
Calibre choice 9 mm => .22	10 dB	10 dB	10 dB	To ensure compliance with guideline value or environmental permit requirements.	Seldom possible
.308 => .22LR	10 dB	10 dB	10 dB		
Silencer	3–8 dB	10–20 dB	10–15 dB (open area) 3 dB (w/ enclosure)	To ensure compliance with guideline value or environmental permit requirements.	Possible with some shooting sports. Competition rules and the purpose of use of military weapons limit the use of silencers.
Controlling noise propagation					
Firing line enclosure with tight structure	0 dB	3–8 dB	5–15 dB	Almost always at pistol and rifle ranges	Safety, lighting, and ventilation must be taken into consideration
Partitioning walls between firing stands	0 dB	3–5 dB	0–2 dB	Need for additional noise control to the sides	Safety, lighting, and ventilation must be taken into consideration
Noise berm or noise screen	0–7 dB	5–10 dB	5–10 dB	Need for additional noise control in the desired direction	Increases safety. Screen structure must take into consideration the ricochet and bullet penetration hazards. Impact to the rear only with no enclosure.
Cladding the interior surfaces of the enclosure with a sound-absorbing material	0 dB	0–3 dB	0–2 dB	Slightly improves the wall's sound insulation	Reduces the exposure of the shooters
Selecting or changing the firing direction	10–20 dB	10–20 dB	10–20 dB	Must always be considered during the design stage of the range. Can be considered for an existing range with a severe need for noise abatement.	Noise is not reduced, it is redirected.
Vegetation in the vicinity of the range	0–4 dB	0–4 dB	0–4 dB	Trees between the range and the sites exposed to the noise should be left standing.	
Baffles	0–5 dB	0–5 dB	0 dB*	Must be carefully designed. *Reflection to the rear must be attenuated	
Reduction of the elevation of the firing stand	0–2 dB	0–5 dB	0–5 dB	Additional need for noise abatement. Used in combination with berms and screens	The moved earth can be utilised as, for example, noise berms

In the rear directions, a noise-attenuating enclosure is the BAT. In this regard, the most important feature of the enclosure is that the back and side walls are solid (Figure 9.7). The possibly required ventilation for the enclosure must be designed to be sound-insulated. At shotgun ranges, an enclosure can be used only at a trap range (Figure 9.14).

Other BATs include the following measures. Overhead baffles can be considered if the other measures are insufficient, and if their effect on the noise can be predicted sufficiently reliably. The ground in front of the firing line enclosure or the firing stand should be soft to reduce ground reflection. One must, however, take into consideration the possible issues related to the collection of spent casings and shotgun shell wads when selecting the surface material.

Retaining vegetation in the vicinity of the shooting range is important, particularly if the vegetation is dense and high (>7...10 m) between the shooting range and the area subjected to noise. Particularly, the zone bordering the range up to a distance of around 100 m is important.

Table 10.2 presents a compilation of the different measures and their estimated effects.

10.3

Best available noise abatement practices

The harm caused by noise and, to some extent, the propagation of noise to the vicinity of the range, can be reduced through regulations and procedures controlling the operations, or Best Environmental Practices (BEP).

Measures reducing the disturbances related to shooting range activities include:

- Planning the usage times
- Permits and regulations controlling the operations, and their monitoring
- Communications and interaction with the stakeholders, particularly the neighbours.

The usage times of the shooting range should be planned specifically for the ranges of all different sports in co-operation with the shooters, authorities and, where possible, the residents and other operators in the area. The planning should take into consideration the special characteristics, operational requirements and noise emissions of the different shooting sports. For instance, the environmental permit limits the use of the shooting range in the evenings of certain weekdays at the shotgun and rifle ranges, while the usage of small .22-calibre firearms that have low noise emissions is allowed without limitations.

Summary of the best techniques and practices

- Best techniques preventing the propagation of noise include correctly designed and dimensioned firing line enclosure structures and noise screens and berms.
- Practices reducing the noise load include the planning of the usage times of the shooting range, communicating information on the activities at the shooting range, and the supervision of the operations to ensure compliance with the regulations
- Techniques for reducing noise emissions include reducing the calibre and using silencers, taking into consideration the limitations set by competition rules, etc.

Procedures related to the use of the shooting range can affect the effectiveness of the implemented noise abatement measures. At rifle and pistol ranges, for instance, shooting should be carried out from the firing stands located closest to the side berm; this allows the berm to best prevent the noise from spreading. Such procedures must be put into writing, and all users of the range made aware of them. Furthermore, effective practices must be established for their monitoring.

In addition to communications, other stakeholder activities also increase acceptance to the operations, therefore reducing the experienced harm. For example, the residents in the vicinity could be offered the chance to visit to the shooting range in order to familiarise themselves with the operations; they could also be informed of the operations at the shooting range being responsible and goal-oriented.

The range structures and their condition must be monitored and reviewed regularly. The operations at the shooting range must be monitored systematically.

11 Development prospects for noise abatement

11.1

Indoor shooting ranges

In many countries, noise impact has played a role in shooting clubs having to move their activities to indoor shooting ranges. In Finland, too, indoor pistol and rifle ranges have been established by the Police and certain other parties. In a similar vein, some commercial shooting ranges have been implemented as indoor ranges in city centres. Although this solves the environmental problems, the indoor shooting ranges may cause health hazards to their users. The range must have good ventilation in order to extract the powder gases and the dust and smoke generated during shooting. Building long ranges is also a financial issue; for example, the construction of a 150 m rifle range with 30 firing stands costs easily several millions of euros.

11.2

Taking the weather into consideration

One way of managing the noise impact of shooting ranges that is possible in principle is taking the weather conditions into consideration so that there is no shooting at the range during weather conditions that are detrimental for the exposed sites. There is some experience of this method from abroad, for example at heavy weapons firing ranges. However, this causes uncontrollable situations in, for example, competitions,

professional tests, and qualification tests, when conflicts and arguments may arise concerning the application of the weather rules. Automatic weather stations are currently available that allow the registering of the weather conditions at both the shooting range and the exposed site. Experience from such systems gained in some countries has been varying.

11.3

Silencers

The Firearms Act and the Hunting Act do not stipulate conditions on the use of silencers, but in competitive shooting, for instance, the rules usually prohibit their use. There are a couple of companies manufacturing silencers in Finland. Their structure and technology have not significantly changed over the last years; mostly they have become smaller in size and somewhat more comfortable to use. When considering using silencers, one must take into consideration many other issues than just noise prevention. The firearm's centre of mass changes. The silencer reduces the recoil of the firearm. The silencer does not negatively affect the firearm's dispersion, and the change in the aiming point can be corrected by adjusting the sights. The use of silencers may increase the risk of an accident. The silencer may become clogged and cause the firearm or silencer to explode. The use of silencers is allowed during practice and hunting, and as a consequence, their use has become more common.

Silencers have a large effect in reducing the noise exposure of the shooter, group of shooters, and the audience (10–20 dB). Similarly, the reduction of environmental noise to the sides and to the rear can be around 10–20 dB. However, the maximum attenuation of the muzzle blast to the frontal sector is around 10 dB. The reduction of the total noise can also be clearly lower in the direction where the bullet noise is a significant factor. The attenuation of the silencers can be determined by measuring the noise emission of the firearms (measured without a silencer and with a silencer). If requirements or recommendations concerning the use of silencers are presented, for example, during the environmental permit proceedings, a performance assessment method must be prepared for that purpose. Noise emission measurements are performed on silencers using different kinds of equipment, but more research is required with regard to the assessment of environmental noise.

11.4

Enclosures and baffles

At some ranges, for example elk target shooting ranges, noise control structures have been built into the firing enclosures. Many of them have been implemented without researched/verified data of their environmental impact. Figure 9.7 above presented an example of an improved enclosure at a large rifle range, attenuating noise in the oblique forward directions. The same principle can also be applied to, for example, the one- or two-stand firing enclosures at an elk target shooting range.

There is relatively little experience of improving the attenuation of enclosures in the oblique forward directions. It could be useful to perform further studies on the noise attenuation of extended partition walls and roofs, or an actual firing tube, and other corresponding structures. The effect of baffles on noise propagation should also be studied.



12 Assessment of the economical viability of the techniques and practices

12.1

The principles of the assessment of the cost-effectiveness and financial reasonableness

As part of this BAT report, the reasonableness of the costs incurred by environmental protection measures at shooting ranges has been examined. The objective of the assessment of the reasonableness of the costs is to determine the economical viability included in the concept of BAT in shooting hobby activities. The starting point is that the benefits achieved with the measures must be clearly more significant than the costs, and that the costs of the measures must be bearable for the industry. The financial status of an individual operator does not affect the requirement level as such; at most, flexibility is possible in the timing of the protection measures (Kosola and Leivonen, 2003). In this context, sector refers to the business category, mainly an industrial sector.

The cost-benefit ratio refers to the general costs of the measure relative to its impact, for example EUR/dB or EUR/removed kg of Pb. When the cost-benefit analysis is used as a decision-making tool, all benefits and costs related to the measure should be determined and converted into monetary values. However, the monetary evaluation of environmental benefits is extremely difficult in practice, as there are no reference or market prices for the evaluated quantities.

The assessment of the economical viability of environmental protection at shooting ranges is based on the simplified assumption that the benefits can be considered to be sufficient when the selected solution makes it possible to site-specifically achieve the environmental and health protection objectives, or an acceptable risk level. The operations will then meet the site-specific minimum environmental protection requirements and, as a rule, the prerequisites for the environmental permit are fulfilled. Acceptable risk level can be considered to be, for instance, noise situations as per Table 10.1 or pollutant emissions that even in the long term do not cause health hazards; significant contamination of the environment or the risk thereof; deterioration of special natural conditions; endangering of water supply or other use important of groundwater in the impact area of operations; or undue burden to the neighbours referred to in the Adjoining Properties Act. The environmental protection legislation also requires that the operations strive to minimise the harmful environmental impact and prevent any harm. During the selection of the best available techniques, one must thus also assess the degree of additional benefit relative to cost of measures exceeding the minimum level the implementation of which requires investments that can be considered reasonable. If the benefit achievable by further measures is assessed to be significant while the overall cost remains at a level deemed reasonable, the application of a requirement level higher than minimum can be considered justified.

No specific, commonly accepted methods or tools are available for the sector-level assessment of the financial reasonableness of environmental protection costs. In practice, the assessment has usually been carried out through a discussion between the different parties and expert evaluations (Seitsalo et al., 2008). There are, however, instructions on the assessment of economical viability during the determination of the BAT in the EU Economics and Cross-media Effects reference document (Commission 2006). The process has been designed for the industry, but its principles can be applied as the framework of assessing the financial reasonableness of environmental protection in the shooting range sector. See Figure 12.1 for the framework of the financial reasonableness assessment process as per the EU ECM document.

The key aspects that must be taken into consideration in the sector-specific analysis are:

- The structure of the sector, or the special characteristics of the operations
- The structure of the market, or its scope and competitive situation
- The financial resiliency, or the ability to bear costs
- The implementation timetable, or will postponing the deadline affect the viability of the measures?

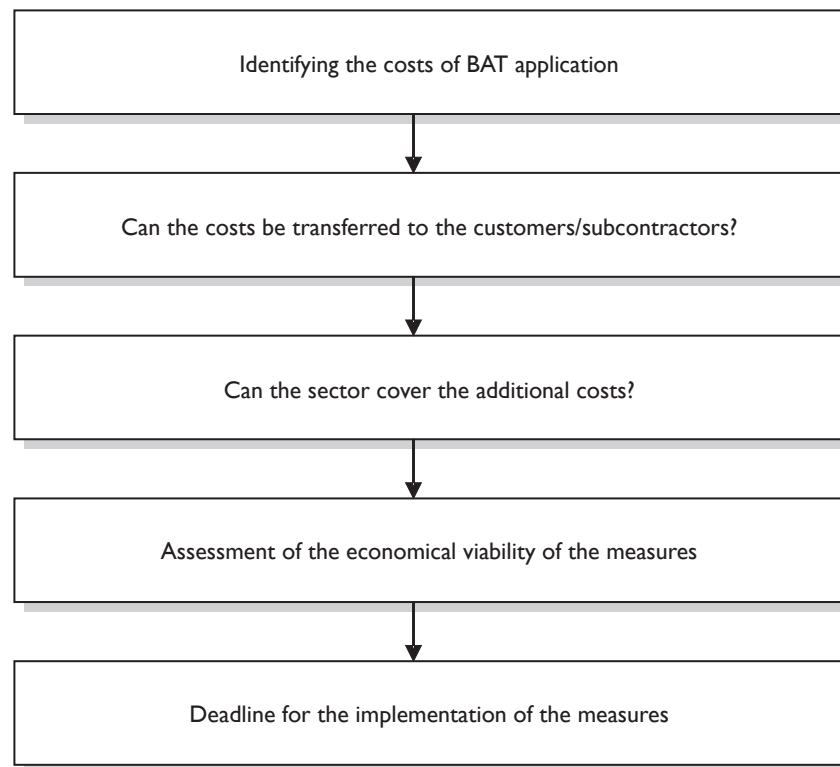


Figure 12.1. A framework for the assessment process of the sector-specific economical viability, adapting the EU ECM document.

Applying the assessment at shooting ranges

In the case of shooting range operations, one cannot directly use the term 'sector' in the same sense than in the EU-ECM reference document, as shooting ranges do not usually operate commercially. However, the assessment can be applied with discretion, taking into consideration the special characteristics of shooting activities.

Sector and market structure

- With regard to shooting range operations, it should be noted that in Finland, they are primarily run either as a hobby or for the official purposes of the authorities. A majority of the ranges are maintained by shooting clubs, meaning that the operators are generally non-profit organisations.
- The size of the ranges and the volume of the operations vary greatly, but numerically around half of the ranges are small shooting ranges with less than 10,000 shots per year.
- Hobby usage of shooting ranges is mainly local with a small number of users. The operations are largely based on voluntary work. There are currently only a few larger shooting sports centres in Finland that operate at a sufficiently large scale to enable business-like operations, if they wished to do so.

Financial resiliency

- Today, the costs of shooting as a hobby, excluding equipment purchase, are comparably low. The annual costs of shooting club membership (including the share paid to the umbrella organisation) and using the club's shooting range usually vary between few dozens to a couple of hundreds of euros. At an average hobby shooting frequency, the cost of using the range per one session is rather affordable compared to most other hobbies requiring separate facilities. For example, according to a study conducted in the Joensuu region, the average annual costs of hunting as a hobby is around EUR 1,023 (in 2012), of which the share of the club membership fee is EUR 49 (4.8%). Correspondingly, the annual costs for active competitive shooters are estimated at around EUR 6,490, of which the share of membership fees and competitive licenses is EUR 150 (2.3%). According to the study, the largest cost items were equipment (cartridges and shells, guns, clothes, etc.) and travel. Their share of the total costs is around 70%. (Regional Council of North Karelia, 2013).
- Due to the nature of the operations, shooting ranges are primarily located in areas with no access by public transport. In densely populated areas, the distances to shooting ranges are often long. Due to the poor accessibility of the shooting ranges, travel costs often form a significant part of the costs of the hobby.

The effect of postponing the deadline on the viability of the measures

The immediate or rapid implementation of the measures is usually extremely challenging, taking the cost structure of the operations into consideration. The hobby clubs operate on a zero-sum budget and have hardly any cash at hand. Even carrying out the studies and analyses may be financially challenging for them. Postponing the deadline and giving the operator the chance to prepare for the investments may significantly improve the viability of the measures.

In addition to the direct design and implementation costs, the costs of the environmental protection measures must include an estimate of the operating and maintenance costs, and the costs avoided due to the measures. With regard to pollutants, the last item refers to taking the costs of terminating operations into consideration as part of the cost analysis. On the other hand, the costs that would be incurred by the operator if the avoided risks were to be realised, weighted by their likelihood. For instance, the costs of soil remediation after the termination of operations vary by a significant amount, and they may have a major impact on the total costs of the different environmental protection solutions with regard to pollutant management. A period of, for example, ten years can be used as the observation period for the operating costs and the amortisation period of the investments. The cost assessment takes into consideration the possibilities of getting various investment subsidies, and the effect of the implementation schedule on the viability of the project.

The measures do not often directly benefit the operator. However, the noise area of a shooting range may be significantly reduced as a result of noise management, which will have a direct impact on the land use in the vicinity, making it possible, for example, to build in areas that were earlier within the noise area. Such issues should be brought up when applying for financial support for the measures. The interests of land use and the environmental protection at shooting ranges see eye to eye particularly well, when the municipality is the operator. These kinds of municipal recreational facilities have better opportunities for both the management of environmental impacts and commercial or commercial-like operations compared to hobbyists.

In practice, consideration of the financial resiliency of the operations entails an assessment of transferring the costs of environmental protection to the users of the shooting ranges. As a rule, it should be possible to continue the operations, i.e., the costs of using the shooting range should be acceptable from the perspective of shooting enthusiasts and operators. In practice, for hobby shooters this means comparing the ultimate costs of an individual range user with the costs of other hobbies. A cost per shooting session is estimated for the shooting range, including not only the environmental protection costs, but also the other costs related to the management and maintenance of the range, such as land lease, energy and waste management. The cost is compared to the cost level of other regular hobbies requiring separate facilities or structures.

Transferring the environmental protection costs in full to be borne by the shooting enthusiasts may cause increased competition between different operators. As the costs of the hobby increase, the enthusiasts will likely demand the best possible value for their money and move to ranges where the quality of the operations best matches the costs. The importance of the quality factors of the operations (functionality, atmosphere, services) would likely be emphasised, and the significance of the distance to the shooting range could decrease up to a certain limit. The concentration of the operations would, in turn, foster the regional development of sufficiently viable and financially sound hobby centres. On the other hand, some of the smaller ranges might close down, which would cause a deficiency in the network of shooting ranges and pressure to renovate the sites.

The economical viability assessment principle applied to environmental protection at shooting ranges is presented in Figure 12.2.

The target level of the environmental impact management can be determined using the methods described in Sections 6 (pollutants) and 10 (noise). Additionally, you must also estimate whether an increase in the requirement levels and additional investments deemed reasonable make it possible to achieve such a significant environmental benefit that the implementation of the measures is both justified and reasonable.

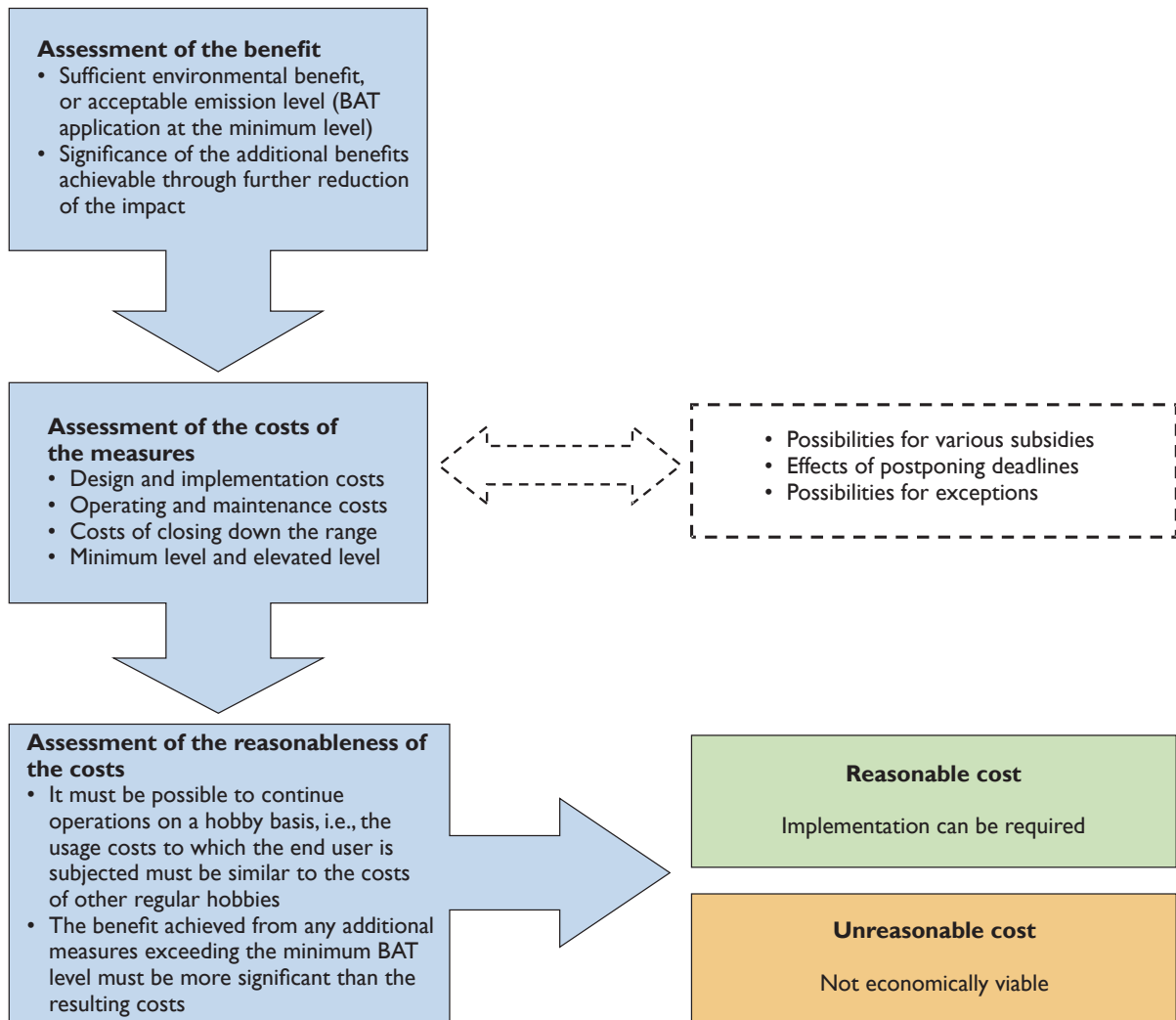


Figure 12.2. Assessment process for the economical viability of environmental protection measures at shooting ranges.

The environmental protection costs may exceed the financial bearing capacity of the operations at shooting ranges where the minimum environmental protection requirements are high in relation to the volume of operations. In practice, this could apply to sites with a high environmental risk that are in relatively minor use, such as a shooting range with a long history of pollutant load in a sensitive groundwater environment, or a shooting range with significant noise emissions located close to a residential area.

Table 12.1 presents examples on how to carry out the assessment of the economical viability of environmental protection measures at shooting ranges of different types. Two calculations are presented for each sample case: the top calculation includes the environmental remediation measures related to the termination of operations, while the bottom one disregards them or assumes that the said costs are not incurred due to the selected technical solution. Other costs related to the planning and implementation of pollutant and noise management, maintenance, environmental monitoring, and range area management, such as the lease, energy, and waste management, are allocated per time of use over a ten-year period (simplified calculation without interest assumptions or index or other corrections). The limit of economical viability has been set to a theoretical cost of EUR 20 for one shooting session.

Table 12.1. Examples of the assessment of the economical viability of the environmental protection measures at shooting ranges of different types.

General information					Pollutant management, EUR			Noise, EUR			Total costs, EUR				
Site type	No. of shots per year	Estimate of annual shooting sessions (80 shots per session)	Risk level, pollutant management	Noise management goals	Design and implementation	Maintenance and monitoring / 10y	Costs of closing down the range	Design and implementation	Maintenance and monitoring / 10y	Costs of closing down the range	Total costs 10y	Environmental protection costs / session	Other range costs / 10y	Total costs / session	Assessment of reasonableness
Shooting sports centre	550,000	6,875	2B	Significant need for reduction	250,000	60,000	250,000	570,000	15,000	0	1,145,000	17	100,000	18	Must be considered
Shooting sports centre	550,000	6,875	2B	Significant need for reduction	250,000	60,000	0	570,000	15,000	0	895,000	13	100,000	14	Reasonable
Shooting sports centre	380,000	4,750	2A	No need for measures	270,000	60,000	330,000	0	0	0	660,000	14	100,000	16	Reasonable
Shooting sports centre	380,000	4750	2A	No need for measures	270,000	60,000	0	0	0	0	330,000	7	100,000	9	Reasonable
Shooting range	100,000	1,250	2B	Need for reduction	60,000	20,000	70,000	50,000	6,000	0	206,000	16	15,000	18	Must be considered
Shooting range	100,000	1250	2B	Need for reduction	60,000	20,000	0	50,000	6,000	0	136,000	11	15,000	12	Reasonable
Shooting range	100,000	1250	Basic level	Need for reduction	20,000	20,000	30,000	50,000	6,000	0	126,000	10	15,000	11	Reasonable
Shooting range	100,000	1250	Basic level	Need for reduction	20,000	20,000	0	50,000	6,000	0	96,000	8	15,000	9	Reasonable
Small shooting range	10,000	125	Basic level	Need for reduction	5,000	5,000	20,000	30,000	0	0	60,000	48	8,000	54	Unreasonable
Small shooting range	10,000	125	Basic level	Need for reduction	5,000	5,000	0	30,000	0	0	40,000	32	8,000	38	Unreasonable
Small shooting range	10,000	125	Basic level	No need for measures	5,000	5,000	20,000	0	0	0	30,000	24	8,000	30	Unreasonable
Small shooting range	10,000	125	Basic level	No need for measures	5,000	5,000	0	0	0	0	10,000	8	8,000	14	Reasonable
Shotgun range	350,000	4375	2A	No need for measures	500,000	50,000	300,000	0	0	0	850,000	19	100,000	22	Must be considered
Shotgun range	350,000	4375	2A	No need for measures	500,000	50,000	0	0	0	0	550,000	13	100,000	15	Reasonable
Shotgun range	350,000	4375	2B	No need for measures	1,500,000	50,000	3,000,000	0	0	0	4,500,000	103	100,000	105	Unreasonable
Shotgun range	350,000	4375	2B	No need for measures	1,500,000	50,000	0	0	0	0	1,500,000	34	100,000	37	Unreasonable
Shotgun range	100,000	1250	Basic level	No need for measures	20,000	20,000	300,000	0	0	0	340,000	27	15,000	28	Unreasonable
Shotgun range	100,000	1250	Basic level	No need for measures	20,000	20,000	0	0	0	0	40,000	3	15,000	4	Reasonable
Shotgun range	400,000	5000	Basic level	Need for reduction	20,000	20,000	300,000	2,500,000	15,000	0	2,855,000	57	100,000	59	Unreasonable
Shotgun range	400,000	5000	Basic level	Need for reduction	20,000	20,000	0	2,500,000	15,000	0	2,555,000	51	100,000	53	Unreasonable

Summary of the assessment of the cost-effectiveness and economical viability of the measures

- The assessment of the benefits of environmental protection measures at shooting ranges is based on the assumption that the benefits at a minimum level can be considered to be sufficient, when the acceptable emission or maximum risk level is not exceeded using the chosen solution.
- Acceptable load can be considered to be, for instance, noise emission situations as per Table 10.1 or pollutant emissions that even in the long term do not cause health hazards; significant contamination of the environment or the risk thereof; deterioration of special natural conditions; endangering of water supply or other use important of groundwater in the impact area of operations; or undue burden to the neighbours referred to in the Adjoining Properties Act.
- The environmental protection legislation also requires that the operations strive to minimise the harmful environmental impact and prevent any harm. During the selection of the best available techniques, one must thus also assess the degree of additional benefit relative to cost of measures exceeding the minimum level the implementation of which requires investments that can be considered reasonable. If the benefit achievable by further measures is assessed to be significant while the overall cost remains at a level deemed reasonable, the application of a requirement level higher than minimum can be considered justified.
- The assessment of the operating costs should include the planning and implementation of the measures, maintenance of the structures, and the measures related to the termination of the operations.
- The analysis may also take into consideration the possibilities of receiving various subsidies and the effect of the schedule on the viability.
- Economical viability considerations are based on the premise that it must be possible to continue operations on a hobby basis in such a manner that the end users' fees for using the range are comparable to the one-time fees of other corresponding hobbies.



13 Waste from shooting range operations

Waste from shooting range operations can be divided into waste generated during shooting activities and waste that can be considered to be normal community waste. Table 13.1 presents the typical waste fractions generated from the operations and the best practices for their processing.

Shooting with pistols and rifles generates metal waste from the cases and the bullets ending up in the backstop berm. Case waste is brass and can be easily collected from the vicinity of the firing stands. The bullet waste, containing lead and brass, ends up in the backstop berm or other bullet recovery system, from where the waste is removed when necessary, either during a renovation or at intervals required by the environmental permit. Recovery of bullet waste in recyclable form requires special measures or, for example, the use of bullet traps. Bullet waste mixed with soil or soil containing bullets is classified as contaminated soil.

Shotgun shooting generates shot waste in the spreading area of the shot. Clay pigeons and their fragments spreading into the range structures in their flight zone also constitute waste. The regular collection of shot and clay pigeon waste during operations requires special range structures. At a range with no special structures, collecting this waste is, in practice, only possible when the topsoil in the shot spreading area is renovated. Separating shot and clay pigeon fragments from the soil removed from the range surface is challenging; in practice, the mass in its entirety must usually be processed as contaminated soil or as soil mixed with waste.

Shotgun shooting also generates shell waste containing plastic and metal; it can easily be collected from the vicinity of the firing stands. Shotgun shooting also generates plastic wad waste that spreads to a distance of around 30 metres from the firing stand. The metal waste should be utilised as much as possible; the plastic parts are mixed or energy waste.

Shooting ranges also generate normal community waste such as mixed waste, energy waste, cardboard and wood waste that must be sorted and processed in accordance with the municipal waste management regulations. If wastewater or lavatory waste is generated during the operations, they must be processed in accordance with the regulations.

Table 13.1. Waste fractions typically generated during shooting activities and their treatment alternatives.

Waste fraction	EWG code	Utilisation and treatment alternatives
Bullet and shot waste	170403 Construction and demolition waste, lead	1. Utilisation as material 2. Final disposal
Bullet and shot scrap mixed with soil; or soil	170503* or 170504 Soil and stones containing dangerous substances, other soil and stones.	1. Utilisation as material 2. Final disposal
Cases (metal)	200140 Municipal waste, metal	1. Reuse 2. Utilisation as material
Plastic wads	200139 Municipal waste, plastic	1. Utilisation as energy 2. Final disposal
Spent shotgun shells – plastic and metal parts separated to the extent possible	200140 Municipal waste, metal 200139 Municipal waste, plastic	Metal 1. Utilisation as material 2. Final disposal Plastic 1. Utilisation as energy 2. Final disposal
Clay pigeon waste	170904 Mixed construction and demolition waste	1. Reuse to the extent possible 2. Final disposal
Cardboard waste	200101 Municipal waste, paper and cardboard	1. Utilisation as material 2. Utilisation as energy
Cartridge packaging waste	150101 Paper and cardboard packaging	1. Reuse to the extent possible 2. Utilisation as material 3. Utilisation as energy
Wood waste	200138 Municipal waste, wood (untreated)	1. Utilisation as material 2. Utilisation as energy
Mixed waste	200301 Mixed municipal waste	1. Utilisation as energy 2. Final disposal

Any soil generated during shooting range operations is classified as follows:

Uncontaminated soil

Uncontaminated soil refers to soil excavated from rock or ground that is in natural state or does not contain pollutants to such a degree that it could cause environmental contamination or a risk of it.

Uncontaminated soil with elevated pollutant concentrations

Uncontaminated soil with elevated pollutant concentrations refers to excavated soil the representative concentration of one or more pollutant of which exceeds the threshold value defined in the Government Decree on the Assessment of Soil Contamination and Remediation Needs (the so-called PIMA Decree, VNA 214/2007) and the regional background concentration, but is below the lower guideline value.

Contaminated soil

Contaminated soil refers to soil excavated from the ground the representative concentration of one or more pollutant of which exceeds the lower guideline value defined in the so-called PIMA Decree (VNa 214/2007). If the soil contains substances for which no guideline values have been defined, the contamination assessment criteria must be defined case-specifically. The assessment criteria of the guideline values can be utilised in the assessment process. Contaminated soil does not refer to waste fractions that are in separate layers or fractions in the soil.

14 Operational safety of shooting ranges

The environmental protection solutions for shooting ranges described in this report take into account issues related to the operational safety of the structures. These include bullet ricochets from the structures, unblocked visibility of range area, and visibility, lighting, and ventilation in the firing enclosure. The possibility of supervising the shooting activities has been considered to be a primary design criterion. In order to avoid hazardous situations, the range manager or supervisor must be able to see all shooters at the range at the same time.

The recommendability of metal bullet traps and other structures with hard surfaces located in the target area or the backstop berm has been reduced by the risk of ricochets. The sample work descriptions use 34° as the safe slope of the backstop berm in accordance with the safety regulations of the Finnish Defence Forces.

There is always a risk of hearing damage present when shooting without hearing protection. The shooter's and supervisor's risk of hearing damage is somewhat reduced by the cladding of the interior surfaces of the firing enclosure with an acoustic material in accordance with the structural drawings for the enclosure (Appendix J). The use of absorption material on the ceiling and the walls does not, however, remove the necessity for wearing hearing protection.

When firearms with powder-using cartridges are fired, the combustion of the powder gases generates carbon monoxide and nitrogen oxides that remain in the firing enclosure in some weather conditions. Ventilation must be taken into consideration when designing the noise prevention structures of the firing line enclosures. In the structural drawings found in Appendix J to this report, this has been solved by placing a gravity intake air duct to the top part of the enclosure or beneath the seat. In firing enclosures that are open at the front, the air pollutant concentrations do not rise too high in normal weather conditions.

Other safety issues not discussed in this report are also connected to shooting range operations. Risks related to persons, property, and operations can be examined through a risk assessment, based on which the necessary measures and preparation for incidents can be planned.

15 Other development needs

The working group supports the AMPY working group's proposal on the development of a funding system for the soil and groundwater remediation of shooting ranges that have stopped their operations. The system could be based on, for example, the Soili programme developed for the remediation of service and fuel distribution stations, the funding of which is based on industry and government transfers. Alternatively, models where funding is collected in the form of a tax (e.g. on bullets and cartridges) or other mandatory fee, or a model similar to the waste collateral system based on primary responsibility could be considered.

Furthermore, we are of the opinion that the objective of a national network of shooting ranges, presented by Ampumaharrastusfoorumi, is worthy of support. A network that would comprise provincial shooting centres and local shooting ranges would enable upon its implementation the more comprehensive management and development of environmental protection in shooting activities, and the better allocation of the available resources. This issue and its promotion should be further analysed jointly by all parties practising shooting operations and the authorities controlling the operations.

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Appendix A. Basic information on target shooting and shooting ranges

A.1 Outside shooting ranges

A.1.1 Shooting sports

The estimated number of shooting ranges in operation in Finland varies from six hundred to about one thousand. A shooting range facility typically includes lanes for several different shooting sports. The majority of the shooting ranges are maintained by shooting and hunting clubs. The largest individual operator is the Finnish Defence Forces. Other authorities also operate shooting ranges, such as the police, the Finnish Border Guard, and customs. Shooting ranges are necessary for supervised shooting in a location fit for purpose.

There are numerous different shooting sports for different firearms and distances (Table A.1). In 2012, the Finnish Defence Forces had 48 shooting ranges, with around 200 separate lanes for rifles, pistols, running targets and other sports (Finnish Defence Forces, communication 2012). Shooting and hunting clubs mostly have rifle, pistol and shotgun ranges.

A.2 Shooting range structures

A.2.1 Pistol and rifle ranges

Pistol and rifle sports comprise shooting at fixed or moving targets using bullet cartridges. The bullets accumulate in bullet traps or the target backstop berm in a strip a couple of dozen metres wide. Lane lengths vary depending on the sport, usually from 25 metres to 300 metres. In silhouette shooting, the lane length can be up to 500 metres, and even longer in bench rest shooting.

The basic structures of pistol and rifle ranges are similar. The structures include the firing stand, intermediate area, target area and backstop berm (Figure A.1). At rifle ranges, there may be firing stands at 50-metre intervals in the intermediate area (between the firing enclosure and the targets). The target equipment is usually protected by a front berm (earthen berm or a wooden or concrete structure). At older rifle ranges, there is usually a target pit for activities during shooting. Newer ranges do not usually have a target pit due to the structure of the target equipment or electronic targets. The structure of the backstop berm is the same at all rifle and pistol ranges. A separately built backstop berm or the surface layer of a slope used as the backstop berm of a shooting range form part of the structure of the shooting range. The topsoil in the intermediate area, where waste generated during shooting accumulates, is also part of the shooting range structure (Ministry of the Environment 2012).

Firing stand

There is usually a wooden enclosure with a concrete floor at the firing stands. The enclosure mainly acts as cover from the weather. The height of the enclosure is usually around 3 metres, with a depth of around 4 to 6 metres. The width of one firing stand varies depending on the shooting sport. The minimum width is 1 to 1.7 metres. For example, the width of the firing line enclosure at a rifle range with 30 firing stands is thus around 50 metres. There may be partitioning walls between the firing stands.

The front of the firing stands is usually sand or gravel. Some low vegetation may grow in it. Rain and meltwater is directed into the environment to the extent possible so that puddles are not created at the firing stands. The ground in front of the firing stands is covered at some shooting ranges (Figure A.2). The primary purpose of the covering is to make it easier to collect cases from the front of the firing enclosure.

Table A.1. The most common shooting sports and their descriptions (Ministry of the Environment 2012, modified).

Type of firearm	Shooting sport	Description
Rifle	Air rifle shooting	Shooting distance 10 metres, at a fixed or running target. Calibre 4.5 mm
	Sport rifle (women's small bore rifle) and .22 LR rifle	Shooting distance typically 50 metres. Calibre .22.
	Biathlon	Shooting distance 50 metres. Calibre .22. Targets are metal targets that flip.
	Silhouette shooting	Shooting distance 50–200 metres. Calibre 5.6–11 mm. Silhouette shooting involves shooting at metal targets installed on rails with the purpose of knocking them over.
	Game shooting	Shooting distances 75–100 metres. Calibre 6–11 mm. Depending on the game shooting sport, the shooters shoot at either fixed or running targets.
	Game target	Shooting distances 75–100 metres. Calibre 6–11 mm. Game target shooting involves shooting at running targets with rifles. The target always features an image of a game animal, where a target is marked in what is known as the kill zone.
	Bench rest shooting	Shooting distance 100-600 metres. Calibre 6-10 mm. The purpose is to shoot as small a group as possible from the determined distances.
	Standard and free rifle shooting	Shooting distance 300 metres. Maximum calibre 8 mm.
Shotgun	Skeet	Clay pigeons propelled from two towers are shot at with a shotgun at a semi-circular range. There are eight firing stands. Calibre 12 cal.
	Trap	Clay pigeons flying away from the shooter are shot with a shotgun. There are five firing stands. Calibre 12 cal.
	Game shooting	(= game shotgun or game trap). Shooting distance 5–35 metres, similar to skeet and trap. Calibre 12 cal.
	Sporting clays	Shooting takes place at a range laid out on natural terrain with several shooting stations. Each station features clay pigeons that need to be shot differently, emulating different hunting situations. Calibre 12 cal.
	Compak sporting	Similar to actual sporting clays. However, in Compak sporting the shooter does not walk from one station to another; the five firing stands of the range are located in a straight line at roughly 4-metre intervals. Calibre 12 cal.
	Game trail shooting	Shooting takes place at a range laid out on natural terrain with several shooting stations. Differs from sporting clays in that the targets include both clay pigeons and game animal shapes that may move along a cable or rise up, for example. Calibre 12 cal.
Pistol	Air pistol	Shooting distance 10 metres, calibre 4.5 mm
	25 m pistol and 50 m pistol	Shooting distance 25 and 50 metres. Calibre .22.
	Centre-fire pistol, standard pistol, .22 pistol	Shooting distance 25 metres. Calibre 5.6–10 mm.
	Silhouette shooting	Shooting distances typically 50–200 m. Calibre 6–11 mm. Silhouette shooting involves shooting at metal targets installed on rails with the purpose of knocking them over.
Rifle, shotgun and pistol	SRA shooting	In SRA, a shooting task is prepared for the shooting station matching each shooting performance; the shooter will perform the task as required by the description of the situation given in advance.
	Practical shooting	In practical, the objective is to score as many points as possible in relation to the time used. In competitions, the valuation of accuracy and speed is proportioned by using Comstock count scoring, where the points scored during the stage are divided by the time spent.

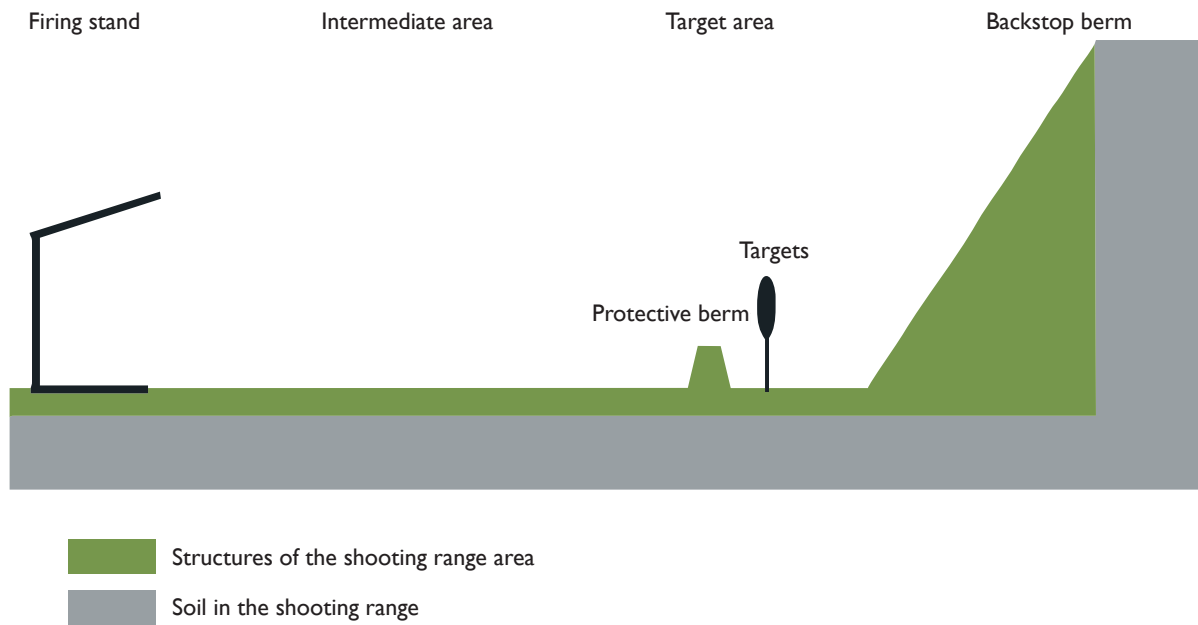


Figure A.1. Structures of a pistol and rifle range (Ministry of the Environment 2012, modified).



Figure A.2. Examples of a pistol range firing enclosure and its covered front (Keski-Suomen Ampujat, Laukaa). Photo: Jorma Riissanen

Intermediate area

The intermediate area refers to the range area between the firing stands and the targets. There may be protective berms or baffles at the sides of the intermediate area. They prevent stray shots from going outside the range. There are also top baffles at some ranges. Baffles are plates installed one after another above the bullet's trajectory to prevent bullets from straying outside the shooting range. In addition to safety, side berms and baffles also have some effect on noise propagation. Baffles are used particularly at shooting ranges located close to a population centre.

Shooting ranges may also have firing stands in the intermediate area of the range, for instance at a distance of 150 metres on a 300-metre range. The firing stands in the intermediate area are usually level gravel or concrete platforms, and they are usually uncovered.

There may be intermediate berms in the intermediate areas of rifle ranges protecting, for example, the firing stands for shorter distances. The purpose of the intermediate berms is to protect the structures and prevent ricochets. The intermediate berms are constructed from earth. At silhouette ranges, the targets are in the intermediate area, with low intermediate berms behind the targets (Figure A.3).

Water collection has not usually been arranged in the intermediate area; rainwater flows into the side ditches of the range or is absorbed into the soil.



Figure A.3. Silhouette range at the Sipoo shooting range (Finnish Shooting Sport Federation 2014).

Target area

Target area refers to an area where a possible front berm, target equipment, and a backstop berm behind them are located. Front berm refers to a protective berm in front of the targets; its purpose is to protect the target equipment and target pit, if any, and prevent ricochets. The front berm is traditionally an earthen berm. At some shooting ranges, the front berm has been replaced by a vertical wall that reduces ricochets.

Target equipment varies from paper or cardboard targets fastened to plywood, building board, etc. to electronic target systems with rubber bands or metal targets. At running target ranges, such as elk target shooting ranges, instead of target equipment there is a rail or cable in front of the backstop berm along which the target silhouettes move across the target area.

The backstop berm behind the targets is the most important protective berm at a shooting range; its purpose is to stop the fired bullets. The minimum dimensions, surface material, and other safety factors of the backstop berm are defined in the safety regulations of the Finnish Defence Forces, for example. The height of the backstop berm depends on the length of the range. At a 300-metre range, for instance, the backstop berm is around 6 metres high. For shooting at a running target, the backstop berm can be built to curve against the firing direction. The backstop berm must have an incline of at least 34 ° throughout relative to the trajectory of the bullets. The surface of the backstop berm must be sand or gravel (grain size less than thirty-five (35) mm), and any rocks remaining in the backstop berm must be buried at a depth of at least 30 cm. In order to retain the shape of the berm, the surface can be planted with grass. The backstop berm can be covered, preventing rainwater from leaching into the soil of the backstop berm.

Some ranges use bullet traps for collecting the bullets. Bullet traps can be used in addition to the backstop berm or, in some cases, they can be used to entirely replace the backstop berm. Some bullet traps use a filler material that makes a bullet lose its energy and stop upon impact; in some, the kinetic energy of the bullet is reduced by directing it into a collection container with metal plates, for example. The objective is to collect the bullets in as pure a material as possible for further processing.

With a few exceptions, water collection from the target area has not been implemented at the current shooting ranges. The water is often directed to the border ditches of the area, or it is absorbed into the soil.

A.2.2 Shotgun ranges

Shotgun sports use flying clay pigeons as targets. The clay pigeons are launched from throwers that are located in towers or at ground level, depending on the sport. The throwers allow the trajectory of the clay pigeons to change (height and angle). During the event, shooters switch firing stands; for example, there are eight firing stands at a skeet range and five at a trap range.

With regard to range structures, the shooting ranges can be divided into two areas: the firing stands with their throwers and towers, and the target area, where the clay pigeons and shot accumulate. (Figure A.4). Shotgun ranges usually have no backstop structures that would stop the clay pigeons and shot; they spread into a wide area in the surrounding terrain. The topsoil in the range area, where waste generated during shooting accumulates, is also part of the shooting range structure (Ministry of the Environment 2012).

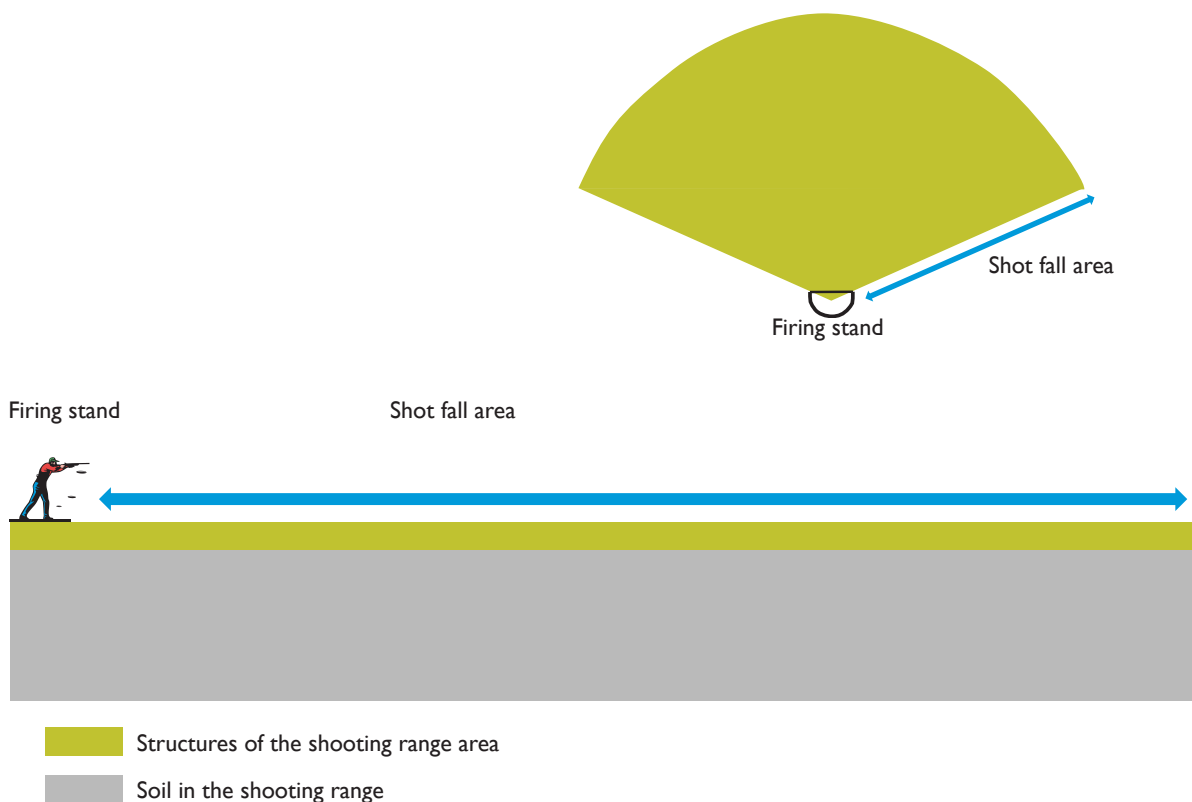


Figure A.4. The topsoil in the shotgun range area, where waste generated during shooting accumulates, is also part of the shooting range structure (Ministry of the Environment 2012, modified).

A.3 The environmental impact of shooting ranges

The significant environmental impacts of shooting range operations are related to environmental contamination by pollutants, noise and waste. The impacts are assessed case-specifically, taking into account the special characteristics of the site. The impacts vary based on the shooting range's location and environment, opening hours, rate of use, age, the existing range structures, and the shooting sports practised at the range, for example.

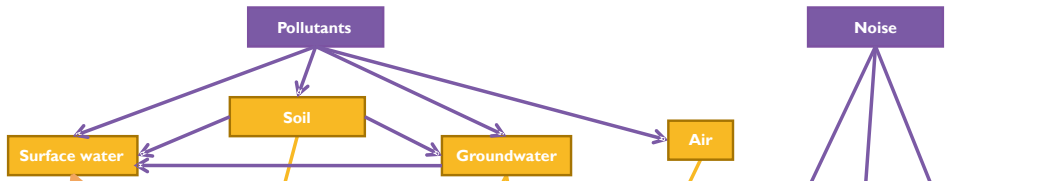
The area of impact examined during the assessment of the environmental impact of shooting ranges is larger than the actual range area. Pollutants contained by the cartridges can spread outside the range area borne by surface and groundwater, or dust. The environmental impact related to the spread of pollutants usually becomes evident over a long period of time. Noise from shooting often propagates to a large area around the range, but exposure to the noise occurs only during the shooting and is thus short-term in duration. Figure A.5 is a simplified representation of the factors affecting the emissions from shooting ranges, and the spreading routes and possible impacts of the emissions.

The emissions and possible impacts from shooting operations are described in more detail in sections II and III and Appendix H.

Factors affecting the magnitude and extent of the environmental impact



Impact causes



Impact duration

Long term
Tens to hundreds of years

Short term, the shooting event
Minutes to hours

Exposed sites



Exposed



Figure A.5. Emissions from shooting ranges and their impacts

Pollutant management

Appendix B. Results of the analyses commissioned for the clay pigeons

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Pvm: 27.12.2010

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Tutkimustodistus

1/2

Projekti: 89105934/1

Ramboll Finland Oy, Tampere

PL 718
33101 TAMPERE

Tutkimuksen nimi:	82130606 PHRAKL, Ampumarata-BAT, Kiekkojäte, Kaatopaikkakelpoisuus, kokonaispitoisuudet	Näytteenottopvm:	12.11.2010
Näytteenottopiste:	Kiekkojäte, kok.pit.	Näyte saapui:	15.11.2010
Näytteenottaja:	Juha Parviainen	Analysointi aloitettu:	15.11.2010

Tutkimustulokset

Määrittäminen	10SS02245	Yksikkö	Menetelmä
Kuiva-aine	100	m-%	RA4016
Esikäsittely, jauhatus	tehty		
Orgaaninen hiili, vedetön TOC	32	m-%	ISO 10694/SFS-EN 13137
Esikäsittely, mikroaaltohajotus, kuningasvesi	tehty		RA3007
Metallit 1	tehty		
Antimoni (Sb)	<0,5	mg/kg ka	RA3000
Arseeni (As)	4,4	mg/kg ka	RA3000
Barium (Ba)	26	mg/kg ka	RA3000
Elohopea (Hg)	<0,2	mg/kg ka	RA3000
Kadmium (Cd)	0,68	mg/kg ka	RA3000
Kromi (Cr)	19	mg/kg ka	RA3000
Kupari (Cu)	<10	mg/kg ka	RA3000
Lyijy (Pb)	46	mg/kg ka	RA3000
Molybdeeni (Mo)	<2	mg/kg ka	RA3000
Nikkeli (Ni)	7,3	mg/kg ka	RA3000
Seleen (Se)	<1	mg/kg ka	RA3000
Sinkki (Zn)	46	mg/kg ka	RA3000
Polyaromaattiset hiilivedyt yht.	11000	mg/kg ka	RA4053
Antraseeni	280	mg/kg ka	RA4053
Asenaftteeni	310	mg/kg ka	RA4053
Asenaftyleeni	0,5	mg/kg ka	RA4053
Bentso(a)antraseeni	810	mg/kg ka	RA4053
Bentso(a)pyreeni	1200	mg/kg ka	RA4053
Bentso(b)fluoranteeni	1500	mg/kg ka	RA4053
Bentso(g,h,i)perylenei	890	mg/kg ka	RA4053
Bentso(k)fluoranteeni	620	mg/kg ka	RA4053
Dibentso(a,h)antraseeni	150	mg/kg ka	RA4053
Fenantreeni	670	mg/kg ka	RA4053
Fluoranteeni	1300	mg/kg ka	RA4053
Fluoreeni	150	mg/kg ka	RA4053
Indeno(1,2,3-c,d)pyreeni	870	mg/kg ka	RA4053
Kryseeni	810	mg/kg ka	RA4053
Naftaleeni	44	mg/kg ka	RA4053
Pyreeni	1200	mg/kg ka	RA4053

Tutkimustodistuksen osittainen julkaiseminen on sallittu vain laboratorion kirjallisella luvalla. Testaustulokset koskevat vain tutkittua näytettä.

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Tutkimuksen nimi:	82130606 PHRAKL, Ampumarata-BAT, Kiekkojäte, 2-vaiheinen ravistelutesti	Näytteenottopvm:	12.11.2010
		Näyte saapui:	15.11.2010
Näytteenottaja:	Juha Parviainen	Analysointi aloitettu:	15.11.2010

Tutkimustulokset

			Yksikkö	Menetelmä
Näytteenottopisteet	Kiekkojät e, L/S=2	Kiekkojät e, L/S=10		
Näytenumero	10SS 02248	10SS 02249		
MÄÄRITYKSET				
Esikäsittely, ravistelu L/S 10		tehty		
Esikäsittely, ravistelu L/S 2	tehty			
pH-alku	10,0	9,8		
pH-loppu	10,0	9,7		
Sähkönjohtavuus	39,1	11,6	mS/m	RA2013
DOC	110	190	mg/kg ka	RA2007
Kloridi	21	27	mg Cl/kg ka	RA2018
Fluoridi	<0,20	<0,96	mg F/kg ka	RA2050
Sulfaatti	220	230	mg SO4/kg ka	RA2018
Metallit 1	tehty	tehty		
Antimoni (Sb)	<0,020	<0,020	mg/kg ka	RA3000
Arseeni (As)	<0,020	0,026	mg/kg ka	RA3000
Barium (Ba)	0,087	0,25	mg/kg ka	RA3000
Elohopea (Hg)	<0,003	<0,003	mg/kg ka	RA3000
Kadmium (Cd)	<0,020	<0,020	mg/kg ka	RA3000
Kromi (Cr)	<0,020	<0,020	mg/kg ka	RA3000
Kupari (Cu)	0,038	0,053	mg/kg ka	RA3000
Lyijy (Pb)	<0,020	<0,020	mg/kg ka	RA3000
Molybdeeni (Mo)	<0,020	<0,020	mg/kg ka	RA3000
Nikkeli (Ni)	<0,020	<0,020	mg/kg ka	RA3000
Seleen (Se)	<0,020	<0,020	mg/kg ka	RA3000
Sinkki (Zn)	<0,020	<0,020	mg/kg ka	RA3000
Vanadiini (V)	<0,020	<0,020	mg/kg ka	RA3000
Fenoli-indeksi	1,1	1,6	mg/kg ka	RA2051

Tutkimustodistuksen osittainen julkaiseminen on sallittu vain laboratorion kirjallisella luvalla. Testaustulokset koskevat vain tutkittua näytettä.

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Näytteenottopiste:	Tavallinen kiekko, kok.pit.	Näyte saapui:	15.11.2010
Näytteenottaja:	Juha Parviainen	Analysointi aloitettu:	15.11.2010

Tutkimustulokset

Määrittäminen	10SS02250	Yksikkö	Menetelmä
Kuiva-aine	100	m-%	RA4016
Esikäsitteily, jauhatus	tehty		
Polyaromaattiset hiilivedyt yht.	25000	mg/kg ka	RA4053
Antraseeni	250	mg/kg ka	RA4053
Asenaftteeni	350	mg/kg ka	RA4053
Asenaftyleeni	0,5	mg/kg ka	RA4053
Bentso(a)antraseeni	2100	mg/kg ka	RA4053
Bentso(a)pyreeni	3300	mg/kg ka	RA4053
Bentso(b)fluoranteeni	4100	mg/kg ka	RA4053
Bentso(g,h,i)peryleeni	2300	mg/kg ka	RA4053
Bentso(k)fluoranteeni	1600	mg/kg ka	RA4053
Dibentso(a,h)antraseeni	350	mg/kg ka	RA4053
Fenantreeni	880	mg/kg ka	RA4053
Fluoranteeni	2500	mg/kg ka	RA4053
Fluoreeni	100	mg/kg ka	RA4053
Indeno(1,2,3-c,d)pyreeni	2500	mg/kg ka	RA4053
Kryseeni	1900	mg/kg ka	RA4053
Naftaleeni	39	mg/kg ka	RA4053
Pyreeni	2300	mg/kg ka	RA4053

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Tutkimuksen nimi:	82130606 PHRAKL, Ampumarata-BAT, Tavallinen kiekko, 1-vaiheinen ravistelutesti	Näytteenottopvm:	12.11.2010
		Näyte saapui:	15.11.2010
Näytteenottaja:	Juha Parviainen	Analysointi aloitettu:	15.11.2010

Tutkimustulokset

			Yksikkö	Menetelmä
Näytteenottopisteet	Kiekko- jäte L/S=10	Tavalli- nen kiekko L/S=10		
Näyttenumero	10SS 02251	10SS 02252		
MÄÄRITYKSET				
Esikäsittely, ravistelu L/S 10	tehty	tehty		
pH-alku	8,9	9,1		
pH-loppu	9,7	10,5		
Polyaromaattiset hiilivedyt yht.	1,1	0,9	mg/kg ka	RA4053
Antraseeni	0,05	0,04	mg/kg ka	RA4053
Asenaftteeni	0,27	0,29	mg/kg ka	RA4053
Asenaftyleeni	<0,01	<0,01	mg/kg ka	RA4053
Bentso(a)antraseeni	0,02	0,02	mg/kg ka	RA4053
Bentso(a)pyreeni	<0,01	0,01	mg/kg ka	RA4053
Bentso(b)fluoranteeni	<0,01	0,02	mg/kg ka	RA4053
Bentso(g,h,i)peryleeni	<0,01	<0,01	mg/kg ka	RA4053
Bentso(k)fluoranteeni	<0,01	<0,01	mg/kg ka	RA4053
Dibentso(a,h)antraseeni	<0,01	<0,01	mg/kg ka	RA4053
Fenantreeni	0,26	0,14	mg/kg ka	RA4053
Fluoranteeni	0,10	0,11	mg/kg ka	RA4053
Fuoreeni	0,09	0,05	mg/kg ka	RA4053
Indeno(1,2,3-c,d)pyreeni	<0,01	0,01	mg/kg ka	RA4053
Kryseeni	0,01	0,02	mg/kg ka	RA4053
Naftaleeni	0,19	0,11	mg/kg ka	RA4053
Pyreeni	0,08	0,08	mg/kg ka	RA4053

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Ramboll Finland Oy, Tampere

PL 718
33101 TAMPERE

Tutkimuksen nimi:	82130606 PHRAKL, Ampumarata-BAT, Ekokiekko, Kaatopaikkakelpoisuus, kokonaispitoisuudet	Näytteenottopvm:	12.11.2010
Näytteenottopiste:	Ekokiekko, kok.pit.	Näyte saapui:	15.11.2010
Näytteenottaja:	Juha Parviainen	Analysointi aloitettu:	15.11.2010

Tutkimustulokset

Määrittys	10SS02253	Yksikkö	Menetelmä
Kuiva-aine	100	m-%	RA4016
Esikäsitteily, jauhatus	tehty		
Polyaromaattiset hiilivedyt yht.	<10	mg/kg ka	RA4053*
Antraseeni	<1	mg/kg ka	RA4053*
Asenaftteeni	<0,3	mg/kg ka	RA4053*
Asenaftyleeni	<1	mg/kg ka	RA4053*
Bentso(a)antraseeni	<0,2	mg/kg ka	RA4053*
Bentso(a)pyreeni	0,2	mg/kg ka	RA4053*
Bentso(b)fluoranteeni	<0,3	mg/kg ka	RA4053*
Bentso(g,h,i)peryleeni	0,2	mg/kg ka	RA4053*
Bentso(k)fluoranteeni	<0,2	mg/kg ka	RA4053*
Dibentso(a,h)antraseeni	<0,1	mg/kg ka	RA4053*
Fenantreeni	<1	mg/kg ka	RA4053*
Fluoranteeni	<0,2	mg/kg ka	RA4053*
Fluoreeni	<6	mg/kg ka	RA4053*
Indeno(1,2,3-c,d)pyreeni	<0,2	mg/kg ka	RA4053*
Kryseeni	<1	mg/kg ka	RA4053*
Naftaleeni	0,4	mg/kg ka	RA4053*
Pyreeni	<0,5	mg/kg ka	RA4053*

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Ramboll Analytics Oy

Tutkimustodistus

Projekti: 89105934/5

Pvm: 17.12.2010

2/2

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* FINAS -akkreditoitu menetelmä. Mittausepävarmuus ilmoitetaan tarvittaessa. Akkreditointi ei koske lausuntoa.

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10SS02253 PAH-analysissä määrittäysrajoja jouduttiin nostamaan grammissa näkyvien häiriöpiikkien vuoksi.

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FINAS
Finnish Accreditation Service
T029 (EN ISO/IEC 17025)

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Näytteenottopiste:	Ekokiekko, L/S=10	Näyte saapui:	15.11.2010
Näytteenottaja:	Juha Parviainen	Analysointi aloitettu:	15.11.2010

Tutkimustulokset

Määrittys	10SS02255	Yksikkö	Menetelmä
Esikäsitteily, ravistelu L/S 10	tehty		
pH-alku	8,3		
pH-loppu	8,4		
Polyaromaattiset hiilivedyt yht.	<0,2	mg/kg ka	RA4053
Antraseeni	<0,01	mg/kg ka	RA4053
Asenaftteeni	<0,01	mg/kg ka	RA4053
Asenaftyleeni	<0,01	mg/kg ka	RA4053
Bentso(a)antraseeni	<0,01	mg/kg ka	RA4053
Bentso(a)pyreeni	<0,01	mg/kg ka	RA4053
Bentso(b)fluoranteeni	<0,01	mg/kg ka	RA4053
Bentso(g,h,i)peryleeni	<0,01	mg/kg ka	RA4053
Bentso(k)fluoranteeni	<0,01	mg/kg ka	RA4053
Dibentso(a,h)antraseeni	<0,01	mg/kg ka	RA4053
Fenantreeni	<0,01	mg/kg ka	RA4053
Fluoranteeni	<0,01	mg/kg ka	RA4053
Fluoreeni	<0,1	mg/kg ka	RA4053
Indeno(1,2,3-c,d)pyreeni	<0,01	mg/kg ka	RA4053
Kryseeni	<0,01	mg/kg ka	RA4053
Naftaleeni	<0,01	mg/kg ka	RA4053
Pyreeni	<0,01	mg/kg ka	RA4053

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Tutkimustodistus

Projekti: 89105934/6

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Appendix C. The studies used in the pollutant research summary

Site/name of shooting range	Report name	Analysis performed by	Year
Lippo shooting range	Shotgun range soil survey report	Ramboll Finland Oy	2011
	Final report for contaminated soil remediation	Ramboll Finland Oy	2009
Velaatta shooting range	Velaatta shooting range, assessment of contamination and need for remediation	Ramboll Finland Oy	2009
Riippa shooting range	Eligibility of soil from shooting ranges for utilisation and landfills	KVVY	2010
	Kälviä shooting range, research report	Environmental Centre for Western Finland	2005
Santahaka shooting range	Eligibility of soil from shooting ranges for utilisation and landfills	Environmental Centre for Western Finland	2008
	Research report: Santahaka shooting range Kokkola	Environmental Centre for Western Finland	2007
Räiskylä shooting range	Analysis and risk assessment of the condition of the environment of the Signal Regiment of Riihimäki shooting range	Ramboll Finland Oy	2007
	Environmental technology survey of the Signal Regiment of Riihimäki's Räiskylä shooting range in Riihimäki	Ramboll Finland Oy	2004
Virttaa shooting range, Alastaro	Virttaa shooting range, assessment of soil contamination and need for remediation	Ramboll Finland Oy	2009
Peräkangas shooting range	Peräkangas shooting range, update of the assessment of soil contamination and need for remediation, and a design for covering structures for the backstop berm	Ramboll Finland Oy	2010
Former Huhtiniemi shooting range	Determination of the remediation goals of the former Huhtiniemi shooting range in Lappeenranta through risk assessment	Ramboll Finland Oy	2007
Kaikula shooting range	Kaikula shooting range, Forssa, Remediation plan	Ramboll Finland Oy	2007
Shooting range of the Halli garrison	Environmental survey of the shooting range of the Halli garrison, Kuorevesi	Ramboll Finland Oy	2004
Hyrylä shooting range	Helsinki Air Defence Regiment, environmental survey of the Hyrylä shooting range	Ramboll Finland Oy	2005
Hälvälä shooting range	Hälvälä shooting range, assessment of soil contamination and need for remediation	Ramboll Finland Oy	2010
	Environmental survey of the shooting range of the Häme Regiment, Hälvälä	Ramboll Finland Oy	2004
Kontioranta shooting range	North Karelia Brigade, environmental survey of the Kontioranta shooting range	Ramboll Finland Oy	2005
Niinisalo shooting range	Niinisalo Artillery Brigade, environmental survey of the Niinisalo shooting range	Ramboll Finland Oy	2005
Hättilä shooting range	Etu-Hättilä shooting range, assessment of soil contamination and need for remediation	Ramboll Finland Oy	2010
	Armoured Brigade, environmental survey of the Hättilä shooting range in Hämeenlinna	Ramboll Finland Oy	2004
Parolannummi shooting range	Parolannummi shooting range, assessment of soil contamination and need for remediation	Ramboll Finland Oy	2010
	Environmental survey of the shooting range of the Parolannummi Armoured Brigade	Ramboll Finland Oy	2004

Site/name of shooting range	Report name	Analysis performed by	Year
Tyrri shooting range	Uti Jaeger Regiment, environmental survey of the Tyrri shooting range	Ramboll Finland Oy	2005
Hiukkavaara shooting range	Shooting range backstop berm studies, Hiukkavaara, Oulu	Ramboll Finland Oy	2006
Former Nummenmäki shooting range	Soil analysis of the shooting ranges and pile storage located in the Nummenmäki area	Ramboll Finland Oy	2005
Kankaanlukko shooting range	Summary report of study results, Kankaanlukko shooting range, Pälkäne	Pirkanmaa Environmental Centre	2004
Lehmussuo shooting range	Summary report of study results, Lehmussuo shooting range, Urjala	Pirkanmaa Environmental Centre	2004
Levo shooting range	Summary report of study results, Levo shooting range, Vammala	Pirkanmaa Environmental Centre	2004
Matinsuo shooting range	Summary report of study results, Matinsuo shooting range, Vammala	Pirkanmaa Environmental Centre	2004
Tappikangas shooting range	Summary report of study results, Tappikangas shooting range, Ylöjärvi	Pirkanmaa Environmental Centre	2004
Padasjoki shooting range	Padasjoki shooting range, assessment of soil contamination and need for remediation	Ramboll Finland Oy	2010
Tammela shooting range	Tammela warehouse shooting range, assessment of soil contamination and need for remediation	Ramboll Finland Oy	2010
Uusikylä warehouse shooting range	Uusikylä warehouse shooting range, assessment of soil contamination and need for remediation	Ramboll Finland Oy	2010
Uusikylä shooting range, Hyvinkää	Ridasjärvi, Hyvinkää, groundwater and surface water analysis of the shooting range	Ramboll Finland Oy	2010
Old Houraati shooting range	Study report of the Houraati shooting ranges	Environmental Centre for Western Finland	2004
New Houraati shooting range	Study report of the Houraati shooting ranges	Environmental Centre for Western Finland	2004
Tannilanvaara shooting range	Tannilanvaara shooting range, Eno, assessment of the need for remediation	Environmental Centre for Northern Karelia.	2002
Old Onttola shotgun range	Old Onttola shotgun range, soil and groundwater contamination analysis	FCC IP-Tekniikka Oy	2008
Anttonen shooting range	Anttonen shooting range, assessment of the need for remediation	Environmental Centre for Northern Karelia.	1999
Kokkola shooting range	Study report, Kokkola shooting range	Environmental Centre for Western Finland	2008
Huosiuskangas shooting range	Studies of the Huosiuskangas shooting range 1999 and 2000	Suomen IP-Tekniikka Oy200	2000
Lempoonsuo shooting range	Lempoonsuo shooting range remediation plan	SCC Viatek Oy	2003

Appendix D. Reference plans for pistol and rifle ranges

Appendix D1. Lining the backstop berms with bentonite

Introduction

This is a reference work description of the construction of a liner structure into the backstop berm of a shooting range. The reference work description has been written in such a manner that it can be used as a basis for contracts. In small contracts, unnecessarily detailed sections can be left out and the applicable parts of the description utilised.

The reference work description describes the work in as much detail as possible, taking into consideration that it must suit sites of very different sizes. Issues that are necessary in the work description but that could not be written in detail are in cursive.

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DI_1 GENERAL INSTRUCTIONS

D1_1.1 General

This work description defines the technical quality requirements and scope of the work of the project. The contractor's financial and legal liabilities and the contractor's other obligations are presented in a separate contract programme that shall take precedence over this description.

Attached to the work description, there is a list of the work performances and amounts that are included in the contract, and for which the contract price is calculated using unit prices.

The contractor must carefully go over the work site before submitting a contract offer.

D1_1.2 Work site

Information on the site's location, scope and ownership. Site location is presented in location map 1. The contract area is presented in drawing 2.

Information on existing structures.

A liner structure for the backstop berm of a shooting range is built on the site.

Customer's contact information.

D1_1.3 Nomenclature

This work description uses the InfraRYL 2010 (Part 1) nomenclature.

D1_1.4 Scope and implementation schedule of the backstop berm liner structure

The liner structure is built inside the backstop berms of pistol and rifle ranges from bentonite mat that acts as a mineral sealing layer. Underground drainage is built at the bottom of the sealing layer at ground level to collect the percolating water into a *water management system*. A protective layer and a damping layer are built on top of the liner structure to protect the liner from bullet impacts. The liner structure extends from the ground level to the backstop berm's top and over the entire width of the berm.

The underground drainage is built in an excavation made in the bottom part of the existing backstop berm. The excavation mass is primarily utilised on site. The soil in the backstop berm can be contaminated by pollutants from bullets. The contamination of the excavated soil must be properly analysed, and any soil removed from the site must be properly treated.

As a rule, the contract can be stated to include:

- Protection of the work site
- Clearing
- Soil excavation, sorting and storage in piles on the site
- Separation of contaminated and clean soil
- Transportation of clean or contaminated soil to reception facilities with the appropriate permits
- Drainage and water redirection during excavation
- Installation of the bentonite mat
- Installation of the underground drainage pipes
- Construction of the protective and damping layers.

When the contractor hands the contract over, the backstop berm liner structure has been built in its entirety.

Start and end dates of the contract period.

D1_1.5 Documents, permits

The work must be performed in accordance with the currently valid national and EU laws, decrees and other official regulations, decisions and guidelines, and the norms and standards applying to the field. The treatment of waste and extraneous materials must follow the regulations and instructions issued by the authorities.

If there is a need to remove contaminated soil from the site, the ELY Centre for the region or the Environment Centre of the City of Helsinki or the City of Turku must be notified of the remediation of a contaminated area. The removal of contaminated soil requires an environmental technology supervisor to analyse the concentrations in the removed soil, direct the materials to the correct disposal location, and prepare transport documents with the contractor's assistance for each removed soil load in duplicate as per Government Decision 659/96. One copy of the transport document is given to the recipient of the load and the other to the supervisor.

Documents to be followed during the performance of the work comprise:

- This work description
- Contract schedule
- Design drawings
- Environmental permit for the site
- Decision of the ELY Centre concerning the remediation of a contaminated area at the site
- InfraRYL 2010, General quality requirements for infrastructure construction 2010 (Part I routes and areas)
- Environment guide for an earthwork site, Environment Guide 31, Finnish Environment Institute 1997
- Labour protection guide for the analysis and remediation of a contaminated land area, Guidelines of the environmental administration 7/2006
- Final report on the remediation of a contaminated land area, Environmental guide Ympäristöopas 2010.
- Publication of the Labour Protection Administration, narrow excavations 1992
- Construction excavation instructions 1989
- The material suppliers' instructions on storage, handling, and installation.

Before beginning the construction work, the contractor must submit an advance notification of the work site with the appropriate labour protection authority and the customer, if the work will take longer than a month. The advance notification must be clearly displayed at the construction site, and it must be kept up to date in the necessary parts.

D1_1.6 Reviews

The initial and final reviews are arranged in accordance with YSE98.

Before the mass replacement work begins, an **initial review** is arranged, with the customer's work supervisor, the environmental technology supervisor (if necessary), the designer's representative (if necessary), the local representative of environmental control, and the representative of the ELY Centre. If necessary, the work methods are specified in more detail and the requirement level determined during the initial review. At the same time, a **plan review** can also be arranged, checking the sufficiency of the plans and the need for additional planning, based on a more comprehensive idea on the materials to be used.

The **acceptance inspection** for the work is carried out after the completion of the work or a work stage is taken into use.

If any defects are identified during the reviews or inspections, they must be corrected before the final approval

D1_1.6.1 Inspection of the liner installation surface

The contractor hands over the measurement results from the installation surface. During the meeting, the parties verify that the installation surface has been excavated in accordance with the plans and that it is a suitable construction bed for the liner; that its load-bearing capacity is sufficient; and that the elevation and surface flatness requirements have been met.

D1_1.6.2 Inspection of the bentonite mat

The contractor's work performance is verified during the inspection. The bentonite mat is also checked to ensure that it has been installed according to the plans to a sufficient extent, that the quality assurance has been carried out acceptably, and that the set requirements have been fulfilled. As a rule, if the structure is found not to meet the set requirements, it is corrected by removing the incorrect structure and rebuilding it.

D1_1.7 Site meetings

Site meetings are arranged regularly at the work site. Minutes are prepared for the meetings.

D1_1.8 Reporting of the work results

In accordance with YSE98, the contractor will keep a work site journal, in which all matters related to the performance of the work are recorded. The customer's representative approves the work with his/her signature. The work site journal and the daily measurement results must be available at the work site.

Particular attention must be paid to the documentation of quality control measurements and corrective measures. All measurement results and inspections are recorded in the work site journal. All defects, quality deviations, errors and their corrections, and the results of the verification measurements are also recorded in the work site journal.

The contractor shall ensure that the subcontractors compile the material, inspection, measurement and test results obtained during the work. After the completion of the work, a summary of the quality control documents (validity document) is delivered to the customer.

D1_1.9 Contractor's plans and advance reports

No less than two weeks prior to beginning a contract work stage, the contractor must present a quality plan including the following plans and information:

1. work site plan
2. quality plan
3. schedule
4. measurement plan
5. work method plan by stage, including the stage-specific quality control measures
6. labour protection plan
7. product information of the bentonite mat
8. installation plan for the bentonite mat
9. quality control plan for the liner.

The plans are delivered to the customer and, if necessary, the environmental technology supervisor, designer and environmental authorities for approval before the work commences.

- The work site plan presents, for instance:
- the location of the construction site buildings
- material storage locations
- driving routes and parking spaces

- water, electricity and waste stations
- location of the first aid kits and firefighting equipment.

The quality plan presents, for instance:

- the site organisation and the persons responsible for quality control
- the subcontractors and their contact persons
- material suppliers
- the measuring services used and their contact persons
- material approval procedure
- the contractor's own quality control plan based on the work description (particularly if it deviates from the plan, or different materials are used)
 - the quality control methods used (equipment and the determination method or standard)
 - sampling and field measurement plan
 - quality requirements, including the allowed tolerances
 - measures to be taken with regard to deviations and changes
 - correction documentation procedure
 - inspections.

The schedule presents, for instance:

- major work stages by week.

The measurement plan presents, for instance:

- the responsible persons
- the initial and reference points used
- the measuring equipment and format
- codes and other identifiers used in the measurements
- the measured levels, lines, pipelines, wells, etc.
- printouts and the printing format, or a list of the drawings to be generated.

The work method plan presents, for instance:

- the materials used
- equipment
- work methods
- work plan.

The bentonite mat installation plan presents, for instance:

- a spreading plan in picture form, including the spreading directions
- lead-throughs
- equipment
- work methods
- work plan.

The plans are updated during work when necessary.

All materials must be approved by the customer and, if necessary, the ELY Centre and the supervisors before their acquisition and use. If the contractor uses materials or work methods that deviate from this work description, the contractor must present the construction work method description and a report on the characteristics of the materials used and their suitability for the application in question before commencing work. Furthermore, the results of the preliminary tests and material information for the contractor's materials must be presented before the commencement of the work. Quality control of the contractor's materials during work is the responsibility of the contractor.

Depending on the materials used, the results of the preliminary tests include:

- granularity curves of the materials used
- other required information, such as water content, humus content, water permeability, gas permeability, or the amount of soluble substances.

D1_1.9.1 Warehouses and storage areas

The raw materials and other materials are stored in the immediate vicinity of the work site. The materials are stored in accordance with the instructions of the material suppliers in such a manner that handling, humidity, sunlight or uneven ground do not cause deformation or damage to the materials. The packaging must remain intact and the product and material specifications readable. The product and material specifications are documented as part of the final report.

The contractor shall present the precise locations of the storage areas in the work site plan.

D1_1.9.2 Traffic arrangements and safety measures

The contractor is responsible for the traffic arrangements and work site roads during the work. The contractor is responsible for site maintenance and cleaning, and plans and implements work site roads, security fences and safety structures, if necessary, in accordance with InfraRYL2010. The contractor acquires and installs the required traffic and warning signs.

D1_1.10 Action plan for different weather conditions

The silting up and dusting of the materials must be avoided.

The bentonite mat must not be installed during periods of rainfall, and it must not be allowed to freeze. The work plan must take into account the fact that the bentonite mat must be immediately covered with a protective layer of earth (at least 300 mm). A soaked and swollen bentonite mat must be rejected and replaced with a new one at the contractor's expense.

The plastic film must not be installed when the temperature is below 0°C. On sunny days, the film is covered during the coolest hours of the day.

D1_1.11 Environmental requirements, occupational health and safety

The work must be performed in accordance with the currently valid laws and regulations without causing undue disturbance to the environment, traffic, and the residents in the vicinity. The spread of pollutants caused by transport must be prevented through transport route selection, covering of the loads, use of tight lorry beds, and, if necessary, cleaning the tyres. Contaminated soil must not spread outside the work site by the lorries.

The contractor is responsible for the work being performed in a manner that is safe for the environment and the different parties, observing particular caution. The contractor is responsible for the necessary safety measures at the work site and equips its workers with the necessary personal safety equipment (helmet, gloves, respirators, safety boots, etc.).

The customer must prepare a work site safety document.

The customer must appoint a safety coordinator for the work site.

D1_1.12 Measurements during work

The contractor performs all elevation and location measurements required for the performance of the work in accordance with the design documents. The contractor prepares a measurement plan based on the construction plans. The contractor measures the initial terrain model of the work site upon the commencement of the work.

The measurement results must be collected in such a format that they can be used for the analysis of the dimensional and positional accuracy of the structures during quality control. As work progresses, all measurement results are immediately delivered to the customer's supervisor in digital format and as paper printouts. The measurement results are marked down on the base map supplied upon commencement of the work.

D1_1.12.1 Marking the plan in the terrain

Reference points in the area are used as the starting point for the measurements, based on which the contractor performs the measurements. Before starting work, the contractor must compare the elevation and location data of the reference points to the design elevations and dimensions.

The plan is marked in the terrain as required by each work stage. A sufficient number of survey poles, elevation markers, slope stakes or other markers will be placed in the terrain to guarantee that the work can be performed according to plan and that it is possible to reliably verify the work's conformance with the plans based on these markers. During the construction work, checks must be made sufficiently often to ensure that the marker locations have not changed. If necessary, the survey is repeated and the markers replaced into the terrain. When a laser beam is used as an alignment mark or for directing a work machine, the beam must be aimed with sufficient accuracy to make it possible to follow the precision requirements set for the construction. The contractor chooses the measurement methods based on how the location and dimensions of the structure have been presented in the plan.

The slope inclinations and elevation levels presented in the plans are indicative.

D1_1.12.2 Measured levels

The excavation bottoms and slopes are measured in a 10x10 m grid as x,y,z points. The top and bottom ends of the slopes are measured as break lines with a maximum distance of 10 m between points. The contractor prints out the measurements on the plan map as level curves in such a manner that the results can be compared with the plans and delivered to the customer's supervisor at each stage of the work.

D1_1.12.3 Other measurements

The measurements to be carried out before the structures are covered and the other verification measurements of the finished structure are presented in the structure-specific quality requirements. Additionally, the locations of the quality control measurement points and the residual concentration sampling points are measured, if necessary.

D1_1.12.4 Work amount measurements

The amounts are measured in accordance with InfraRYL 2010 and based on the dimensions marked on the plans, taking into consideration any changes to them agreed during the work and the actual elevation of the ground level.

D1_1.12.5 As-built drawings

The contractor is obligated to mark down in the design drawings all differences and deviations from the original plan detected during the work. These drawings are handed over to the customer once the work has been finished and approved. The structures may not be covered before the measurements for the preparation of the as-built drawings have been made.

The contractor supplies the customer and the environmental technology supervisor with contours printed out on 1:500 maps based on the survey data, indicating the actual finished subgrade surface and the finished surface of the excavated landfill. The same materials are also delivered in electronic format. The locations of the pipelines and wells, water flows, and elevations are marked on the map. Well information cards are prepared of the wells.

D1_1.13 Quality control of work performance and the outcome

Quality control is used to prove that the materials used and the construction work done conform with the plans and the requirements of the environmental permit.

Quality control comprises the following parts:

- quality control of product manufacturing (product specifications and the parameters inspected of the manufacturing lot in question)
- preliminary tests and acceptance tests
- field quality control measurements and functional tests carried out during work.

The material and structure-specific quality requirements and quality control methods are presented separately for each work stage.

D1_1.13.1 Contractor's quality control

The contractor bears the main responsibility for performing the work in accordance with the plans. The fulfilment of the requirements is verified by quality assurance measurements during work.

The contractor carries out daily quality control at the work site. The contractor performs tests and analyses specified below before beginning the actual work, and during the work. Measurements are made with regard to both quantities and surface areas.

The results and observations from the contractor's quality control are handed over to the customer's supervisor immediately after they are complete. The contractor and the customer's representative also inspect the area under work on a weekly basis.

The contractor must take note of the comments made by the supervisor based on the quality control measurements.

After the completion of the work, a summary of the quality control documents (validity document) is delivered to the customer.

Based on this work description, the contractor prepares a quality plan that is approved by the customer and, if necessary, the designer.

D1_1.13.2 Customer's supervision

The customer's supervision does not limit the contractor's liability.

D1_1.13.3 Customer's on-site supervisor

The customer may appoint supervisors to supervise the contractor's work performance and monitor the amounts.

If necessary, the environmental technology supervisor is responsible for taking soil samples directing the remediation of contaminated soil, sending the samples to a laboratory, and reviewing the contractor's work site journal. In addition to field analyses, soil samples are sent to a laboratory for analysis. The supervisor directs the removal of the contaminated soil, its sorting for suitable reception facilities, and is responsible for preparing the transport documents and informing the reception locations.

D1_1.13.4 Supervision by the authorities

The environmental authorities may make inspection visits, and participate in site meetings, inspections and reviews, for example.

D1_1.13.5 Material quality control

Before off-the-shelf parts and materials are taken into use, the tests are performed and the certificates acquired that are specified in the plan, this work description, or the documents that are referred to in the appropriate place of the plan or this work description.

If the tested sample does not meet the requirements set for it, the material batch that the test result in question represents will not be used in construction before further analysis. Two new tests may be carried out before making the decision to reject the batch. Only if both new test results meet the set requirements may the material

batch represented by the test results be used in construction. After improvements or corrective measures on the material, its validity must be proven with two new tests.

The number of tests and inspections carried out during quality control may increase if the material quality is observed to vary during a visual inspection.

D1_1.13.6 Quality control of removed materials

The quantity, quality, pollutant content and treatment or delivery method of any soil removed from the site is recorded in the work site journal on a daily basis. A transport document as per Government Decision 659/96 is delivered with each load transported to a treatment facility; it indicates the material type and the pollutant concentration, determined by field measurements or laboratory analysis. If necessary, the quality and pollutant concentration of soil remaining at the work area is determined by field measurements and partially by laboratory analyses, and documented in the as-is measurements. If necessary, the environmental technology supervisor is responsible for the above-mentioned concentration measurements.

D1_1.13.7 Supervision of lining work

The compactness of structures constructed from soil is monitored if a compactness requirement has been specified for the structure, either in the design documents or the general work description.

Degree of compaction refers to a percentage that indicates the ratio of the dry density determined from a sample taken from the structure or directly measured from the structural layer to the maximum dry density determined with the improved or standard Proctor compaction test.

The procedure is selected based on the number of compactions and the compactor machines used.

I 1000 EXISTING STRUCTURES AND STRUCTURAL PARTS

11200 Removed, moved and protected structures

Present information on the structures and equipment located in the work area and their dismantling or protection.

I 2000 CONTAMINATED SOIL

12100 Removed contaminated soil

Present information on the contaminated soil located in the work area and its treatment.

12200 Liner structures

12200.1 Lining materials

A bentonite mat is used as the lining material in accordance with Appendix T15 to the technical requirement 14231.1.1. The bentonite mat must have at least the following minimum characteristics:

- amount of bentonite no less than 3.7 kg/m² (measure of dispersion 20%, SFS-EN 14196), testing frequency 5,000 m²
- flux < 7 × 10⁻⁹ (m³/m²)/s (ASTM D 5887-95)
- montmorillonite content determined with XRD > 75% and methylene blue adsorption test > 300 mg/g (VDG P 69), testing frequency 30,000 m²
- the bentonite must be natural sodium bentonite without organic additives that increase its swelling or reduce its water permeability
- bentonite swelling index no less than 24 ml/2g (ASTM D 5890), testing frequency 5,000 m²
- water adsorption on the bentonite ≥ 500% (DIN 18132, 24 h)
- delivery water content ≤ 15%

- tensile strength in both directions ≥ 9 kN/m (EN-ISO 10319), testing frequency 5,000 m²
- tearing resistance ≥ 60 N/10 cm (SFS-EN ISO 10319), testing frequency 5,000 m²
- static puncture resistance ≥ 1.5 kN (SFS-EN ISO 12236)
- deformation at maximum load $5\% > \epsilon < 50\%$ (SFS-EN ISO 10319), testing frequency 5,000 m²
- the top fabric must be needle-punched, weight by square metre ≥ 200 g/m² (SFS-EN ISO 9864 or SFS-EN 14196), testing frequency 5,000 m²
- the bottom fabric must be woven, weight by square metre ≥ 100 g/m² (SFS-EN ISO 9864 or SFS-EN 14196), testing frequency 5,000 m²

At the tendering stage, the contractor must report the manufacturer, type and factory manufacturing specifications of the bentonite mat it uses. The contractor must show that the mats it offers are suitable for use as a lining layer. For the products, information on the quality control during manufacturing must be presented (testing methods and frequency). The contractor commits to using the bentonite mats specified in its tender and approved by the customer. The mat types approved by the customer during contract negotiations may not be changed during the construction stage. The batch-specific quality control results for the bentonite mats must correspond with the materials reported in advance. The above also applies to the approval of plastic films.

The bentonite mat is stored on a dry and firm platform, protected from sunlight and rain. The mats may not be installed during periods of rainfall or into water. The excavations must be kept dry during work, until a layer of earth at least 300 mm thick has been spread over the bentonite mat.

Plastic film is used as the lining material in accordance with Appendix T16 to the technical requirement 14234.1.1. The plastic film must have at least the following minimum characteristics:

- Thickness ≥ 0.5 mm (SFS-EN 1849-2)
- Oxidation $> 70\%$ (SFS-EN ISO 13438)
- Stress crack resistance ≥ 200 h (ASTM D 5397)
- Plastic type LLDPE, FPE or LDPE

12200.2 *Liner structure bed*

The levelness requirement of the liner structure bed is ± 50 mm. Tree roots and other such unevenness is removed from the surface of the bed, and the surface is compacted with a vibrating plate, for instance, so that it is level and firm. No sharp edges over 10 mm in size, or pits, footprints or other sharp depressions over 20 mm in size may be left in the bed. The bed is primarily made of excavated and levelled backstop berm material.

If a bed meeting the levelness and grain size requirements cannot be constructed from the backstop berm material, the bed is constructed from a suitable material. The maximum grain size of natural materials used as primary layer material is 32 mm and 16 mm for crushed materials.

If the subgrade at the bottom edge of the backstop berm is wet silt, wet silt moraine, soft clay or humus soil, a primary layer structure must be constructed in order to improve load-bearing capacity and to prevent capillary water rise. There is a strainer of usage class N3 at the bottom, with a 200 mm layer of gravel or aggregate or 300 mm of wide-graded, non-freezing sand.

The plastic film is installed directly on top of the bentonite mat.

12200.3 *Building the liner structure*

Before laying out the bentonite mats, the contractor must prepare an installation plan and have it approved by the customer. The bentonite mat is spread on a levelled bed with an installation beam, for example; the mats must not be dragged. The mat is

seamed by overlapping by at least 300 mm; 500 mm at extension joints. Bentonite powder is added to the seam in accordance with the manufacturer's instructions, unless self-sealing mats are used. Joints on a slope should be avoided, and "roof tile overlapping" is used for the joints, i.e. the fabric that is higher in the direction of flow is placed on top of the lower one at the joint. The bentonite mat is extended up to the top edge of the backstop berm slope and anchored to the crown of the backstop berm. The location of each bentonite mat strip is measured and presented in the as-built drawing. The mat strips are installed crosswise in relation to the slope.

The laid out mats must be covered with a protective soil layer of at least 300 mm during the same work shift and before they get wet. In case of rain, an uncovered mat must be temporarily covered with plastic sheeting. Machines should not be driven on the uncovered bentonite mat. Heavy work machines are not allowed to be driven on top of the bentonite mat until the mat is covered by a soil layer of at least 500 mm. Material specified in InfraRYL figure 18320:K1a is used as the protective layer, so that the maximum grain size of natural materials used as protective layer material is 32 mm and 16 mm for crushed materials. In the underground drainage trench section, a plastic film (LLDPE/FPE/LDPE 0.5 mm) is installed directly on top of the bentonite mat. The plastic film is seamed by overlapping it by 500 mm. The thickness of the protective layer of the bentonite mat is reduced to 100 mm with regard to the underground drainage trench.

A 0.7 m wide and 0.4 m deep trench is excavated on the crown of the backstop berm for the purpose of anchoring the top edge of the bentonite mat. The anchoring length is 0.4 m.

The bottom edge of the bentonite mat is taken halfway to the opposite slope of the underground drainage trench or 0.2 m to the outside of the underground drainage trench.

12200.4 Finished liner structure

The liner structure's conformity with the plans is verified during the inspection of the bentonite mat as presented in the general part of section 1.6.2. The finished surface of the liner layer is inspected and approved so that the supervisory work does not cause interruptions to the work. The approval is recorded in the work site journal and confirmed with signatures. The approved surface must be immediately protected from harmful moisture, drying, erosion, freezing and mechanical damage with a layer of protective earth.

12200.5 Proving the validity of the liner structure

The contractor will present the layer thicknesses and the location of the liner materials in the as-built drawings, measured in a 10 x 10 m square. The quality assurance information of the soil layers and materials is presented in the validity document.

I 4300 DRAINAGE STRUCTURES

14311 Area underground drainage

14311.1 Underground drainage material

The diameter of the underground drainage is DN100, the pipe material must meet the requirements of standard SFS 5675, and its ring stiffness must be at least class SN8. Unperforated PE plastic pipes of at least class SN4 are used as drain pipes. The validity of the underground drainages is verified based on the pipe markings and delivery documents of the delivery batch, and presented in the validity document.

14311.2 Underground drainage bed

The underground drainage is installed in an underground drainage trench dug into the bottom edge of the backstop berm's slope, on top of the protective layer of the bentonite mat.

Insofar as the underground drainage passes over the liner structure, underground drainage pipes are used. A drain pipe is used from the edge of the liner structure to the monitoring well. See drawing 4 for a detail of the pass-through of the liner structure's edge. The edge of the liner material is lifted up, and the drain pipe is passed through the liner. The principle of InfraRYL figure 14231:K2 is followed in the pass-through. The pass-through is equipped with a collar tightener that is sealed with bentonite paste.

14311.3 Underground drainage installation

The gradient of the underground drainage is 0.4%. The plastic pipes are connected to each other with sleeve joints; if necessary, extension sleeves are used. The pipes are connected to the well with a watertight seal; use a rigid plastic pipe of a suitable size as the sheathing. The sheathing must extend 0.5 m to hard ground.

Leave about 0.3 m of the end of the drain pipe visible. The bottom edge of the drain hole is placed above the average water level and at least 20 cm above the bottom of the ditch. Prevent small animals from entering the pipe by installing a mesh.

The sidefill material for the underground drainage is underground drainage sand, gravel or aggregate that meets the granularity requirements for underground drainage materials, for instance as per InfraRYL figure 18320:K1a.

The location of the underground drainage is presented in drawings 3 and 4.

14311.4 Finished underground drainage

The maximum allowed deviation of the pipe gradient is +0.08%, as the gradient must not go below the minimum value. The horizontal tolerance of the underground drainage's location is ± 200 mm and vertical ± 50 mm.

14311.5 Proving the validity of the underground drainage

The location of the underground drainage is measured as-built every ten metres. A location drawing is drawn up of the pipeline, with the wells, inspection pipes and drain holes marked. The pipeline information is compiled into the validity document.

14320 Wells and inspection pipes of the underground drainage

14320.1 Material of the wells and inspection pipes of the underground drainage

The minimum inner diameter DN/ID of the inspection pipe is 200 mm. The underground drainage is connected to the water management system chosen for the site.

14320.2 Bed of the wells and inspection pipes of the underground drainage

The wells and inspection pipes are installed on a level subgrade. If necessary, the surface of the subgrade is levelled with an installation bed constructed from a well-compacting material. If necessary, the thickness of the installation bed is 150 mm.

14320.3 Installation of the wells and inspection pipes of the underground drainage

The wells and inspection pipes are installed in a vertical position.

14320.4 Finished well or inspection pipe of the underground drainage

The maximum vertical deviation of a well or inspection pipe is 10 mm over a distance of 1 m.

14320.5 Proving the validity of the wells and inspection pipes

A location drawing is drawn up of the pipeline, with the wells, inspection pipes and drain holes marked. Information cards are prepared for the wells. The pipeline information is compiled into the validity document.

I 6000 EXCAVATIONS

16110 Excavation, unspecified

16110.3 Making an excavation

The wall of the backstop berm is excavated if the construction of the liner structure bed so requires. The bed is primarily made of excavated and levelled backstop berm material.

Due to the friction angle of the construction materials, the steepness of the slope of the backstop berm may be a maximum of 1:1.5 (33.4°).

A trench 0.5 m deep with 1:1 slopes is excavated into the bottom end of the backstop berm's slope for the construction of the underground drainage. The gradient of the excavation is 0.4% in the direction of the water management system. The top edge of the excavation's slope on the side of the backstop berm merges with the primary layer so that the bentonite mat goes down along the berm slope to the bottom of the trench and to the opposite slope. The width of the trench bottom is 0.5 m. The trench travels in front of the backstop berm and ends in a location determined by the water management system. The soil is excavated so that the excavation bottom does not loosen detrimentally. The location of the excavation is presented in drawings 3 and 4.

If the locations of the other structures at the shooting range allow, a berm 1.5 m wide and 0.5 m high is constructed of the excavated mass on the side of the firing stands in front of the excavation. The berm prevents water from the intermediate area from getting into the underground drainage and improves the flow of the percolating water from the backstop berm into the underground drainage.

16110.4 Finished excavation

The excavation conforms with the presented dimensions and requirements. No part of the excavation's bottom may be above the planned elevation, and it must have no water-accumulating depressions or loosened soil layers. Disturbed layers have been properly compacted. The tolerance for the elevation of the excavation bottom is 0...-100 mm, and no individual pit may be deeper than -50 mm. The horizontal tolerance for the excavation bottom is ±150 mm.

16110.5 Proving the validity of the excavation

The slope gradients and excavation depth are checked by measuring at ten metre intervals. The other evenness of the excavation surface is verified visually or, if necessary, using a straight board measuring three metres in length. The contractor will prove the validity of the excavation through measurement results in the validity document.

I 8000 EMBANKMENTS, DYKES AND FILLS

18110 Earthen embankments

18110.1 Earthen embankment materials, general

The damping layer of the backstop berm is constructed as an earthen embankment. Sand 0...8 is used as the material for the damping layer. The validity of the material is verified with a sand grain size analysis prior to construction, and every time the source changes or the material becomes visually different.

18110.2 Earthen embankment bed

The damping layer is constructed on top of the underground drainage's sidefill, and on the backstop berm slope, on top of the strainer installed on top of the protective layer of the bentonite mat.

18110.3 *Constructing an earthen embankment*

On the backstop berm slope, the damping layer is constructed on top of a strainer, and at its foot, on top of the underground drainage's sidefill. The thickness of the damping layer on the slope is 600 mm, and it must be constructed to a uniform quality. Because heavy work machines cannot be driven on top of the liner structures before they are covered with a sufficiently thick layer of protective soil, the earthen embankment is constructed from the intermediate area or from the top of the backstop berm. See drawing 3 for the principle of the construction of the damping layer.

18110.4 *Finished earthen embankment*

The compacted top surface of the damping layer conforms with the design documents. The thickness of the layer must not be less than the required 600 mm. The maximum allowed deviation is +50 mm.

The layer's connection to the existing structures on top of the backstop berm and in the intermediate area is implemented case-specifically.

18110.5 *Proving the validity of the earthen embankment*

The surface of the damping layer is measured into a 10 x 10 m square and presented in an as-built drawing. The quality control information on the material is presented in the validity document.

21100 FILTRATION STRUCTURES

21120 Strainers

21120.1 *Strainer materials*

A light-coloured fabric of usage class N2 is used as the strainer. The service life of the strainer fabric must be at least 25 years. The strainer rolls are stored on a dry and firm platform, protected from sunlight and rain.

21120.2 *Strainer bed*

The strainer is installed on the protective layer of the bentonite mat as described in section 12200.3. The area over which the strainer is installed is presented in drawings 3 and 4.

21120.3 *Installation of strainers*

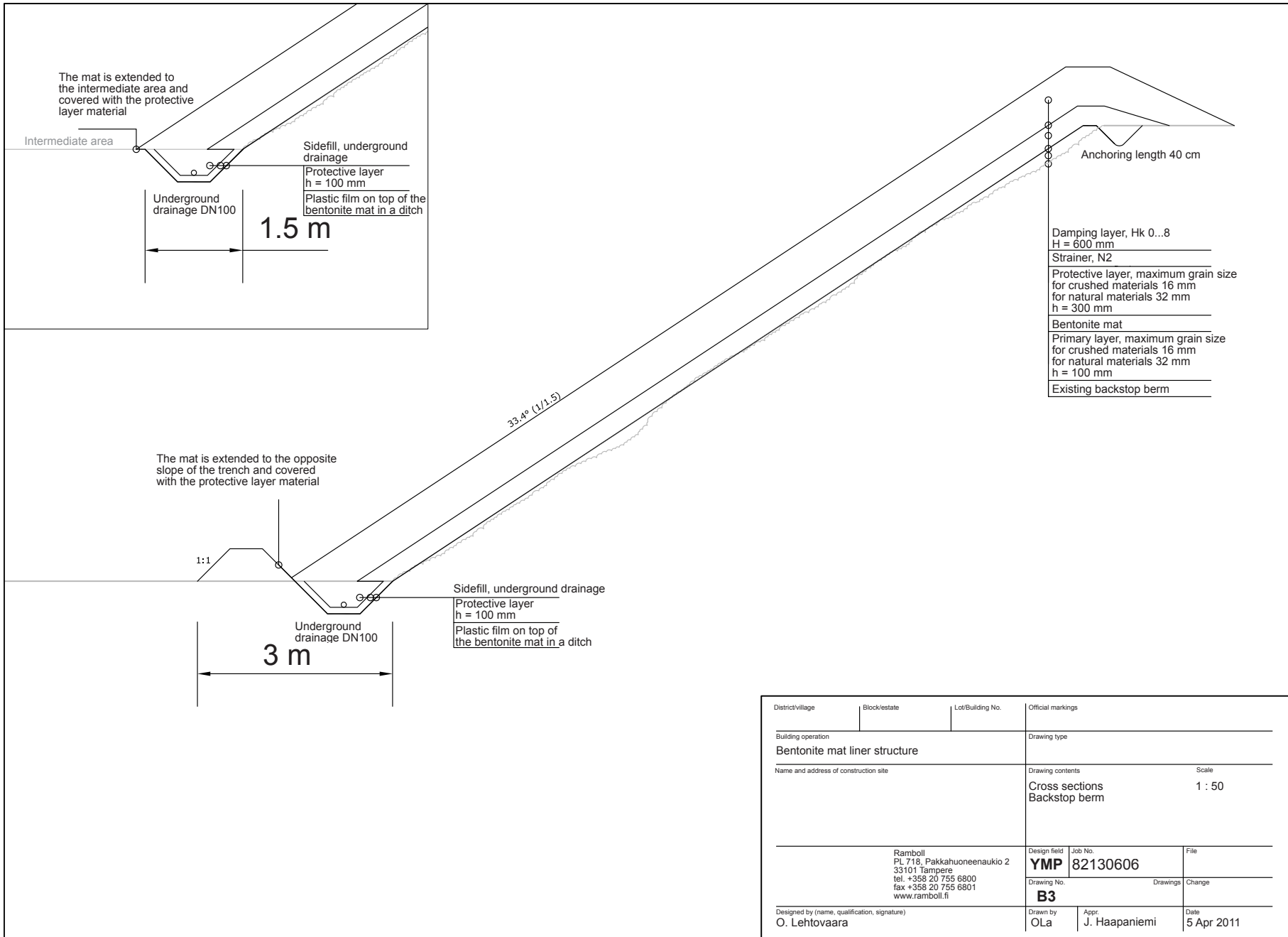
The strainers must not be left spread out exposed to sunlight for longer than one week. The strainers are spread in the same orientation as the bentonite mat. The strainers are seamed by overlapping them by 500 mm. The overlapping is done in the same order as on the bentonite mat. Light work machines may be driven on top of the strainer once it has been covered by 300 mm of damping layer material, and heavy work machines may be driven on top of it once it has been covered by 500 mm of damping layer material.

21120.4 *Finished strainer*

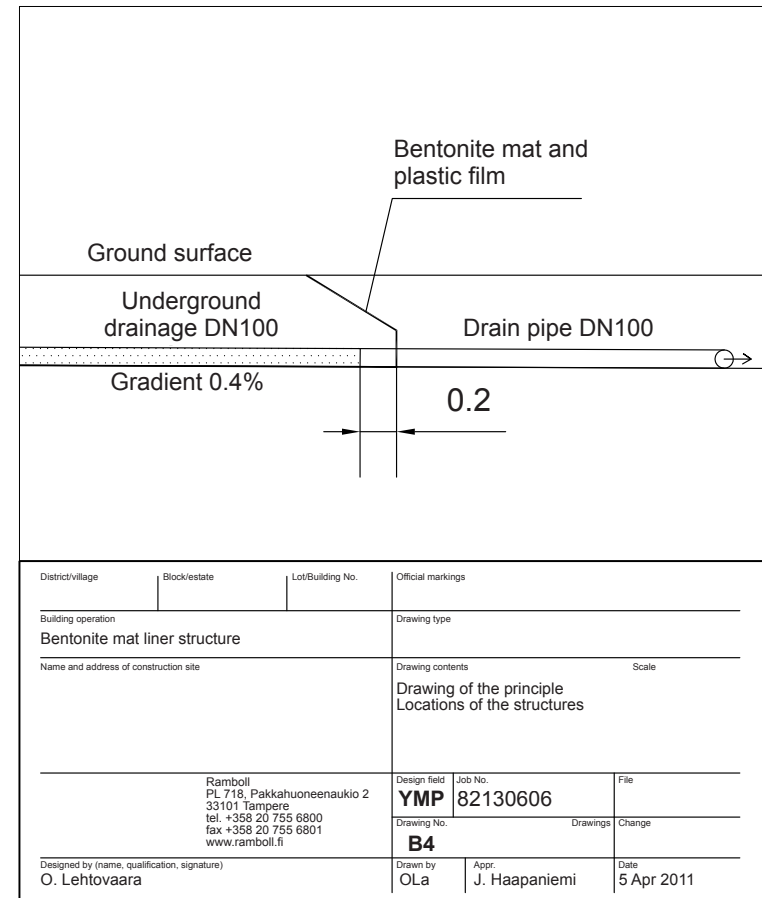
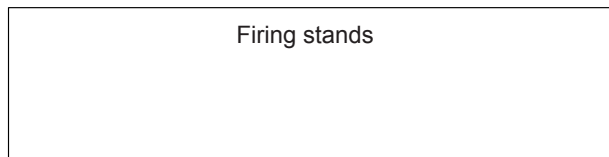
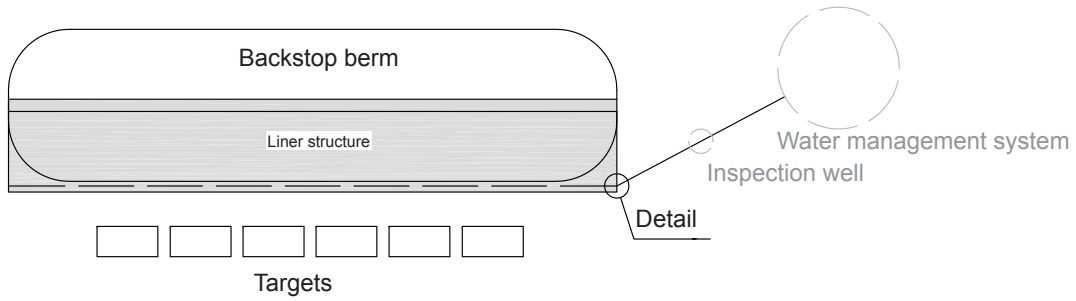
The strainer has been installed and overlapped in accordance with the design over the area of the bentonite mat's protective layer.

21120.5 *Proving the validity of the installed strainers*

The overlapping and seaming of the strainers are inspected during the work stage. The as-built drawings of the validity document show the actual location and category of use of the strainers.



District/village	Block/estate	Lot/Building No.	Official markings
Building operation Bentonite mat liner structure			Drawing type
Name and address of construction site			Drawing contents Cross sections Backstop berm
Ramboll PL 718, Pakkahuoneenaukio 2 33101 Tampere tel. +358 20 755 6800 fax +358 20 755 6801 www.ramboll.fi			Scale 1 : 50
Design field YMP		Job No. 82130606	File
Drawing No. B3		Drawings	Change
Designed by (name, qualification, signature) O. Lehtovaara		Drawn by OLa	Appr. J. Haapaniemi
		Date 5 Apr 2011	



Appendix D2. Lining the backstop berms with plastic film

Introduction

This is a reference work description of the construction of a liner structure into the backstop berm of a shooting range. The reference work description has been written in such a manner that it can be used even in large contracts. In small contracts, unnecessarily detailed sections can be left out and the applicable parts of the description utilised.

The reference work description describes the work in as much detail as possible, taking into consideration the fact that it must suit sites of very different sizes. Issues that are necessary in the work description but that could not be written in detail are in *cursive*.

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DRAWINGS

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D2_I GENERAL INSTRUCTIONS

D2_1 General

This work description defines the technical quality requirements and scope of the work of the project. The contractor's financial and legal liabilities and the contractor's other obligations are presented in a separate contract programme that shall take precedence over this description.

Attached to the work description, there is a list of the work performances and amounts that are included in the contract, and for which the contract price is calculated using unit prices.

The contractor must carefully go over the work site before submitting a contract offer.

D2_1.2 Work site

Information on the site's location, scope and ownership. The site location is presented in location map 1. The contract area is presented in drawing 2.

Information on existing structures.

A liner structure for the backstop berm of a shooting range is built on the site.

Customer's contact information.

D2_1.3 Nomenclature

This work description uses the InfraRYL 2010 (Part 1) nomenclature.

D2_1.4 Scope and implementation schedule of the backstop berm liner structure

The liner structure is built inside the backstop berms of pistol and rifle ranges from plastic film that acts as a sealing layer. Underground drainage is built at the bottom of the sealing layer at ground level to collect the percolating water into a *water management system*. A protective layer and a damping layer are built on top of the liner structure to protect the liner from bullet impacts. The liner structure extends from the ground level to the backstop berm's top and over the entire width of the berm.

The underground drainage is built in an excavation made in the bottom part of the existing backstop berm. The excavation mass is primarily utilised on-site. The soil in the backstop berm can be contaminated by pollutants from bullets. The contamination of the excavated soil must be properly analysed, and any soil removed from the site must be properly treated.

As a rule, the contract can be stated to include:

- Protection of the work site
- Clearing
- Soil excavation, sorting and storage in piles on the site
- Transportation of clean or contaminated soil to reception facilities with the appropriate permits
- Separation of contaminated and clean soil
- Drainage and water redirection during excavation
- Installation of the plastic film
- Installation of the underground drainage pipes
- Construction of the protective and damping layers.

When the contractor hands the contract over, the backstop berm liner structure has been built in its entirety.

Start and end dates of the contract period.

D2_1.5 Documents, permits

The work must be performed in accordance with the currently valid national and EU laws, decrees, and other official regulations, decisions and guidelines, and the norms and standards applying to the field. The treatment of waste and extraneous materials must follow the regulations and instructions issued by the authorities.

If there is a need to remove contaminated soil from the site, the ELY Centre for the region or the Environment Centre of the City of Helsinki or the City of Turku must be notified of the remediation of a contaminated area. The removal of contaminated soil requires an environmental technology supervisor who analyses the concentrations in the removed soil, directs the materials to the correct disposal location, and prepares transport documents with the contractor's assistance for each removed soil load in duplicate as per Government Decision 659/96. One copy of the transport document is given to the recipient of the load and the other to the supervisor.

Documents to be followed during the performance of the work comprise:

- this work description
- contract schedule
- design drawings
- environmental permit for the site
- decision of the ELY Centre concerning the remediation of a contaminated area at the site
- InfraRYL 2010, General quality requirements for infrastructure construction 2010 (Part I routes and areas)
- Environment guide for an earthwork site, Environment Guide 31, Finnish Environment Institute 1997
- Labour protection guide for the analysis and remediation of a contaminated land area, Guidelines of the environmental administration 7/2006
- Final report on the remediation of a contaminated land area, Environmental guide Ympäristöopas 2010.
- Publication of the Labour Protection Administration, narrow excavations 1992
- Construction excavation instructions 1989
- The material suppliers' instructions on storage, handling and installation.

Before the beginning of the construction work, the contractor must submit an advance notification of the work site with the appropriate labour protection authority and the customer, if the work will take longer than a month. The advance notification must be clearly displayed at the construction site, and it must be kept up to date in the necessary parts.

D2_1.6 Reviews

The initial and final reviews are arranged in accordance with YSE98.

Before the mass replacement work begins, an **initial review** is arranged, with the customer's work supervisor, the environmental technology supervisor (if necessary), the designer's representative (if necessary), the local environmental control representative, and the representative of the ELY Centre present. If necessary, the work methods are specified in more detail and the requirement level determined during the initial review. At the same time, a **plan review** can also be arranged, checking the sufficiency of the plans and the need for additional planning, based on a more comprehensive idea of the materials to be used.

The **acceptance inspection** for the work is carried out after the completion of the work or a work stage taken into use.

If any defects are identified during the reviews or inspections, they must be corrected before the final approval

D2_1.6.1 Inspection of the liner installation surface

The contractor hands over the measurement results from the installation surface. During the meeting, the parties verify that the installation surface has been excavated in accordance with the plans and that it is a suitable construction bed for the liner; that its load-bearing capacity is sufficient; and that the elevation and surface flatness requirements have been met.

D2_1.6.2 Inspection of the plastic film

The contractor's work performance is verified during the inspection. The plastic film is also checked to ensure that it has been installed according to the plans to a sufficient extent, that the quality assurance has been carried out acceptably, and that the set requirements have been fulfilled. As a rule, if the structure is found not to meet the set requirements, it is corrected by removing the incorrect structure and rebuilding it.

D2_1.7 Site meetings

Site meetings are arranged regularly at the work site. Minutes are prepared for the meetings.

D2_1.8 Reporting of the work results

In accordance with YSE98, the contractor will keep a work site journal, in which all matters related to the performance of the work are recorded. The customer's representative approves the work with his/her signature. The work site journal and the daily measurement results must be available at the work site.

Particular attention must be paid to the documentation of quality control measurements and corrective measures. All measurement results and inspections are recorded in the work site journal. All defects, quality deviations, errors and their corrections, and the results of the verification measurements are also recorded in the work site journal.

The contractor shall ensure that the subcontractors compile the material, inspection, measurement and test results obtained during the work. After the completion of the work, a summary of the quality control documents (validity document) is delivered to the customer.

D2_1.9 Contractor's plans and advance reports

No less than two weeks prior to beginning a contract work stage, the contractor must present a quality plan including the following plans and information:

1. work site plan
2. quality plan
3. schedule
4. measurement plan
5. work method plan by stage, including the stage-specific quality control measures
6. labour protection plan
7. product information on the plastic film
8. installation plan for the plastic film
9. quality control plan for the liner.

The plans are delivered to the customer and, if necessary, the environmental technology supervisor, designer and environmental authorities for approval before the work commences.

- The work site plan presents, for instance:
 - the location of the construction site buildings
 - material storage locations
 - driving routes and parking spaces
 - water, electricity and waste stations
 - location of the first aid kits and firefighting equipment.

The quality plan presents, for instance:

- the site organisation and the persons responsible for quality control
- the subcontractors and their contact persons
- material suppliers
- the measuring services used and their contact persons
- material approval procedure
- the contractor's own quality control plan based on the work description (particularly if it deviates from the plan, or different materials are used)
 - the quality control methods used (equipment and the determination method or standard)
 - sampling and field measurement plan
 - quality requirements, including the allowed tolerances
 - measures to be taken with regard to deviations and changes
 - correction documentation procedure
 - inspections.

The schedule presents, for instance:

- major work stages by week.

The measurement plan presents, for instance:

- the responsible persons
- the initial and reference points used
- the measuring equipment and format
- codes and other identifiers used in the measurements
- the measured levels, lines, pipelines, wells, etc.
- printouts and the printing format, or a list of the drawings to be generated.

The work method plan presents, for instance:

- the materials used
- equipment
- work methods
- work plan.

The plastic film installation plan presents, for instance:

- a spreading plan in picture form, including the spreading directions
- lead-throughs
- equipment
- work methods
- work plan.

The plans are updated during work when necessary.

All materials must be approved by the customer and, if necessary, the ELY Centre and the supervisors before their acquisition and use. If the contractor uses materials or work methods that deviate from this work description, the contractor must present the construction work method description and a report on the characteristics of the materials used and their suitability for the application in question before commencing work. Furthermore, the results of the preliminary tests and material information for the contractor's materials must be presented before the commencement of the work. Quality control of the contractor's materials during work is the responsibility of the contractor.

Depending on the materials used, the results of the preliminary tests include:

- granularity curves of the materials used
- other required information, such as water content, humus content, water permeability, gas permeability, or the amount of soluble substances.

D2_1.9.1 Warehouses and storage areas

The raw materials and other materials are stored in the immediate vicinity of the work site. The materials are stored in accordance with the instructions of the material suppliers in such a manner that handling, humidity, sunlight or uneven ground do not cause deformations or damage to the materials. The packaging must remain intact and the product and material specifications readable. The product and material specifications are documented as part of the final report.

The contractor shall present the precise locations of the storage areas in the work site plan.

D2_1.9.2 Traffic arrangements and safety measures

The contractor is responsible for the traffic arrangements and work site roads during the work. The contractor is responsible for site maintenance and cleaning, and plans and implements work site roads, security fences and safety structures, if necessary, in accordance with InfraRYL2010. The contractor acquires and installs the required traffic and warning signs.

D2_1.10 Action plan for different weather conditions

The silting up and dusting of the materials must be avoided.

The plastic film must not be installed when the temperature is below 0°C. On sunny days, the film is covered during the coolest hours of the day.

D2_1.11 Environmental requirements, occupational health and safety

The work must be performed in accordance with the currently valid laws and regulations without causing undue disturbance to the environment, traffic, and the residents in the vicinity. The spread of pollutants caused by transport must be prevented through transport route selection, covering of the loads, use of tight lorry beds, and, if necessary, cleaning the tyres. Contaminated soil must not be spread outside the work site by the lorries.

The contractor is responsible for the work being performed in a manner that is safe for the environment and the different parties, observing particular caution. The contractor is responsible for the necessary safety measures at the work site and equips its workers with the necessary personal safety equipment (helmet, gloves, respirators, safety boots, etc.).

The customer must prepare a work site safety document.

The customer must appoint a safety coordinator for the work site.

D2_1.12 Measurements during work

The contractor performs all elevation and location measurements required for the performance of the work in accordance with the design documents. The contractor prepares a measurement plan based on the construction plans. The contractor measures the initial terrain model of the work site upon the commencement of the work.

The measurement results must be collected in such a format that they can be used for the analysis of the dimensional and positional accuracy of the structures during quality control. As work progresses, all measurement results are immediately delivered to the customer's supervisor in digital format and as paper printouts. The measurement results are marked on the base map supplied at the commencement of the work.

D2_1.12.1 Marking the plan in the terrain

Reference points in the area are used as the starting point for the measurements, based on which the contractor performs the measurements. Before starting work, the contractor must compare the elevation and location data of the reference points to the design elevations and dimensions.

The plan is marked in the terrain as required by each work stage. A sufficient number of survey poles, elevation markers, slope stakes or other markers will be placed in the terrain to guarantee that the work can be performed according to plan and that it is possible to reliably verify the work's conformance with the plans based on these markers. During the construction work, checks must be made sufficiently often to ensure that the marker locations have not changed. If necessary, the survey is repeated and the markers replaced in the terrain. When a laser beam is used as an alignment mark or for directing a work machine, the beam must be aimed with sufficient accuracy to make it possible to follow the precision requirements set for the construction. The contractor chooses the measurement methods based on how the location and dimensions of the structure have been presented in the plan.

The slope inclinations and elevation levels presented in the plans are indicative.

D2_1.12.2 Measured levels

The excavation bottoms and slopes are measured into a 10x10 m grid as x,y,z points. The top and bottom ends of the slopes are measured as break lines with a maximum distance of 10 m between points. The contractor prints out the measurements on the plan map as level curves in such a manner that the results can be compared with the plans and delivered to the customer's supervisor at each stage of the work.

D2_1.12.3 Other measurements

The measurements to be carried out before the structures are covered and the other verification measurements of the finished structure are presented in the structure-specific quality requirements. Additionally, the locations of the quality control measurement points and the residual concentration sampling points are measured, if necessary.

D2_1.12.4 Work amount measurements

The amounts are measured in accordance with InfraRYL 2010 and based on the dimensions marked on the plans, taking into consideration any changes to them agreed during the work and the actual elevation of the ground level.

D2_1.12.5 As-built drawings

The contractor is obligated to mark down in the design drawings all differences and deviations from the original plan detected during the work. These drawings are handed over to the customer once the work has been finished and approved. The structures may not be covered before the measurements for the preparation of the as-built drawings have been made.

The contractor supplies the customer and the environmental technology supervisor with contours printed out on 1:500 maps based on the survey data, indicating the actual finished subgrade surface and the finished surface of the excavated landfill. The same materials are also delivered in electronic format. The locations of the pipelines and wells, water flows and elevations are marked on the map. Information cards are prepared for the wells.

D2_1.13 Quality control of work performance and the outcome

Quality control is used to prove that the materials used and the construction work done conform with the plans and the requirements of the environmental permit.

Quality control comprises the following parts:

- quality control of product manufacturing (product specifications and the parameters inspected of the manufacturing batch in question)
- preliminary tests and acceptance tests
- field quality control measurements and functional tests carried out during work.

The material and structure-specific quality requirements and quality control methods are presented separately for each work stage.

D2_1.13.1 Contractor's quality control

The contractor bears the main responsibility for performing the work in accordance with the plans. The fulfilment of the requirements is verified by quality assurance measurements during work.

The contractor carries out daily quality control at the work site. The contractor performs tests and analyses specified below before beginning the actual work, and during the work. Measurements are made with regard to both quantities and surface areas.

The results and observations from the contractor's quality control are handed over to the customer's supervisor as soon as they are complete. The contractor and the customer's representative also inspect the area under work on a weekly basis.

The contractor must take note of the comments made by the supervisor based on the quality control measurements.

After the completion of the work, a summary of the quality control documents (validity document) is delivered to the customer.

Based on this work description, the contractor prepares a quality plan that is approved by the customer and, if necessary, the designer.

D2_1.13.2 Customer's supervision

The customer's supervision does not limit the contractor's liability.

D2_1.13.3 Customer's on-site supervisor

The customer may appoint supervisors to supervise the contractor's work performance and monitor the amounts.

If necessary, the environmental technology supervisor is responsible for taking soil samples directing the remediation of contaminated soil, sending the samples to a laboratory, and also reviews the contractor's work site journal. In addition to field analyses, soil samples are sent to a laboratory to be analysed. The supervisor directs the removal of the contaminated soil, its sorting for suitable reception facilities, and is responsible for preparing the transport documents and informing the reception locations.

D2_1.13.4 Supervision by the authorities

The environmental authorities may make inspection visits, and participate in site meetings, inspections and reviews, for example.

D2_1.13.5 Material quality control

Before off-the-shelf parts and materials are taken into use, the tests are performed and the certificates acquired that are specified in the plan, this work description, or the documents that are referred to in the appropriate place of the plan or this work description.

If the tested sample does not meet the requirements set for it, the material batch that the test result in question represents will not be used in construction before further analysis. Two new tests may be carried out before making the decision to reject the batch. Only if both new test results meet the set requirements, the material batch represented by the test results may be used in construction. After improvements or corrective measures on the material, its validity must be proven with two new tests.

The number of tests and inspections carried out during quality control are increased, if the material quality is observed to vary during a visual inspection.

D2_1.13.6 Quality control of removed materials

The quantity, quality, pollutant content and treatment or delivery method of any soil removed from the site is recorded in the work site journal on a daily basis. A transport document as per Government Decision 659/96 is delivered with each load transported to a treatment facility; it indicates the material type and the pollutant concentration, determined by field measurements or laboratory analysis. If necessary, the quality and pollutant concentration of soil remaining at the work area is determined by field

measurements, partially by laboratory analyses, and documented in the as-is measurements. If necessary, the environmental technology supervisor is responsible for the above-mentioned concentration measurements.

D2_1.13.7 Supervision of lining work

The compactness of structures constructed from soil is monitored if a compactness requirement has been specified for the structure, either in the design documents or the general work description.

Degree of compaction refers to a percentage that indicates the ratio of the dry density determined from a sample taken from the structure or directly measured from the structural layer to the maximum dry density determined with the improved or standard Proctor compaction test.

The procedure is selected based on the number of compactions and the compactor machines used.

I 1000 EXISTING STRUCTURES AND STRUCTURAL PARTS

11200 Removed, moved and protected structures

Present information on the structures and equipment located in the work area and their dismantling or protection.

12000 CONTAMINATED SOIL

12100 Removed contaminated soil

Present information on the contaminated soil located in the work area and its treatment.

12200 Liner structures

12200.1 Lining materials

Plastic film is used as the lining material in accordance with Appendix T16 to the technical requirement 14234.1.1. The plastic film must have at least the following minimum characteristics:

- Thickness ≥ 0.7 mm (SFS-EN 1849-2)
- Oxidation $>70\%$ (SFS-EN ISO 13438)
- Stress crack resistance ≥ 200 hrs (ASTM D 5397)
- Plastic type LLDPE, HDPE or FPE

The plastic film must be textured. At the tendering stage, the contractor must report the manufacturer, type and factory manufacturing specifications of the plastic film it uses. The contractor must show that the plastic film it offers is suitable for use as a lining layer. For the products, information on the quality control during manufacturing must be presented (testing methods and frequency). The contractor commits to using the plastic film specified in its tender and approved by the customer. The plastic film approved by the customer during contract negotiations may not be changed during the construction stage. The batch-specific quality control results for the plastic film must correspond with the material reported in advance.

The plastic film is stored on a dry and firm platform, protected from sunlight and rain. When the film is handled, the rolls may not be lifted without the inner tube or dragged over the ground.

12200.2 Liner structure bed

The levelness requirement of the liner structure bed is ± 50 mm. Tree roots and other such unevenness is removed from the surface of the bed, and the surface is compacted with a vibrating plate, for instance, so that it is level and firm. No sharp edges over 10 mm in size, or pits, footprints or other sharp depressions over 20 mm in size may be left in the bed. The bed is primarily made of excavated and levelled backstop berm material.

If a bed meeting the levelness and grain size requirements cannot be constructed from the backstop berm material, the bed is constructed from a suitable alternative. The primary layer is constructed of non-cohesive soil with a maximum grain size of 22 mm, when at least 70% passes through a 2 mm sieve, and a maximum of 12 mm, when 30..70% passes through a 2 mm sieve.

If the subgrade at the bottom edge of the backstop berm is wet silt, wet silt moraine, soft clay or humus soil, a primary layer structure must be constructed in order to improve load-bearing capacity and to prevent capillary water rise. There is a strainer of usage class N3 at the bottom, with a 200 mm layer of gravel or aggregate or 300 mm of wide-graded, non-freezing sand.

12200.3 Building the liner structure

Before laying out the plastic film, the contractor must prepare an installation plan and have it approved by the customer. The plastic film mat is spread on a levelled bed with an installation beam, for example; the film must not be dragged. The film is seamed by overlapping by at least 500 mm. Joints on a slope should be avoided, and "roof tile overlapping" is used for the joints, i.e. the fabric that is higher in the direction of flow is placed on top of the lower one at the joint. The plastic film is extended up to the top edge of the backstop berm slope and anchored to the crown of the backstop berm. The location of each plastic film strip is measured and presented in the as-built drawing. The film strips are installed crosswise in relation to the slope.

The laid-out films must be covered with a protective soil layer of at least 300 mm during the same work shift. Only the workers installing the film may move on top of the uncovered plastic film on foot, and no one is allowed to drive work machines over the film. Light work machines may be driven on top of the plastic film once it has been covered by at least 300 mm of soil, and heavy work machines may be driven on top of it once it has been covered by 500 mm of soil. The material requirements for the protective layer are the same as those for the installation bed material. The protective layer of the plastic film is reduced to 100 mm in the underground drainage trench section.

A 0.7 m wide and 0.4 m deep trench is excavated on the crown of the backstop berm for the purpose of anchoring the top edge of the plastic film. The anchoring length is 0.4 m.

The bottom edge of the plastic film is taken halfway to the opposite slope of the underground drainage trench or 0.2 m to the outside of the underground drainage trench.

12200.4 Finished liner structure

The liner structure's conformity with the plans is verified during the inspection of the plastic film as presented in the general segment of section 1.6.2. The finished surface of the liner layer is inspected and approved so that the supervisory work does not cause interruptions to the work. The approval is recorded in the work site journal and confirmed with signatures. The approved surface must be immediately protected from harmful moisture, drying, erosion, freezing and mechanical damage with a layer of protective earth.

12200.5 Proving the validity of the liner structure

The contractor will present the layer thicknesses and the location of the liner materials in the as-built drawings, measured in a 10 x 10 m square. The quality assurance information of the soil layers and materials is presented in the validity document.

14300 DRAINAGE STRUCTURES

14311 Area underground drainage

14311.1 *Underground drainage material*

The diameter of the underground drainage is DN100, the pipe material must meet the requirements of standard SFS 5675, and its ring stiffness must be at least class SN8. Unperforated PE plastic pipes of at least class SN4 are used as drain pipes. The validity of the underground drainages is verified based on the pipe markings and delivery documents of the delivery batch, and presented in the validity document.

14311.2 *Underground drainage bed*

The underground drainage is installed in an underground drainage trench dug in the bottom edge of the backstop berm's slope, directly on top of the plastic film.

Insofar as the underground drainage passes over the liner structure, underground drainage pipes are used. A drain pipe is used from the edge of the liner structure to the monitoring well. See drawing 4 for a detail of the pass-through of the liner structure's edge. The edge of the liner material is lifted up, and the drain pipe is passed through the liner. The principle of InfraRYL figure 14231:K2 is followed in the pass-through. The pass-through is equipped with a collar tightener that is sealed with bentonite paste.

14311.3 *Underground drainage installation*

The gradient of the underground drainage is 0.4%. The plastic pipes are connected to each other with sleeve joints; if necessary, extension sleeves are used. The pipes are connected to the well with a watertight seal; use a rigid plastic pipe of a suitable size as the sheathing. The sheathing must extend 0.5 m to hard ground.

Leave about 0.3 m of the end of the drain pipe visible. The bottom edge of the drain hole is placed above the average water level and at least 20 cm above the bottom of the ditch. Prevent small animals from entering the pipe by installing a mesh.

The sidefill material for the underground drainage is underground drainage sand, gravel, or aggregate that meets the granularity requirements for underground drainage materials, for instance as per InfraRYL figure 18320:K1a.

The location of the underground drainage is presented in drawings 3 and 4.

14311.4 *Finished underground drainage*

The maximum allowed deviation of the pipe gradient is +0.08%, as the gradient must not go below the minimum value. The horizontal tolerance of the underground drainage's location is ± 200 mm and vertical ± 50 mm.

14311.5 *Proving the validity of the underground drainage*

The location of the underground drainage is measured as-built at every ten metres. A location drawing is drawn up of the pipeline, with the wells, inspection pipes and drain holes marked. The pipeline information is compiled into the validity document.

14320 Wells and inspection pipes of the underground drainage

14320.1 *Material of the wells and inspection pipes of the underground drainage*

The minimum inner diameter DN/ID of the inspection pipe is 200 mm. The underground drainage is connected to the water management system chosen for the site.

14320.2 *Bed of the wells and inspection pipes of the underground drainage*

The wells and inspection pipes are installed on a level subgrade. If necessary, the surface of the subgrade is levelled with an installation bed constructed from a well-compacting material. If necessary, the thickness of the installation bed is 150 mm.

14320.3 *Installation of the wells and inspection pipes of the underground drainage*

The wells and inspection pipes are installed in a vertical position.

14320.4 *Finished well or inspection pipe of the underground drainage*

The maximum vertical deviation of a well or inspection pipe is 10 mm over a distance of 1 m.

14320.5 *Proving the validity of the wells and inspection pipes*

A location drawing of the pipeline is drawn, with the wells, inspection pipes and drain holes marked. Information cards are prepared of the wells. The pipeline information is compiled into the validity document.

I 6000 EXCAVATIONS

16110 Excavation, unspecified

16110.3 *Making an excavation*

The wall of the backstop berm is excavated if the construction of the liner structure bed so requires. The bed is primarily made of excavated and levelled backstop berm material.

Due to the friction angle of the construction materials, the steepness of the slope of the backstop berm may be a maximum of 1:1.5 (33.4°).

A trench 0.5 m deep with 1:1 slopes is excavated into the bottom end of the backstop berm's slope for the construction of the underground drainage. The gradient of the excavation is 0.4% in the direction of the water management system. The top edge of the excavation's slope on the side of the backstop berm merges with the primary layer so that the plastic film goes down along the berm slope to the bottom of the trench and to the opposite slope. The width of the trench bottom is 0.5 m. The trench travels in front of the backstop berm and ends in a location determined by the water management system. The soil is excavated so that the excavation bottom does not loosen detrimentally. The location of the excavation is presented in drawings 3 and 4.

If the locations of the other structures at the shooting range allow, a berm 1.5 m wide and 0.5 m high is constructed of the excavated mass on the side of the firing stands in front of the excavation. The berm prevents water from the intermediate area from getting into the underground drainage and improves the flow of the percolating water from the backstop berm into the underground drainage.

16110.4 *Finished excavation*

The excavation conforms with the presented dimensions and requirements. No part of the excavation's bottom may be above the planned elevation, and it has no water-accumulating depressions or loosened soil layers. Disturbed layers have been properly compacted. The tolerance for the elevation of the excavation bottom is 0...-100 mm, and no individual pit may be deeper than -50 mm. The horizontal tolerance for the excavation bottom is ±150 mm.

16110.5 *Proving the validity of the excavation*

The slope gradients and excavation depth are checked by measuring at intervals of ten metres. The other evenness of the excavation surface is verified visually or, if necessary, using a straight board measuring three metres. The contractor will prove the validity of the excavation through measurement results in the validity document.

I 8000 EMBANKMENTS, DYKES AND FILLS

18110 Earthen embankments

18110.1 *Earthen embankment materials, general*

The damping layer of the backstop berm is constructed as an earthen embankment. Sand 0...8 is used as the material for the damping layer. The validity of the material is verified with a sand grain size analysis prior to construction, and every time the source changes or the material becomes visually different.

18110.2 *Earthen embankment bed*

The damping layer is constructed on top of the underground drainage's sidefill, and on the backstop berm slope, on top of the strainer installed on top of the protective layer of the plastic film.

18110.3 *Constructing an earthen embankment*

On the backstop berm slope, the damping layer is constructed on top of a strainer, and at its foot, on top of the underground drainage's sidefill. The thickness of the damping layer on the slope is 600 mm, and it must be constructed to a uniform quality. Because heavy work machines cannot be driven on top of the liner structures before they are covered with a sufficiently thick layer of protective soil, the earthen embankment is constructed from the intermediate area or from the top of the backstop berm. See drawing 3 for a presentation of the construction of the damping layer.

18110.4 *Finished earthen embankment*

The compacted top surface of the damping layer conforms with the design documents. The thickness of the layer must not be less than the required 600 mm. The maximum allowed deviation is +50 mm.

The layer's connection to the existing structures on top of the backstop berm and in the intermediate area is implemented case-specifically.

18110.5 *Proving the validity of the earthen embankment*

The surface of the damping layer is measured in a 10 x 10 m square and presented in an as-built drawing. The quality control information on the material is presented in the validity document.

21100 FILTRATION STRUCTURES

21120 Strainers

21120.1 *Strainer materials*

A light-coloured fabric of usage class N2 is used as the strainer. The service life of the strainer fabric must be at least 25 years. The strainer rolls are stored on a dry and firm platform, protected from sunlight and rain. When the strainer is handled, the rolls may not be lifted without the inner tube or dragged over the ground.

21120.2 *Strainer bed*

The strainer is installed on the protective layer of the plastic film described in section 12200.3. The area over which the strainer is installed is presented in drawings 3 and 4.

21120.3 *Installation of strainers*

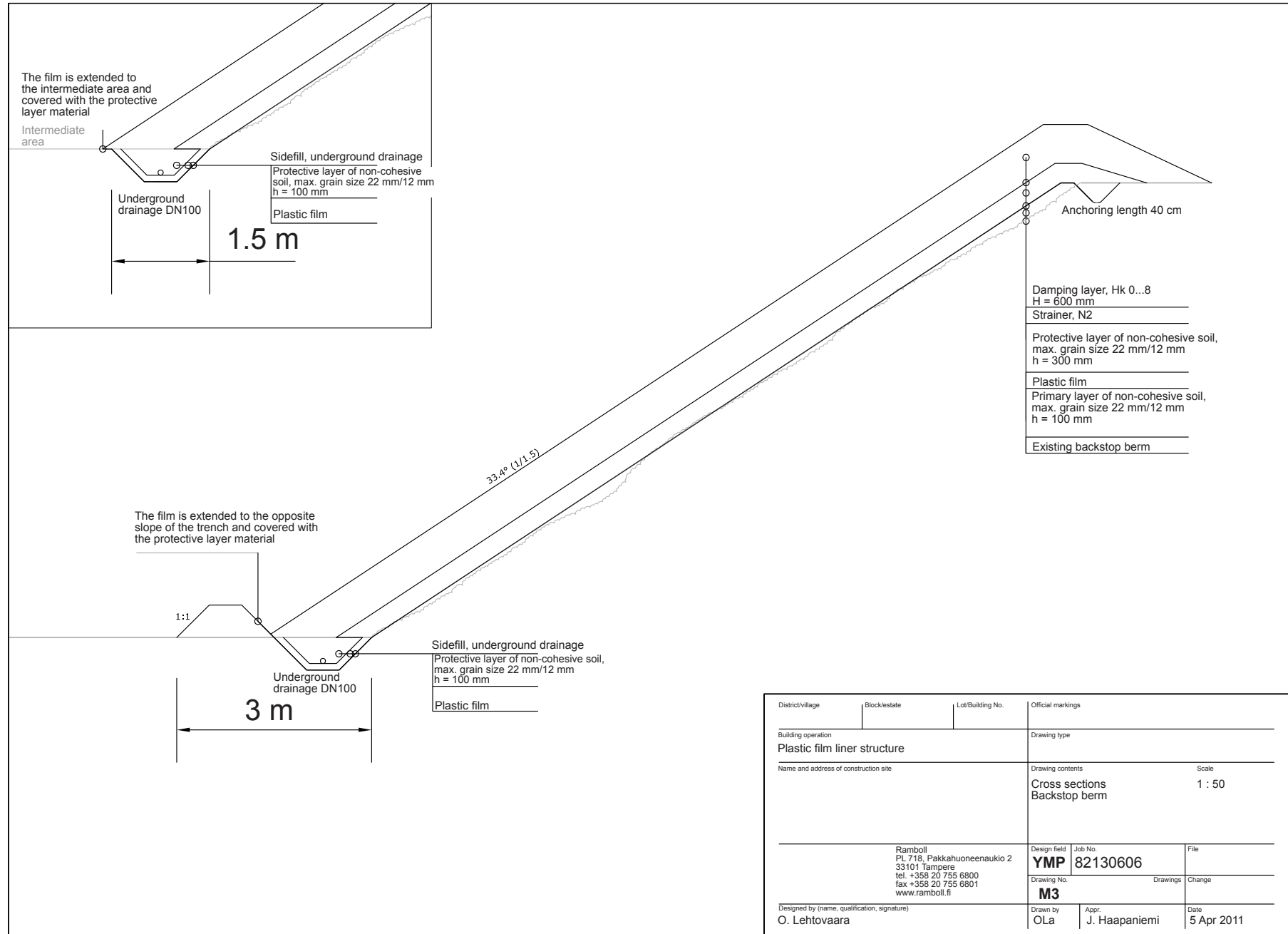
The strainers must not be left spread out and exposed to sunlight for more than one week. The strainers are spread in the same orientation as the plastic film. The strainers are seamed by overlapping them by 500 mm. The overlapping is done in the same order as on the plastic film. Light work machines may be driven on top of the strainer once it has been covered by 300 mm of damping layer material, and heavy work machines may be driven on top of it once it has been covered by 500 mm of damping layer material.

21120.4 *Finished strainer*

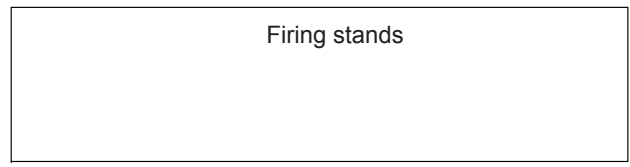
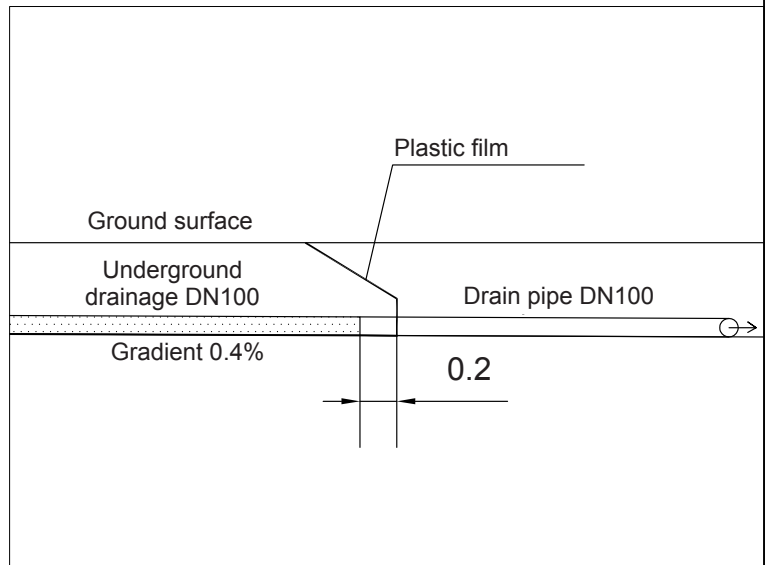
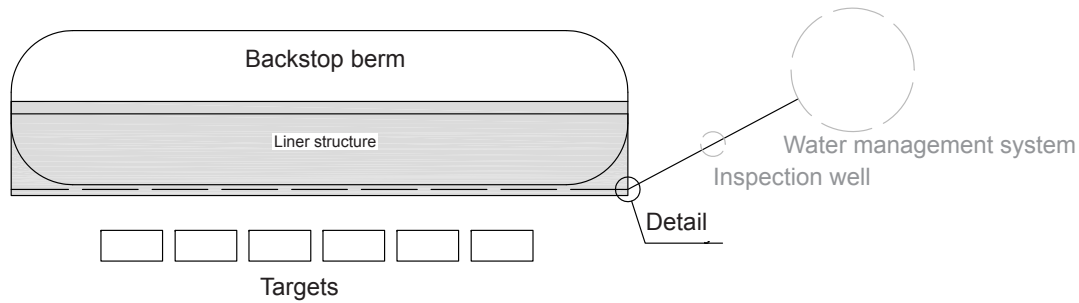
The strainer has been installed and overlapped in accordance with the design over the area of the plastic film's protective layer.

21120.5 *Proving the validity of the installed strainers*

The overlapping and seaming of the strainers are inspected during the work stage. The as-built drawings of the validity document show the actual location and category of use of the strainers.



District/village	Block/estate	Lot/Building No.	Official markings
Building operation Plastic film liner structure			Drawing type
Name and address of construction site			Drawing contents Cross sections Backstop berm
			Scale 1 : 50
Ramboll PL 718, Pakkahuoneenaukio 2 33101 Tampere tel. +358 20 755 6800 fax +358 20 755 6801 www.ramboll.fi		Design field YMP	Job No. 82130606
		Drawing No. M3	File Change
Designed by (name, qualification, signature) O. Lehtovaara		Drawn by OLA	Appr. J. Haapaniemi
			Date 5 Apr 2011



District/village	Block/estate	Lot/Building No.	Official markings	
Building operation			Drawing type	
Plastic film liner structure				
Name and address of construction site			Drawing contents	Scale
			Drawing of the principle Locations of the structures	
Ramboll PL 718, Pakkahuoneenaukio 2 33101 Tampere tel. +358 20 755 6800 fax +358 20 755 6801 www.ramboll.fi		Design field	Job No.	File
		YMP	82130606	
		Drawing No.	Drawings	Change
		M4		
Designed by (name, qualification, signature)		Drawn by	Appr.	Date
O. Lehtovaara		OLa	J. Haapaniemi	5 Apr 2011

Appendix D3. Lining the backstop berms with dense asphalt

D3_1 Introduction

This reference work description presents the implementation of groundwater protection structures for the backstop berms of rifle ranges using dense asphalt structures. Each implementation must be designed site-specifically. The type solutions presented here show the design principles, and the cost estimates are therefore very indicative and need to be specified on a case-by-case basis. The presented environmental protection structure for the backstop berm of a rifle range is also suitable for use in the backstop berms of pistol ranges.

The asphalt layer withstands mechanical stress well, and the topsoil can be replaced with an excavator, for example, without damaging the structures. Furthermore, the front of the backstop berm can be paved with asphalt, providing a good working platform for the required maintenance activities.

D3_2 Constructing a new backstop berm for a rifle range

When a new backstop berm is constructed, the liner structure can be installed at the base of the backstop berm. An asphalt liner structure presented in figures 1 and 2 is constructed at the base of the front part of the shooting range's backstop berm. The base structure allows for the collection of water percolating through the backstop berm's soil and its redirection to monitoring and treatment wells or basins. The front part of the shooting range's backstop berm is constructed from soil layers.

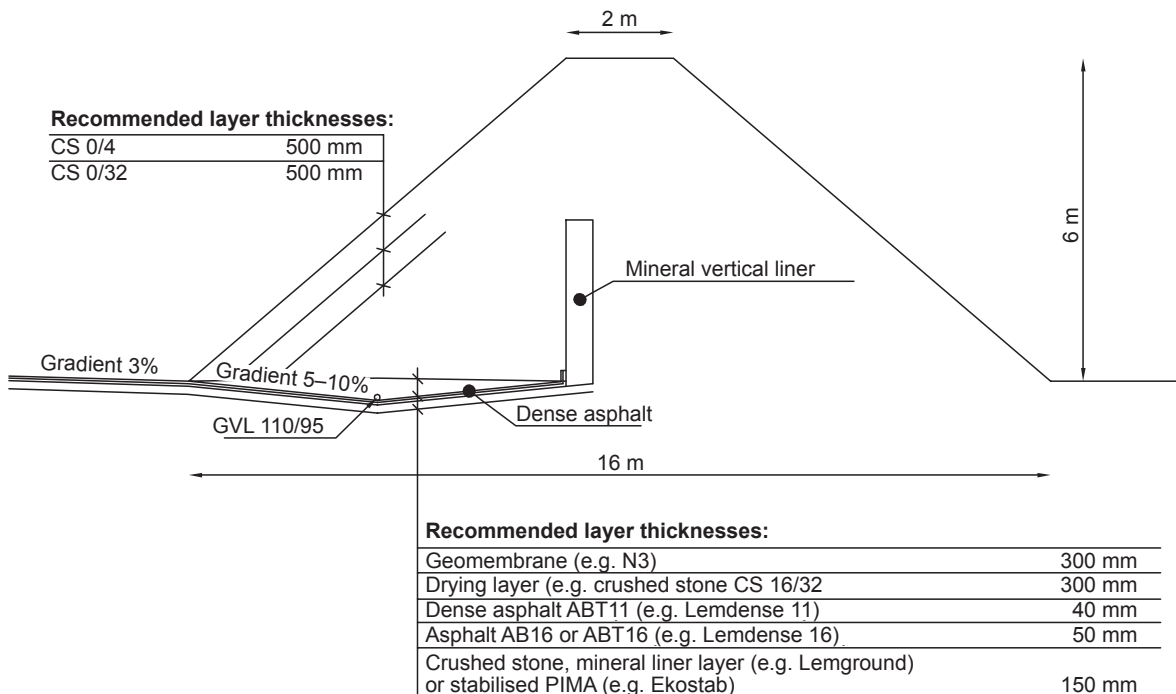


Figure 1. Environmental protection structure for a rifle range.

The structural solution comprises the following parts:

1) Watertight asphalt base structure

A dense, two-layer asphalt structure is constructed at the base of the backstop berm so that the topmost layer is made watertight (void space < 3%) using dense asphalt ABT11 (e.g. Lemdense 11, 40 mm) and the bottom layer is made from dense asphalt ABT16 (e.g. Lemdense 16, 50 mm) or asphalt concrete AB16 (50 mm). Crushed rock is spread on top of the asphalt layer (CR 16/32) as an underground drainage layer. An underground drainage pipe (diam. 110/95 mm) is installed in the underground drainage layer to collect the water percolating into the backstop berm.

The dense asphalt layer requires a firm base structure. A firm base structure can be constructed from a layer of crushed rock, or, if the environmental permit allows, the contaminated soil at the site can be solidified and utilised in the base structure.

The width and gradient (5–10%) of the asphalt layer at the base of the backstop berm has been designed to be constructed so that the asphalt can be spread and compacted using asphalt laying machines, mostly in the direction of the berm. The dimensioning of the asphalt base structure (e.g. depth from the front bottom edge of the berm) follows the principle that all water percolating from the berm's area contaminated by bullets is collected with the watertight base structure and underground drainage for water treatment.

2) Underground drainage structure

The underground drainage layer is constructed of crushed rock (CR 16/32), into which an underground drainage pipe is installed (diam. 110/95 mm). To prevent the fines in the backstop berm sand from migrating and clogging the underground drainage layer, a strainer is installed in between them (e.g. N3). The structure is presented in drawing 2.

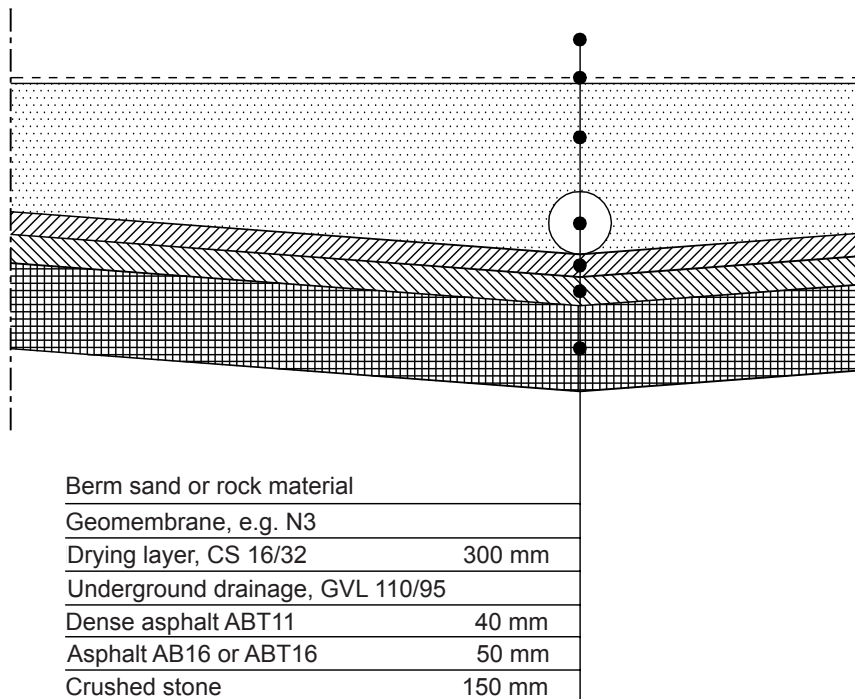


Figure 2. Detail of the underground drainage structure.

3) The inclined surface structure of the backstop berm

The following structure is proposed for the inclined surface layer of the backstop berm which the bullets hit:

- Crushed materials (angle of internal friction $\geq 40^\circ$) can be used for the top part of the surface layer (500 mm), such as stone dust (CS 0/4), which is a replaceable surface material.
- Use a coarser material below the surface layer (e.g. CS 0/32) (500 mm), which can also be replaced if necessary.
- A marker mesh can be installed below them, making future renovations easier (known excavation depth).

4) Vertical liner inside the berm

If necessary, a vertical mineral liner 3 m high and 0.5 m wide, for instance, can be installed into the core of the backstop berm (e.g. using Lemground bentonite). The purpose of the vertical liner is to separate and redirect rainwater. The vertical liner may be necessary if it is estimated that contaminated percolating water also gets into the back of the berm. (In this case, the base liner can also be constructed underneath the entire backstop berm.)

5) Front of the backstop berm

The front of the backstop berm can be paved with asphalt while the base liner is being constructed, providing a working platform for the required backstop berm maintenance activities.

D3_3 Protecting the backstop berm of an old range with a dense asphalt structure

At an existing shooting range, a dense asphalt structure is constructed into the backstop berm, allowing the collection of percolating water with contaminants dissolved from bullets. The environmental protection structure is presented in drawing 3.

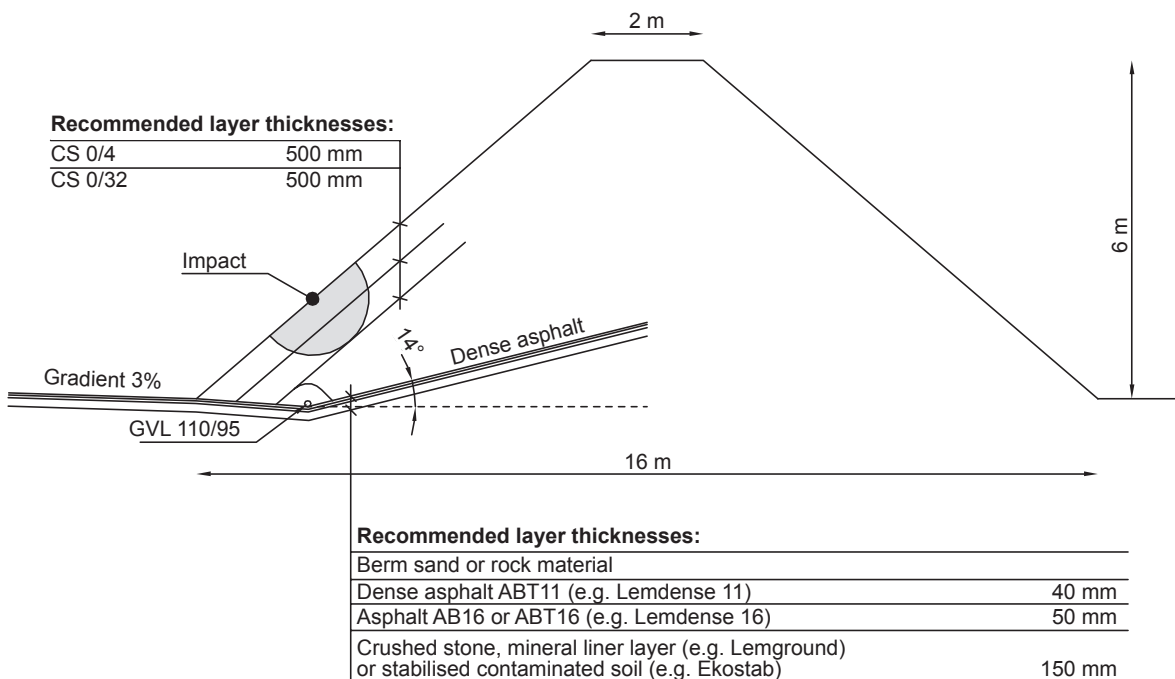


Figure 3. Environmental protection structure for a rifle range.

The structural solution comprises the following parts:

1) Removal of soil containing bullet waste from the backstop berm

Soil containing bullet waste is removed and treated in accordance with the requirements of the environmental permit or a decision by the authorities.

2) Watertight asphalt structure constructed into the backstop berm

This environmental protection solution proposes asphalt paving inside the backstop berm at a maximum angle of 14 degrees (1:4), the purpose of which is to redirect rainwater absorbed from the front side of the berm into the water management system in a controlled manner. The watertight asphalt layer extends either to the centre of the berm (Figure 3), or the paving extends inside the berm to a depth of around 5 metres so that the rainwater percolating through the backstop berm soil contaminated by bullets is directed onto the paving and, from there, to water treatment.

The dimensioning of the asphalt protective structure follows the principle that all rainwater percolating from the bullet-contaminated area at the front of the berm flows to the asphalt paving and thereafter to water treatment. The dimensioning of the asphalt paving that extends to a depth of 5 m into the berm used the following initial data:

- Berm slope is 34 °
- The centre point of the bullet impact area at the front of the berm is at a height of around 1.5–2 m above ground level
- Rainwater percolating into the berm on the front side of the berm at a height of 3 m flows onto the asphalt paving (surety for stray shots + 1 m from the impact area)
- The calculation has estimated that the rainwater percolating into the berm flows in a sideways direction at a max. angle of 45 ° relative to a flow directed straight down. Precipitation is even over the entire berm, which means that during periods of rainfall, the pore space of the berm sand is saturated with water, and the hydraulic pressure is directed away from the berm.

The asphalt layer is constructed as a two-layer paving from dense asphalt ABT11 (e.g. Lemdense 11, 40 mm) and dense asphalt ABT16 (e.g. Lemdense 16, 50 mm) or asphalt concrete AB16 (50 mm). The asphalt paving is laid on top of a firm layer of crushed rock (150 mm). The underground drainage area is also paved with the above-mentioned asphalt structure.

3) Underground drainage structure

The underground drainage layer is constructed of crushed rock (CR 16/32), into which an underground drainage pipe is installed (diam. 110/95 mm). To prevent the fines in the backstop berm sand from migrating and clogging the underground drainage layer, a strainer is installed in between them (e.g. N3). The structure is presented in drawing 4.

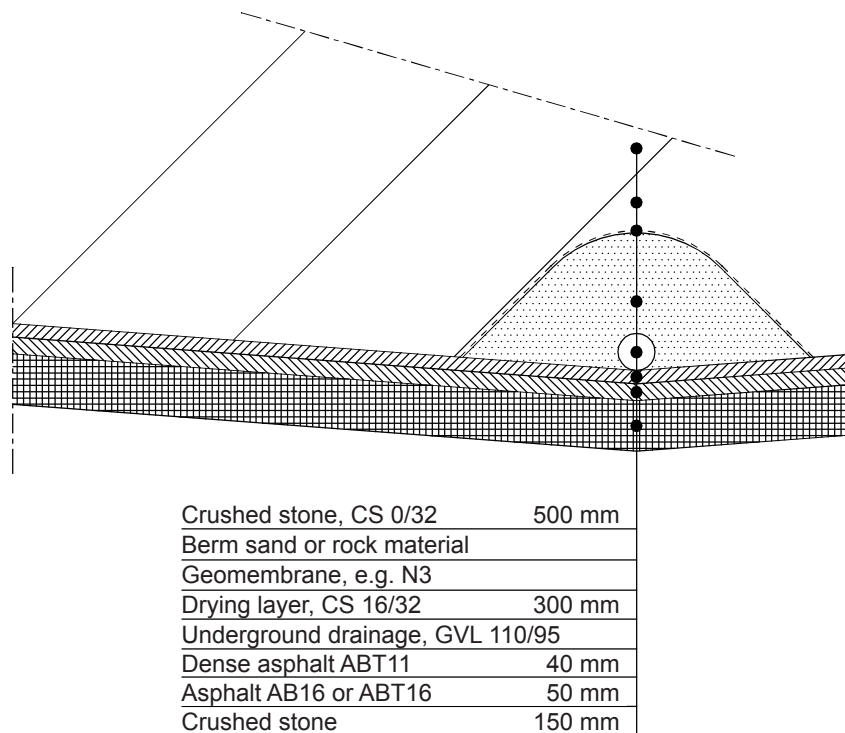


Figure 4. Detail of the underground drainage layer.

4) The inclined surface structure of the backstop berm

The following structure is proposed for the inclined surface layer of the backstop berm which the bullets hit:

- Crushed materials (angle of internal friction $\geq 40^\circ$) can be used for the top part of the surface layer (500 mm), for example stone dust (CS 0/4), which is a replaceable surface material.
- Use a coarser material below the surface layer (e.g. CS 0/32) (500 mm), which can also be replaced if necessary.
- A marker mesh can be installed below them, making future renovations easier (known excavation depth).

At old backstop berm renovation sites, soil suitable for construction can be moved back onto the finished asphalt surface, or the berm can be constructed of entirely new, uncontaminated material for the necessary parts.

D3_4 Cost estimates for the environmental protection structures

The cost estimates for the rifle range structures have been calculated for the backstop berm of a rifle range, but the same protective structure can also be used in the backstop berms of pistol ranges.

The following initial data has been used in the dimensioning and cost estimates of rifle range structures:

- Backstop berm length 50 m, height 6 m, depth 16 m, crown width 2 m
- Berm slope 40 °
- Working platform at the front of the backstop berm, width 4 m, length 50 m.

D3_4.1 Cost estimate for the new backstop berm structure at a rifle range

An indicative cost estimate for a new berm structure is EUR 140,000 (VAT 0%).

The costs of the structure include the following:

- Material and labour costs: EUR 40,000 (VAT 0%)
- Berm groundwork (300 m²)
- Berm asphalt laying work (300 m²)
- Asphalt working platform at the front of the berm (200 m²)
- Construction of the inclined front of the berm
- Underground drainage for the backstop berm
- Berm contouring
- Non-cohesive soil (3,300 m³): EUR 100,000 (VAT 0%).

A vertical liner (75 m³) can also be installed into the backstop berm (made of Lemground bentonite, for example); it will cost EUR 50,000 (VAT 0%).

D3_4.2 Cost estimate for an existing backstop berm structure at a rifle range

The following initial data has been used in the dimensioning and cost estimate of the asphalt structure:

- Asphalt paving at a 14 ° angle (1:4)
- Structure A: The asphalt paving extends to the centre of the berm (Figure 3)
- Structure B: The asphalt paving extends 5 m inside the berm.

An indicative cost estimate for structure A is EUR 40,000 (VAT 0%) and, for structure B, EUR 35,000 (VAT 0%). The cost estimate includes the following material and labour costs:

- Berm groundwork (structure A, 400 m², structure B, 250 m²)
- Berm asphalt laying work (structure A, 400 m², structure B, 250 m²)
- Asphalt working platform at the front of the berm (200 m²)
- Construction of the inclined front of the berm
- Underground drainage for the backstop berm
- Berm excavation and contouring.

If an entirely new backstop berm is constructed at the site, the cost of the non-cohesive soil for a berm with a volume of 3,300 m³ is around EUR 100,000 (VAT 0%) that comes in addition to the above-mentioned costs.

At an existing site, additional costs may be incurred by the treatment of contaminated soil and/or clean non-cohesive soil brought in as a replacement; these have not been considered in this cost estimate.

Appendix D4. Wetland treatment of water at a pistol and rifle range

D4_1 Introduction

This reference plan presents the functional principles of wetlands in the treatment of waters from a pistol and rifle range.

D4_2 Wetland at a pistol and rifle range

Attempts can be made to remove eroded matter from a pistol and rifle range as well as the nutrients and pollutants migrating through surface runoff water in different kinds of wetlands. Wetlands are also diverse natural habitats. The recommended size for the wetland is around 2–4% of the runoff area.

In the wetland, the processes related to water purification take place in flowing water during the time the water remains in the wetland. A delay that is as long as possible improves the retention of substances, while sudden changes in the conditions, such as a flood or anoxia, may cause the substances retained in the wetland to start moving again. The circulation of substances in the water is typical for wetlands in varying hydrological conditions. Permanent total benefits can be obtained from a wetland by creating both retentive conditions and preventing conditions that cause the substances to start moving again, away from the wetland.

Metals have been found to primarily migrate when bonded to mineral fines and organic substances. In a wetland, the flow of the runoff water slows down, and the migrating fines and the metals bonded to them become sediment at the bottom or become bound in the vegetation of the wetland. The sedimentation of mineral fines is easier, but the sedimentation of organic matter is more difficult and requires a long delay.

The delay can be increased in the wetland by increasing their surface area and water volume, redirecting the flow to meander around the wetland, for instance using crosswise levees, and by adjusting the amount and type of vegetation.

D4_3 Functional principle of wetlands

See Figure 1 for a drawing of the principle of a functional wetland. An area with deeper water (> 1.0 m) is reserved at the beginning of the wetland; it should retain water throughout the year, also during dry periods. The majority of solids settle in the deeper water area. We recommend leaving a service road on the shore of the deeper wetland area so that minor maintenance dredging of the wetland is easy and cheap to do when necessary.

The water depth of the actual wetland following the deeper area varies, but is mainly less than 0.5 m. During the driest periods of the summer, the water depth can even be close to zero. Ridges are shaped on the bottom of the wetland area, forcing the water to flow in a meandering channel and extending the delay as much as possible. Aquatic and wetland vegetation often forms naturally in the wetland, but desirable plants may also be introduced to the area, if necessary. The roots of the plants tie up the loose bottom of the wetland, slows down the flow on their part, and filter solids from the water. The more abundant and diverse the vegetation, the better the wetland functions.

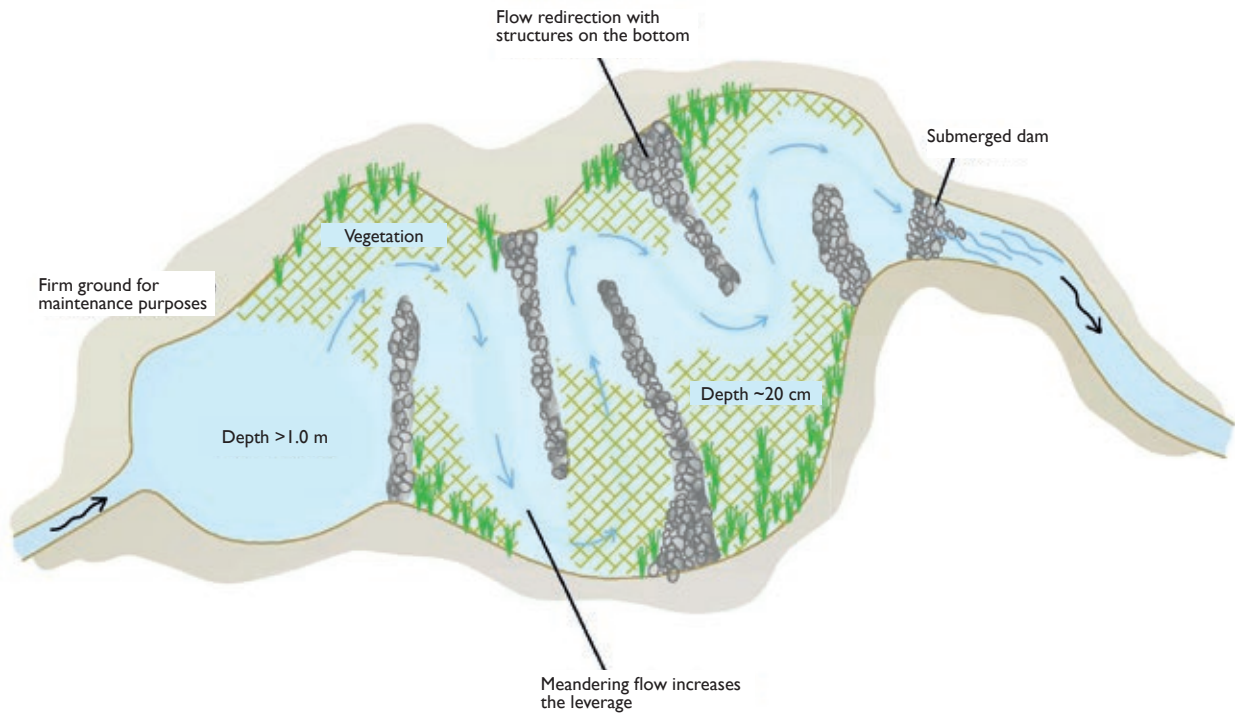


Figure 1. Drawing of the principle of a functional wetland. There is a deeper pool at the beginning of the wetland, into which solids mainly settle. Preferential flows are prevented from forming in the wetland by constructing ridges on the bottom of the wetland. During periods of high water, these ridges are submerged. Wetland vegetation is allowed to grow by itself, or the spread of vegetation is sped up by planting.

D4_4 Constructing the wetland

A wetland is primarily suited to the retention of mineral solids and pollutants bonded to them, but with a sufficiently long delay, organic matter can also be retained to a certain extent.

Wetland construction requires an available area of land that is suitable for a wetland. The best locations for creating a wetland are those that become naturally flooded during the flood season. A wetland can be created either with dykes or by excavating. With dykes, the wetland can be created in a natural ditch depression, and the implementation method is more natural and affordable than excavation.

A site-specific plan prepared by an expert is required for wetland construction. Levelling is carried out in the terrain to determine the precise elevations for the plan. The plan determines the drainage basin of the wetland (optimally, just the shooting range area), based on which the required wetland area and design flows are calculated. The plan also describes the construction method of the wetland and the required materials. When following a well prepared plan, the wetland could even be constructed with an excavator and volunteer labour.

Whether the construction of the wetland requires a permit or not depends on the site and the construction method. The Water Act places some restrictions on the creation of wetlands. Landowners may create wetlands on their land by excavation, or creating dams or embankments, and they can store water in a ditch or a stream without a permit referred to in the Water Act if the impact is limited to their own areas. If the effect of building a dam and storing water in a channel extends to neighbours' land, their permission is required. When a wetland is created by damming a stream that is considered to be a waterway, the Water Act states that you must also build a secure fish passage in connection with the dam. There are also some restrictions

concerning the conservation of the natural state of bodies of water. At large sites, you must consider the Dam Safety Act, and at sites where the landscape will change significantly, you will need a permit for landscape procedure work (section 128 of the Land Use and Building Act).

D4_5 Maintenance and management of the wetland

The wetland's maintenance need depends to a great degree on the amount of solids amassed in the wetland. The larger the amount of amassed solids, the more often the wetland needs to be dredged. The recommended basic principle is to regularly empty the silt basin at the start of the wetland by dredging every 2 to 5 years, leaving the actual wetland area untouched. It may be necessary to dredge the wetland more extensively at intervals of around ten years. Even during more extensive dredging, we recommend leaving the area in the vicinity of the wetland's outflow dam untouched, and also leaving "breeder plants" in the wetland to ensure rapid restoration of the vegetation.

D4_6 Costs

The costs of a wetland as a water treatment method comprise the preparation of the plan, its implementation and maintenance.

- plan preparation, ca. EUR 5,000–10,000
- machine work, 10–200 hours (EUR 1,000–30,000)
- supplies (filter materials, rocks) EUR 1,000–25,000
- silt/mass handling EUR 0–10,000
- maintenance work EUR 1,000–2,000/yr.

Appendix D5. Adsorption treatment of water at a pistol and rifle range

D5_1 Introduction

This reference plan describes the metal removal treatment of water discharged from a pistol and rifle range, based on water filtration through an adsorptive material.

D5_2 Principle of the technique

Runoff water discharged from the shooting range area via underground drainage can be diverted to flow through an adsorption filter. When the water flows through the adsorptive material placed into the filter at the desired speed, water-soluble metals become tightly bonded to it. The purified water is further directed into a ditch, for instance, or absorbed into the ground.

D5_3 Structure of the filtration well

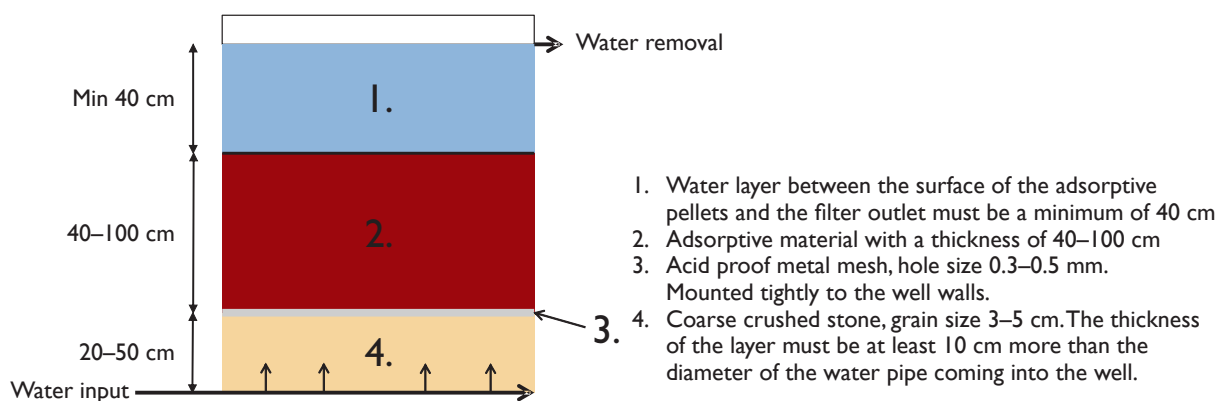
Designing the filtration well first requires an estimate of the maximum water flow m^3/h from the water insulated area; the filtration well is then designed for that amount. The water directed into the filtration well must contain as little solid material as possible, as it may clog the filter and significantly reduce its service life. For this reason, we recommend protecting the underground drainage pipes with a strainer fabric, underground drainage gravel, and a sand layer at least 30 cm deep.

The contact time between the adsorptive material in the filtration well and the water flowing into the well must be at least five minutes. The contact time may also be longer. If the filter is designed for a maximum water flow of $0.5 \text{ m}^3/\text{min}$, for example, the minimum amount of adsorptive material in the filtration well is 2.5 m^3 (~3.0t). The water must flow from the bottom to the top in the filtration well. This provides a more even water flow and a better metal removal result.

The surface area of the filtration well must be large enough for the desired flow. The maximum water permeability of the adsorptive material is $0.5 \text{ m}^3/\text{m}^2/\text{min}$. The surface area of a well designed for a maximum flow of $0.5 \text{ m}^3/\text{min}$ must therefore be at least 1 m^2 .

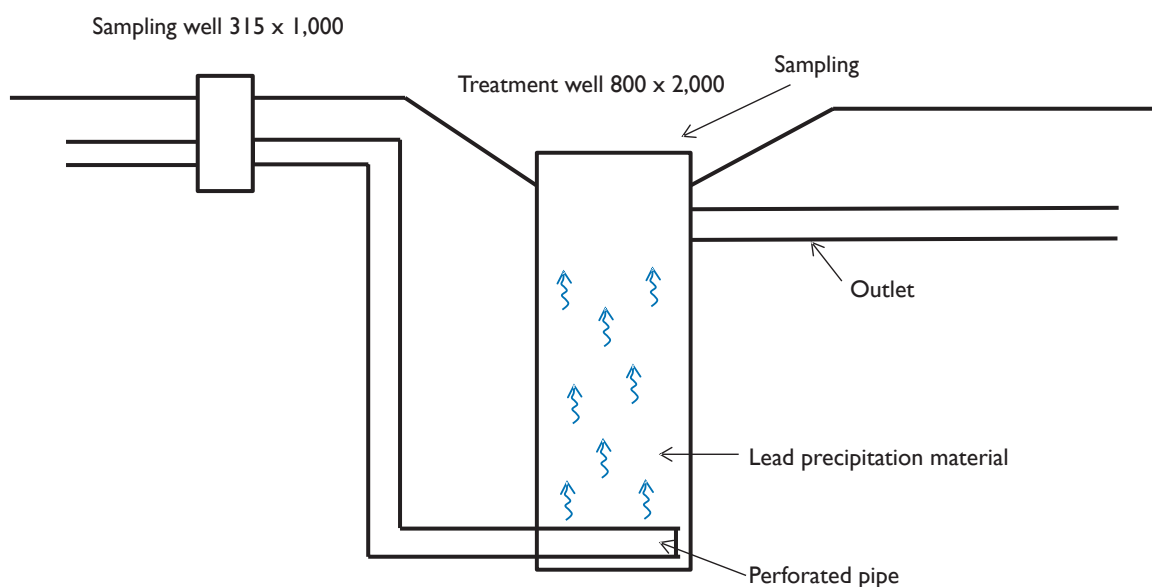
The thickness of the layer of adsorptive material in the filter must be no less than 0.4 m but no more than 1.0 m. If the adsorptive material layer is too thin, it may reduce the effectiveness of the water purification, and if the layer is too thick, it may reduce the water permeability of the filtration well.

The water inlet of the well must be designed so that water can freely enter the entire surface area of the bottom of the well. An example of such a structure is depicted in the figure below:



Water is directed into the filtration well from the underground drainage pipeline with the help of gravity, which means that the filtration well must be at a lower elevation than the underground drainage. The well must be installed so that the well's outlet is at least 1 m lower than the underground drainage. This achieves a hydraulic pressure of around 0.1 bar.

The filtration well can be made of concrete, plastic or metal. The well structures and lead-throughs must be watertight. See below for an indicative cross section of a filtration well with a surface area of 0.5 m². With a maximum layer thickness of 100 cm, no more than 1 m³ of adsorptive mass can be installed in this kind of well, allowing a maximum design flow of 200 l/min.



All joints and lead-throughs are watertight

We recommend designing sampling points for both incoming and outgoing well water for water quality monitoring. The illustration above depicts a sampling well for incoming water; it can be, for example, a regular drainage well. In the figure above, outgoing water is sampled from the filtration well. The filtration well must have a cover that prevents litter from entering the well.

D5_4 Properties and disposal of the adsorptive material

Ferric hydroxide pellets containing iron are suitable for metal removal. The grain size of the material is 1–2 mm and its density 1.2 kg/l. The pH of the material is around 6–7. The adsorptive material is not harmful. Some dusting occurs when the filter is refilled with new pellets.

Used pellets that have lost their capacity to remove metals can be removed from a filter with a vacuum truck, for example. The eligibility for landfill of the used pellets must be analysed, and the waste management facility suitable for final disposal can be decided based on the results.

The adsorptive material can bind a total of around 2–5 g/kg of metals before it needs to be replaced. See Appendix 1 for the brochure of a possible adsorptive material (Kemira CFH 12).

D5_5 Water treatment at a pistol and rifle range

At a pistol and rifle range, the surface area from which water is collected is most commonly the area of the backstop berm, or around 1,000–3,000 m². At a pistol and rifle range, we recommend designing the well for heavy rainfall, as the rather small underground drainage system does not allow for the collection of a significant amount of water. If we assume that the area is 2,000 m² and the design rainfall value has been 7 mm/h (=heavy rain), the maximum amount of water coming into the well is 14 m³/h = 0.23 m³/min. In this case, the amount of adsorptive material in the well must be no less than 1.2 m³ (~1.5 t) to achieve the required minimum contact time of five minutes.

We recommend designing the filtration well so that if necessary, the amount of adsorptive pellets and the contact time can be doubled.

The well structure is designed in accordance with section 3.

kemira

CFH 12

Käyttötarkoitus

Kemira CFH 12 tuote soveltuu hyvin arseenin ja useiden metallien poistamiseen vesiliuoksista. Tuote soveltuu lisäksi fosforin poistoon. Tuotetta voidaan käyttää säiliöissä, altaissa ja maasuodattimissa. Tuotteen toiminta perustuu erilaisten vesiliukoisten epäpuhtauksien adsorboitumiseen ferrihydroksidirakeisiin.

Kemialliset ja fysikaaliset tiedot

Ulkonäkö rakeinen, ruskea tai punaruskea

		Tyypillinen arvo		
Rauta (Fe ³⁺)	39 - 48	44	%	
Vesiliukoinen aines	3,0 - 6,0	4,5	%	(EN 12902)
Kosteus	13 - 19	16	%	

Epäpuhtaudet: Pitoisuus tuotteessa

	Max.	Tyypillinen arvo	
Arseeni (As)	< 1		mg/kg
Kadmium (Cd)	< 1		mg/kg
Kromi (Cr)	< 25	10	mg/kg
Kupari (Cu)	< 20	5	mg/kg
Mangaani (Mn)	< 2500	1000	mg/kg
Nikkeli (Ni)	< 200	140	mg/kg
Lyijy (Pb)	< 20	3	mg/kg

Tyypillinen seula-analyysi

D ₅₀	1,4		mm
98 %	< 2,0		mm
Irtotiheys	1,10 - 1,30	1,20	kg/m

Asennus

Kemira CFH 12 tulee sijoittaa suodattimeen tukimateriaalin päälle. Tukimateriaaliksi soveltuu esimerkiksi hiekka tai riittävän hienojakoinen kivimurske. Kemira CFH 12 lisätään suodattimeen ja suodatin täytetään vedellä. Suodatinta huuhdellaan vedellä vastavirtaan noin 20-kertaisella vesimäärällä asennetun Kemira CFH 12 tuotteen tilavuuteen verrattuna. Vastavirtahuuhtelussa poistetaan adsorbentista pöly ja suurin osa veteen liukelevasta aineesta. Huuhteluvesi tulee pumpata viemäriin.

Appendix E. Reference plans for shotgun ranges

Appendix E1. Adsorption treatment of water at a shotgun range

E1_1 Introduction

This reference plan describes the metal removal treatment of water discharged from a shotgun range, based on water filtration through an adsorptive material.

E1_2 Principle of the technique

Runoff water discharged from the shooting range area via underground drainage can be diverted to flow through an adsorption filter. When the water flows through the adsorptive material placed into the filter at the desired speed, water-soluble metals become tightly bonded to it. The purified water is further directed into a ditch, for instance, or absorbed into the ground.

E1_3 Structure of the filtration well

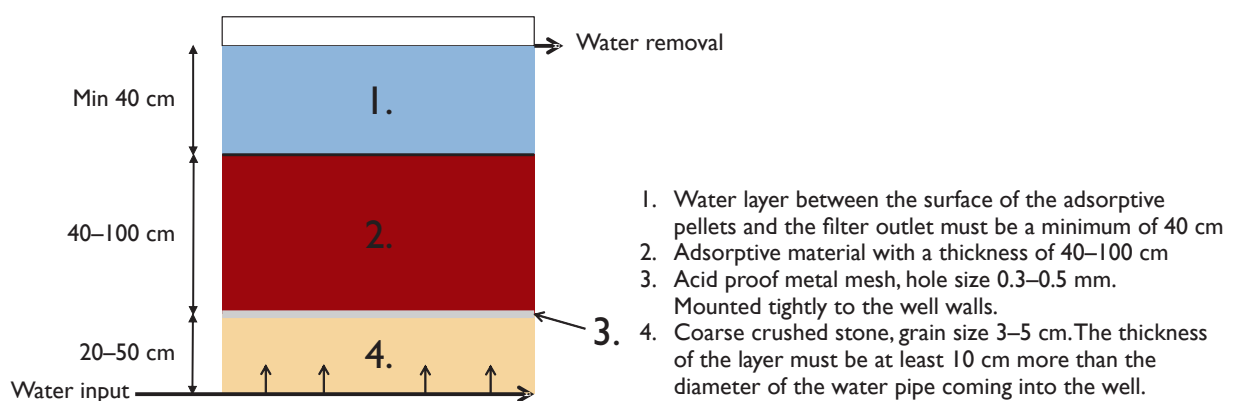
Designing the filtration well first requires an estimate of the maximum water flow m^3/h from the water insulated area; the filtration well is then designed for that amount. The water directed into the filtration well must contain as little solid material as possible, as it may clog the filter and significantly reduce its service life. For this reason, we recommend protecting the underground drainage pipes with a strainer fabric, underground drainage gravel, and a sand layer at least 30 cm deep.

The contact time between the adsorptive material in the filtration well and the water flowing into the well must be at least five minutes. The contact time may also be longer. If the filter is designed for a maximum water flow of $0.5 \text{ m}^3/\text{min}$, for example, the minimum amount of adsorptive material in the filtration well is 2.5 m^3 ($\sim 3.0\text{t}$). The water must flow from the bottom to the top in the filtration well. This provides a more even water flow and a better metal removal result.

The surface area of the filtration well must be large enough for the desired flow. The maximum water permeability of the adsorptive material is $0.5 \text{ m}^3/\text{m}^2/\text{min}$. The surface area of a well designed for a maximum flow of $0.5 \text{ m}^3/\text{min}$ must therefore be at least 1 m^2 .

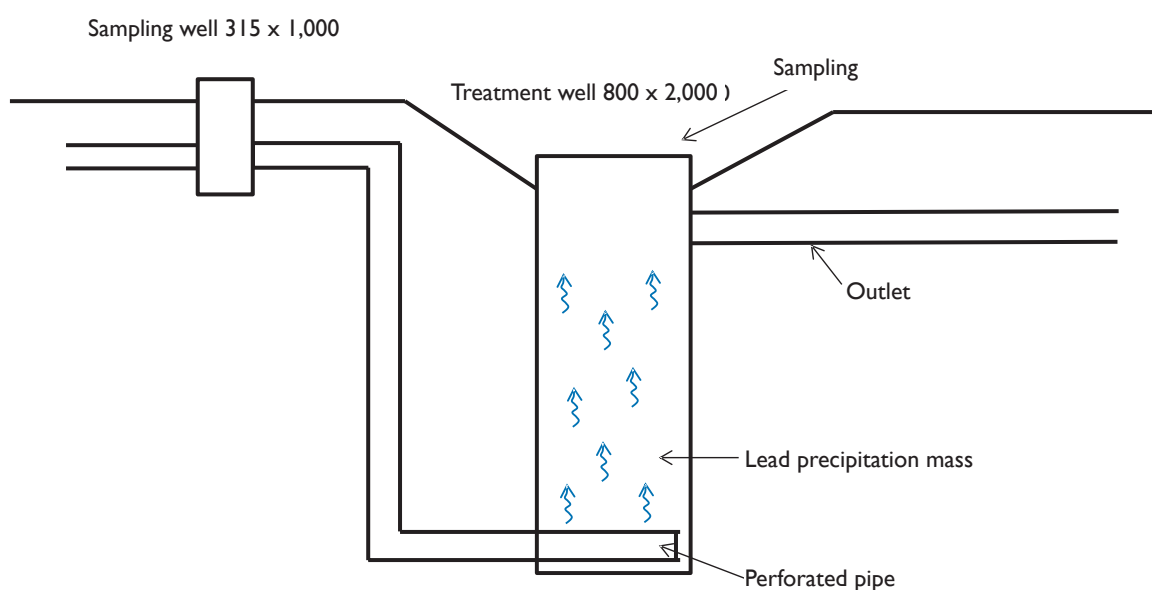
The thickness of the layer of adsorptive material in the filter must be no less than 0.4 m but no more than 1.0 m. If the adsorptive material layer is too thin, it may reduce the effectiveness of the water purification, and if the layer is too thick, it may reduce the water permeability of the filtration well.

The water inlet of the well must be designed so that water can freely enter the entire surface area of the bottom of the well. An example of such a structure is depicted in the figure below:



Water is directed into the filtration well from the underground drainage pipeline with the help of gravity, which means that the filtration well must be at a lower elevation than the underground drainage. The well must be installed so that the well's outlet is at least 1 m lower than the underground drainage. This achieves a hydraulic pressure of around 0.1 bar.

The filtration well can be made of concrete, plastic or metal. The well structures and lead-throughs must be watertight. See below for an indicative cross section of a filtration well with a surface area of 0.5 m². With a maximum layer thickness of 100 cm, no more than 1 m³ of adsorptive mass can be installed in this kind of well, allowing a maximum design flow of 200 l/min.



All joints and lead-throughs are watertight

We recommend designing sampling points for both incoming and outgoing well water for water quality monitoring. The illustration above depicts a sampling well for incoming water; it can be, for example, a regular drainage well. In the figure above, outgoing water is sampled from the filtration well. The filtration well must have a cover that prevents litter from entering the well.

EI_4 Properties and disposal of the adsorptive material

Ferric hydroxide pellets containing iron are suitable for metal removal. The grain size of the material is 1–2 mm and its density 1.2 kg/l. The pH of the material is around 6–7. The adsorptive material is not harmful. Some dusting occurs when the filter is refilled with new pellets.

Used pellets that have lost their capacity to remove metals can be removed from a filter with a vacuum truck, for example. The eligibility for a landfill of the used pellets must be analysed, and the waste management facility suitable for final disposal can be decided based on the results.

The adsorptive material can bind a total of around 2–5 g/kg of metals before it needs to be replaced. See Appendix 1 for the brochure of a suitable adsorptive material (Kemira CFH 12).

EI_5 Water treatment at a shotgun range

At a shotgun range, an area of up to 10,000–30,000 m² needs to be protected and drained. This means that the amount of water discharged from the area to the filtration well is large during periods of rainfall. If we assume that the area is 30,000 m² and the design rainfall value has been 3 mm/h, the maximum amount of water coming into the well is 90 m³/h = 1.5 m³/min. Rainfall of 3 mm/h is not very heavy, but water can be collected in an extensive underground drainage system during heavy rain. At large shotgun range areas, the large amount of water caused by heavy rain can be evened out by constructing several filtration wells around the area.

In this case, the amount of adsorptive material in the well must be no less than 7.5 m³ (9.0 t) to achieve the required minimum contact time of five minutes.

The well structure is designed in accordance with section 3.

kemira

CFH 12

Käyttötarkoitus

Kemira CFH 12 tuote soveltuu hyvin arseenin ja useiden metallien poistamiseen vesiliuoksista. Tuote soveltuu lisäksi fosforin poistoon. Tuotetta voidaan käyttää säiliöissä, altaissa ja maasuodattimissa. Tuotteen toiminta perustuu erilaisten vesiliukoisten epäpuhtauksien adsorboitumiseen ferrihydroksidirakeisiin.

Kemialliset ja fysikaaliset tiedot

Ulkonäkö rakeinen, ruskea tai punaruskea

		Tyypillinen arvo		
Rauta (Fe ³⁺)	39 - 48	44	%	
Vesiliukoinen aines	3,0 - 6,0	4,5	%	(EN 12902)
Kosteus	13 - 19	16	%	

Epäpuhtaudet: Pitoisuus tuotteessa

	Max.	Tyypillinen arvo	
Arseeni (As)	< 1		mg/kg
Kadmium (Cd)	< 1		mg/kg
Kromi (Cr)	< 25	10	mg/kg
Kupari (Cu)	< 20	5	mg/kg
Mangaani (Mn)	< 2500	1000	mg/kg
Nikkeli (Ni)	< 200	140	mg/kg
Lyijy (Pb)	< 20	3	mg/kg

Tyypillinen seula-analyysi

D ₅₀	1,4		mm
98 %	< 2,0		mm
Irtotiheys	1,10 - 1,30	1,20	kg/m

Asennus

Kemira CFH 12 tulee sijoittaa suodattimeen tukimateriaalin päälle. Tukimateriaaliksi soveltuu esimerkiksi hiekka tai riittävän hienojakoinen kivimurske. Kemira CFH 12 lisätään suodattimeen ja suodatin täytetään vedellä. Suodatinta huuhdellaan vedellä vastavirtaan noin 20-kertaisella vesimäärällä asennetun Kemira CFH 12 tuotteen tilavuuteen verrattuna. Vastavirtahuuhtelussa poistetaan adsorbentista pöly ja suurin osa veteen liukevasta aineesta. Huuhteluvesi tulee pumpata viemäriin.

Appendix E2. Limiting the flight trajectory of shot

Introduction

This reference work description describes the construction of a backstop berm for a shotgun range. Site-specific plans for various ranges can be prepared and competitive tendering can be arranged for contracts based on this reference design. A shotgun range with both skeet and trap ranges, located on level, firm ground, has been used as the default range. The objective of this reference work description has been to achieve a backstop berm solution that allows stopping the majority (90–95%) of shot.

The reference work description describes the work in as much detail as possible, taking into consideration the fact that it must suit sites of very different sizes. The reference work description has been prepared in a manner that allows it be used as a framework for the work description in request for tender documents, even in large backstop berm contracts. In small contracts, unnecessary sections and subheadings can be left out. Issues that are necessary in the work description but that could not be written in detail are in *cursive*, as are issues that must be taken into consideration when necessary based on the site-specific plans.

The total height of the backstop berm and the separate elevation structure possibly designed on top of the berm must be determined in the site-specific plans. If there is a natural slope in the area that can be utilised, the height of the constructed backstop berm structure can differ significantly from that presented in the reference design. The relationships between the elevations of the backstop berm and the possible separate elevation structure must be taken into account site-specifically, considering issues such as the availability of earth and transport distances. The need for noise prevention must also be taken into account in the height of the berm. The load-bearing capacity of the soil, sufficient protection level of the soil and groundwater, any structural protective solutions, and water management solutions for the range area must also be examined site-specifically.

At skeet and trap ranges, the location of the berm relative to the firing stands may be different. In general, it can be stated that the closer the berm structure is to the firing stands, the better it prevents the spread of noise and pollutants into the environment. The rules and nature of shotgun sports, however, place their own requirements on the distances of the structures. At a trap range, the firing stands are located 15 metres behind the thrower trench, and the clay pigeon must be allowed an unobstructed flight distance of at least 76 metres. This means that the minimum distance of the foot of the berm from the shooter is 91 metres. At a skeet range, the berm can as a rule be located significantly closer to the firing stands than at a trap range. However, an unobstructed flight distance of around 67 metres is required for the clay pigeon for it to be possible to calibrate the throwers. In an actual shooting situation, the flight trajectories of the clay pigeons can be restricted, for example with portable nets. If no official competitions are arranged at the range, these distances may be deviated from.

The heights and distances of the berm structures based on the likely flight trajectories of the shot are presented in drawings 01 and 02.

The reference plan for asphalt paving used as a liner structure is presented as an appendix to the BAT report for outdoor shooting ranges, as is this reference plan. Asphalt paving is not discussed in this reference plan, except in the general sections where a reference is made to a liner structure constructed when necessary.

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E2_1 GENERAL INSTRUCTIONS

E2_1.1 General

This work description specifies the technical quality requirements for the project, and instructions on working methods and the construction supplies used. The financial and legal liabilities of the contractor and the customer and the other obligations of the parties are presented in a separate contract schedule.

Attached to the work description, there is a list of the work performances and amounts that are included in the contract, and for which the contract price is calculated using unit prices.

The contractor must carefully go over the work site before submitting a contract offer.

E2_1.2 Work site

Information on the site's location, scope and ownership.

Site location is presented on location map 1. The contract area is presented in drawing 2.

Information on existing structures.

A backstop berm restricting the flight trajectories of the shot and an elevation structure are constructed at the site. The contract comprises the construction of the following:

- shooting range backstop berm and the related elevation structure
- *water management system, if necessary*
- *liner structure inside the backstop berm and the front of the berm, if necessary*
- *remediation of contaminated soil, if necessary*

Customer's contact information.

If necessary, the contact information of the designer and the environmental authority.

E2_1.3 Nomenclature

This work description uses the InfraRYL 2010 nomenclature.

E2_1.4 Scope and implementation schedule of the project

An earthen backstop berm and an elevation structure made of metal mesh are constructed at the shotgun range.

If necessary, liner structures are installed inside the backstop berm and at the front of the berm. If necessary, a water management system is constructed at ground level to the bottom of the berm, and to the front of the berm in the area of the liner structure.

The scope of the contract is determined site-specifically. The contract area is usually specified with a contract border (map drawing). The contract may involve

- *Protection of the work site*
- *Clearing*
- *Drainage and water redirection during construction*
- *Construction of a water management system*
- *Construction of an earthen berm*
- *Construction of an elevation structure for a protective berm and its foundations*
- *Construction of a liner structure inside the berm and at front of it*

When the contractor hands over the contract, the work described here has been completed in full.

Start and end dates of the contract period.

E2_1.5 Documents, permits

The work must be performed in accordance with the currently valid national and EU laws, decrees, and other official regulations, decisions and guidelines, and the norms and standards applying to the field.

If contaminated soil needs to be removed from the site, the regional ELY Centre must be notified of the cleaning of a contaminated area. The supervision of the removal of contaminated soil requires an environmental technology supervisor who analyses the concentrations in the removed soil, directs the materials to the correct disposal location, and prepares the statutory transport documents with the contractor's assistance for each removed soil load in duplicate. One copy of the transport document is given to the recipient of the load and the other to the supervisor.

Documents to be followed during the contract and the performance of the work comprise:

- Contract schedule
- This work description
- Design drawings
- YSE 1998 (General Terms and Conditions of a Construction Contract)
- Environmental permit for the site
- InfraRYL 2010, General Quality Requirements for Infrastructure Construction 2010
- Environment guide for an earthwork site, Environment Guide 31, Finnish Environment Institute 1997
- The material suppliers' instructions on storage, handling and installation
- *If necessary, other norms and instructions (e.g. asphalt norms, concrete norms, ...)*
- *If necessary, decision of the ELY Centre concerning the remediation of a contaminated area at the site*
- *If necessary, the labour protection guide for the inspection and remediation of a contaminated area of land, Guidelines of the Environmental Administration 7/2006, and the Final report on the remediation of a contaminated land area, Environmental guide 2010.*

Before the beginning of the construction work, the contractor must submit an advance notification of the work site with the appropriate labour protection authority and the customer, if the work will take longer than a month. The advance notification must be clearly displayed at the construction site, and it must be kept up to date in the necessary parts.

E2_1.6 Reviews

E2_1.6.1 Initial and final reviews

The initial and final reviews are arranged in accordance with YSE98.

Before the work begins, an **initial review** is arranged, with the customer's work supervisor, the environmental technology supervisor (if necessary), the designer's representative (if necessary), the local representative of environmental control, and the representative of the ELY Centre present. If necessary, the work methods are specified in more detail and the requirement level determined during the initial review. At the same time, a **plan review** can also be arranged, checking the sufficiency of the plans and the need for additional planning, based on a more comprehensive idea on the materials to be used.

The **acceptance inspection** for the work is carried out after the completion of the work or a work stage having been taken into use.

If any defects are identified during the reviews or inspections, they must be corrected before the final approval.

If necessary, other reviews and inspections are arranged at the site in addition to the initial and final reviews, such as inspection of the foundation of the elevation structure, inspection of the water management system and inspection of the liner structure. The parties to the agreement may, if necessary, request a review of an issue they deem necessary.

E2_1.7 Site meetings

Site meetings are arranged regularly at the work site. Minutes are prepared for the meetings.

E2_1.8 Reporting of the work results

In accordance with YSE98, the contractor will keep a work site journal, into which all matters related to the performance of the work are recorded. The customer's representative approves the work with his/her signature. The work site journal and the daily measurement results must be available at the work site.

Particular attention must be paid to the documentation of quality control measurements and corrective measures. All measurement results and inspections are recorded into the work site journal. All defects, quality deviations, errors and their corrections, and the results of the verification measurements are also recorded into the work site journal.

The contractor shall ensure that the subcontractors compile the material, inspection, measurement, and test results obtained during the work. After the completion of the work, a summary of the quality control documents (validity document) is delivered to the customer.

E2_1.9 Contractor's plans and advance reports

No less than two weeks prior to beginning a contract work stage, the contractor must present a quality plan including the following plans and information:

1. work site plan
 - the location of the construction site buildings
 - material storage locations
 - driving routes and parking spaces
 - water, electricity and waste stations
 - location of the first aid kits and firefighting equipment
2. quality plan
 - the site organisation and the persons responsible for quality control
 - the subcontractors and their contact persons
 - material suppliers
 - the measuring services used and their contact persons
 - material approval procedure
 - the contractor's own quality control plan based on the work description (particularly if it deviates from the plan, or different materials are used)
 - the quality control methods used (equipment and the determination method or standard)
 - sampling and field measurement plan
 - quality requirements, including the allowed tolerances
 - measures to be taken with regard to deviations and changes
 - correction documentation procedure
 - inspections
3. schedule
 - major work stages by week
4. measurement plan
 - the responsible persons
 - the initial and reference points used

- the measuring equipment and format
 - codes and other identifiers used in the measurements
 - the measured levels, lines, pipelines, wells, etc.
 - printouts and the printing format, or a list of the drawings to be generated
5. work method plan by stage, including the stage-specific quality control measures
 - the materials used
 - equipment
 - work methods
 - work plan
 6. labour protection plan
 7. product information of the materials used.

The plans are delivered to the customer *and, if necessary, the environmental technology supervisor, designer and environmental authorities* for approval before the work commences.

Work schedules for detailed structures

- Berm structure
- Foundations of the elevation structure
- *If necessary, liner structure*
- *If necessary, the water management system structures.*

The plans are updated during work when necessary.

All materials must be approved by the customer *and, if necessary, the ELY Centre and the supervisors* before their acquisition and use. If the contractor uses materials or work methods that deviate from this work description, the contractor must present the construction work method description and a report on the characteristics of the materials used and their suitability for the application in question before commencing work. Furthermore, the results of the preliminary tests and material information for the contractor's materials must be presented before the commencement of the work. Quality control of the contractor's materials during work is the responsibility of the contractor.

Depending on the materials used, the results of the preliminary tests include:

- granularity curves of the materials used
- other required information, such as water content, humus content, water permeability, gas permeability, or the amount of soluble substances.

E2_1.9.1 Warehouses and storage areas

The raw materials and other materials are stored in the immediate vicinity of the work site. The materials are stored in accordance with the instructions of the material suppliers in such a manner that handling, humidity, sunlight or uneven ground do not cause deformations or damage to the materials. The packaging must remain intact and the product and material specifications readable. The product and material specifications are documented as part of the final report.

The customer shows the area available for the contract to the contractor. The contractor presents the location of the storage area in its work site plan.

E2_1.9.2 Traffic arrangements and safety measures

Insert any site-specific requirements for traffic arrangements under this section.

The contractor is responsible for the traffic arrangements and work site roads during the work. The contractor is responsible for site maintenance and cleaning, and plans and implements work site roads, security fences and safety structures, if necessary, in accordance with InfraRYL2010. The contractor acquires and installs the required traffic and warning signs.

E2_1.10 Environmental requirements, occupational health and safety

The work must be performed in accordance with the currently valid laws and regulations without causing undue disturbance to the environment, traffic, and the residents in the vicinity.

If contaminated soil remediation measures are taken, the spread of pollutants caused by transport must be prevented through transport route selection, covering of the loads, use of tight lorry beds, and, if necessary, cleaning the tyres. The uncontrolled spread of contaminated soil outside the remediation area must be prevented.

The contractor is responsible for the work being performed in a manner that is safe for the environment and the different parties, exercising particular caution. The contractor is responsible for the necessary safety measures at the work site and equips its workers with the necessary personal safety equipment (helmet, gloves, respirators, safety boots, etc.). In its occupational health and safety planning and monitoring, the contractor shall take into consideration the site-specific special features listed in the safety document prepared by the developer in addition to the normal risks related to construction work.

The developer/customer must prepare a work site safety document in accordance with the Occupational Safety and Health Act.

The developer/customer must appoint a safety coordinator for the work site.

E2_1.11 Measurements during work

The contractor performs all elevation and location measurements required for the performance of the work in accordance with the design documents. The contractor prepares a measurement plan based on the construction plans. The measurement results must be collected in such a format that they can be used for the analysis of the dimensional and positional accuracy of the structures during quality control. As work progresses, all measurement results are immediately delivered to the customer's supervisor in digital format and as paper printouts. The measurement results are marked down on the base map supplied at the commencement of the work.

E2_1.11.1 Marking the plan in the terrain

Reference points in the area are used as the starting point for the measurements, based on which the contractor performs the measurements. Before starting work, the contractor must compare the elevation and location data of the reference points to the design elevations and dimensions.

The plan is marked in the terrain as required by each work stage. A sufficient number of survey poles, elevation markers, slope stakes, or other markers will be placed in the terrain to guarantee that the work can be performed according to plan and that it is possible to reliably verify the work's conformance with the plans based on these markers. During the construction work, checks must be made sufficiently often to ensure that the marker locations have not changed. If necessary, the survey is repeated and the markers replaced into the terrain. When a laser beam is used as an alignment mark or for directing a work machine, the beam must be aimed with sufficient accuracy to make it possible to follow the precision requirements set for the construction. The contractor chooses the measurement methods based on how the location and dimensions of the structure have been presented in the plan.

The slope inclinations and elevation levels presented in the plans are indicative.

E2_1.11.2 Other measurements

The measurements to be carried out before the structures are covered and the other verification measurements of the finished structure are presented in the structure-specific quality requirements. Additionally, the locations of the quality control measurement points *and, if necessary, the residual concentration sampling points* are measured.

E2_1.11.3 Work amount measurements

The amounts are measured in accordance with InfraRYL 2010 and based on the dimensions marked on the plans, taking into consideration any changes to them agreed during the work and the actual elevation of the ground level.

E2_1.11.4 As-built drawings

The contractor is obligated to mark down in the design drawings all differences and deviations from the original plan detected during the work. These drawings are handed over to the customer once the work has been finished and approved. The structures may not be covered before the measurements for the preparation of the as-built drawings have been made.

The contractor supplies the customer *and, if necessary, the environmental technology supervisor*, with contours printed out on 1:500 maps based on the survey data of the contours of the actual surface elevations. The same materials are also delivered in an electronic format. The locations of any pipelines and wells, water flows and elevations are marked on the map. Information cards are prepared for the wells.

E2_1.12 Quality control of work performance and the outcome

Quality control is used to prove that the materials used and the construction work carried out conform with the plans and the requirements of the environmental permit.

Quality control during work comprises quality control measurements and functional tests. The material and structure-specific quality requirements and quality control methods are presented separately for each work stage.

E2_1.12.1 Contractor's quality control

The contractor bears the main responsibility for performing the work in accordance with the plans. The fulfilment of the requirements is verified by quality assurance measurements during work.

The contractor carries out daily quality control at the work site. The contractor performs tests and analyses specified below before beginning the actual work, and during the work. Measurements are made with regard to both quantities and surface areas.

The results and observations from the contractor's quality control are handed over to the customer's supervisor immediately after they are complete. The contractor and the customer's representative also inspect the area under work weekly.

The contractor must take note of the comments made by the supervisor based on the quality control measurements.

After the completion of the work, a summary of the quality control documents (validity document) is delivered to the customer.

Based on this work description, the contractor prepares a quality plan that is approved by the customer and, if necessary, the designer.

E2_1.12.2 Customer's supervision

The customer may appoint supervisors to supervise the contractor's work performance and monitor the amounts. The customer's supervision does not limit the contractor's liability.

If necessary, the environmental technology supervisor is responsible for taking soil samples directing the remediation of contaminated soil, field analyses, and sending the samples to a laboratory. In addition to field analyses, soil samples are sent to a laboratory to be analysed. The supervisor directs the excavation and sorting of the contaminated soil, and its transport to suitable reception facilities. The supervisor is responsible for preparing the transport documents and informing the reception facility.

E2_1.12.3 Supervision by the authorities

The authorities may make inspection visits, and participate in site meetings, inspections and reviews.

E2_1.12.4 Quality control of removed materials

If necessary, the quantity, quality, pollutant content, and treatment or delivery method of soil removed from the site is recorded into the work site journal on a daily basis. A transport document as per the currently valid legislation is delivered with each load transported to a treatment facility; it indicates the material type and the pollutant concentration, determined by field measurements or laboratory analysis. If necessary, the quality and pollutant concentration of soil remaining at the work area is determined by field measurements, and partially laboratory analyses, and documented in the as-is measurements. The environmental technology supervisor is responsible for the above-mentioned concentration measurements.

E2_1.12.5 Quality control of the berm and elevation structures

The quality of the materials used for the structures, and the location, elevation, inclination and water tightness of the structures must be monitored at the minimum as presented in the general work descriptions.

I 0000 EARTHEN, BASE AND ROCK STRUCTURES

11000 EXISTING STRUCTURES AND STRUCTURAL PARTS

Present information on the vegetation, structures, systems, earthen, embankment and top structures, open ditches and trenches at the work site, and their dismantling, moving or protecting, and the dismantling of the protection.

12000 CONTAMINATED SOIL

12100 Removed contaminated soil and structures

If necessary, present information on the contaminated soil or structures located in the work area, and their treatment.

12200 Liner structures

If contaminated soil is placed, for instance, inside the berm's liner structure, the liner structure must be described based on the site-specific plans.

13000 FOUNDATION STRUCTURES

14000 BASE STRUCTURES

14100 Reinforced earthen structures

14200 Protections and linings

14300 Drainage structures

16000 SOIL EXCAVATIONS

17000 ROCK CUTS AND EXCAVATIONS

18000 EMBANKMENTS, DYKES AND FILLS

18100 Embankments

18110 Earthen embankments

18110.1 Earthen embankment materials

Sand or coarser compactable mineral soils are used as material for the backstop berm. The material does not contain rocks or boulders with a diameter larger than 2/3 of the thickness of the layer compacted at a time. The soil in the embankments does not

contain harmful amounts of pollutants. The embankment material does not contain snow, ice, or frozen clumps of earth or materials. The validity of the material is usually determined through a visual inspection.

18110.2 Earthen embankment bed

The characteristics of the ground are determined through ground investigations and testing prior to designing the embankment. During the embankment work, keep watch to ensure that the base ratios have been correctly estimated in the design documents.

Topsoil is not removed from beneath the earthen embankment. Bushes, felling residues and other wood is removed from the entire area to be embanked.

18110.3 Constructing an earthen embankment

The embankment is constructed in layers with uniform quality.

18110.4 Finished earthen embankment

The shapes of the backstop berm's top surface compacted with the excavator bucket and its sides conform with the design documents. The maximum allowed height deviation to the design dimensions is 100 mm.

18110.5 Proving the validity of the earthen embankment

Field measurements are performed on the embankment surface at 20 m intervals by measuring the breakpoints of the cross sections and the distances between breakpoints at 1 m intervals.

Measure the surface of the earthen embankment from the slope on a 10 m grid, and the breakpoints at 5 m intervals. The measurement results are presented in the as-built drawing. The quality control information on the material is presented in the validity document.

18120 Blasted stone embankments

18130 Embankments of recycled materials

18140 Lightened embankments

18300 Excavation fills

20000 TOP AND SURFACE STRUCTURES

21000 TOP STRUCTURE PARTS AND SUBSTRUCTURE LAYERS OF THE RANGE

21100 Filtration structures

21200 Partitioning layers, insulating layers and intermediate layers

21300 Load-bearing layers

21400 Pavements and surface structures

22000 EDGE SUPPORTS, GUTTERS, STEPS AND EROSION PROTECTION

22100 Edge supports, gutters, steps and walls

22200 Slope covering and erosion protection

23000 PLANT STRUCTURES

30000 SYSTEMS

31000 WATER SUPPLY SYSTEMS

31100 Wastewater sewers

31200 Surface runoff sewers

Any surface runoff systems possibly connected to the backstop berm solution are designed site-specifically. A surface runoff system must typically include a sediment trap or a corresponding structure for collecting shot and sand, a monitoring well, and readiness for the installation of water treatment equipment or discharge into a wastewater system.

31300 Water pipes

32000 SAFETY STRUCTURES AND GUIDANCE SYSTEMS

32100 Railings, guides and crash barriers

32200 Fences, beams and gates

40000 CONSTRUCTION ENGINEERING ELEMENTS

41000 UNSPECIFIED CONSTRUCTION ENGINEERING ELEMENTS

The structural details of a shotgun range's backstop berm structures are always designed site-specifically. Depending on the site-specifically designed solutions, the design texts are placed under suitable subheadings. The starting point for this reference design is a backstop berm around 15 m high, and a steel net solution 8 m high constructed on top of the berm. The texts in this plan refer to this berm + net solution.

41100 Concrete structures

The concrete cover requirements also apply to temporary supports.

The position tolerances for the concrete structures are determined according to 42210.4.1 (Position of the top structure). The position tolerances for the bolt groups of the net structure pylons are +/- 5 mm.

41200 Steel structures

The net structure comprises hot-dip galvanised steel parts.

The contractor prepares technical work plans and quality plans for the manufacturing and installation of the steel parts for approval by the customer.

The steel parts are manufactured from steel grade S355J2G3. A testing certificate must be included with material delivery lots for quality assurance purposes in accordance with standard SFS-EN 10204-2.2.

The steel parts are hot-dip galvanised to SFS-EN ISO 1461, Annex F class C.

When installation welding hot-dip galvanised steel, remove the galvanisation from the welded area with an abrasive disc. Remove the slag from the welding seam.

Weld quality level as per standard SFS-EN 25817 level C. Welding is carried out using the welding additive required by the steel grade in question.

The surface finish of the steel complies with the instructions of the paint manufacturer. Surfaces with no zinc plating are painted with a zinc paint in accordance with class B (SFS-EN-ISO 1461) >100µm, first with a brush, and after the paint has dried, the surface is spray painted.

The dimensional accuracy requirements for holes is ± 2 mm.

44000 FOUNDATION AND SUPPORT STRUCTURES

4419 Other foundation structures

The foundations are installed on top of crushed stone. If necessary, water is directed to nearby open ditches via underground drainage. A fill of no less than 0.5 m of non-freezing soil is installed underneath the foundations. The fill is compacted in layers of no more than 250 mm. The compacting is done using a 400 kg vibrating plate with three passes, or a 200 kg vibrating plate with four passes.

45000 ENVIRONMENTAL STRUCTURES

45100 Protection and abatement structures

46000 STRUCTURES AND FIXTURES

46100 Shelters

46200 Fixtures and equipment

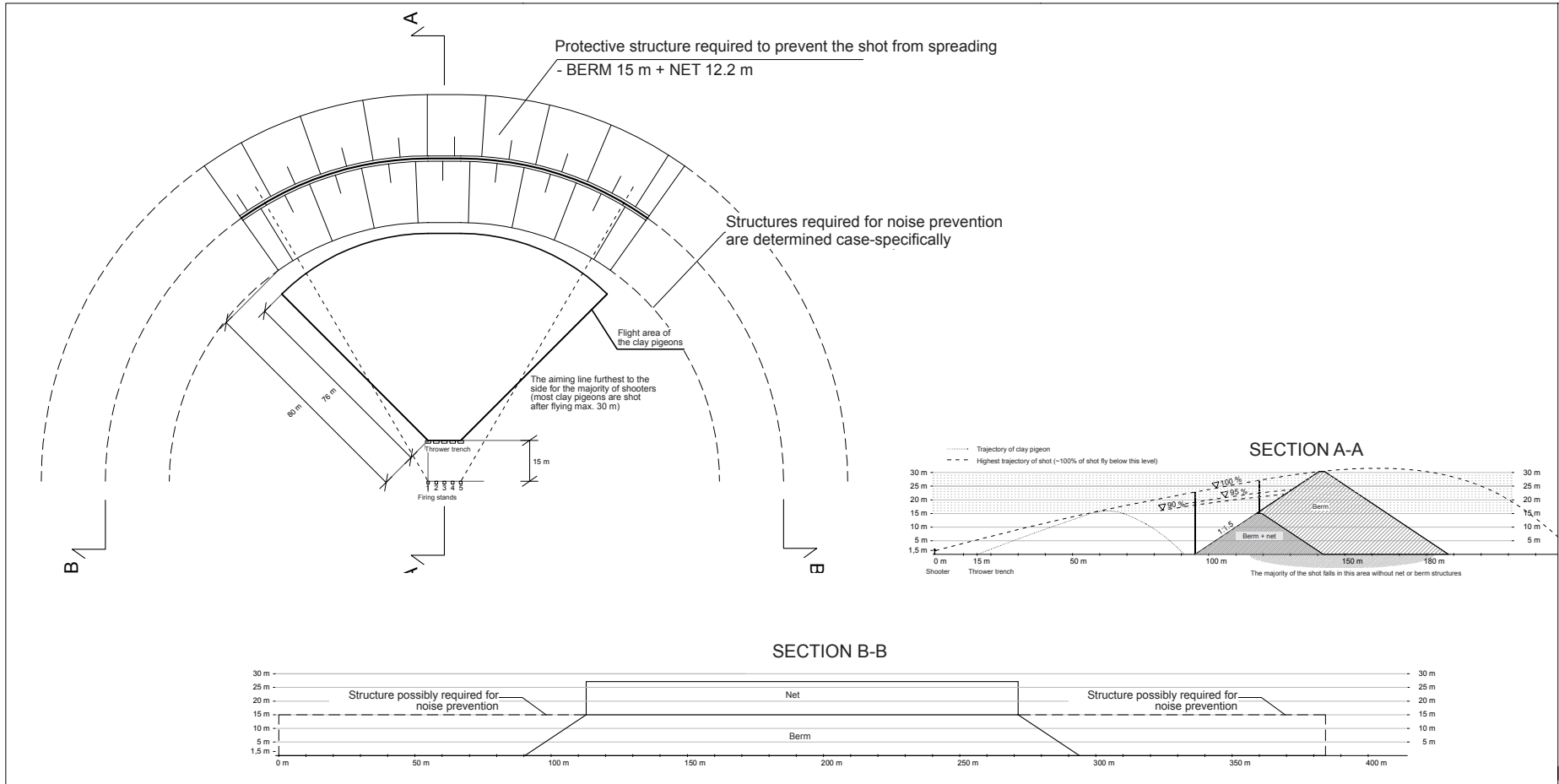
A reference plan for the berm and net solution for a shotgun range
Cost estimate

When the berm material and net must be purchased					
Berm height/m	Net height/m	1 m	Total cost for berm length		
			10 m	100 m	200 m
23	-	EUR 6,300	EUR 63,000	EUR 630,000	EUR 1,260,000
15	8	EUR 4,800	EUR 48,000	EUR 480,000	EUR 960,000
10	13	EUR 5,800	EUR 58,000	EUR 580,000	EUR 1,160,000

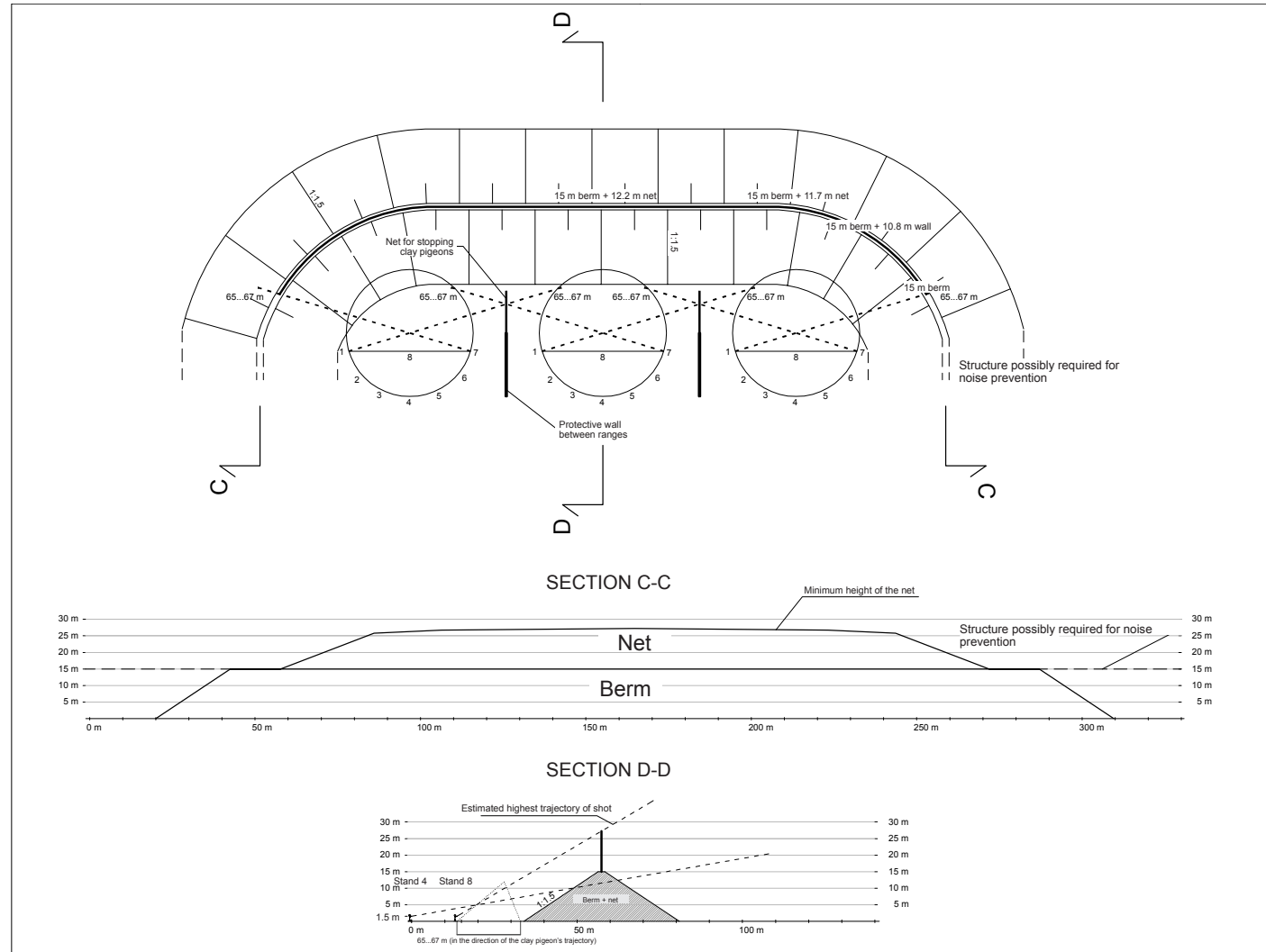
When berm material is available for free, and the net must be purchased					
Berm height/m	Net height/m	1 m	Total cost for berm length		
			10 m	100 m	200 m
23	-	EUR 3,000	EUR 30,000	EUR 300,000	EUR 600,000
15	8	EUR 3,300	EUR 33,000	EUR 330,000	EUR 660,000
10	13	EUR 5,100	EUR 51,000	EUR 510,000	EUR 1,020,000

Assumptions of the cost calculation:

- 1) The slope inclination of the berm is 1:1.5.
- 2) The width of the berm crown is 2 m.
- 3) The material required for the berm has been calculated using the formula $1.5x^2+2x$, where x is the berm height
- 4) The cost of an earthen embankment is EUR 7.5/m³ including the soil and construction work.
- 5) The cost of just the soil is EUR 4/m³ (-> berm construction EUR 3.5/m³)
- 6) Transport costs have not been included, so they need to be added based on the transport distance (roughly).

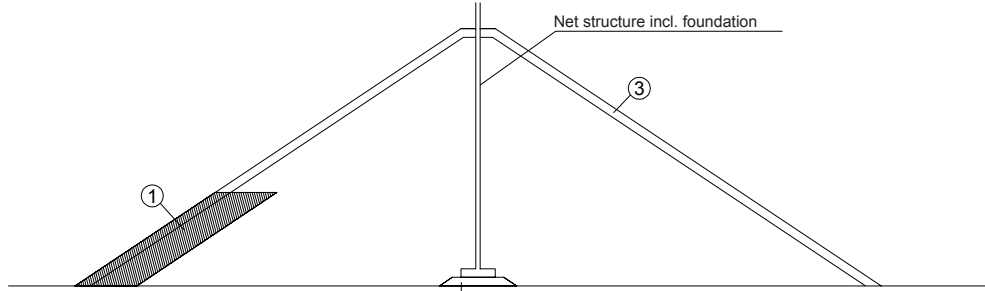


District/village	Block/estate	Lot/Building No.	Official markings	
Building operation		Drawing type		Running No.
Name and address of construction site		Drawing contents		Scale
Sample design for a shotgun range Trap range		Trap range backstop berm and heightening		1:100
		Sections A-A and B-B		1:100
Ramboll Finland Oy PL 25, Säterinkatu 6 02601 Espoo tel. +358 20 755 611		Design sector	Job No.	File
		GEO	82140974	
		Drawing number	Change	
		S1		
appr.	drawn by	designed by	Date	
J. Setälä	JULS	J. Sassi/J. Sikiö		

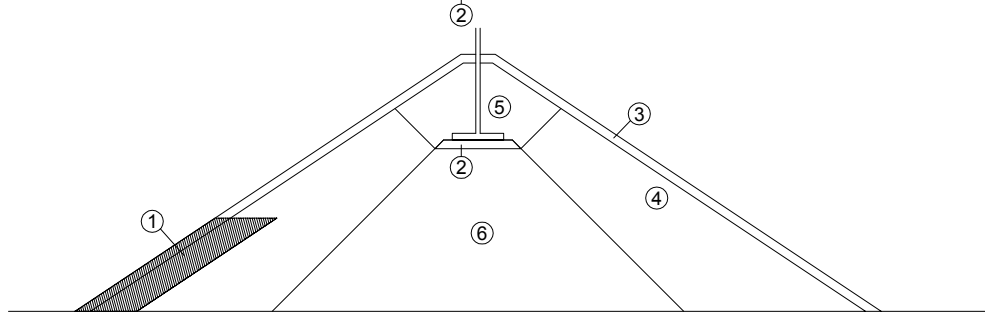


District/village	Block/estate	Lot/Building No.	Official markings	
Building operation			Drawing type	Running No.
Name and address of construction site			Drawing contents	
Sample design for a shotgun range			Skeet range backstop berm and heightening	1:100
Skeet trap			Sections C-C and D-D	1:100
RAMBOLL		Ramboll Finland Oy PL 25, Säterinkatu 6 02601 Espoo tel. +358 20 755 611	Design sector GEO	Job No. 82140974
			Design number S2	Change
appr. J. Setälä			drawn by JULS	designed by J. Sassa/J. Sikiö
			Date	

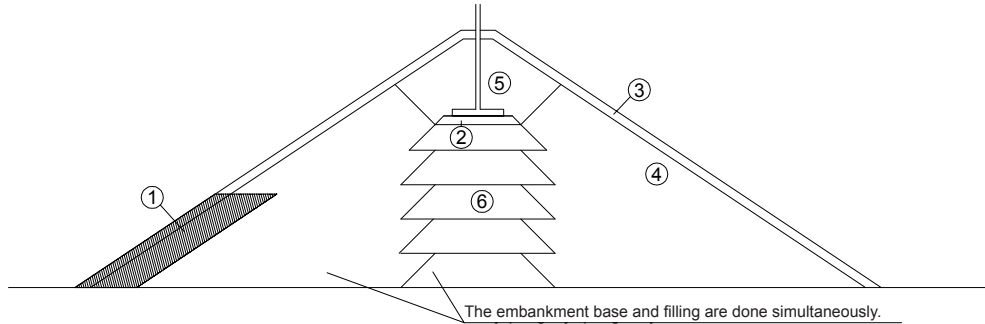
VE1



VE2



VE3

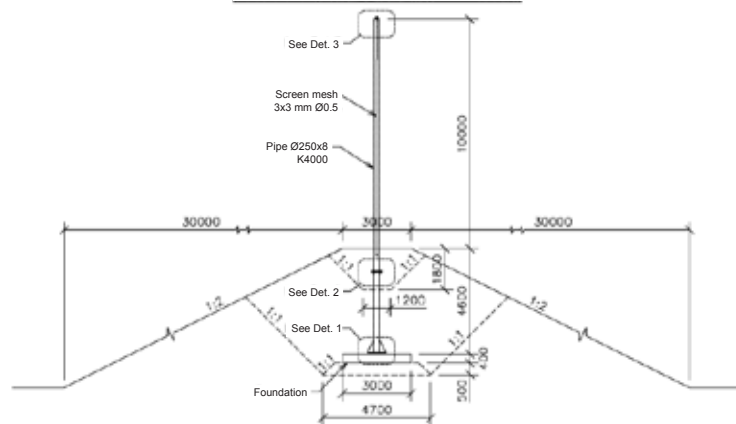


①	Structures of the water collection system
②	Grillage
③	Slope covering, erosion protection
④	Embankment filling
⑤	Filling of the top of the base
⑥	Embankment base

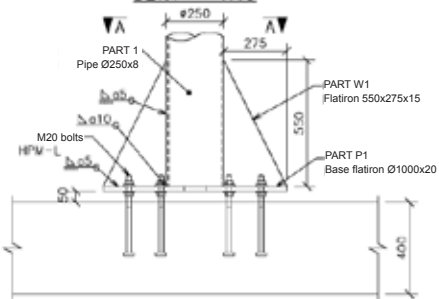
Height of the earthen embankment is 15 m.

District/village	Block/estate	Lot/Building No.	Official markings	
Building operation			Drawing type	Running No.
Name and address of construction site			Drawing contents	Scale
Sample design for a shotgun range Backstop berm structure			Backstop berm cross sections VE1-VE3 1:200	
RAMBOLL		Ramboll Finland Oy Pl. 25, Säterinkatu 6 02601 Espoo tel. +358 20 755 611	Design sector	Job No.
sign		drawn by	designed by	File
J. Setälä	JULS	J. Sassa/J. Sikiö	GEO 82140974	Change
		Drawing number	S3	Date

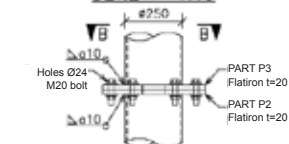
TYPE CROSS SECTION – 1:100



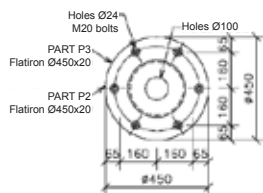
DET.1 – 1:10



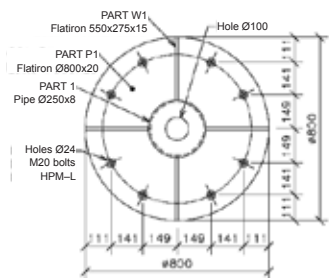
DET.2 – 1:10



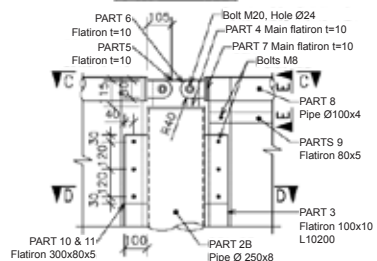
B-B (PARTS K1 & K2) 1:10



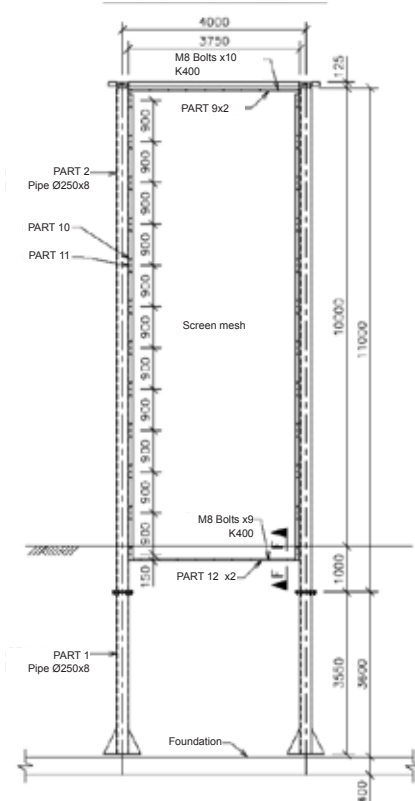
A-A (PART P1) 1:10



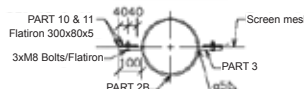
DET.3 – 1:10



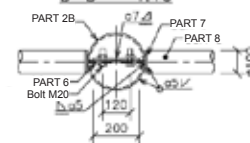
TYPE SIDE VIEW – 1:50



C-C – 1:10



D-D – 1:10



E-E – 1:10



F-F – 1:10



Parts List

PART	NAME	LENGTH	HEIGHT	THICKNESS	PCS	A WEIGHT	TOTAL WEIGHT	UNIT
P1	PIPE Ø250x8	10000	250	8	20	15.71	314.20	Kg
P2	PIPE Ø250x8	3600	250	8	20	15.71	314.20	Kg
P3	FLATORN 550x275x15	4700	15	15	20	15.71	314.20	Kg
P4	FLATORN 800x20	4700	20	20	20	15.71	314.20	Kg
P5	FLATORN 80x5	4700	5	5	20	15.71	314.20	Kg
P6	BOLT M20	100	20	20	20	15.71	314.20	Kg
P7	FLATORN 100x10	4700	10	10	20	15.71	314.20	Kg
P8	FLATORN 100x4	4700	4	4	20	15.71	314.20	Kg
P9	SCREEN MESH	4000	11000	1.25	20	15.71	314.20	Kg
P10	PIPE Ø250x8	3600	250	8	20	15.71	314.20	Kg
P11	FLATORN 300x80x5	4000	5	5	20	15.71	314.20	Kg
P12	FLATORN 100x20	4000	20	20	20	15.71	314.20	Kg
In total						314.20		

Client/owner	Block/lot	Lot/building No.	Other markings
Building operation	Drawing type	Running No.	
Name and address of construction site	Drawing content	Scale	
Sample design for a shotgun range	Structural type drawing	1:100, 1:50, 1:10	
Drawn by	Checked by	Design leader	Scale
E. Salmela	E. Salmela	RAK 82140974	1:100
Drawn by	Checked by	Drawing number	Change
E. Salmela	E. Salmela	84	
Date	Approved by	Date	
	E. Salmela		

Appendix E3. Paving the shot fall area with asphalt

E3_1 Introduction

This reference work description presents the implementation of groundwater protection structures for shotgun ranges using dense asphalt structures. Each implementation must be designed site-specifically. The type solutions presented here show the principles of the design, and the cost estimates are therefore very indicative and need to be specified on a case-by-case basis.

The asphalt layer withstands mechanical stresses well, and it also provides a good working platform for the required maintenance activities.

E3_2 Paving shotgun ranges with watertight asphalt for the removal of shot and clay pigeon waste and protecting the groundwater

Skeet and trap shotgun ranges are sector-shaped. Figure 1 presents the spread of shot at a skeet range.

In order to limit the spread of shot, we recommend using a berm or net structure when a watertight paving is used in order to reduce the size of the spread area and thus the area that needs to be paved. In the plans, the distance to the front edge of the berm or net structure is 100 m from the firing stand. There are two structure alternatives; in the first, the field between the firing stand and the berm is paved almost entirely with the exception of a 20 m strip in front of the firing stand in order to reduce the noise impact (Figure 2), and in the second, only the front of the berm is paved at a width of 20 m (Figure 3). Shot and clay pigeon fragments can also be removed mechanically from the paved structure.

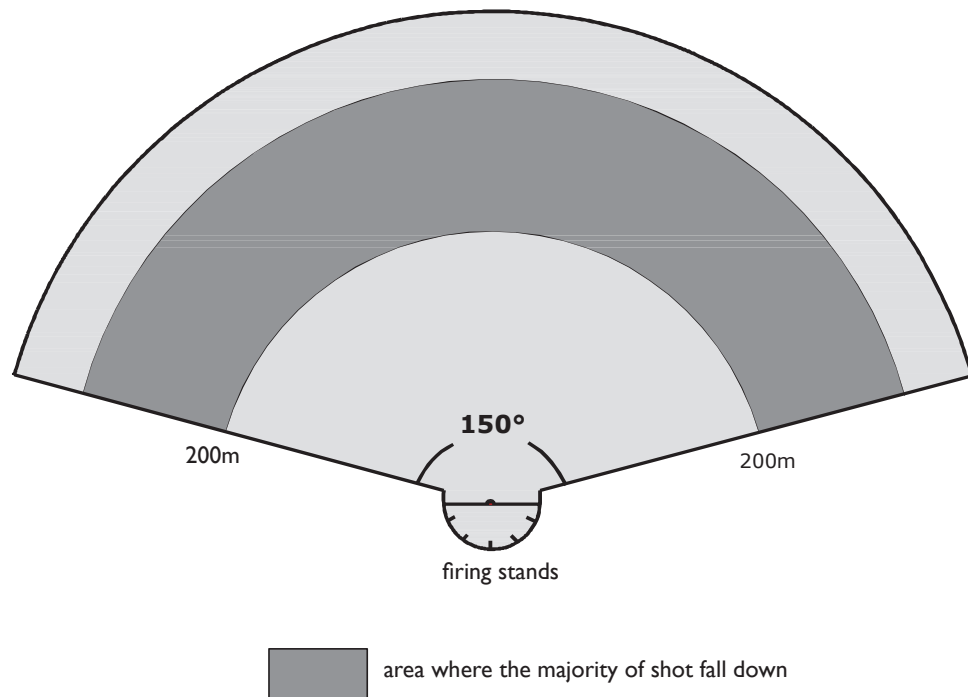


Figure 1. Shot spread area at a skeet range.

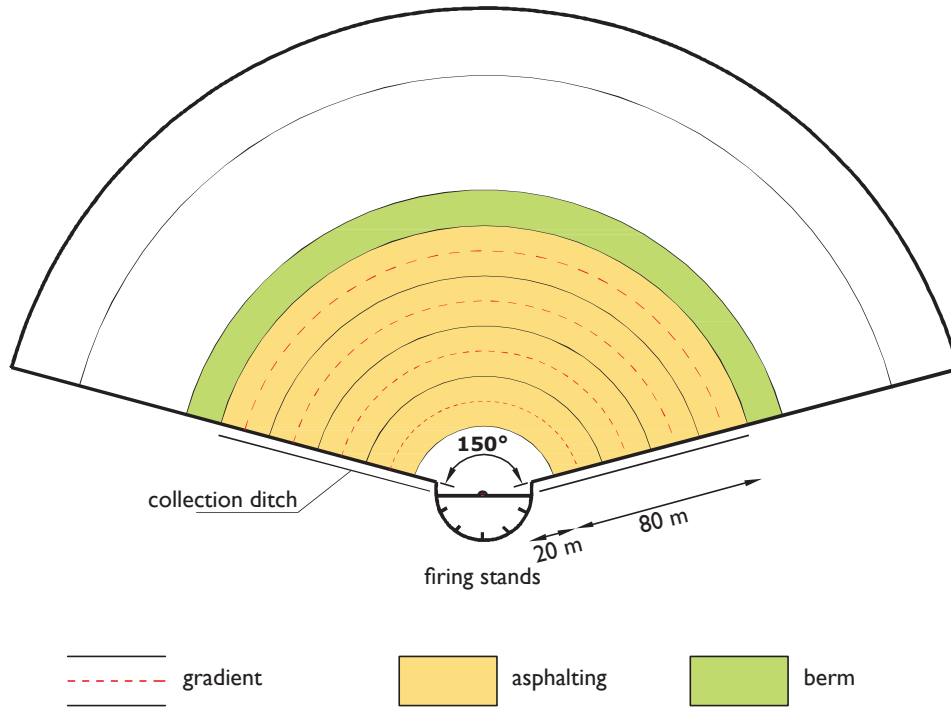


Figure 2. The field is paved almost completely (except 20 m at the front of the firing stand).

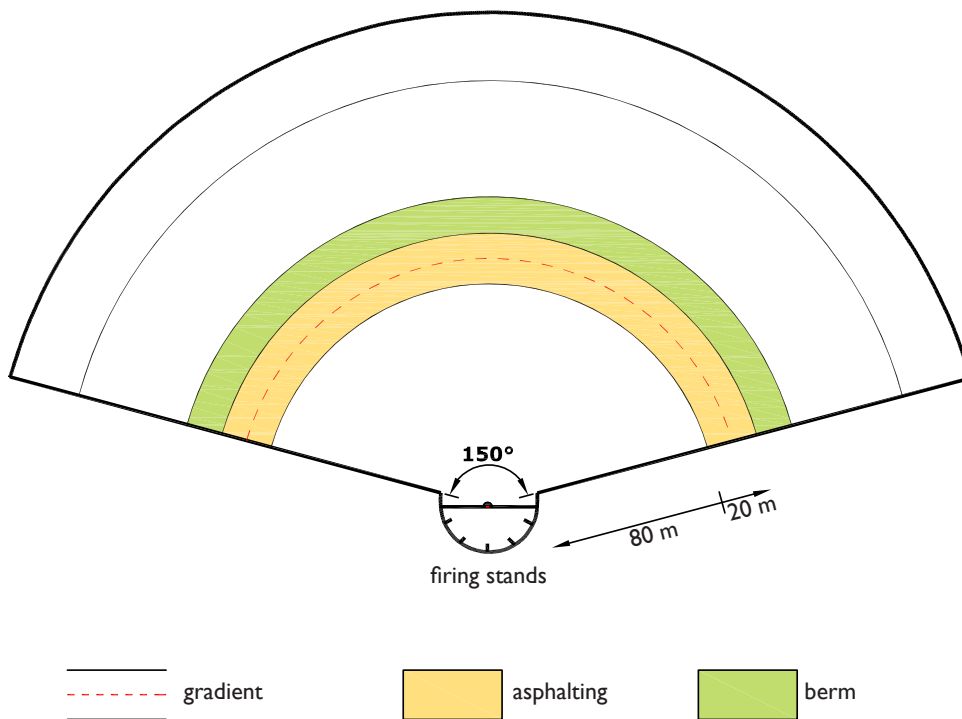


Figure 3. Part of the field is paved.

The surface structure is paved with dense asphalt. The structure can be implemented using either one thick, watertight asphalt layer ($> 120 \text{ kg/m}^2$, 50 mm) or two asphalt layers, the uppermost of which must be watertight. Use rubber bitumen as a binder in the surface layer asphalt, if you wish to minimise the cracking of the asphalt (due to freezing) (dense asphalt ABT 11, e.g. Lemdense 11). A watertight asphalt layer requires a firm base structure, so the load-bearing capacity of soft ground must be improved, for example by stabilising.

The field is built using gentle gradients (2–4%) in accordance with figures 2–4. The gradients allow the controlled direction of rainwater into water collection. The gradients can be gentle, enabling the mechanical cleaning of the field. Prevent surface runoff from outside the range area into the range area with ditches, if necessary.

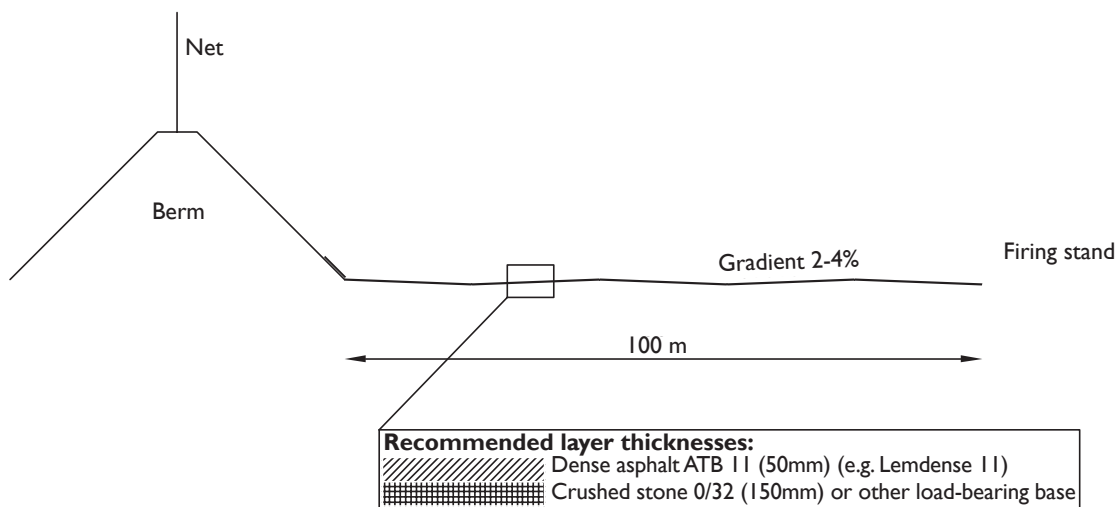


Figure 4. Cross section of the asphalt paving at a shotgun range.

E3_3 Cost estimate for the shotgun range structure

The following initial data has been used in the dimensioning and cost calculations of the shotgun range:

- The distance to the front edge of the berm from the firing stand is 100 m
- The entire field is paved with asphalt (except 20 m at the front of the firing stand); the surface area of the asphalt pavement is 13,000 m²
- The front of the front edge of the berm is paved at a width of 20 m; the surface area of the asphalt pavement is 5,000 m².

The indicative cost estimate includes the material and labour costs of paving

- Almost the entire field is paved: EUR 230,000 (VAT 0%)
- The front of the berm is paved: EUR 90,000 (VAT 0%).

Appendix F. Assessment of the need for pollutant management at a shooting range. Technical guide

F1 Introduction

This document has been prepared in connection with the study project concerning the best available techniques for the management of the environmental impact of shooting ranges, "Management of the environmental impact of shooting ranges – Best Available Techniques (BAT)". In accordance with the so-called shooting range BAT report, the need and level of the management of the environmental impact of shooting ranges is determined based on the likely environmental impact and risks of the site. The objective of this document is to provide guidelines for determining the magnitude of the pollutant emissions from an existing shooting range, and the environmental risk they cause, so that the need for pollutant management can be determined based on the result in accordance with the BAT report and the necessary measures can be planned. This study is intended to be carried out in connection with the environmental permit process, and its contents also facilitate the preparation of the environmental permit application to a great extent. These guidelines are intended for practitioners of shooting range activities, the authorities processing environmental permits, and the experts performing environmental analyses on shooting ranges.

F2 The objectives and implementation of the study

These guidelines are primarily intended for the assessment of the environmental risk caused by pollutant emissions from a shooting range, and their purpose is to act as a tool for applying the BATs, not, for example, for planning soil remediation. These guidelines, or the categories of required studies presented in them, are not intended to be binding in nature, and they do not suit all ranges as such. When planning the analyses for each shooting range, one must take into consideration the operational and environmental special characteristics, and decide on what analyses to perform based on them. The sufficient level of the analyses is determined by each site and its environment, and the type and scope of the operations.

Sufficient expertise in environmental research, environmental sampling, risk assessment and environmental planning should be used in performing the study. There are several consulting firms with competence in environmental analysis from which a shooting range operator can ask for a quote on the preparation of an analysis schedule and performing the analyses.

F3 Preliminary studies

In order to correctly target the analyses and to optimise the available resources, the available initial data on the site and its environment should be determined as comprehensively as possible. If no such data is available, a mention must be made of this. The operator must compile some of the initial data, while some can be assigned to be determined by the expert performing the environmental analysis. Studies performed by the operator reduce the need for expert work, thus reducing costs. Data can be obtained from the environmental authority and building inspector of the municipality, the regional ELY Centre, or the databases of the environmental administration, such as the Oiva service (www.ymparisto.fi/oiva), for example. The data can be complemented with a review of the terrain and map data, available from the National Land Survey of Finland's website (kansalaisen.karttapaikka.fi).

F3.1 Things to be determined by the operator

The operators should compile basic information on the site and information concerning the operations. The following information is required as the initial data for planning the assessment of the need for risk management (if necessary, some of these may be left for the expert performing the work to determine):

- Site location
 - Address
 - cadastral register ID
 - position coordinates and the coordinate system used
 - bordering neighbours
 - zoning situation
- Possessory relations of the site
 - Owner
 - possessor (if other than the owner)
 - user(s) (if other than the owner/possessor)
- Description of the operations
 - active shooting ranges in the region
 - shooting sports and range structures per range
 - commissioning year per range
 - number of shots/year per range
 - location and number of firing stands per range
 - other special issues, such as cartridge type or non-standard materials
 - usage history
 - any functional changes, such as in firing directions
 - shooting ranges (etc.) that have terminated operations
 - shooting sports, range structures and bullet/cartridge materials per range
 - commissioning and termination years per range
 - location and number of firing stands
- Implemented environmental protection and remediation measures, and studies
 - any technical emission control structures (e.g. bullet traps) per range
 - any soil remediations/modifications in the area (e.g. backstop berm raising, removal of contaminated soil)
 - previous environmental studies in the area or its vicinity
 - environmental monitoring and its results
- Known or planned changes in land use in the vicinity of the area
- Other factors possibly affecting the quality of the environment, such as previous forms of land use that cause a contamination risk or, for example, the use of earth filling in the structures.

In addition to a written description, a site layout drawing must be prepared of the site, showing the location and structures of the existing and terminated (if any) ranges.

F3.2 Things to be determined by the expert

The following things are, as a rule, determined by the environmental technology expert. However, the operator's participation in the compilation of this information, according to his/her expertise and particularly with regard to issues requiring local knowledge, is desirable.

- Geological conditions
 - estimate of the main soil types in the area
 - estimate of the depth of bedrock surface in the area
 - ground elevation in the area
 - direction of ground gradient in the area

- Groundwater and its use
 - is the range located in a classified groundwater area (information on the groundwater area)
 - distance to the nearest classified groundwater area
 - groundwater formation and its direction of flow
 - locations of wells in the area and its vicinity
 - water abstraction facilities and observation wells in the area and its vicinity
 - amount of groundwater use
 - observation well types (metal/plastic, diameter) and condition (mention if damaged, bent, clogged, etc.)
 - existing information on the groundwater quality in the area
 - estimate of the distance between the ground surface and groundwater surface
- Surface waters
 - ditches in the range area and their directions of flow
 - the drainage basins of the main ditches departing from the range area and the amount of surface water generated in them
 - closest bodies of water
 - wetlands and swamps
- Environmentally sensitive sites
 - nature conservation areas
 - Natura areas
 - other known sensitive sites.

F4 Scope of the study

The analyses made should be comprehensive enough so that their results allow reliable conclusions on the emissions to the environment from the shooting range area in its current state, their impact, and any long-term risks. The scope and targeting to different aspects of the environment of the analyses required to achieve this objective do, however, vary from site to site. The planning of the study starts from the operations, their volume, and the environmental conditions. A more limited, basic-level study is usually sufficient, if the volume of operations is small and the shooting range is not located in a classified groundwater area. More extensive studies are usually required at shooting ranges located in groundwater areas or in the vicinity of household water wells, or at ranges with sites that are particularly sensitive to risks or with special natural value located in the vicinity.

Shooting ranges have been divided into three categories of required studies for the purpose of planning the analyses. The classification is made based on the information from the preliminary study, taking the entire shooting range area into consideration. This division is indicative only, and it can be deviated from when justifiable. At small pistol and rifle ranges, where the total amount of lead embedded in the range structures is relatively low, there is as a rule no need for terrain surveys; the conclusions on the need for measures can be drawn based on the preliminary study information. The normative maximum amount of lead in the range structures is 5 t of lead (Pb). At shotgun ranges, the analyses are usually necessary in all size categories due to the size of the area loaded with pollutants and the greater solubility of shot compared to bullets. This can be deviated from, however, using case-specific discretion.

A *basic-level study* is carried out at sites where the initial data does not suggest a significant risk of surface water or groundwater contamination.

A *study expanded with regard to surface waters* is carried out at sites where the initial data or basic-level analysis suggests a significant risk of surface water contamination.

A *study expanded with regard to groundwater* is carried out at sites where the initial data or basic-level analysis suggests a significant risk of groundwater contamination.

At sites where the conditions are such that surface runoff and percolating water is both absorbed into the ground in significant amounts and discharged via surface water, the study must be carried out as the expanded version for both surface waters and groundwater, particularly if the groundwater is used as household water.

With regard to protected sites located in the vicinity of the shooting range area, the scope and targeting of the necessary study is assessed on a case-by-case basis.

For the technical requirements for the categories of the required studies, see table F.1 and Figure F.1 below.

Table F.1. Assessing the need for study at various shooting ranges

Need for a study	Range area pollutant load	Surface water conditions	Groundwater conditions
No need for analyses	Small or rather new pistol and rifle range Lead accumulation < 5t Pb and no special risk factors at the site or in its vicinity	No special risk factors	No special risk factors
Basic-level study	An average-sized small pistol and rifle range, or a small one that has operated for a long time, or a rather new large range, or a small shotgun range. Lead accumulation < 50 t Pb	Distance to receiving water body is greater than 300 m, and no special risk factors are related to the water body or its use	Not located in a groundwater area, and groundwater is not used at a distance of less than 300 m from the range area, downstream from the assumed flow direction
Study expanded with regard to surface waters	A large shooting range or an average-sized one that has operated for a long time Lead accumulation > 50 t Pb	Runoff water is formed in the range area, directed into a water body, or there is a wetland/swamp in the range area	
	An average-sized small pistol and rifle range, or a small one that has operated for a long time, or a rather new large range, or a small shotgun range Lead accumulation < 50 t Pb	Receiving water body or its use is particularly sensitive, or distance to the water body is less than 300 m, or there is a wetland/swamp in the range area	
Study expanded with regard to groundwater	A large range, an average-sized one, or small one that has operated for a long time		Located in a classified groundwater area
	Shotgun ranges; pistol and rifle ranges where lead accumulation > 5t Pb		Groundwater is used at a distance of less than 300 m from the range area, downstream from the assumed flow direction

F5 Study plan

A study plan is prepared on the basis of the preliminary study data. As a rule, an expert specialising in environmental analysis should be used for the preparation of the plan. The study plan should present:

- The preliminary study data and the conclusions drawn based on it
- Required scope of the study
- Objectives of the study
- Delimitation of the studied area
- Implementation of the study, including
 - the number of any soil samples, collection instructions for composite samples, and the required amount of samples
 - the locations of any surface water sampling points and sampling instructions
 - the locations and technical specifications of any groundwater sampling and observation points, and sampling instructions

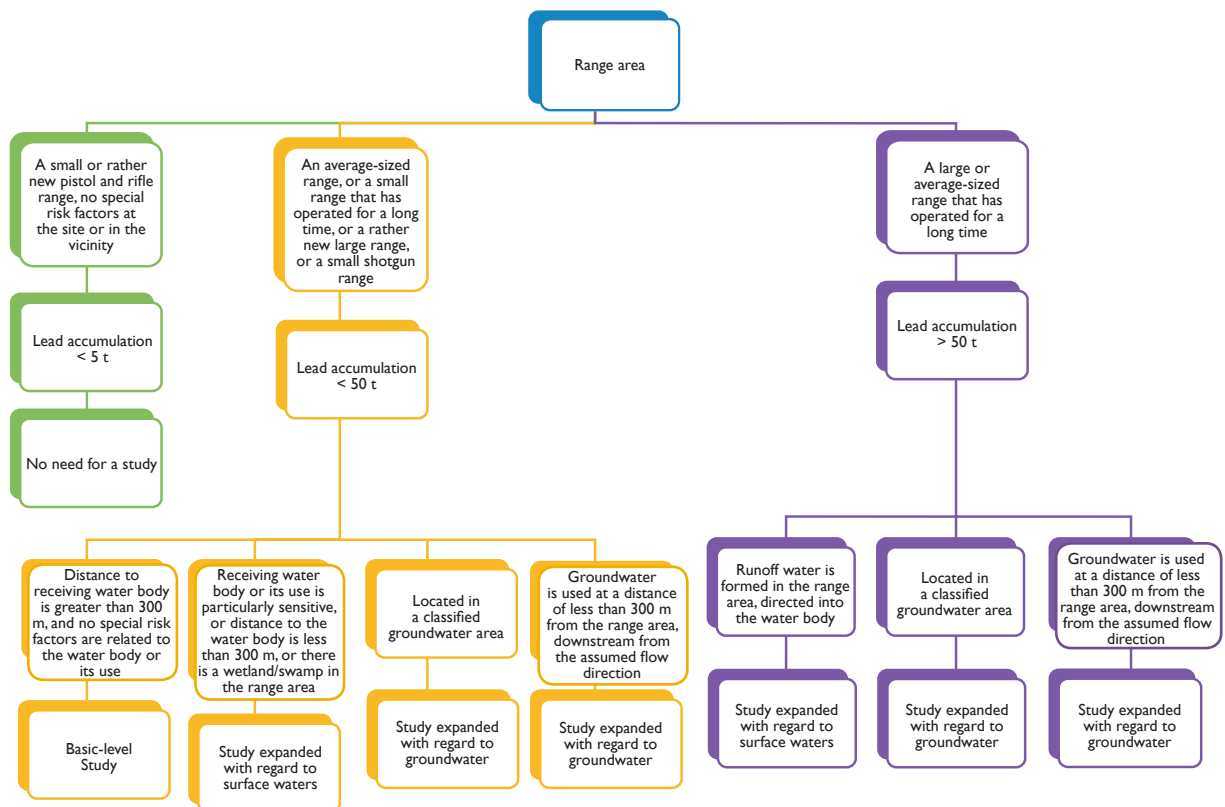


Figure F.1. Assessing the need for study at various shooting ranges

- implementation of any lysimeter or other additional analyses
- the necessary analyses
- Schedule.

We recommend having the study plan checked by a competent environmental authority (municipality, ELY Centre, Regional State Administrative Agency).

F5.1 Objectives of the study

The objective of the study is to produce sufficient information on the environmental conditions of an existing shooting range area (surface water, groundwater, soil) and the possible impact of shooting activities on these. Furthermore, the objective is to assess the long-term environmental and health risk caused by the shooting range operations through the identification of emissions, conditions and subjects of exposure in such a manner that the results enable the determination of the need for and the level of pollutant management at the shooting range in accordance with the risk level categorisation of the BAT report (BAT report, Table 6.3).

The risk of pollutant migration beyond the range area is the most significant factor to be taken into account when the required technical and operational measures for protecting the environment of the shooting range are assessed. In accordance with the AMPY report (Ministry of the Environment 2012), range structures such as the backstop berm and the topsoil of the range area are not considered to be soil; they are considered to be structures that will be removed after the operations have ended. For this reason, the determination of the metal amounts and concentrations in the structural layers of a shooting range in active use is not the primary purpose of the study; the objective is to assess the possible impact from the migration of metals into the

environment. The amount of pollutants in the structures is primarily assessed based on the number of shots fired and the time the shooting range has been in operation.

The objectives of the study must be specified and set out in the study plan, for instance as follows:

- The objective is to determine the pollutant emissions from the range area and their environmental impact for the assessment of the need for risk management. The study comprises the following parts:
 - Determination of the soil, surface water and groundwater conditions, and the use of surface waters and groundwater insofar as the preliminary study data is incomplete
 - Determination of the emissions, impact and risks to surface waters
 - Determination of the emissions, impact and risks to groundwater
 - Determination of the impact and risks to the biota in the area and protected organisms present in the impact area of the operations as needed.

F5.2 Delimitation of the study area

The study plan presents a justified delimitation of the study area, and the scale of study and sampling. These are decided based on the preliminary study and the study objectives. The principle is that the studies are extended as far as impacts are or can be detected. If necessary, the study area is divided into areas that depict the type or magnitude of the environmental load and from which the samples representing these areas are taken.

F5.3 Study implementation

The study plan should present the scope of the study and describe its practical implementation. Information presented on the implementation of the study comprises sample amounts, locations of sampling points, and the general and specific instructions for sampling and sample handling. The required field measurements and laboratory analyses required are also listed. The plan also presents the schedule for the implementation of the study, and any factors affecting the schedule.

Sections F6–F7 contain a normative description of the contents of studies of different levels with regard to surface water and groundwater analyses. The determination of the impacts on and risks to the biota is planned site-specifically if necessary.

F6 Basic-level study

F6.1 General

This section describes on a general level the analyses we recommend to be performed at all sites, where the lead pollutant load of the range structures can be assessed to possibly cause emissions that are harmful to the environment. The main objective is to determine the surface water emissions from the shooting range activities and the resulting pollutant load on the nearest body of water, and the current condition of the body of water. If the soil is so water-permeable that actual surface water is not generated in the area, the groundwater conditions and quality are studied in accordance with the classification of the studies required.

As a rule, a certified or experienced environmental sampling expert should take the samples, or the work should be carried out under the supervision of an expert.

We recommend taking photographs at the analysis sites during sample-taking. The locations and directions of the photographs are marked on a map.

These guidelines are not binding; they can be adapted if made necessary by the circumstances. If the basic-level study shows that the preliminary assessment of the risks caused by the site was too optimistic, additional analyses must be carried out at the site.

F6.2 Soil analyses

Soil analyses can be performed to determine the environmental conditions, such as the soil quality and water permeability, and the depth of the bedrock surface, if the preliminary study data is incomplete in this regard.

The amount of pollutants in the range structures is mainly estimated based on the number of shots. In a basic-level study, the analysis of pollutant concentrations in the soil in different sections of the shooting range is not considered necessary.

F6.3 Surface water analyses

The objective of the surface water analyses is to produce the required data on the surface water emissions from the shooting range operations, the current status of the surface waters, and to assess the long-term risks the operations cause to the surface water.

As a rule, emissions to surface waters should be determined by analysing the annual average of the pollutant concentrations in the surface water from the ditch departing from the range area. The acceptability of the emissions is assessed by comparing the results for lead to a calculated concentration that can in no situation cause the environmental quality norm to be exceeded in the receiving body of water.

The acceptable emission level thus determined can be utilised in setting the goals for and planning the risk management, and in the monitoring of the actual values, for instance, as a long-term reference value of the monitoring of runoff water. The acceptable emission level is not intended to be used as a limit value in such a manner that a detected value in excess of it would trigger an immediate need for action.

The possible impact of an existing shooting range on the closest body of water is determined through sampling. If no drainage ditch departs from the shooting range area, or the flow in the ditch is minor throughout the year, or determining the surface water emission is otherwise unreliable or impossible, the basic-level study will determine only the status of the receiving body of water with regard to pollutants.

F6.3.1 Surface water sampling

F6.3.1.1 Sampling from the drainage ditch of the shooting range

In order to determine the annual average, sampling is performed either by taking individual samples once per month when the water is unfrozen to even out the variance between seasons, or by using a passive collector.

Individual samples should be taken from ditch water from the centre of the channel underneath the surface without disturbing the bottom silt. We recommend taking the sample directly to a flask specified by the laboratory. Close the flask tightly immediately after sampling. In order to minimise the possibility for errors, the samples should be taken by an expert in the field.

The samples are analysed for the total concentrations and soluble concentrations of at least lead, copper, zinc and antimony, and at ranges that operated prior to 1960, nickel, and at shotgun ranges, arsenic¹. The sample can also be analysed for its pH, oxygen content, and organic matter concentration.

The results from individual sampling are not treated individually; an annual average is calculated and compared with the pollutant load deemed acceptable for the site. During sampling, we recommend measuring or estimating the flow of the ditch for the interpreting the results.

There are several commercial models of passive sample collectors. The passive sample collector must be allowed to stay in the water for a sufficiently long time in accordance with the manufacturer's instructions (e.g. 4 weeks, 3 months or 8 months). The idea of the passive sample collector is to compile an average concentration over

¹ Soluble concentration refers to a water sample filtered through a 0.45 µm filter

the entire sampling period, evening out any temporary variations. Passive sample collectors allow the monitoring to be carried out either by installing several (2 or 3) short-term collectors per year, or one long-term collector to compile the annual average for the period during which the water is unfrozen. The flow of the ditch should be measured for interpreting the results also when a passive sample collector is used. In that case, the flow is measured when the collector is installed and when it is removed.

The samples from the passive collectors are analysed for the concentrations of at least lead, copper, zinc, antimony, and at ranges that operated prior to 1960, also nickel. At shotgun ranges, the arsenic concentration is also analysed.

In addition to samples taken for the purpose of determining pollutant migration and the pollutant load they cause, a reference sample (or several, if necessary) should always be taken from the study area in order to determine the background concentrations. We recommend using the same method for taking background concentration samples as is used for taking the actual samples.

F6.3.1.2 Sampling from a body of water

In order to determine the current status of a shooting range in active use, water quality is analysed for shooting range pollutants from the nearest body of water into which runoff water from the shooting range area is discharged. We recommend performing the analysis by calculating an annual average from the results of samples taken once a month during unfrozen water. In larger bodies of water, where seasonal variations after mixing are minor, an individual sample can be used. The samples should be taken after sufficient mixing, i.e. not in the immediate vicinity of the discharge point.

The sample must be taken from below the surface without disturbing the bottom silt. We recommend taking the sample directly to a flask specified by the laboratory. Close the flask tightly immediately after sampling. In order to minimise the possibility for errors, the samples should be taken by an expert in the field.

The samples are analysed for the total concentrations and soluble concentrations of lead, copper, zinc, and antimony, and at ranges that operated prior to 1960, nickel, and at shotgun ranges, arsenic. The sample can also be analysed for its pH, oxygen content and organic matter concentration.

When interpreting the results, any other metal load to which the body of water is subjected should be taken into consideration. In situations where metal load is detected in the body of water (e.g. lead), but the cause of the load is unclear, the share of the load caused by the shooting range should be assessed based on the emission study.

F6.3.2 Determining the acceptable emission level

According to Government Decree 1022/2006, pollutant concentration in surface waters may not exceed the environmental quality norm set for it. In this context, surface waters refer to a body of water as defined in the Water Act (587/2011), or a pond, river, brook or other natural waterway, and a reservoir, channel or other corresponding artificial waterway. A rivulet is not considered to be a body of water; it refers to a watercourse that is smaller than a brook, has a drainage basin that is less than ten square kilometres in size, and in which water does not constantly flow and fish passage is not possible to any significant extent, or a ditch.

According to Government Decree 1022/2006, the environmental quality norm set for the lead concentration of surface waters is 7.2 µg/l as an annual average (= the arithmetic mean of the measured results of each individual, representative monitoring point over one year). Should the operator so request, the environmental permit may also specifically lay down provisions on a mixing zone, where the pollutant concentration(s) may exceed the environmental quality norm defined in the section in question, if the rest of the surface water body conforms to the norms in question. The size of the mixing zone is limited in the environmental permit to the vicinity of

the emission source so that it is in correct ratio with regard to the pollutant concentrations at the emission source, and that the general principles laid down in Section 4 of the Environmental Protection Act applied to operations causing an environmental contamination hazard are followed.

If no mixing zone has been defined, the primary goal of the risk management can be considered to be that the lead concentration of the surface water discharged from the shooting range area into the receiving body of water at the point of discharge does not exceed the environmental quality norm (7.2 µg/l as an annual average at the sampling points of the body of water). According to Government Decree 1022/2006, compliance with the environmental quality norm is monitored in the body of water only after a sufficient amount of mixing, which means that discharging water that meets the environmental quality norm into the body of water cannot significantly deteriorate its state.

The maximum acceptable lead concentration in the water discharged from the shooting range can then be estimated, for example, by dividing the environmental quality norm by the ratio of the surface areas of the shooting range area and the drainage basin of the ditch leading from the range to the body of water (mixing factor).

Example:

The drainage basin of a ditch leading from the shooting range to the body of water is 10 ha, or 100,000 m². The total surface area of the shooting ranges is 20,000 m². The mixing factor is then 0.2 and the acceptable emission level from the range area comes to 36 µg/l (= 7.2 µg/l /0.2). Due to the mixing taking place in the ditch, the average concentration in the ditch water discharging from the range area to the body of water will not exceed the environmental quality norm for lead at the discharge point.

Lead acts as the primary indicator for the pollutant emissions from shooting ranges. With regard to other metals, the acceptable emission level can be determined, if necessary, based on a risk assessment during a more detailed analysis. An environmental quality norm has been defined for nickel (20 µg/l as an annual average), but limit values have not been set for other metals present at shooting ranges. Nickel may be present at old shooting ranges.

F6.4 Groundwater analyses

As a rule, there is no cause for groundwater analyses more extensive than the preliminary study in a basic-level study. In accordance with the classification of the required studies, sites studied at the basic level are not located in a classified groundwater area, and there are no household water wells in their vicinity.

F7 Expanded studies

F7.1 Expanded surface water studies

F7.1.1 Sediment sampling

During an expanded surface water study, the pollutant concentrations in the sediment in sedimentation areas of drainage ditches departing the shooting ranges and the receiving body of water should also be analysed.

The sample taken from a drainage ditch is compiled as a composite of around 30 incremental samples from the channel's end closest to the shooting range, representing a distance of around 10 metres. Additionally, corresponding composite samples comprising around 30 incremental samples, representing a distance of 10 metres, are taken from further along the channel, for instance at distances of around 50–100 metres and 200–500 metres, in order to determine the migration rate.

Samples are taken from the bottom sediment of the receiving body of water using the same method where the drainage ditch meets the body of water, within a radius of around 10 metres of the discharge point. If necessary, additional samples can be taken from further away. When interpreting the results, any other metal load to which the body of water is subjected should be taken into consideration. In situations where metal load is detected in the sediment (e.g. lead), but the cause of the load is unclear, the share of the load caused by the shooting range should be assessed based on the emission study.

The sediment must be analysed for, at least, lead, copper, zinc, antimony and, at ranges that operated prior to 1960, nickel. At shotgun ranges, arsenic concentrations must also be analysed.

F7.2 Groundwater analyses

The objective of the groundwater analyses is to produce the necessary data on the groundwater flow field and quality in the shooting range area and its vicinity, and assess the long-term groundwater risks caused by the operations.

In addition to the groundwater flow field and quality analyses, the magnitude and acceptability of the load to which the groundwater is subjected (sections F7.2.3 and F7.2.4). This procedure is justified particularly in situations where the shooting range operations or groundwater conditions suggest an elevated groundwater risk, but sufficient information cannot be obtained on the risk level through other analyses. Such particular risk factors could include the closeness of a groundwater water abstraction facility, extensive operations that have continued for a long time, particularly favourable soil conditions for pollutant solubility and migration, etc. The assessment of an acceptable pollutant load level may also be necessary during risk management planning when you wish to determine what kind of water can be safely infiltrated into the ground.

F7.2.1 Determining the groundwater flow conditions

The groundwater flow field can be determined with groundwater level measurements performed from observation wells (usually at least three observation points), or with the help of an expert through map analysis or geophysical methods, for example.

The locations of the groundwater observation wells in the study area are checked, and their water levels measured even if no samples are taken. The data is collected on observation point cards. If there is an insufficient number of observation wells for determining the groundwater quality both upstream and downstream of the site, a sufficient number of observation wells are installed. The purpose of the installation of permanent observation wells is that they will later act as monitoring points for the operations.

The groundwater observation wells are installed according to the principle shown in Figure F.2.

If there are perched groundwater layers in the area, or the conditions support the presence of perched groundwater, the installation of the observation wells must be planned separately in connection with the study plan, taking the sample-taking from the correct groundwater layer into account.

The locations of the groundwater observation wells and the elevations of the pipe end and ground level are measured during the installation of the wells. Groundwater observation well cards are drawn up based on this data; they must include at least the following information:

- Observation well name
- Observation well location (coordinates and coordinate system)
- Installation date
- Observation well installer

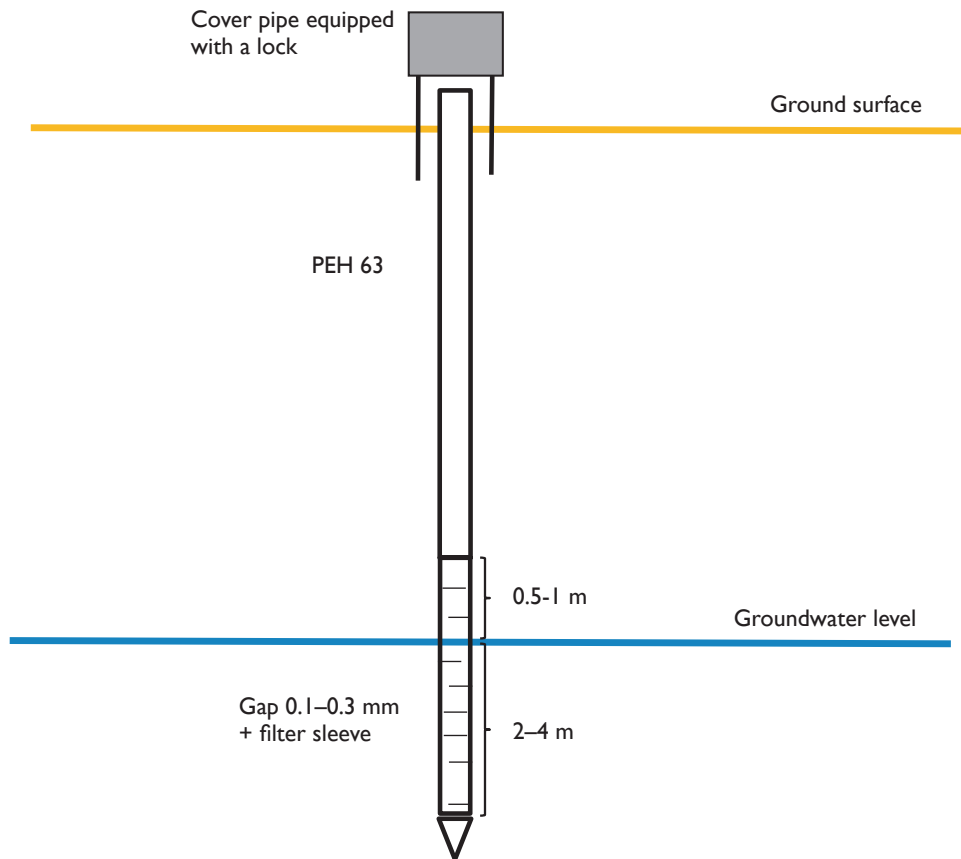


Figure F2. Drawing of the principle of installing a groundwater observation well

- Observation well end height from ground level and the vertical reference system
- Ground elevation and the vertical reference system
- Length of the sieve section
- Sieve type
- Total length of observation well
- Observation well material and diameter
- Water level at time of installation and the vertical reference system
- Is the observation well locked? With what key? Who has the key?

F7.2.2 Groundwater quality analyses

For the purpose of determining the groundwater quality, water samples are taken either from the observation wells or other wells located in the area. Both a reference sample and a sample or samples representing the possible impact of the operations must always be taken from the area. The reference sample is taken from upstream of the shooting range. The sample(s) representing the impact of the operations must be taken from downstream of the shooting range, preferably from a groundwater observation well in good condition.

Groundwater samples should be taken using a pump whenever possible. Water is pumped from the observation well at an even flow (usually 5 l/min or less) until the water runs clear, or at least 3 x the pipe volume of water has been pumped from the pipe. The samples should be as clear water as possible, avoiding solids, because the objective is to analyse the concentrations of dissolved metals. Metals migrate via groundwater mainly in soluble form.

If the water is turbid and there are fines in the soil, we recommend taking the sample using the low flow sampling method². The sample can also be filtered in order to remove the fines. We recommend performing the filtering in the field immediately after sampling so that precipitation or dissolving does not have time to occur should the conditions change. However, if the circumstances require, it can also be done at the laboratory. The filtering is performed using a 0.45 µm filter. We also recommend measuring the pH in field conditions.

It is important to note the danger of contamination during groundwater sampling. You can avoid contamination by using clean sampling equipment and clean sampling containers supplied by the laboratory. Perform sampling from the point assumed to be the cleanest towards the more contaminated points, i.e., take the reference sample first. If necessary, the sampling equipment is washed between the different sampling points.

Parameters analysed from the groundwater at shooting ranges include at least lead, antimony, copper, zinc, oxygen and pH. Furthermore, at ranges that were in operation prior to 1960, the nickel concentration must be analysed. At shotgun ranges, arsenic concentrations must also be analysed.

F7.2.3 Assessing the pollutant load on groundwater

The primary goal of groundwater quality protection in accordance with the groundwater contamination prohibition laid down in the Environmental Protection Act is to safeguard the use of the groundwater as a household water supply. Based on this goal, it is justifiable to use the quality requirements for household water as the goal for groundwater quality (Government Decree 461/2000; Pb 10 µg/l, Ni 20 µg/l, and Cu 2 mg/l).

Environmental quality norms have also been defined for groundwater under an EU Directive, presented in Decree 1040/2006 (Pb 5 µg/l, Sb 2.5 µg/l, Cu 20 µg/l, Ni 10 µg/l, and As 5 µg/l). With regard to metals present at shooting ranges, the quality norms are stricter than the quality requirements for household water. The quality norm has been primarily drafted to direct the work of the authorities, but on the other hand, these norms can also be adapted when estimating the acceptable pollutant concentration of groundwater at the shooting range. Indeed, before performing the analyses, we recommend agreeing with the local ELY Centre on what quality criteria shall be applied to the groundwater. One option could be that household water limit values are applied at the range area, while the environmental quality norms are applied outside the range area. The site-specific conditions such as groundwater utilisation and the cycle period of the aquifer can also steer the selection of the quality criteria so that, as a rule, the household water quality requirements are applied, but at particularly sensitive sites, stricter environmental protection measures may be required.

The acceptable pollutant load on groundwater can be determined using the mixing factor as follows:

The site-specific mixing factor can be determined based on the conditions at the shooting range. The most important variables in the determination of the mixing factor are the length of the area in the direction of groundwater flow, and the amount of water absorbed from the precipitation. The mixing factor is calculated based on the following formula:

$$DF = \frac{L_{gw} \times I}{v_{gw} \times d_{mix} + (L_{gw} + x) \times I}$$

² Low flow sampling is a method developed by the US EPA for groundwater sampling. For more information, see <http://www.epa.gov/region1/lab/qa/pdfs/EQASOP-GW001.pdf> (26 June 2013)

Where

- DF is the mixing factor
- L_{gw} is the length of the area with pollutant concentration in the direction of groundwater flow in metres (m)
- I is the amount of water infiltrating into the groundwater in metres per year (m/a) (generally 0.2–0.3 m/a)
- vgw is the groundwater flow; 1 m/d or 365 m/a is usually used as the value if there is no measurement data from the site
- d_{mix} is the mixing layer at the surface part of the groundwater; 1 m is always used as this value
- x is the distance to the monitoring point; 0 m is usually used as this value.

When the predefined values are entered into the formula, it can be presented as follows:

$$DF = \frac{L_{gw} \times I}{365 + L_{gw} \times I}$$

If no data is available to perform the calculation, you can use the value 0.1 as the mixing factor, which is a conservative value.

The acceptable concentration in the percolating water at the range area, or the pollutant concentration in the water percolating into the groundwater, can be obtained by dividing the safe groundwater concentration for the substance in question (usually the household water limit value or the environmental quality norm) by the mixing factor. The result can be used as a reference value, for example, during risk management planning, when estimating the quality of water that can be safely absorbed into the ground. The acceptable pollutant concentrations in percolating water are not intended to be used as limit values in such a manner that a measurement above the limit value would trigger an immediate need for remediation.

F7.2.4 Analysis of percolating water and the soil beneath the range structure

The quality of water percolating in the shooting range area and the status of the soil beneath the range structure can be analysed using three alternative methods, if necessary: with a lysimeter, solubility test, or soil sampling. Of these three, the lysimeter test is the most reliable and can therefore be recommended, although it usually takes one year. If results are needed sooner, solubility tests can be used in laboratory conditions to determine how much pollutants dissolve from the soil in specific conditions. These results do not directly represent the quality of the percolating water, but they can help the assessment of the magnitude of migration via pore water. Analysis of the soil beneath the range structures provides information on the retention of pollutants contained by the percolating water in the soil beneath the range structures. The quality of the percolating water cannot be assessed based on the soil samples, but they can often be used to get a rough idea of the extent and time frame of pollutant migration. The following describes the analyses in question.

F7.2.4.1 Percolating water quality analysis with a lysimeter

A lysimeter is a simple device into which representative soil samples are collected from the area being analysed. For the analysis, define an area with sufficiently homogeneous conditions and pollutant load and install the lysimeter to analyse its condition. Leave the device in place for a period of 3 to 12 months, for example. We recommend installing the lysimeter for a period of 12 months, as the groundwater reference value is considered as an annual average.

Rain and meltwater infiltrate the collection container through the collected soil sample. After the testing period ends, a sample is taken from the percolated water, and the required analyses are made on the sample (e.g. Pb, Sb, Cu). Samples can also be taken during the duration of the test, if you wish to monitor how the situation develops. We recommend filtering the water sample, as fines may be flushed into the collection container from the soil sample, skewing the results of the analysis. In addition to easy installation, the lysimeter has the added benefit of it allowing you to directly determine the amount of percolating water absorbed into the ground in the area. The amount of percolating water is used in the determination of the groundwater mixing factor (formula I).

A lysimeter can be used to study the percolating water quality in the entire range area and, if necessary, also in subareas (backstop berm, the front of the firing stands, etc.). The study areas should be selected so that they correspond to the subareas selected in the determination of the mixing factor.

Carried out as described above, the lysimeter test usually overestimates the amount of pollutants in the percolating water. Dissolving is usually greater in a disturbed sample than in an undisturbed one, and the test does not take into consideration pollutant retention in the soil layers beneath the analysed layer.

F7.2.4.2 Percolating water quality analysis with solubility tests

The quality of the percolating water can also be analysed using solubility tests on a soil sample. Solubility tests are performed by, for example, environmental laboratories. A solubility test can also be used to determine the soil sample's eligibility for landfill disposal. The eligibility for landfill disposal must often be proven, if contaminated soil is delivered to reception facilities during soil remediation.

When the quality of the percolating water is analysed using solubility tests, you should separately define the study area(s) for which you wish to determine the quality of the percolating water. A representative composite sample is taken from each study area for the solubility test. For interpreting the results, you also need to estimate the amount of percolating water formed in each study area. The amount of infiltrating water can vary due to surface inclination, soil type, and plant cover, for example, due to which the amount of percolating water should be determined with site-specific measurements.

F7.2.4.3 Analysis of the quality of soil beneath the range structure

The migration of metals (Pb, Cu, Sb, Ni) from the range area to the soil can also be determined by taking soil samples from beneath the range structure. When taking the soil sample, particular attention must be paid to its representativeness. A single sample will not give a comprehensive picture of the situation at the entire range, which is why we recommend collecting several samples from a separately defined depth in the studied area. Samples from each study area can be combined into a single composite sample and analysed to determine the average metal concentrations in the studied area. By using several vertical sample sets, you can also obtain an assessment on the depthwise migration of pollutants depicting the actual conditions.

Taking soil samples from beneath the range structure usually requires the use of a coring machine. The sample must be taken by coring through a range structure containing metals, which may cause contamination. The soil sampling should therefore be planned and implemented with care. The amount of water absorbed in the area also cannot be determined based on the soil samples, but estimates can be made of the amount of absorbed water with the help of soil type observations, or the amount of percolating water can be determined by site-specific measurements.

F8 Assessment of the need for pollutant management

In order to guarantee the transparency of the conclusions and the uniformity of the studies, the environmental risk caused by the operations should also be described both in writing and numerically in accordance with the scoring system created for this purpose (see Appendix F_1).

The emission potential (load), surface water risk, and groundwater risk are scored and described separately. The report presents the score for each aspect, justification for the score, and the total score for each section. The risk assessment of small pistol and rifle ranges is performed based on the preliminary study data; study data is used for other sites. The scoring is applied in the assessment of the need for pollutant management in accordance with Table 6.3 of the BAT report. The need for pollutant management as a risk level in accordance with the BAT report and recommendations for the risk management methods are presented as the conclusion of the assessment.

In expanded studies, the justifications of the assessment of environmental risks can concentrate on the parts of the environment considered to be subjected to a significant risk.

F9 Reporting

The preliminary study data, all analyses made, and the conclusions drawn based on them on the emissions, their impact and risk, and the requirement level for their management are reported. Particular attention should be paid to the assessment of the analysis results, uncertainties, and the significance of the results being meticulously justified. The key purpose of the studies is to assess the significance of environmental contamination or the risk thereof, and to assess what measures need to be taken in order to manage the contamination risk, taking the reasonableness principle into consideration.

The report can be attached to the environmental permit application, or it can be delivered to the environmental authorities as a separate report.

The report must present at least the following:

- Initial data
- Objectives of the study
- Description of the environmental conditions
- Descriptions of sampling and observations made in the area
- Results of the analyses and assessments. The results should be described as clearly as possible, presented in tables, drawings and maps.
- Environmental risk assessment
- a written description of the key environmental impacts and risks caused by the operations, their possible effects, and their significance
- scoring, including justifications
- Conclusions commenting on at least the following:
 - comprehensiveness and sufficiency of the analyses
 - The need for and targeting of risk management, i.e. the risk level as per the BAT report
 - techniques and practices suitable for the site
 - the need for and targeting of environmental monitoring
 - any other need for measures.
- Justified uncertainties with regard to both the analyses and the risk assessment.

APPENDIX F_1

Scoring system for the pollutant emission risk level. The emission potential (load), surface water risk, and groundwater risk are scored separately.

EMISSION POTENTIAL			
Risk factor	Score	Scoring criteria	Notes
Lead amount in range structures L	0	< 5 t Pb	
	1	5–50 t Pb	
	2	50–100t Pb	
	3	> 100 t Pb	
Range age I	0	0	New range
	1	1–20 yrs	
	2	20–50 yrs	
	3	> 50 yrs	
Extent of loaded area: number of pistol and rifle lanes K	1	1–2	
	2	3–5	
	3	> 5	
Additionally, for shotgun ranges	1 ... x	One additional point for every shotgun range located in the range area	
Pollutant load total	L+I+K		
Max.	9 + number of shotgun ranges		

Significance of the emission potential

Low 1–4 points

Moderate 5–8 points

High > 9 points

SURFACE WATER RISK			
Risk factor	Score	Scoring criteria	Notes
Soil water permeability K	0	Water-permeable	E.g. Sand, gravel, sand moraine
	1	Somewhat water-permeable	E.g. Silty sand
	2	Water retentive	E.g. Clay, fine-grained till
	3	Swamp, wetland	
Mixing factor in the ditch departing from the range area SK	0	< 0.01	
	1	0.01–0.1	
	2	0.1–0.25	
	3	> 0.25	
Current situation, pollutant concentrations in the surface water and sediment N	0	No detectable impact	Pollutants from shooting activities in the vicinity of the range area
	1	Slightly elevated from natural state, local impact	As a rule, natural state refers to the background concentrations in each area
	4	Clearly elevated from natural state and/or impact evident over a wider area	
	6	Pollutant concentration of the sediment impacts the use of the water body, or the environmental quality norm of the surface water is exceeded in the water body receiving water from the range area's ditch	
Severity of the consequences of risk realisation S	0	Presumably no significant impact	E.g. pollutants accumulate over time locally in the bottom sediment of the ditches leading away from the range area
	1	Limited impact possible	Impact local and minor or manageable
	4	Serious impact possible	Local impact on special natural values or species or the use of surface water, for example
	6	Extremely serious impact possible	Wider than local impact on special natural values or species or the use of surface water, for example
Surface water risk total	K+SK+N+S		
Max.	18		

Significance of the surface water risk

Low 0–9 points

Moderate 9–14 points

High >14 points or N>4

GROUNDWATER RISK			
Risk factor	Score	Scoring criteria	Notes
Soil water permeability K	0	Poor water permeability or swamp	E.g. Clay, silt, fine-grained till, swamp
	1	Somewhat water-permeable	E.g. Silty sand
	2	Water-permeable	E.g. Fine sand, sand moraine
	3	High water permeability	Coarse sand, gravel
Distance to groundwater level E	1	>10 m	
	2	4-10 m	
	3	<4 m	
Current situation, pollutant concentration in soil, percolating water and groundwater N	0	Pollutant concentrations from shooting activities are limited to the shooting range structures, percolating water concentrations at acceptable levels, no detectable impact on groundwater	
	1	Elevated pollutant concentrations in the soil beneath the shooting range, percolating water concentrations at acceptable levels or slightly elevated, no detectable impact on groundwater	
	4	Pollutant concentrations exceeding the background concentrations detectable in groundwater, percolating water concentrations above acceptable level, or pollutants have migrated deep into the soil	
	6	Pollutant concentrations in groundwater exceed the reference values set for household or groundwater quality	Presupposing that the background concentrations are below the norms in question
Severity of the consequences of risk realisation S	0	Presumably no significant impact	E.g. site is not located in a classified groundwater area, soil or groundwater contamination is limited to the immediate vicinity of the site, groundwater is not used, and its future use is unlikely
	1	Limited impact possible	E.g. impact local and minor or manageable
	4	Serious impact possible	E.g. jeopardises the use of groundwater from household water wells
	6	Extremely serious impact possible	E.g. jeopardises the use of a significant water abstraction facility or other important site
Groundwater risk total	K+E+N+S		
Max.	18		

Significance of the groundwater risk
 Low 0–9 points
 Moderate 9–14 points
 High >14 points or N>4

APPENDIX G. Emission and impact monitoring of shooting range pollutants. Design guide

G1 Introduction

As a rule, the environmental permits for shooting ranges require monitoring of the pollutant emissions from the operations and their impact. Shooting activities may cause metal load either to groundwater or surface water, or both, depending on the conditions in the area and the nature of the operations. The objective of emission and impact monitoring is to ensure the environmental safety of the operations and preventing any harm. A systematic, purposeful and correctly targeted monitoring is a cost-effective way of producing the necessary information on the environmental impact of the operations.

Designing the monitoring is based on the assessed environmental impact of the shooting range, their targeting, and the implemented management measures. The initial data used can be the assessment of the need for pollutant management at a shooting range, and the measures planned or implemented based on it, or equivalent data. Guidelines for the assessment procedure for the need for pollutant management can be found in Appendix F of the Management of the environmental impact of shooting ranges – Best Available Techniques report (the Shooting Range BAT). The guidelines describe the principles of preparing the monitoring plan, implementing the monitoring, and reporting. The guidelines have been prepared in connection with the Shooting Range BAT report, and are included in the report in question as Appendix G. These guidelines are intended for practitioners of shooting range activities, the authorities processing environmental permits, and the experts performing environmental analyses on shooting ranges.

G2 Objectives of the monitoring

The objective of the monitoring is to observe the pollutant load from the shooting range, emissions beyond the range area, and any environmental impacts. The monitoring is targeted at those aspects of the environment that could be subjected to possible impacts based on the conditions in the area. Metal load on the range structures is monitored primarily through the monitoring of the number of shots fired. Emissions beyond the area and the environmental impact of the operations are observed by monitoring the quality of the surface water discharged from the shooting range area, sediment in the ditches, the receiving body of water, the groundwater, and, if necessary, the generated percolating water. The monitoring is used to determine both the level of the pollutant load and the changes taking place in the environment as a result of the operations. The effectiveness of the risk management measures, acceptability of the load, and the need for any further measures are assessed based on the results.

The site-specific objectives of the monitoring are defined during the planning of the monitoring and recorded on the monitoring plan and the reports prepared based on the results.

G3 Monitoring plan

A plan is prepared for the monitoring, taking into consideration the conditions and special characteristics of the operations at the shooting range in question. In practice, the planning is based on the results of the assessment of the need for pollutant management, if one has been carried out, the implemented protective measures, prior monitoring results, and any other studies and reports made in the area. A proposal

of the principles and objectives of the monitoring is attached to the environmental permit application, or an application to revise an environmental permit.

The monitoring plan presents the monitored sites and points, including their selection criteria, sampling instructions, and the monitoring cycle. Reporting is also described. The acceptable pollutant load from the range area to the environment has been defined during the assessment of the need for pollutant management. If the assessment has not been carried out, the monitoring plan can specify a site-specific, acceptable pollutant load for the surface water or groundwater. For instructions on how to define the acceptable pollutant load, see Appendix F of the Shooting Range BAT report.

We recommend preparing the monitoring plan in cooperation with the authorities. The plan should also be submitted to the supervising authority for approval before beginning the monitoring, if the monitoring is not planned in connection with applying for an environmental permit or its revision.

The planning and implementation of the monitoring, and the reporting, must use a sufficient amount of expertise in the environmental field. The sample takers must be certified or otherwise experienced professionals in the field.

G4 Monitoring of the use

Pollutant accumulation in the shooting range structures and, through that, the pollutant load potential, are monitored by keeping track of the number of shots. The number of shots is tracked lane-specifically on an annual level. When possible, the number of shots is tracked by firearm and cartridge type; at the minimum level, shots fired are tracked separately for shotguns, and pistols and rifles. The use of special cartridges containing non-standard materials (particularly if they contain substances causing a pollutant load other than lead, antimony, zinc, copper and arsenic) is recorded. The opening hours of the range are also monitored.

G5 Surface water monitoring

G5.1 Need for monitoring

Pollutant load to surface waters is caused particularly in areas where the soil has poor water permeability, and the rainwater is not absorbed into the ground. The surface runoff from the range area is collected into ditches and directed to the closest body of water via a system of ditches. Clean runoff water from the surrounding areas is usually directed around the range area via a system of ditches.

The Government Decree on Substances Dangerous and Harmful to the Aquatic Environment (1022/2006) stipulate the following on the surface water monitoring requirements:

Section 7 Operators of activities subject to an environmental permit must carry out monitoring of the surface water to which substances referred to in paragraph C of Annex 1 are discharged or leached. Operators of activities subject to an environmental permit must carry out monitoring of surface water to which significant amounts of substances referred to in paragraph D of Annex 1 are discharged or leached. The surface water is monitored as concentration in the water, sediment, or biota as stipulated hereinafter.

The pollutants from shooting operations listed in paragraph C of Annex 1 are lead and nickel. The decree is applied in accordance to its Section 2 to water bodies, rivulets, ditches and groundwater referred to in the Water Act (587/2011), and Finland's territorial waters and economic area. The surface water impact from shooting range operations must thus be monitored practically every time when the amount of surface

runoff generated in the range area and discharged into the environment is greater than minor.

The operator is obligated to be aware of the environmental impact of the operations. Other pollutants from shooting ranges in addition to lead and nickel have proven environmental impacts, so their emissions and impact must be monitored as well.

G5.2 Sampling frequency

The Government Decree on Substances Dangerous and Harmful to the Aquatic Environment (1022/2006) defines a generally sufficient sampling frequency as follows:

Section 9 The frequency and timing of surface water monitoring shall be chosen so as to achieve an acceptable level of confidence and precision. The impacts of both nature and human operations on surface water must be taken into consideration when deciding on the frequency of monitoring. The impact of natural seasonal variation on results shall be minimised.

Substances referred to in paragraph C of Annex 1 must be monitored once a month as a concentration in water, no less than 12 times a year. Substances referred to in paragraph C of Annex 1 for which a quality norm in the biota or sediment has been specified must be monitored in the sediment or the biota no less than once per year. In such cases, these substances do not need to be monitored as concentrations in water in order to verify compliance with the environmental quality norm. Substances referred to in paragraph D of Annex 1 must be monitored at three-month intervals as a concentration in water, no less than four times a year. (7.10.2010/868)

The frequency of monitoring referred to in subsection 2 above can be altered if it is justifiable on the basis of changed circumstances, technical knowledge or expert assessment.

As per the decree, the monitoring frequency required for lead and nickel is once per month. However, the decree allows for alteration of the monitoring frequency when it is justifiable. The load caused by shooting ranges is not sudden, and annual changes are not large, regardless of the cumulative nature of the load, unless significant changes in the operations take place. Based on this, we propose a monitoring cycle comprising annual average monitoring that takes seasonal changes into consideration at intervals of one to six years, depending on the sensitivity of the nature. If, according to the need for the pollutant management report, the load is targeted at sensitive water bodies, and the risk level as per Table 6.3 of the BAT report is 3, or extremely demanding, the suitable sampling frequency is one to 6 years, depending on the protective measures implemented at the site. If the surface water risk is reasonable, or the risk level is 2A, sampling can be carried out at intervals of three to six years. At risk level 1 sites, the need for and frequency of monitoring is determined site-specifically based on whether surface runoff with metal content is estimated to migrate into surface waters.

G5.3 Selection of the monitoring points and sampling

The Government Decree on Substances Dangerous and Harmful to the Aquatic Environment (1022/2006) stipulates the following on the monitoring points:

Section 8 The number of surface water monitoring sites must be sufficient in order to allow an assessment of the magnitude and impact of the emission or leaching on the status of surface water and to observe the consequences of measures set forth in the programme of measures referred to in section 12 of the Water Management Act on the status of waters. Provisions on monitoring sites are given in the monitoring regulations referred to in section 46 of the Environmental Protection Act.

Monitoring sites in order to verify compliance with environmental quality standards are to be located so that the emission or leaching is mixed with surface water to a sufficient extent. As necessary, the provisions of Section 6 b on the determination of the mixing zone must be taken into consideration when the monitoring sites are located. (7.10.2010/868)

Monitoring sites in order to verify compliance with environmental quality standards are to be located so that the emission or leaching is mixed with surface water to a sufficient extent.

Monitoring sites of surface water intended for the preparation of drinking water are to be placed in a part of surface water significant to water abstraction.

The magnitude of the emissions leached from the range area into the environment is monitored from the water discharged from the range area into the main ditch leading to a water body. The observations are then compared with the site-specifically determined acceptable emission level. If the water body receiving the water from the range area is located at such a distance from the shooting range that pollutants can reasonably be assumed to migrate into it, the water body also needs to be monitored. The purpose of the monitoring of the receiving water body is to verify conformance with the environmental quality norm. Furthermore, for the interpretation of the results, we also recommend measuring the regional background concentration from a location that is as representative as possible.

In order to determine the annual average, sampling is performed either as individual sampling 8 to 10 times per year in order to level out seasonal variance, or with regard to flowing water, using passive sample collectors suitable for the monitoring of metals.

Sampling is carried out when the water is unfrozen and flowing. Individual samples should be taken from ditch water from the centre of the channel, or a water body after sufficient mixing, from underneath the surface without disturbing the bottom silt. We recommend taking the sample directly into a flask specified by the laboratory. Close the flask tightly immediately after sampling. In order to minimise sampling-related errors, the sample taker should be an expert or someone who has been sufficiently familiarised with the task. When samples are taken from flowing water, the flow at the sampling point is measured for the interpretation of the results.

The results of individual samples are not handled separately; an arithmetic annual average is formed of them and compared with the acceptable pollutant load determined during the assessment of the need for pollutant management or in the monitoring plan, or, in the case of a water body, the environmental quality norm. If a reliable or representative arithmetic average of the concentration in the main ditch of the shooting range area cannot be determined for some reason, you must assess whether the reliability of the result can be improved by using a flow weighted average.

There are dozens of different commercial models of passive sample collectors used in flowing water analyses, several of which are suitable for use in the monitoring of metal concentrations. When choosing a passive collector, you should check, for example, that it supports the analysis of shooting range metals (lead, antimony, copper, zinc) and that it gives results that are sufficiently accurate. The passive sample collector must be allowed to stay in the water for a sufficiently long time in accordance with the manufacturer's instructions, e.g. 4 weeks, 3 months or 8 months, depending on the type of collector. The idea of the passive sample collector is to compile an average concentration over the entire sampling period, evening out any temporary variations in the flow and concentration. A passive sample collector allows the monitoring to be carried out either by installing several short-term collectors over the year, or one long-term collector to compile the annual average for the period during which the water is unfrozen. You can install a stand for the passive collector in a suitable

location in the channel, making it easy and quick to install and remove by just about anybody. The use of a passive collector allows the operator to participate in taking the samples, if the installation does not require special expertise (e.g. when a stand is used). When the passive collector is installed removed, the flow in the channel can also be measured for the interpretation of the results.

G5.4 Sediment sampling

In order to complement surface water sampling, particularly if pollutants are found to migrate bound to solids to a significant degree, you can take sediment samples from a main ditch or the target water body in order to determine the extent of the impact area and the need for measures. Determining the sedimentation areas of the channel is recommended for planning the sediment sampling, but this is often challenging. Sediment samples are not taken from a rocky bottom, only from soft matter. Sediment sampling is carried out at three-year intervals, or more seldom based on the results when justifiable. The samples can be taken, for example, in connection with surface water sampling. Based on the length of the channel, the samples are taken from two or three different areas, for example, from the border of the range area, at a distance of 50–100 m, and at a distance of 200–500 m. The samples are taken in a representative manner from a previously defined sampling area (for example, a 10 m long area in the channel), represented by a composite sample of at least 30 incremental samples taken evenly. The samples are taken from the surface layer of the sediment and immediately stored in a jar in accordance with the laboratory's instructions. If the target water body is particularly sensitive, sediment samples can be taken in a similar manner in bands from around the discharge point of the shooting range area's main ditch.

G5.5 Analyses

In a laboratory, both the surface water samples and sediment samples are analysed for at least the metals causing a pollutant load on surface water typical to shooting ranges, i.e. lead, antimony, copper and zinc, and also the arsenic concentration, if there is a shotgun range at the range area. Furthermore, at ranges that were in operation prior to 1960, the nickel concentration must be analysed. In order to improve the interpretation of the results, we also recommend analysing the water samples for pH, turbidity, and organic matter concentration, and the sediment samples for the organic matter and clay matter concentrations.

The metal concentrations of the water samples are analysed as both total concentrations and soluble concentrations (0.45 µm filter). The soluble concentrations are used as the reference values for the acceptability of the emission and conformance with the environmental quality norm. The total concentration gives information on the migration vector of the metals at the site, and the results can be used in assessing the pollutant load on the sediment.

G6 Groundwater monitoring

G6.1 Need for monitoring

There are no corresponding legal provisions on the need to monitor groundwater as there are for surface water. When a shooting range is located in a classified groundwater area, or there is a well in its vicinity that is in household water use and subjected to groundwater flow from the shooting range area based on the risk management study, groundwater monitoring is, as a rule, necessary, if the range's risk level as per the BAT report is 2b (moderate groundwater risk) or 3 (high groundwater risk). At risk level 1 (low groundwater risk) sites, the need for monitoring is determined site-specifically.

G6.2 Implementing the monitoring and sampling

Groundwater monitoring is mainly implemented by monitoring the impact of the operations on the aquifer using observation wells and inspection wells. Additionally, or alternatively, the pollutant load on groundwater can be monitored using a fixed or temporary lysimeter. At sites with a groundwater protection structure that collects, directs, or treats percolating water, the quality of water absorbed into the ground or discharged into a water body from the protective structure is monitored. The applicable monitoring is determined on a case-by-case basis, for example, based on the conditions at the site and the existing structures.

Lysimeter monitoring has the benefit of enabling the detection of a risk to groundwater and the assessment of its significance already before the emissions have migrated into the groundwater. The method is particularly recommended for use at high-risk sites. Monitoring via groundwater observation wells shows a rising trend when metals have already migrated into the groundwater. Monitoring using observation wells is simple to implement and matches its purpose in the sense that it can be used to track conformance with the environmental quality norms in the aquifer. Observation well monitoring is usually sufficient for low and moderate risk sites.

G6.3.1 *Monitoring with groundwater observation wells*

The metal concentrations in the groundwater are monitored from a observation well installed downstream of the groundwater flow, in the immediate vicinity of the range area, or from a network of observation wells installed more extensively in the area. The locations and number of observation points depend on the groundwater conditions and the use of the groundwater. The observation point network is planned site-specifically.

It is important for the reliability of the monitoring that the groundwater flow characteristics at the site are known sufficiently well. Taking a background concentration reference sample in each monitoring cycle is not necessary after the assessment of the need for pollutant management has been completed, because the purpose of the monitoring is to track the range area's long-term local impact on groundwater. Reference samples can, however, be utilised case-specifically to obtain information on pollutant load coming from outside the range area.

Groundwater samples should be taken using a pump whenever possible. Water is pumped from the observation well at an even flow (usually 5 l/min or less) until the water runs clear, or at least 3 x pipe volume of water has been pumped from the pipe. The samples should be as clear water as possible, avoiding solids, because the objective is to analyse the concentrations of dissolved metals. Metals migrate via groundwater mainly in soluble form.

If the water is turbid and there are fines in the soil, we recommend taking the sample using the low flow sampling method. The sample can also be filtered in order to remove the fines. We recommend performing the filtering in the field immediately after sampling so that precipitation or dissolving does not have time to occur should the conditions change; however, if the circumstances require, it can also be done at the laboratory. The filtering is performed using a 0.45 µm filter. We also recommend measuring the pH in field conditions.

It is important to note the danger of contamination during groundwater sampling. You can avoid contamination by using clean sampling equipment and clean sampling containers supplied by the laboratory.

The groundwater monitoring cycle is proportioned to the risk level and the implemented risk management measures. However, the monitoring cycle must be sufficient for detecting a possible rising trend. A suitable monitoring interval could be, for instance, one to three years. The sampling time is not highly significant, but a good time

for sampling, taking into consideration the absorption of meltwater into the ground and the weather conditions, could be between May and September.

G6.3.2 *Lysimeter monitoring*

A lysimeter can be used to monitor the concentrations in the percolating water formed in the target area of the shooting range or other area subjected to pollutant load and to compare them with the acceptable load determined during the assessment of the need for pollutant management or the preparation of the monitoring plan.

A lysimeter is a simple device into which a representative soil sample (as undisturbed as possible) is collected from the area being analysed. The device is left in the range area or its vicinity. However, the rainfall in the area should match that in the range area. Rain and meltwater infiltrate the collection container through the collected soil sample. Alternatively, the device can be permanently installed at the monitored site (e.g. backstop berm) so that sample collection from the collection container is possible.

At its simplest, a lysimeter comprises two containers, the upper of which is filled with the soil sample being analysed, and the lower collecting the percolating water from which samples are then taken. The bottom of the upper container must be perforated so that the percolating water flowing through the soil can flow into the lower sampling container. See Figure G1 for the principle of a simple lysimeter.

Percolating water samples are taken from the lysimeter, for example, one to three times during the monitoring year. We recommend filtering the water sample, as fines may be flushed into the collection container from the soil sample, skewing the results of the analysis.

Lysimeter monitoring is carried out using a single lysimeter for a period of one year, and the monitoring is repeated at intervals defined on a case-by-case basis. If the pollutant load is targeted to sensitive sites, and the risk level as per the BAT report is 3, or extremely demanding, the suitable sampling frequency is one to three years, depending on the protective measures implemented at the site. If the groundwater risk is reasonable, or the risk level is 2B, the lysimeter analysis can be carried out at three to six year intervals. In order to guarantee the reliability of the analysis, at least two lysimeters are analysed from the same site. If there are several sites causing pollutant load, the percolating water from each site is analysed using at least two lysimeters.

G6.4 Analyses

In a laboratory, the composite water samples from groundwater, percolating water and protective structures are analysed for at least the metals causing a pollutant load on surface water typical to shooting ranges, i.e. lead, antimony, copper and zinc, and also the arsenic concentration, if there is a shotgun range at the range area. Furthermore, at ranges that were in operation prior to 1960, the nickel concentration must be analysed. In order to improve the interpretation of the results, we also recommend analysing the samples for pH (if not measured in the field), oxygen content, turbidity, and organic matter concentration. Oxygen content is not analysed from the samples from lysimeters or the inspection wells of the protective structures.

The concentrations of the analysed metals are determined as soluble concentrations (0.45 µm filter or sampling using the low flow method).

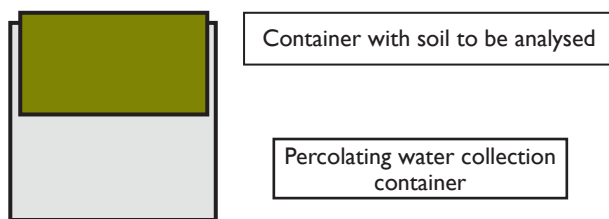


Figure G1. Principle of a simple lysimeter.

G7 Reporting

The results of the emission and impact monitoring and the usage monitoring at the shooting range are compiled, analysed and reported by an expert in accordance with the requirements of the authorities.

The monitoring report should include at least the following information:

- Objective of the monitoring
- A description of the operations at the shooting range during the monitoring period, including the number of shots and special situations
- A description of the implementation of the monitoring, including a description of the sampling procedure
- The locations of the observation points on a map with sufficient precision
- Special observations made during sampling
- Analysis results
- The development trends of pollutant concentrations as graphs over the entire monitoring period, including the results from previous years
- A comparison with the site-specific acceptable pollutant load and, if necessary, with other relevant reference values
- The uncertainties related to the monitoring programme or its implementation
- Conclusions from the results and any suggestions for changes.

If it is found during monitoring that the emissions from the shooting range exceed the site-specifically defined acceptable level, a risk assessment must be prepared of the situation, based on which the supervisory authority will decide whether any measures need to be taken.

Noise management

Appendix H. Basic information on shooting range noise

H1 Basic concepts of noise: emission, propagation and exposure

The basic concepts used in the study of environmental noise from shooting and the assessment of the impact of the noise, and the physical characteristics of noise, are largely the same or correspond to those of other environmental noise (Lahti 2003). Shooting noise differs from other environmental noise primarily with regard to its temporal characteristics.

The most important concepts describing environmental noise from shooting are

- noise emission from the noise source, and
- the noise level at the site subjected to the noise.

Noise propagation from the source to the receiver determines how the noise level is formed as a result of the noise emission. Noise propagation is affected by attenuation along the transmission path. (Figure H1).

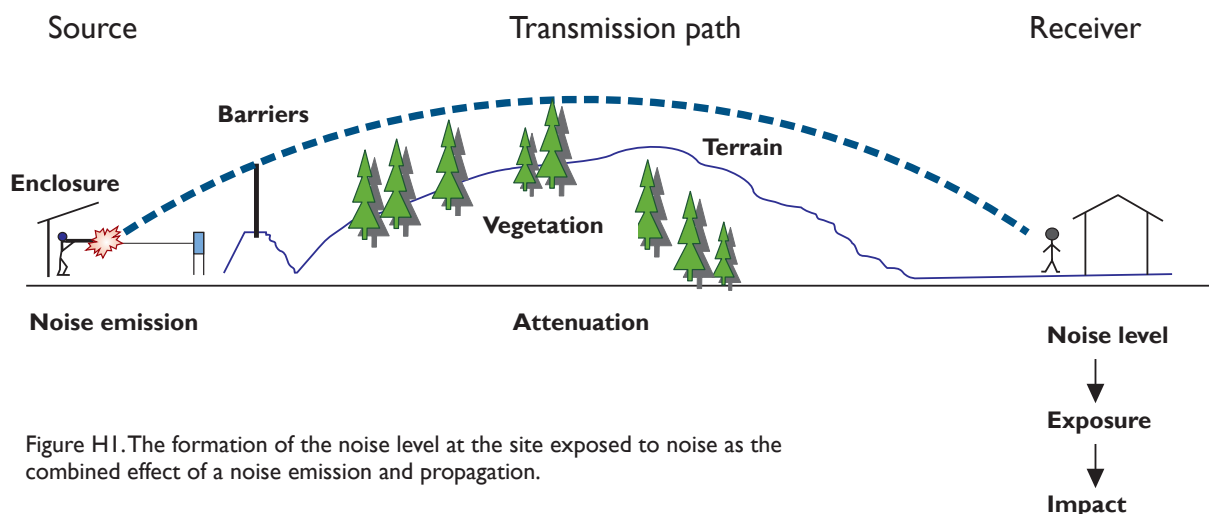


Figure H1. The formation of the noise level at the site exposed to noise as the combined effect of a noise emission and propagation.

H1.1 Noise emission

H1.1.1 Sound energy level

The basic instance of shooting noise is a single sound event with a very short duration. For this reason, the noise emission from shooting is not depicted using the acoustic power of the sound, like other environmental noise, but the sound power is replaced by the acoustic energy of the sound.

The noise emission from shooting is a colloquial synonym for the precise concept of sound energy level emitted by a noise source L_Q . In principle, the noise emission could be given directly as sound energy, or in joules. The standard method is, however, to use sound energy level, the unit of which is the decibel. Noise emission, or the emitted sound energy, is a basic characteristic of the noise sources, independent of the location and environment of the source.

The sound energy level is defined as follows:

$$L_Q = 10 \lg (Q / Q_0) \quad [\text{dB}]$$

where Q is the sound energy. Reference energy is $Q_0 = 1 \text{ pJ}$ (picojoule).

The sound energy level is usually given as a spectrum, or a function of frequency. The A-weighted sound energy level L_{QA} can be used to report it using a single value.

Both the ordinary sound level (sound pressure level) and sound energy level have the same unit, decibel (dB). This may cause confusion, although the numerical values of these levels are very different from each other. The value of the sound energy level is usually a lot greater than that of the regular sound level. In order to avoid confusion, the noise emission quantity, sound energy level, and its symbol, L_Q or L_{QA} , should always be separately mentioned.

H1.1.2 Emission management and control

Noise emission is a similar concept to the other emissions of environmental pollutants, but only up to a certain limit. The analogy should not be continued too far. The emission of sound, just like other common physical phenomena, differs from the emissions of chemical pollutants insofar as the exposure it creates will not linger, as there is no residue. On the other hand, a noise emission does not cause disturbance, or contamination of the environment, if there is no exposure, i.e. there is no one to hear the noise level.

A noise emission is significant and, on the whole, meaningful as a concept only at the moment it reaches its impact site and someone hears it. After that, the emission is insignificant, as the sound energy disappears by converting into heat within a few seconds. For this reason, setting noise requirements, for instance permit conditions, for noise emission alone is not suitable as a rule for environmental noise; the common way of regulating the noise level at the impact site is more meaningful.

H1.2 Propagation and attenuation

The noise emission and noise level are linked by the transmission path. A noise source emits a noise emission. The emitted energy propagates outwards from the source, and causes a noise level upon arriving at the impact site. The transmission path's response, or propagation attenuation, indicates how the noise level is formed of the noise emission. If there are reflections on the way, there are several paths the noise travels, and the transmission route comprises their total effect.

In principle, propagation attenuation $D(f)$ is defined with the formula

$$L_p(f) = L_Q(f) - D(f)$$

where $L_p(f)$ is the noise level and $L_Q(f)$ the noise emission, presented as spectra, or functions of the frequency f .

Noise level is thus determined by the noise emission at the source and the characteristics of the propagation route together. Propagation attenuation is used in the calculation models for noise propagation, for example. Propagation attenuation is always a function of the frequency (Figure H2).

H1.3 Noise exposure and noise level

At the noise impact site, those within earshot can be exposed to noise. Usually in the case of environmental noise, the primary sites examined comprise residential buildings, sites sensitive to noise, or other comparable buildings and their yards. The examination may also concern zoned recreational areas and nature conservation areas.

The harmfulness of the noise is assessed with the help of the concept of noise level. To be more precise, the noise level is the ordinary sound level A of the noise occurring at the impact site, or the A-weighted sound pressure level. A-weighting is used almost without exception in the assessment of the harmfulness of noise. It is a weighting of different frequencies in the noise, emulating human hearing. The noise level at the impact site is a corresponding concept as the environmental load used in some other fields of environmental protection.

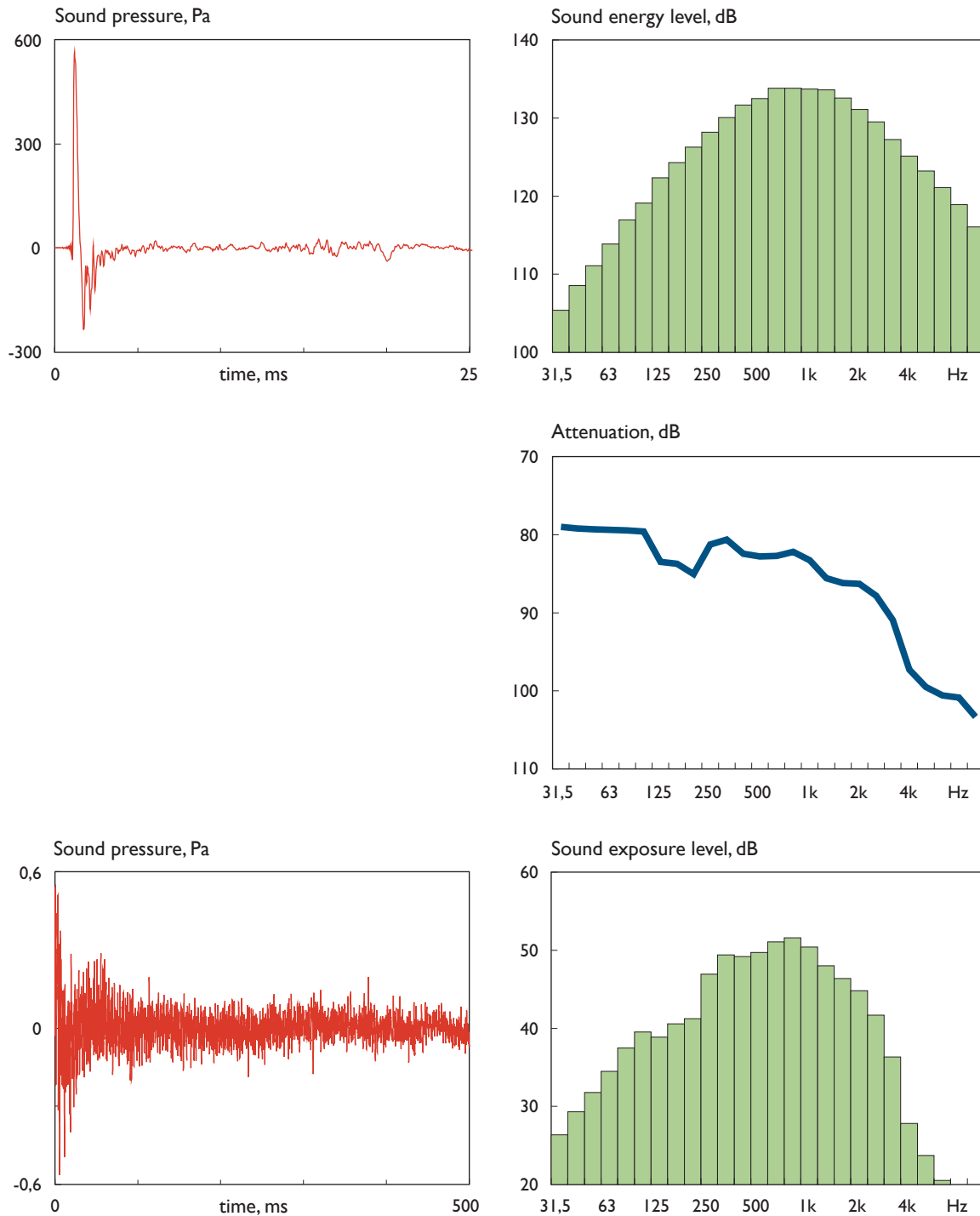


Figure H2. The noise level at the site (bottom line) is obtained by subtracting the attenuation of the transmission path from the source to the receiver (middle line; left middle image is missing, as the calculation can only be performed on spectra) from the noise emission (top line). The figures present a shot from an assault rifle at distances of 10 m and 640 m.

There are several different A-sound levels, and when talking about noise level, one must often specify which A-sound level is being referred to. In the case of shooting range noise, the following two alternatives come into question:

- AI-maximum sound level $L_{AI_{max}}$, more precisely A-frequency weighted and I-time weighted maximum sound level. The primary level quantity for the assessment of shooting range noise, as the guideline values for shooting range noise in Finland have been set using this quantity. Does not take the number of shots into consideration.

- Average sound level L_{Aeq} , more precisely the A-weighted average sound level for a specific (reported) time period, or A-weighted equivalent sound level. The impacts of most other types of environmental noise are assessed using this level quantity. It can also be used for shooting range noise as a secondary quantity. Takes the number of shots into consideration.

When shooting range noise is assessed using the average sound level, a special impulse correction must be added to the measurement or calculation result. The correction is defined in the international standard ISO 1996-1, and its value is 12 dB.

A third noise level sometimes needed in the calculation and measurements of shooting range noise is the sound exposure level L_E . When it is presented as a spectrum, it is the same as the noise level $L_p(f)$ appearing above in the propagation attenuation formula. A-weighted sound exposure level L_{AE} is a raw result produced by a calculation model before moving to an AI-weighted maximum sound level or average sound level. If one wishes to measure the average sound level of shooting range noise or initial values for the calculation model, the A-weighted sound exposure level or exposure level as a spectrum is then also the raw quantity to be measured.

H2 Generation of shooting noise

Shooting range noise usually has two different sound generation mechanisms, meaning that the noise comprises two different components: the firing noise, or muzzle blast, and the bullet's flight noise, or supersonic boom.

The firing noise, or muzzle blast, is caused by the combustion gas expelled from the barrel of the firearm, caused by the combustion of the powder. It expands rapidly and causes a pressure, or sound wave. The flying bullet generates a second, separate noise, the supersonic boom, if the bullet's velocity is higher than the speed of sound (around 330–340 m/s, depending on temperature).

In some special cases, the bullet impact to a hard target generates a third noise, the impact noise, which is louder than usual. Impact noise is usually insignificant when compared to the other noise components. Bullet traps with hard surfaces may increase the impact noise somewhat.

H2.1 Muzzle blast

The bullet starts moving when pushed by the combustion gas pressure generated by combusting propellant. When the bullet exits the muzzle, the combustion gas pressure in the barrel of a rifle is typically around 100 MPa, or 100,000 kPa, or 1,000 atmospheres.

When the bullet exits the muzzle, the combustion gas behind it is free to move past the bullet and expand in all directions. The expanding combustion gas generates a spherical, expanding shockwave around the muzzle. The leading edge of the shockwave is very sudden, and the expansion speed of the wave is initially higher than the speed of sound.

The combustion gases and the remaining granules of powder continue burning for a moment. This creates the muzzle flash sometimes connected to firing a gun.

The expansion speed of the shockwave and the temperature of the combustion gas decrease rapidly, but the wave also emits a pressure wave, or a sound wave, that also expands spherically and propagates at the normal speed of sound. At this stage, the sound wave comprises one short and strong half-wave of positive overpressure, and one, weaker, half-wave of negative underpressure following it.

Until a distance of around 10 metres, the sound wave is in the nonlinear region. This means that the wave pressure is so high and so close to air pressure that the acoustic characteristics of the medium are different at the positive overpressure of the leading edge of the wave and the negative underpressure following it.

Air pressure is around 100 kPa, so its pressure level is 194 dB. If the sound wave pressure is greater than around 1% of this, or around 154 dB, the sound wave is non-linear. The local speed of sound observed by the wave is higher at the positive overpressure than at the negative underpressure. As a result, the positive pressure moves faster than the negative, and the leading edge of the wave remains sharp and sudden.

After a distance of around 10 m, the sound wave has attenuated as a result of expansion to such a degree, and it settles down into a regular, linear sound wave. At the same time, its sharp and sudden shape begins to soften slowly as a result of several mechanisms.

The border between nonlinear and linear acoustics has significant practical importance in the measurement and calculation of noise. Measurements related to environmental noise, such as for determining noise emissions, should not be attempted inside this border. Prediction models are also based on the rules of acoustics and assumptions on attenuation, which are valid only in the linear region.

Some firearms have muzzle brakes to alleviate recoil. A muzzle brake is a structure added to the muzzle, containing holes directed to the sides or obliquely towards the rear. The muzzle brake directs the expanding combustion gases in the desired way, reducing the reaction force pushing the firearm backwards, or recoil. At the same time, the muzzle brake affects the direction of the pressure from the expanding combustion gas, and thereafter the generation of the sound wave and the directivity of the sound emission.

Muzzle brakes are used in assault rifles, Olympic pistols and practical firearms, for example.

The sound wave generated by the muzzle blast is spherical, i.e. it spreads evenly in all directions. The wave strength is not the same in the different directions, however. Generally the loudest sound occurs straight in front of the firearm's barrel, and the weakest towards the rear (Figure H3).

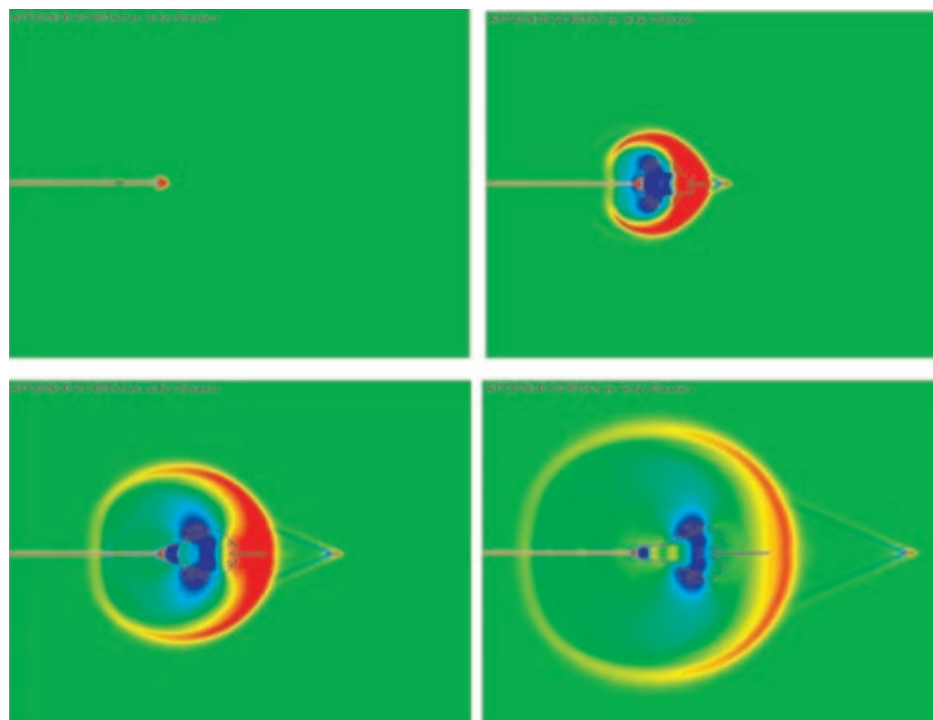


Figure H3. Initial stages of the creation of a muzzle blast: the red line on the left depicts the barrel of the firearm; the red and yellow depict overpressure; different shades of blue depict underpressure. The expanding pressure wave is spherical, but its strength is different in different directions; the centre point of the sphere is at the muzzle of the firearm. A supersonic bullet appears to the front of the pressure wave on the right (Teland et al. 2007).

The strength of the muzzle blast's noise emission in different directions is referred to as its directivity. Figure H4 presents examples of the noise emissions of certain firearms as a function of direction.

H2.2 Bullet noise

The bullet velocity of most pistols and rifles is at first clearly greater the speed of sound, due to which the bullet causes a sonic boom. Its creation principle is similar to the bow wave generated by a motorboat in water. It is also acoustically the same phenomenon that occurs when an aeroplane flies at supersonic speeds.

The sound wave of a sonic boom expands in a conical shape; the apex of the cone is coincident with the tip of the bullet at all times. The cross section of the wave, or signal, is in the shape of the letter 'N' (Figure H5). The bullet tip generates a sharp positive overpressure from its front edge, and the rear of the bullet generates a sudden underpressure from its back edge. The same nonlinear local variance in the speed of sound that was described above in the case of the muzzle blast retains the sharp front and back edges of the wave for a relatively long time: the positive pressure moves at a higher speed of sound than the negative pressure.

The conical wave means that the sonic boom propagates only to a certain sector obliquely forward. The angle of the cone and the wave's propagation direction are determined by the bullet's velocity. The bullet noise cannot be heard at all directly to the front or too far to the sides. (Figures H5 and H6.)

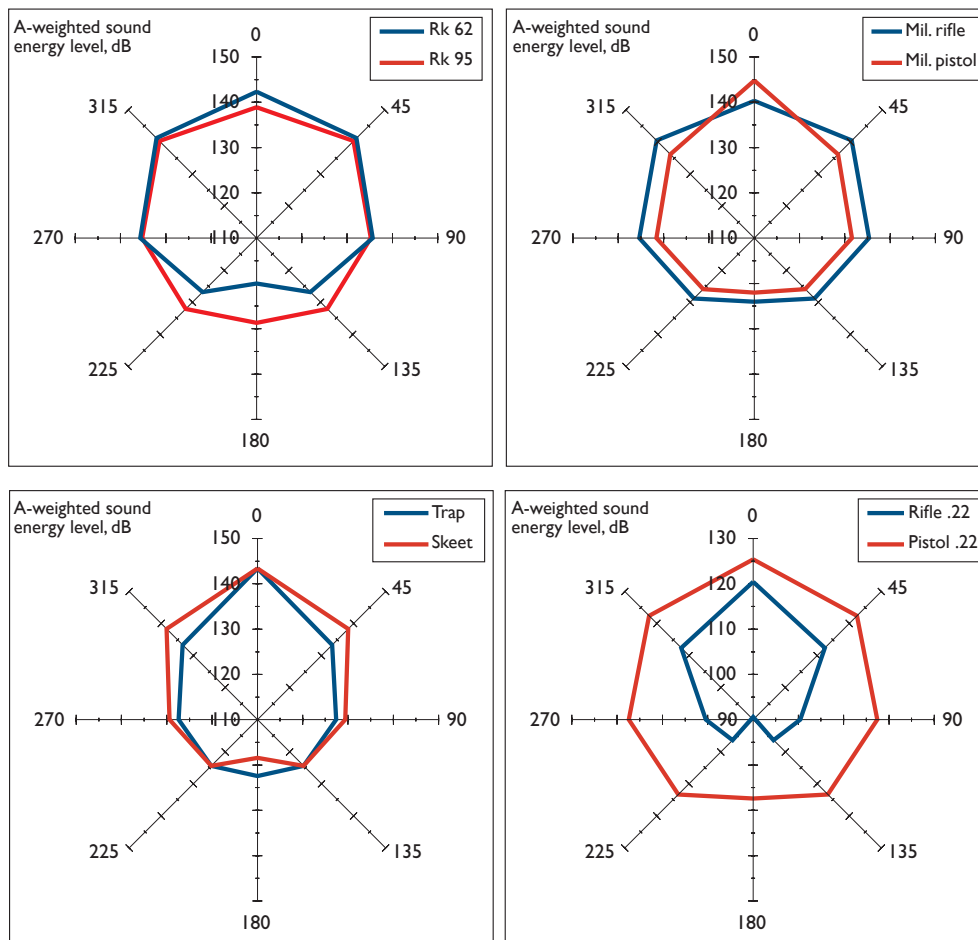


Figure H4. The directivity of the sound energy level of the muzzle blast from certain firearms: (top left) assault rifles, (top right) military rifle and pistol, (bottom left) shotguns, (bottom right) small-bore rifle and pistol. NB: the level axis of the chart at bottom right is 20 dB smaller than in the other charts.

The bullet noise cone of a bullet flying at supersonic velocity is sharp, and the wavefront propagates to the side at a large angle. The bullet's velocity decreases during flight, making the bullet noise cone more obtuse, and the wavefront turns into a smaller angle relative to the firing direction. Here is the information for an assault rifle as a numerical example: the muzzle velocity is 710 m/s, and the wavefront of the bullet noise cone propagates to the sides at an angle of 62 °; at a distance of 150 m, bullet velocity is 560 m/s and the flight noise angle 53 °; at 300 m, velocity is 410 m/s and the angle 35 °. The area where the flight noise can be heard is thus the shape of a gently widening fan.

Outside the shooting range, at greater distances, both the muzzle blast and bullet noise are "stretched" in duration; they last a longer time. The stretching is caused by scattering and echoes caused by the terrain and plants. Due to the stretching effect, the muzzle blast and bullet noise occur simultaneously, or overlap, fully or to a great degree.

H2.3 Special characteristics of shotgun shooting

The main factor of noise propagating to the environment from a shotgun is the muzzle blast. Its loudness is about the same as those of a large-bore hunting rifle or an assault rifle, for example.

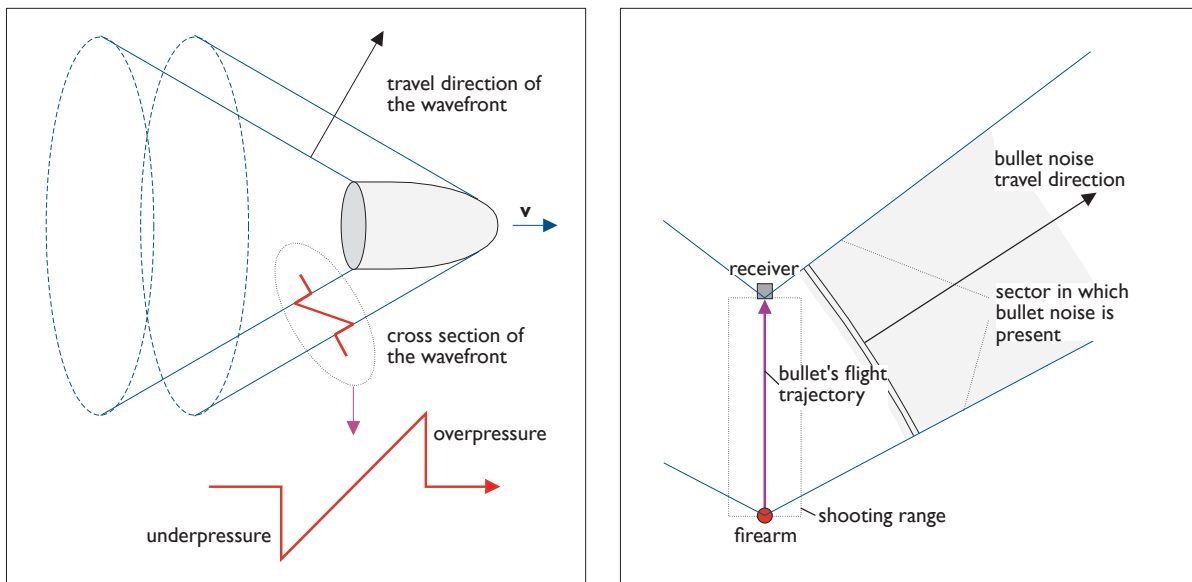


Figure H5. Creation of the bullet noise: (left) principle, (right) propagation seen from above.

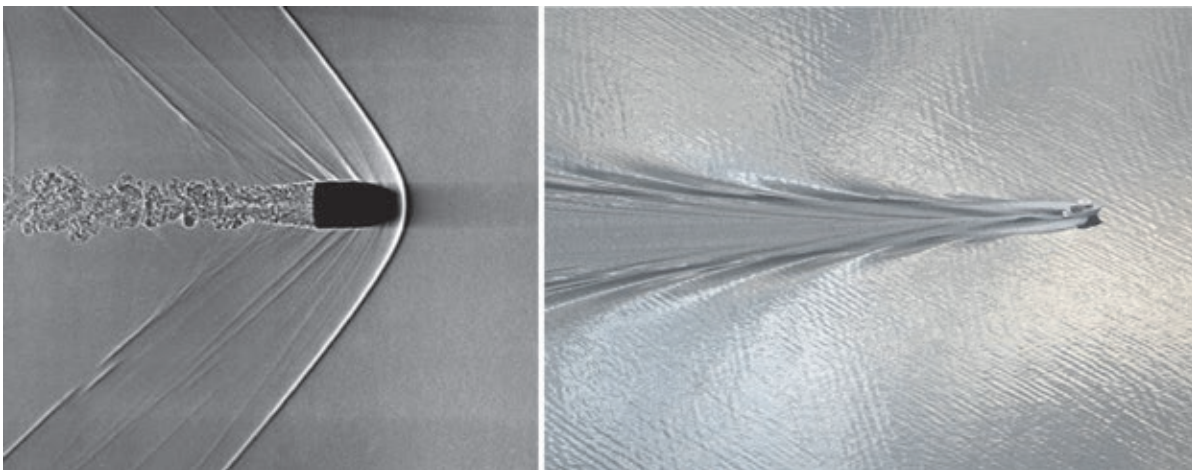


Figure H6. Creation of the bullet noise: (left) photograph of a bullet in flight, (right) creation mechanism resembles the creation of a boat's bow wave. (Source:Wikimedia Commons)

Shotgun noise differs from that from pistols and rifles in the sense that a flight noise caused by a supersonic projectile is not generated as such. The muzzle velocity of the shot is somewhat under 400 m/s, which drops to around 250 m/s at a distance of just 20 m, which is below the speed of sound. The shot may thus generate some flight noise, but its strength and share of the total noise is very minor.

When shot hits a clay pigeon, some noise is generated, but this is not considered to be significant with regard to environmental noise.

The noise emissions from shotgun shooting are directed differently from pistol and rifle ranges, as the firing sector, or firing direction, varies. The firing sector at a skeet range from one end to another is around 150 degrees, while it is around 90 degrees at a trap range. This causes the noise to propagate into a wider area than when firing in just one direction. The changing firing direction also causes the noise level to change in the environment, depending on which direction the shot was fired.

H3 Propagation of shooting noise

The same acoustic phenomena apply to the propagation of shooting range noise as to other environmental noise (Lahti 2003). Unlike previously suggested on some occasions in Finland, the very short duration of shooting noise compared to other, slowly varying or constant environmental noises has no effect whatsoever on the fundamental rules of acoustics controlling its propagation.

H3.1 Basic forms of propagation

A sound source radiates an expanding sound, where the sound energy is spread over a larger surface area as the distance increases. The sound pressure decreases correspondingly. This attenuation due to distance always takes place, regardless of terrain and other factors.

Propagation follows the following main rules: Sound energy is inversely proportional to the surface area of the wavefront, and sound pressure is proportional to the square root of sound energy. The decrease in sound pressure depends on the size and shape of the sound source: Compared to the observation distance, a small noise source is a point source. Acoustically, the muzzle blast component of shooting noise is generated at a single point. The type of the sound source is thus a point source, and the sound wave it creates is a spherical wave. The wave follows the normal propagation rules of a spherical wave.

The generation of the bullet noise and the type of the sound wave are complex phenomena due to the supersonic speed of the bullet. The attenuation of the sound wave that propagates as a conical wave in a certain angle follows its own special shape. To simplify, the conical wave attenuates clearly slower than a spherical wave in the vicinity of the bullet's flight trajectory.

H3.1.1 Spherical wave

The sound energy of a spherical wave decreases in inverse proportion to distance squared. Sound pressure decreases in proportion to distance:

- when the distance doubles, sound pressure decreases to one-half (sound pressure level decreases by 6 dB);
- when the distance becomes tenfold, sound pressure decreases to one-tenth (sound pressure level decreases by 20 dB).

To be precise, sound pressure level here refers to the sound exposure level L_E of the sound pressure.

H3.1.2 Conical wave

A conical wave attenuates more slowly than a spherical wave with distance. Its sound energy decreases in inverse proportion to distance to the power of 5/4, and its sound pressure decreases in inverse proportion to the square root of the previous:

- when the distance doubles, sound pressure decreases to around 0.65 times the starting value (sound pressure level decreases by 3.8 dB).
- when the distance becomes tenfold, sound pressure decreases to around one-quarter (sound pressure level decreases by 12.5 dB).

H3.2 Diffraction and refraction

A sound wave primarily travels in a straight line, in the direction of the normal of the wavefront. This is roughly analogous to the travel of light, such as sun rays. With regard to environmental noise, we need to examine two phenomena that make slight exceptions to this primary rule.

The sound shadow caused by obstacles is not sharp-edged in the same way a light shadow is. A small part of the sound goes around the edge, behind the obstacle in the shadowed area. This phenomenon is called diffraction, and it is clearer the lower the sound, or, the lower its frequency. The spectrum of shooting range noise is typically in the middle frequencies. Diffraction behind an obstacle is not as pronounced as with traffic noise, for example.

When the speed of sound is not the same all around, sound will not travel in a straight line; instead, it bends slightly. The sound tends to bend to the direction where the speed of sound is lower. This phenomenon is called refraction. The phenomenon is usually very weak, but in the case of environmental noise, it may have a significant impact in some cases, particularly at long distances.

H3.3 Atmosphere and weather

H3.3.1 Air absorption

When sound travels in the air for a long distance, some of it is absorbed. High frequencies, or high sounds, are filtered out of the noise due to friction between air molecules; the sound energy is converted into heat. The absorption of sound by the atmosphere is well known, and an international standard has been created of the phenomenon (ISO 9613-1). The absorption is affected by temperature and relative humidity. A rule of thumb for a distance at which absorption begins to clearly affect shooting noise is a round number of one kilometre.

H3.3.2 Wind and temperature

The only actual weather phenomena significant for the propagation of environmental noise are

- the dependency of wind speed on altitude, and
- the dependency of temperature on altitude,

referred to as the vertical wind speed and temperature gradients.

In addition to the vertical gradient, wind speed or direction as such have no other effect on the propagation. With regard to the other weather variables, air pressure has no effect at all on propagation; temperature as such or humidity have no other effect than through air absorption. Due to the altitude differences in wind speed and temperature, noise refracts as it travels, i.e. its path bends. If the wind speed and temperature gradients are positive, sound bends downwards. Sound that started off slightly upwards goes over obstacles and bends back towards the ground.

An acoustic mirage, or bending downwards, takes place in two situations:

- when sound travels downwind, and
- when air temperature increases upwards from the ground.

In meteorology, the latter situation is called inversion. This phenomenon is significant with regard to other environmental noise, but it usually occurs at night, which means that its significance in the case of shooting noise is minor.

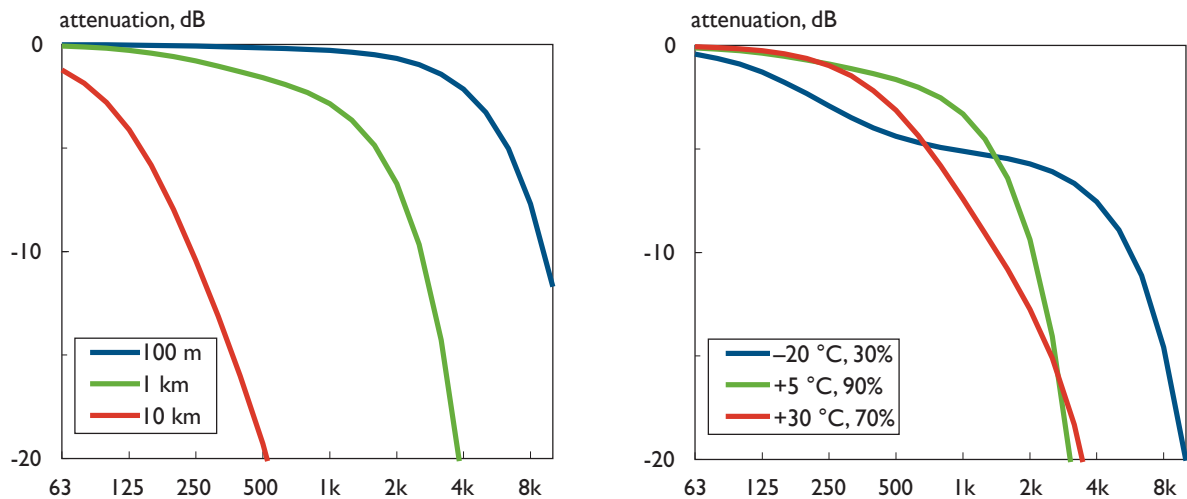


Figure H7. (left) Air absorption at different distances at 10 °C and 70% humidity. (right) Air absorption at a distance of 1 km on a hot day, an autumn or spring day, and in freezing cold.

Bending in the other direction, or upwards, occurs in the opposite situations:

- when sound travels upwind, and
- when air temperature decreases upwards from the ground.

In such cases, a sound shadow may occur even in the case of a direct line of sight. The shadow is not perfect; some of the sound gets into the shadow area due to diffraction. Sidewind has no effect on the propagation of sound, and winds in other directions affect via the wind speed component in the sound's direction of travel.

The speed of sound depends on the temperature; more precisely, the speed of sound is proportional to the square root of the (absolute) temperature. A change in temperature relative to altitude will thus also cause a change in the speed of sound, to which the travelling sound wave reacts.

Wind direction and speed affect sound propagation as follows. The wind speed can be directly summed with the speed of sound in calm weather. Wind speed increases practically always the higher the altitude. The wind speed and also the speed of sound thus have a gradient; in a tailwind, the speed of sound increases higher up, while in headwind it decreases. In a tailwind, sound bends downwards and in a headwind, upwards.

It is easy to deduce the wind direction and even speed using one's own senses. But it is also relatively easy to identify a temperature gradient without any meters. On a sunny afternoon, the ground is warmer than air due to solar radiation, and it heats up the layers of air closest to the ground. Thus, sound will bend upwards. In cloudy, rainy and foggy weather, there is no temperature gradient, i.e. the atmosphere is neutral with regard to noise propagation in this sense, and sound travels in a straight line.

The gradients can both strengthen and cancel each other.

H3.4 Surfaces and obstacles affecting propagation

H3.4.1 Reflection and absorption

Surfaces in the path of sound may cause the sound to be reflected, absorbed and diffracted. When a sound wave hits a surface, some of the sound is reflected and some absorbed into the surface. If the thickness and acoustic properties of the surface are finite, some of the sound may travel through it. In the case of shooting noise, such surfaces could be, for instance, the wall of a firing enclosure or a screen-type noise barrier.

If the reflective surface is large in relation to the wavelength of the sound, the reflection is direct, just like light reflecting from a mirror. Reflection from a small surface

is imperfect, and some of the sound diffracts around the edges of the surface behind it. In the case of shooting noise, such small surfaces typically include tree trunks.

For environmental noise, reflection is probably the most significant phenomenon. There are many different kinds of reflections:

- An almost perfect reflection occurs when sound hits an (acoustically) hard surface.
- If the surface is also smooth in addition to hard, the reflection is like it would be from a mirror.
- From a hard and uneven surface, sound reflects like light from a white matte surface: entirely, but scattering into random directions.
- If the surface is acoustically somewhat soft, the reflection is partial.

Hard and smooth surfaces with regard to sound are calm water surface, and asphalt, concrete, and, usually, building walls. Hard but not smooth surfaces include waves and open rock. In winter time, hard surfaces include uncovered ice and hard frozen snow. Regular soft ground surfaces such as grass, meadows, fields and forest floors are also acoustically soft. Depending on its wetness, a swamp can be almost anything between hard and soft.

If a surface is acoustically very soft, sound can be absorbed into the surface almost entirely, resulting in no detectable reflection. In the natural environment, fresh, soft snow is basically the only surface as soft as this. Indeed, with regard to sound, it is almost the exact opposite of hard, frozen snow.

Direct absorption mainly occurs when sound hits a soft surface at a large angle, more or less perpendicularly. In the case of shooting range noise, this occurs when sound hits an earthen berm, for instance.

H3.4.2 Soft ground

When sound travels almost parallel to the ground (i.e. when the ground is mostly level, and the sound source and the receiver are both at a low elevation), there will be no absorption. Despite the softness of the surface, sound hitting it will be almost entirely reflected. However, the sound wave becomes "inverted", or changes its sign: positive overpressure changes into negative underpressure, and vice versa. After this, the sound that travelled straight and the reflected sound have (almost) opposite signs and almost cancel each other. This is the main reason for the ground attenuation caused by soft ground.

When sound travels a long distance parallel to more or less soft ground, it will be significantly attenuated compared to a hard surface. The effect of ground attenuation on the total sound levels of shooting noise is generally 3–7 dB. On hard surfaces, ground attenuation is missing, which is why sound can be heard particularly well across a lake, for instance. Ground attenuation is at its greatest when the distance is large, around 500 m or more, and when the elevations of the source and the receiver are low, a couple of metres at most.

H3.4.3 Barriers

Attenuation from barriers shielding the propagation path of sound (e.g. a hill, building, or an actual noise barrier) is determined by two factors:

- the dimensions of the barrier, and
- the frequency of the sound.

A rough rule of thumb is that the barrier must block the line of sight to the sound source before barrier attenuation may occur. To be more precise, the attenuation primarily depends on the angle at which the path of the sound wave going around (diffracting) the top of the barrier is bent on its way to the receiver. The more acute the angle of diffraction, the greater the barrier attenuation. A barrier is most effective

when it is very close to either the source or the receiver. The barrier is at its most ineffective midway between the two.

In addition to the difference in distance, barrier attenuation depends on the frequency of the sound. High-frequency sounds attenuate more than low-frequency sounds that diffract to the other side of the barrier more easily. If the height of the barrier is further increased, the barrier attenuation will not, in practice, continue to grow after a certain maximum attenuation has been reached. In practice, shooting range noise attenuates well immediately after an effective barrier, by up to around 20–25 dB.

The ability of vegetation to attenuate noise passing through is often overestimated; trees and other vegetation cannot, in fact, significantly attenuate the energy of a sound wave. A slight attenuation of a couple of decibels can be detected only if the wooded zone is very dense and at least 100 to 200 m in width. In addition to the trees, the undergrowth must be dense. With regard to coniferous trees, spruce is clearly more effective than pine. Deciduous forest provides no abatement during the leafless time of the year.

H4 The physical characteristics of shooting noise

The most important physical characteristics of noise are its level, temporal variation, and frequency distribution, or spectrum. The temporal variation of shooting range noise is obvious: the sounds are very short in duration. The spectrum is usually rather constant, mainly only attenuation may cause noticeable changes in it.

H4.1 Strength (level)

The firing and bullet sounds from shooting are short in duration and repeat more or less identically to each other. The sound pressure of the sound wave from a small-calibre shot fired at close range (ca. 10 m) is up to around 100 Pa – 1 kPa. The unweighted peak sound level $L_{Z_{peak}}$ is around 134–154 dB.

H4.2 Shape and duration of the pulses

The shape of the shot impulse is rather simple close to the muzzle of the firearm. It comprises almost entirely of just one positive and one negative half-wave. A positive overpressure passes the listener first, followed by a negative underpressure. When the sound wave from the shot travels further, the shape of the sound pressure pulse changes significantly through the combined effect of terrain and the atmosphere: its duration increases and its structure becomes more complex. At a close distance, the duration of a shot impulse is a couple of milliseconds (Figure H7). Further away, the duration of the basic pulse of the shot can be a couple of tens of milliseconds.

When the distance increases, the N-shaped pulse of the bullet noise becomes rounder, and the duration of sound energy decay becomes significantly longer. The latter phenomenon resembles the concept of reverberation, familiar from room acoustics and concert halls: outdoors, woods and terrain cause "reverberation" as well, causing the pulse duration to stretch.

The further away the noise is observed, the longer the total duration of the pulses becomes. At very great distances, the total duration observable as a steadily attenuation reverberation can increase to over one second due to reflections and scattering caused by the terrain and the woods.

H4.3 Spectrum

The spectrum of shooting noise is always rather wide, and almost always has a rather smooth shape (Figure H8). In other words, shooting noise never has a narrow-band spectrum. The spectrum reaches its maximum in the medium frequency range, and falls off towards both lower and higher frequencies. The details of the spectrum shape

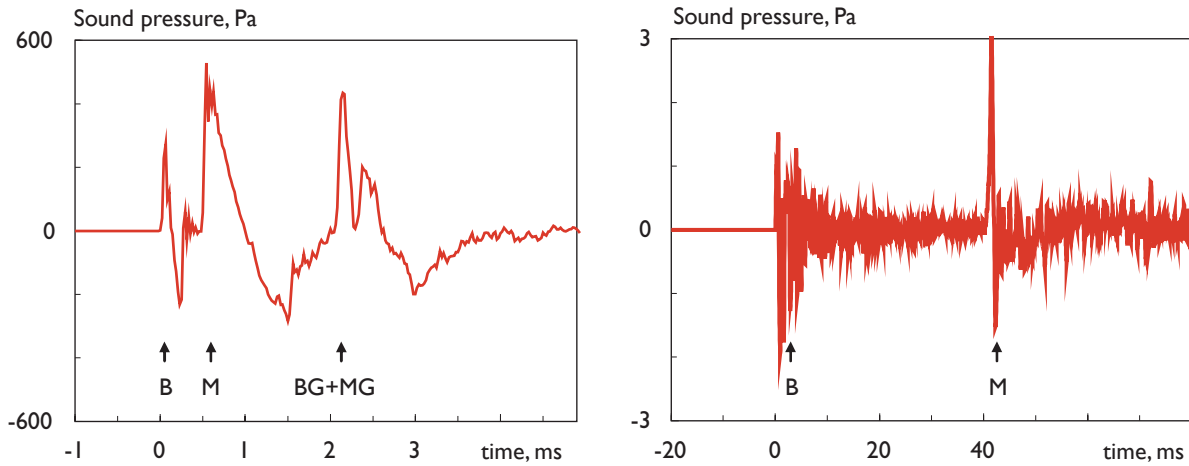


Figure H8. A shot from an assault rifle at a distance of 10 m (left) and 300 m (right); B: bullet noise, M: muzzle blast, BG+MG: ground reflection of the bullet noise and muzzle blast. (The time axes of the images are of different sizes.)

depend on the calibre of the firearm; on the other hand, the shape of the spectrum changes when the observation distance increases.

The spectrum's main frequency range is usually around 250 Hz – 2 kHz, and its peak is commonly around a frequency of about 1 kHz. The ground attenuation typically caused by soft ground causes the spectrum minimum to be in the 100–200 Hz range at greater distances.

H5 Assessment, measurement and calculation of shooting noise

Assessing, measuring and calculating noise are not strictly speaking best available techniques, but they are necessary for determining and dimensioning the techniques. The results of the measurements and the calculations should be congruent. The results have a rather large effect on the dimensioning of the noise abatement need, and the scope and costs of the measures.

H5.1 Measurement of shooting range noise

Shooting range noise is measured in accordance with the measurement instructions of the Ministry of the Environment (Ministry of the Environment 1999). The instructions do not recognise any sound level quantities other than the AI-weighted maximum sound level L_{Amax} used in the guideline values. It is measured as an average of a minimum of five shots. However, the measurement instructions do not specify

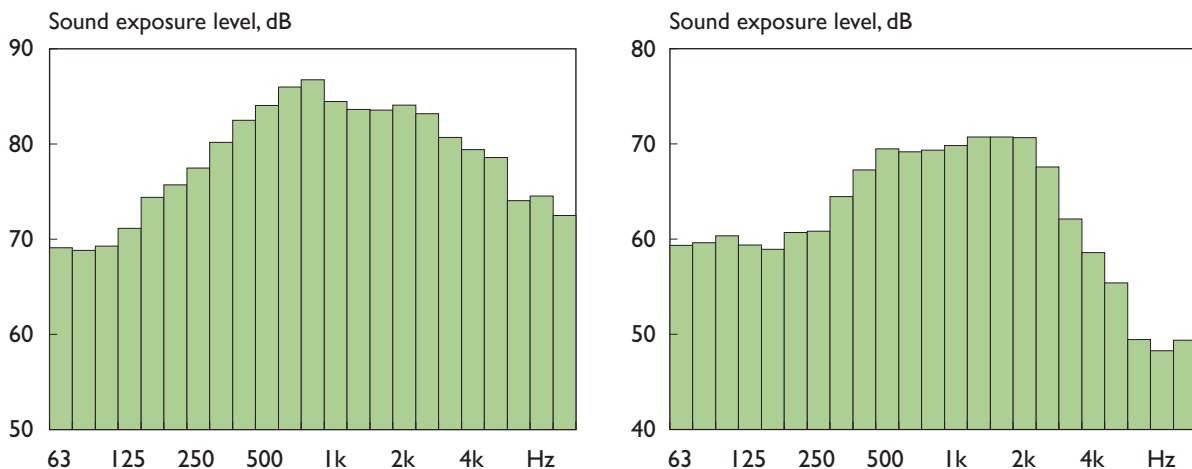


Figure H9. The spectrum of a shot from an assault rifle at a distance of 100 m (left) and 300 m (right), the shot includes both the bullet flight sound and the muzzle blast; background noise from wind is present at the lowest and highest frequency bands.

how the average should be calculated. It has usually been interpreted to refer to the arithmetic mean of the sound levels. However, the interpretation according to which the average refers to the mean-square of the maximum sound pressures, or the energy average, can be considered to be at least as correct. The latter interpretation is based on the I-time weighted sound level also being an RMS value level, and the average of RMS values being always calculated as an energy average.

The measurement instructions specify the recommended weather conditions during the measurements (temperature +10...+25 °C, relative humidity 40–80%, and wind speed 1–5 m/s in direction tailwind $\pm 45^\circ$). The temperature and humidity limits can justifiably be considered altogether too strict. Measurements could be easily allowed at least down to a temperature of 0 °C, perhaps even colder. Humidity up to 100% could also perfectly well be accepted.

The wind direction limitation is strange in the sense that in reality, the positive wind speed gradient is not determined by the sector but the wind direction vector's component in the direction the sound travels, as the crosswise component of the wind direction has no effect on the sound's travel. The instructions do not include limitations on the temperature gradient. This may lead to measurement conditions unfavourable for sound propagation, on a sunny day with low wind.

On the other hand, the instructions do not specify how the results from measurements made on several different days should be processed before they are compared to the guideline values. In other words, should only the highest measurement results be always chosen (as the assessment quantity is a maximum level, too), or should some statistical evaluation be applied to the results? The average of the results would be suitable and purposeful, expanding on the principle of how the results from different shots during one measurement session are processed.

In this case, too, the calculation method for the average must be chosen. In the sense of measurement techniques, the correct average result would be the energy average level of the results from the different measurement sessions (as the assessment quantity is an RMS value level). If the range of the measurement results is no more than around 5 dB, its difference with the arithmetic mean of the sound levels is insignificant, and the average can, in practice, be calculated as an arithmetic mean. If the range is larger, the average should be calculated as an energy average.

H5.2 Calculation of shooting range noise

In Finland, shooting range noise is calculated using the joint Nordic shooting range noise prediction method (NT ACOU 099: 2002). The principal purpose of the prediction method is to directly generate a result representing the long-term noise situation that corresponds as well as possible with the overall results of numerous different measurements performed over a long period of time and in the specified weather and other measurement conditions. The statistical processing of the measurements made on different days is an essential part of the principle of the prediction method. Above, the overall result in question was defined as the energy average level, which is thus also the desired result from the calculations.

The shooting range noise prediction method (or, to be more precise, the industrial noise prediction method on which it is based) is known to calculate the propagation of the signal energy of the noise in accordance with this principle very reliably to a distance of several hundred metres, and relatively reliably to a distance of usually at least slightly over one kilometre.

The prediction method produces the most reliable results on level, open terrain (such as a field or a body of water). The calculation of barrier attenuation is also quite reliable in cases where the barrier is near the noise source (or receiver). At shooting ranges, this mostly means the range's own noise screens or berms. The attenuation of soft ground used by the method is more imprecise and its reliability more uncertain in

varying terrain. The greatest uncertainty is related to highly varying terrain contours in the middle parts of the travel path of the noise.

The prediction method specifies that the initial data must also be entered as AI-weighted levels, determined in octave bands in eight directions at 45 ° intervals. Two factors, significant in principle, place limits on how exactly the prediction method can be complied with:

- Commonly available commercial noise calculation software suites do not include the shooting range noise model, i.e. the calculation of AI-weighted levels.
- Determining the noise emission as AI-weighted levels is more unreliable than measuring the real noise emission, or sound energy levels.

In practice, this deficiency can be solved by using the common Nordic prediction method included in the software suites. The noise emission, or the initial values, are then entered into the model as sound energy levels $L_{Q'}$, so that the raw quantity to be calculated is the A-weighted sound exposure level L_{AE} . Conversion to an AI-weighted maximum sound level can be done reliably by utilising the theoretical difference between the levels. The calculation of the bullet noise, also defined in the model, constitutes an additional problem. This problem is discussed below in more detail.

Based on the latter deficiency, the measurement instructions for the initial values presented in an appendix to the shooting range noise measurement instructions (Ministry of the Environment, 1999) is, in practice, incomplete. The instructions must be adapted so that sound energy level is the measured noise emission quantity, after which one can continue as described above.

Perhaps the most important factor in the use of the shooting range noise prediction method is the reliability of the initial data, or data on the noise emissions of firearms. The situation in Finland is that sufficient and reliable data is only available for the standard firearms used by the Finnish Defence Forces (Markula 2006). The measurements made for the previous version of the prediction method (Saario 1985) are insufficient for modelling purposes, as they do not include data in octave bands.

H5.3 Difference between AI-weighted level measurements and calculations

A common experience in the use of the shooting range noise prediction method is that the calculation results of the AI-weighted maximum sound level L_{AImax} are systematically greater than the results from the shooting range measurements made in accordance with the measurement instructions. The difference is usually about 5 dB.

A calculation result greater than the measurement results is obtained when the method's vegetation correction is not used in the calculation, which has been a common habit at least in the analyses performed for the Finnish Defence Forces. The justification for not using the vegetation correction has been that vegetation in Finland is not usually particularly abundant and dense during the leafless time of the year. In reality, vegetation will not then attenuate the propagating noise much at all. In Southern and Central Finland, the leafless period usually lasts from mid-October to mid-May, or around seven months.

In the prediction method, however, the vegetation correction is also intended for use in another purpose. Section 7, "Vegetation", of the method, states the following: "The correction is different from the source (Kragh et al. 1982) due to the influence of time weighting constant (I) on the actual impulse noise signals."

This explanation is related to the stretching of the shot impulses when the distance increases. In regular terrain, reverberation caused by terrain contours and woods is present. As a consequence of the reverberation, the duration of the shot impulse increases. When the maximum sound level of the shot impulse is measured using I-time weighting, the sound level meter misses the majority of the signal energy of

the shot. Human hearing, however, detects the entire signal energy and evaluates the disturbance caused by the noise based on it.

If the extraneous share of ca. 5 dB were to be separated from the actual vegetation correction, and an additional correction of that magnitude were to be used in the calculations as a separate "I-weighting correction", the systematic difference of around 5 dB mentioned earlier between the shooting range noise measurements and calculations would be eliminated. The method does not allow this kind of a choice, but it could be implemented through separate application instructions. In recent years, in the noise survey calculations for the Finnish Defence Forces, the vegetation correction has been applied in this way.

In the calculations, terrain reverberation as such is automatically taken into consideration. The method would therefore be rather reliable, if the calculated value were the A-weighted sound exposure level L_{AE} instead. All problems with the systematic differences between the calculated and measured results are connected only to the AI-weighted maximum sound level L_{AImax} . If, in the future, the shooting range noise prediction were to be performed using the same noise level quantities as with other environmental noise (sound exposure level and average sound level), this problem would be avoided.

H5.4 Bullet noise calculation

The calculation of the bullet noise of a supersonic projectile is its own separate problem. The phenomenon is acoustically peculiar and complex, and the regular environmental noise prediction method is not suited to handling it. The Nordic shooting range noise prediction method includes separate instructions for calculating the bullet noise. The problem is that the available computer software suites do not include this functionality, at least not off the shelf. In some software suites, the calculation method can be implemented using the included additional tools, albeit very laboriously.

The initial value for the model is formulated based on a theoretical model. The emission of the bullet noise could also be measured for the calculation purposes. A suitable measurement location is usually on top of the side berm of the shooting range. In some flight sound measurements carried out at shooting ranges of the Finnish Defence Forces, it has been observed that the theoretical initial value of the Nordic method and the measured initial value are reasonably close to each other.

However, further calculations from the initial value obtained using either method remains cumbersome. Figure 11.5 presents an example of a model calculation including the bullet noise in accordance with the Nordic method, where the bullet noise component has been calculated using the additional tools of the Cadna/A software.

The recommended procedure for taking the bullet noise into consideration is as follows: The bullet noise is not included in the regular model calculations, if there are no sites exposed to that noise, such as residential buildings, in the theoretically calculated bullet noise sector. If there are such sites, the bullet noise is calculated point by point only for the exposed sites, using the model's calculation procedure with a spreadsheet application, for instance. Alternatively, the total noise including the bullet noise is determined using measurements at the exposed sites only.

H5.5 Assessment outlook in the near future

In 2005–2010, the International Standards Organisation ISO has published a standard series on the measurement, calculation and assessment of shooting range noise, ISO 17201. The noise emission quantity measured in it is the sound energy level L_Q . The primary noise level quantity measured and calculated is the A-weighted sound exposure level L_{AE} . The calculation is performed using standard ISO 9613, which is the same as the common Nordic prediction method with the exception of some small details (Kragh et al. 1982). There is a separate calculation procedure for the bullet

noise, which in turn originates from the same source as the bullet noise calculation of the Nordic shooting range noise prediction method (NT ACOU 099: 2002).

It is evident that in the coming years, the measurement and calculation of shooting range noise will move towards using this standard series in many countries.

H5.6 Need for changes in the noise guideline values

The AI-weighted maximum sound level L_{AImax} is currently used as the guideline value quantity. Its suitability for the assessment of the annoyance from shooting range noise is limited. For a detailed evaluation on its suitability, see the reference (Jokitulppo et al. 2007). In brief, the AI-weighted maximum sound level has two shortcomings:

- the AI-weighted maximum level completely fails to take into consideration the number of shots or the time of their occurrence; basically a single shot determines the level of disturbance. This does not correspond with the actual disturbance verified by research; for instance, it depends directly on the number of shots.
- The time weighting I is unable to correctly express the loudness of shot impulses that have stretched in duration. The annoyance that depends on the acoustic characteristics of shots is primarily determined by the loudness, which in turn depends on the entire energy of the impulse.

The sound levels and their time and frequency weightings are defined in an international standard (IEC 61672-1: 2002). The time weighting I has been removed from the standard, and the notes section judges I-weighting to be unsuitable for determining loudness. Because the annoyance is connected to loudness, the same critique also applies to annoyance. This also means that sound level meters able to measure I-weighting will vanish from the market.

Neither does the recent international standard series on the measurement and calculation of shooting noise (ISO 17201) mention I-weighting.

On these grounds, a need for a re-evaluation of the Finnish guideline values with regard to the assessment quantity is evident in the near future. The quantity could be replaced by the A-weighted average sound level L_{Aeq} , or the quantity used to assess all other environmental noise. It would automatically take into consideration the number of shots, and time-related weightings could be added to it. An impulse correction is also needed.

H5.7 Arranging monitoring

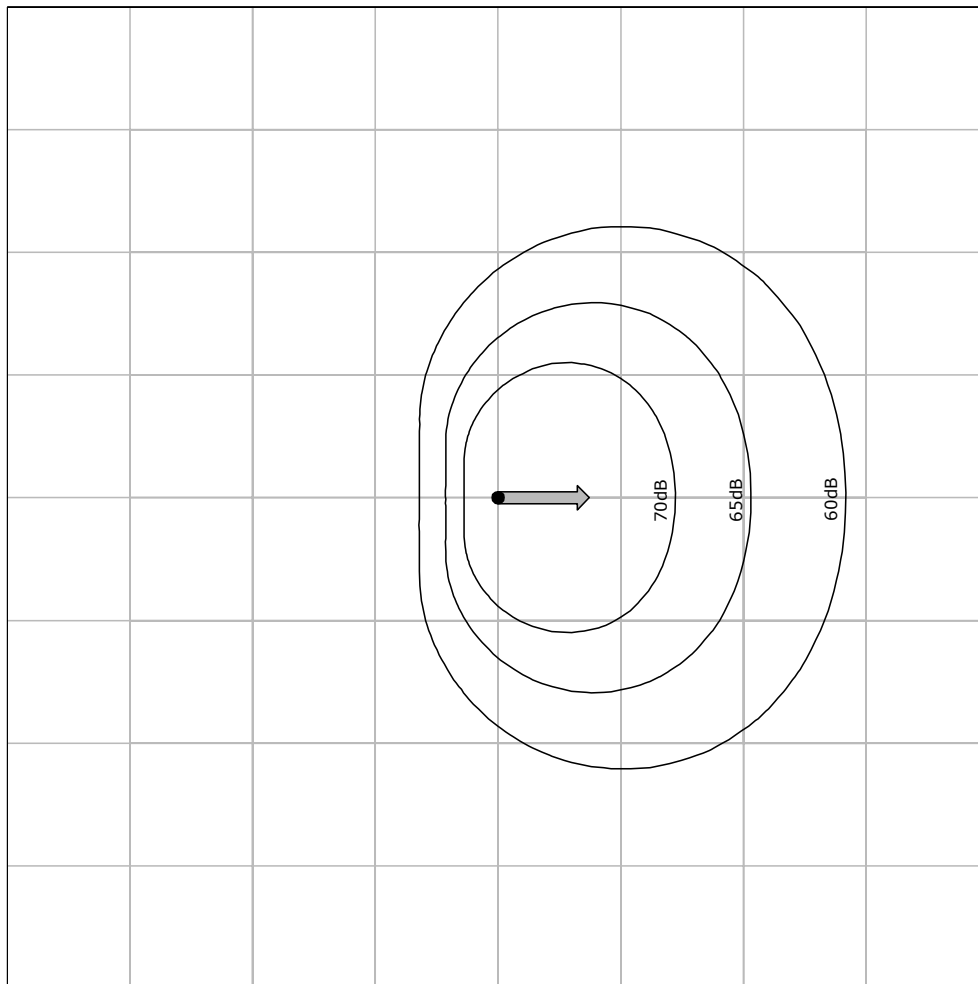
Requirements on arranging monitoring are often given to track the development of the noise situation identified in the noise surveys of shooting ranges and to supervise compliance with the noise limits set in the environmental permits. The monitoring is usually decreed to be done by measurements made at the exposed sites.

If no essential changes affecting noise have taken place at the shooting range after a noise prediction analysis, there is actually very little justification for making additional measurements. Due to the relative unreliability of the measurements, additional information cannot be obtained in practice.

However, monitoring is necessary when essential changes have taken place. The recommended procedure for implementing tracking in such a case is to update the noise prediction analysis. The most important justification for primarily using the noise prediction method is that its result is directly comparable to the prior prediction results. The comparability of measurement results is clearly poorer. It must also be noted that with the current guideline value practice, a change in the number of shots is not a change that should be tracked through prediction analysis or new measurements.

Appendix I. Diagrams (templates, "level open ground models")

II Template rifle 7–9 mm



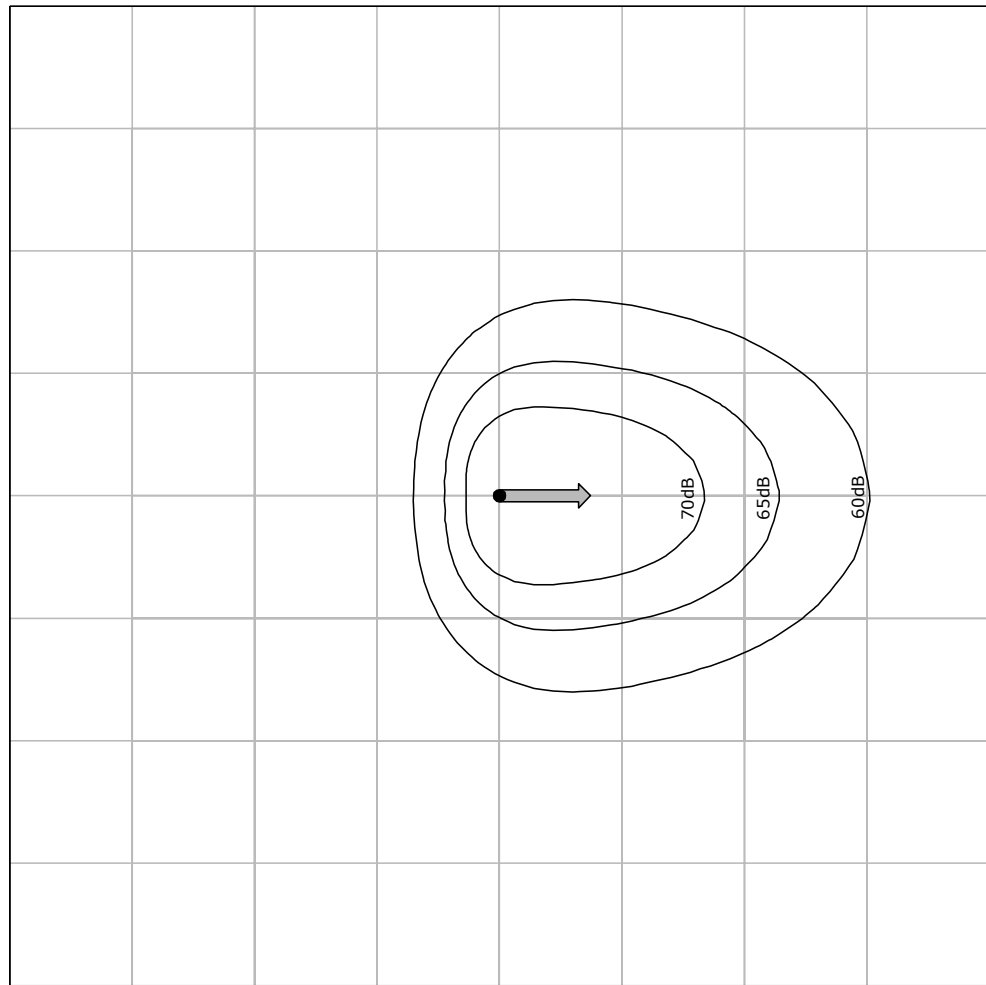
GRID SIZE 1 km x 1 km

Rifles 7-9 mm

Modelled noise propagation
on level, soft terrain without
a firing enclosure

Maximum level L_{AImax}
1:50 000

I2 Template pistol over 7 mm

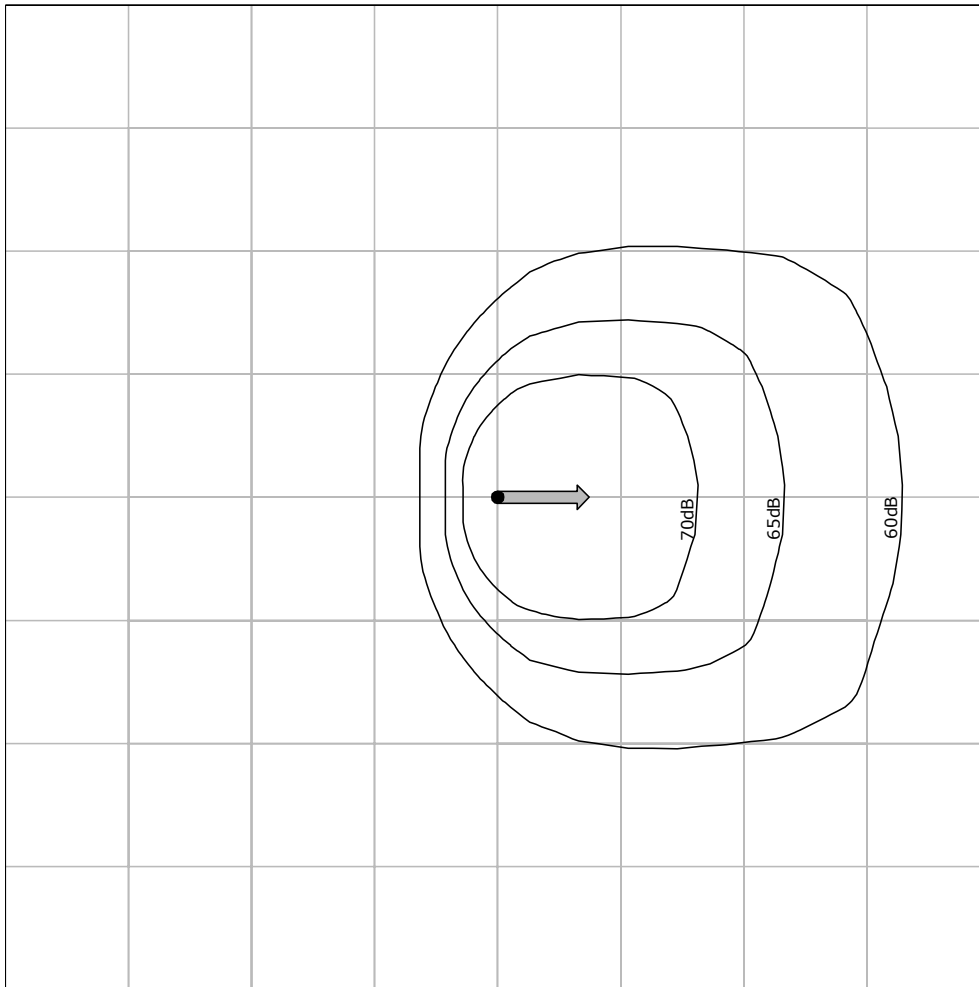


GRID SIZE 1 km x 1 km

Pistols over 7 mm

Modelled noise propagation
on level, soft terrain without
a firing enclosure
Maximum level L_{AImax}
1:50 000

13 Template trap



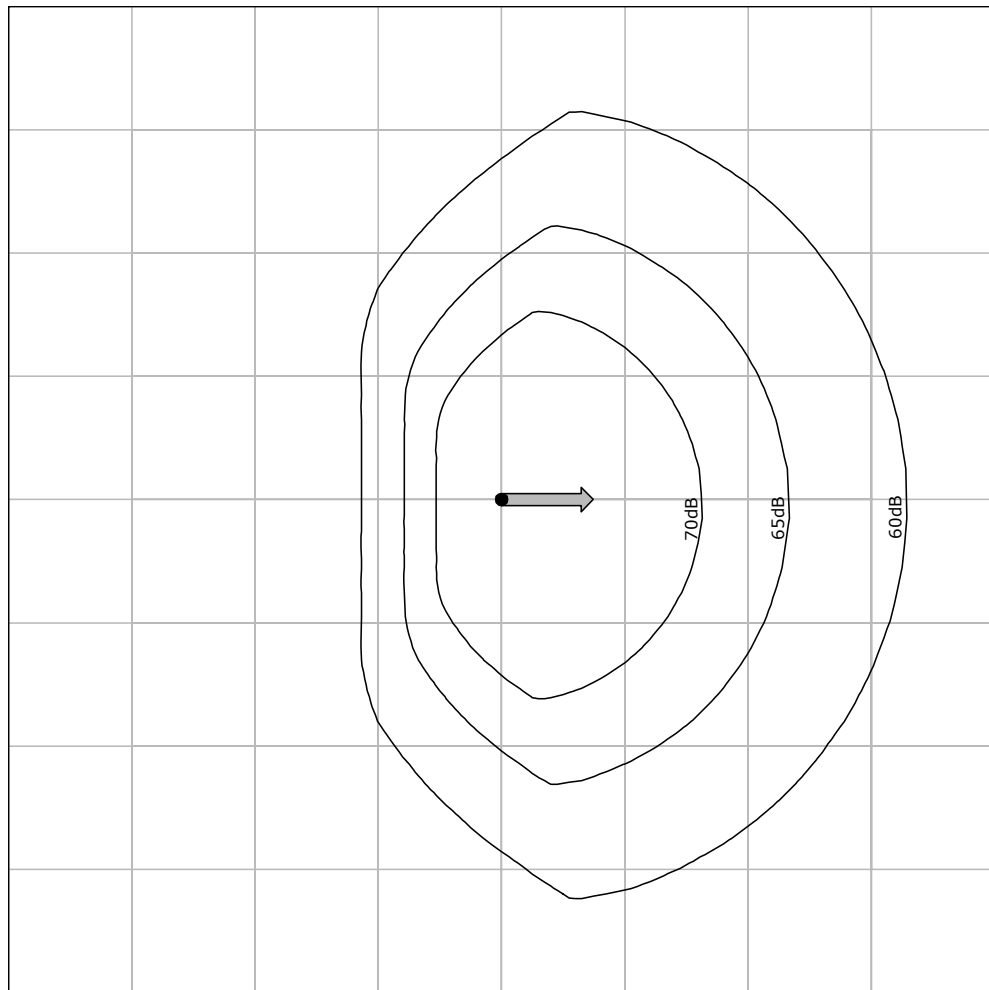
GRID SIZE 1 km x 1 km

Trap, shotgun 12 cal

Modelled noise propagation
on level, soft terrain without
a firing enclosure

Maximum level L_{AImax}
1:50 000

I4 Template skeet

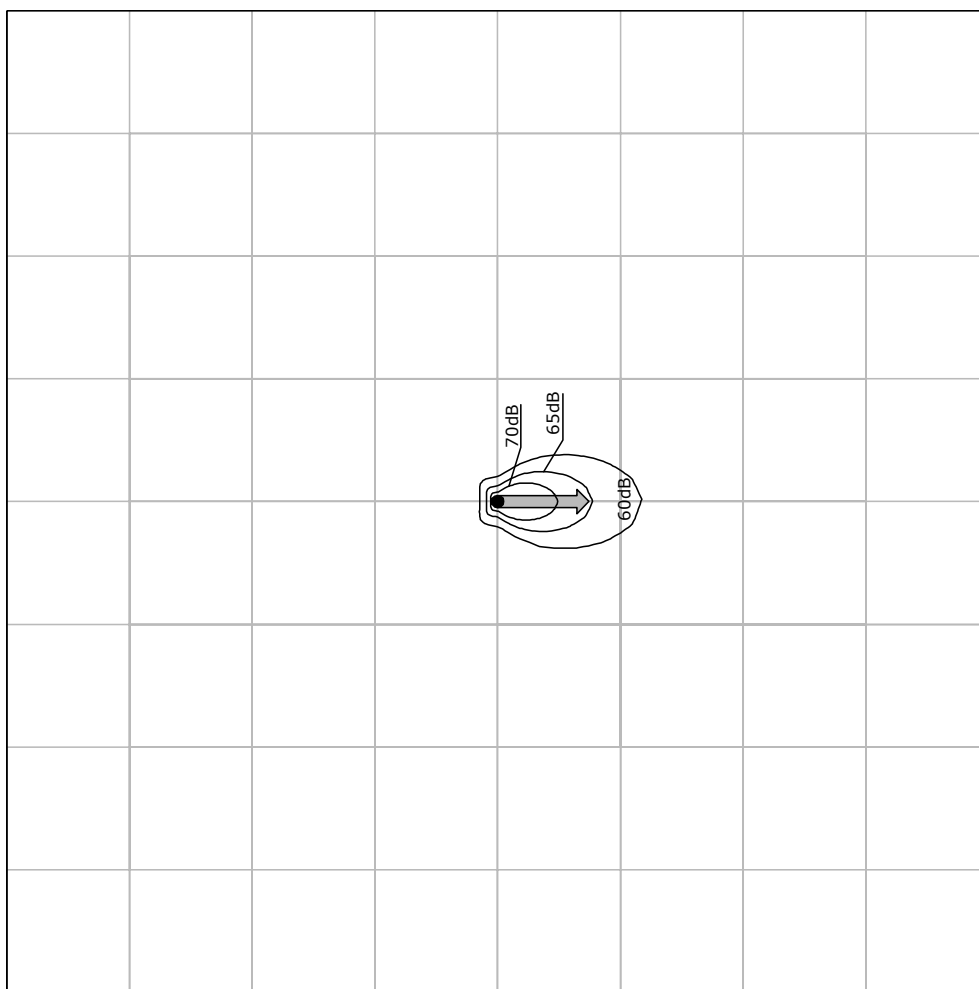


GRID SIZE 1 km x 1 km

Skeet, shotgun 12 cal

Modelled noise propagation
on level, soft terrain without
a firing enclosure

Maximum level L_{A1max}
1:50 000



GRID SIZE 1 km x 1 km

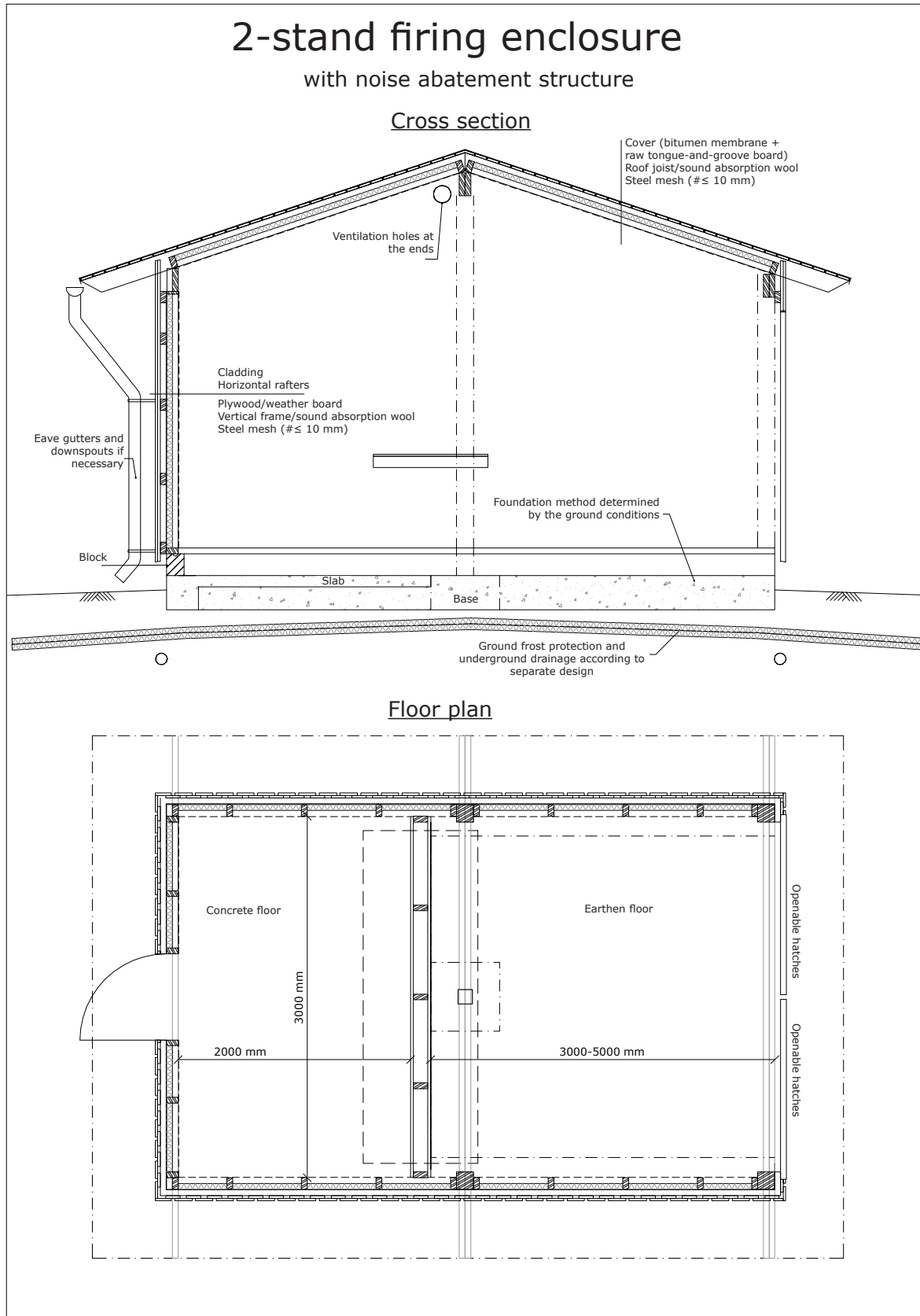
.22-calibre firearms

Modelled noise propagation
on level, soft terrain without
a firing enclosure

Maximum level L_{AImax}
1:50 000

Appendix J. Structural drawings, enclosures

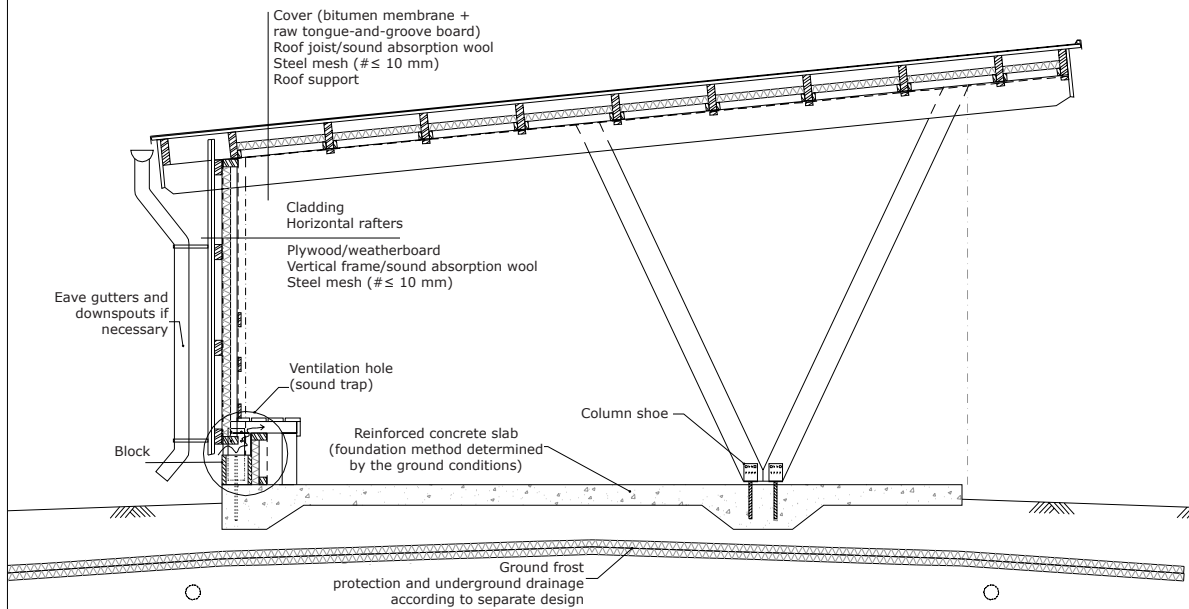
J1.1 2-stand firing enclosure



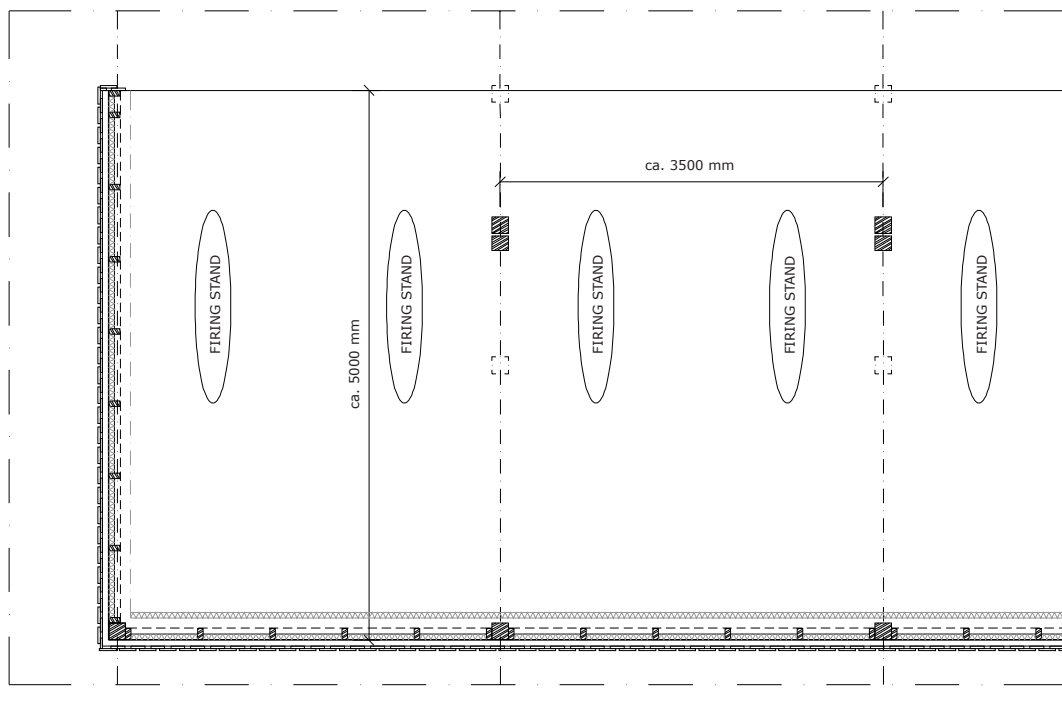
Firing line enclosure, type A

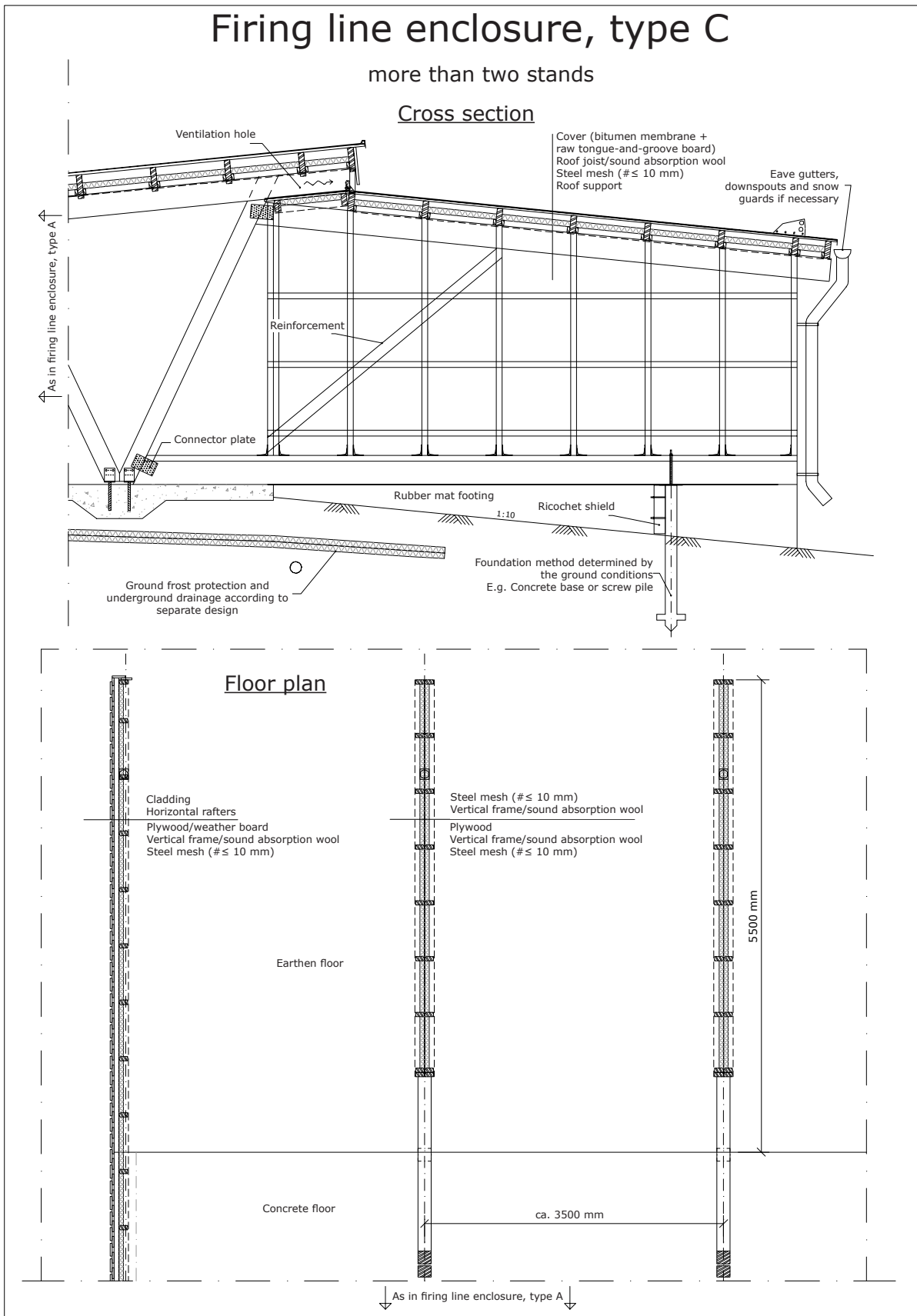
more than two stands

Cross section



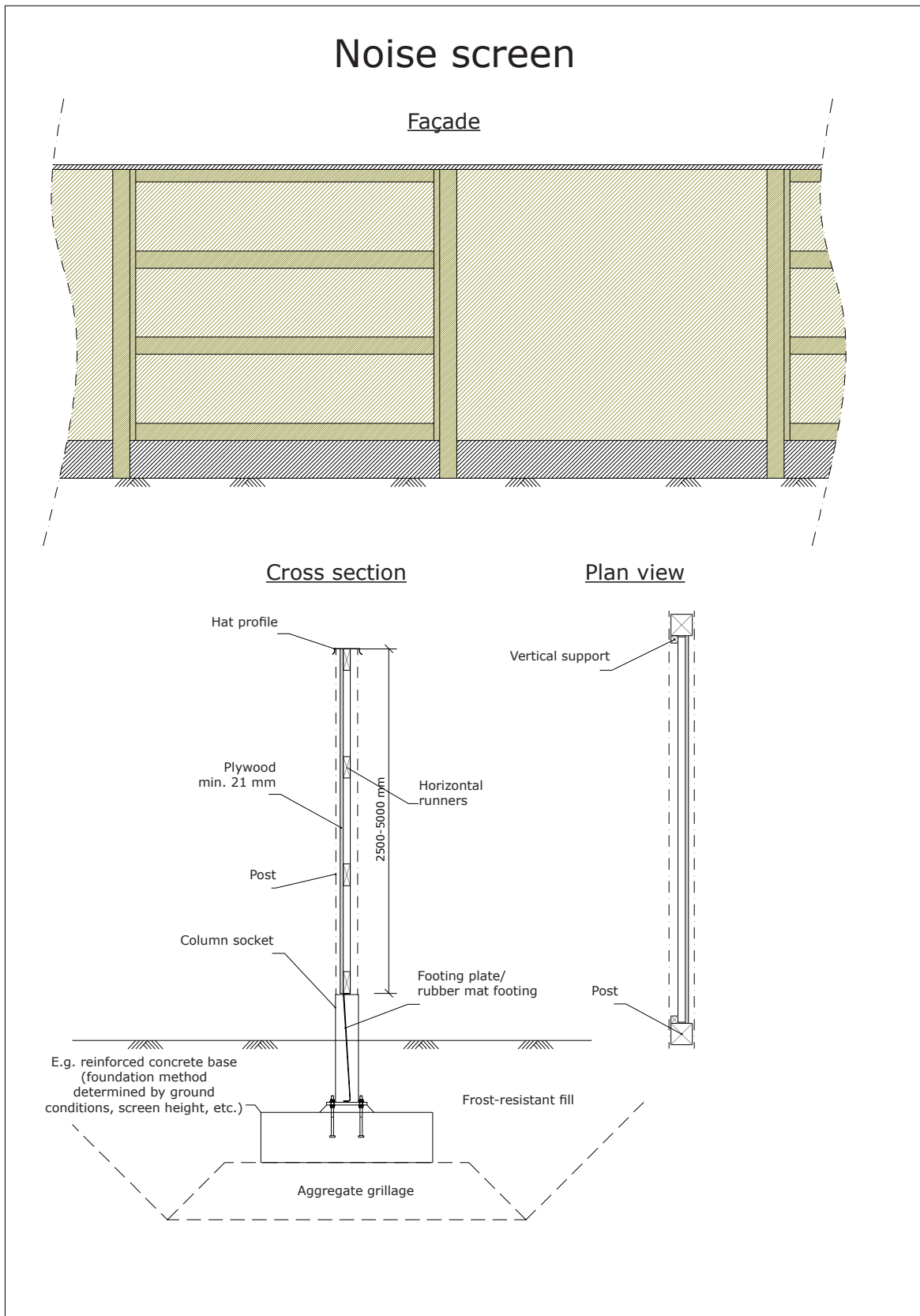
Floor plan



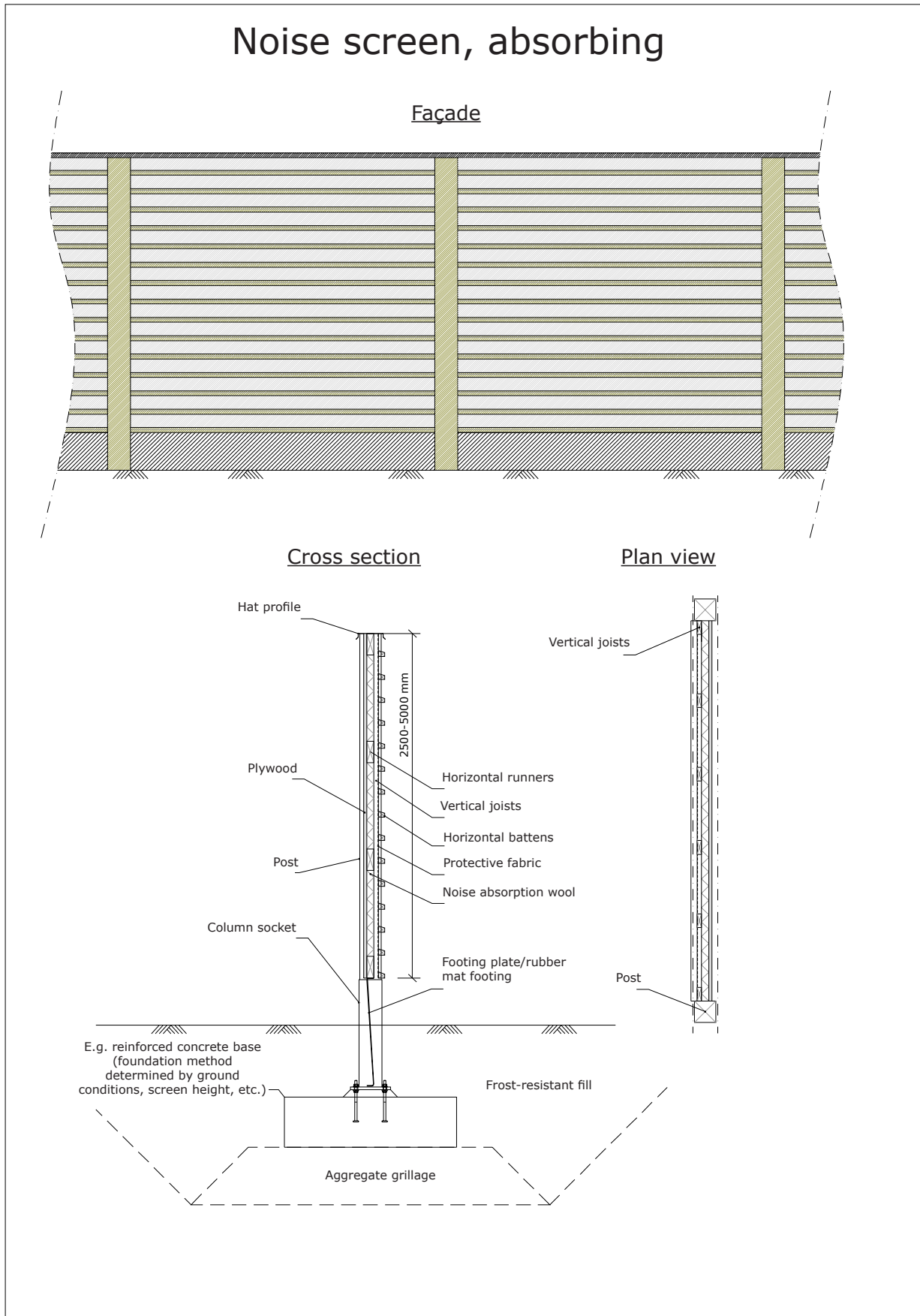


Structural drawings, screens

J2.1 Reflective screen

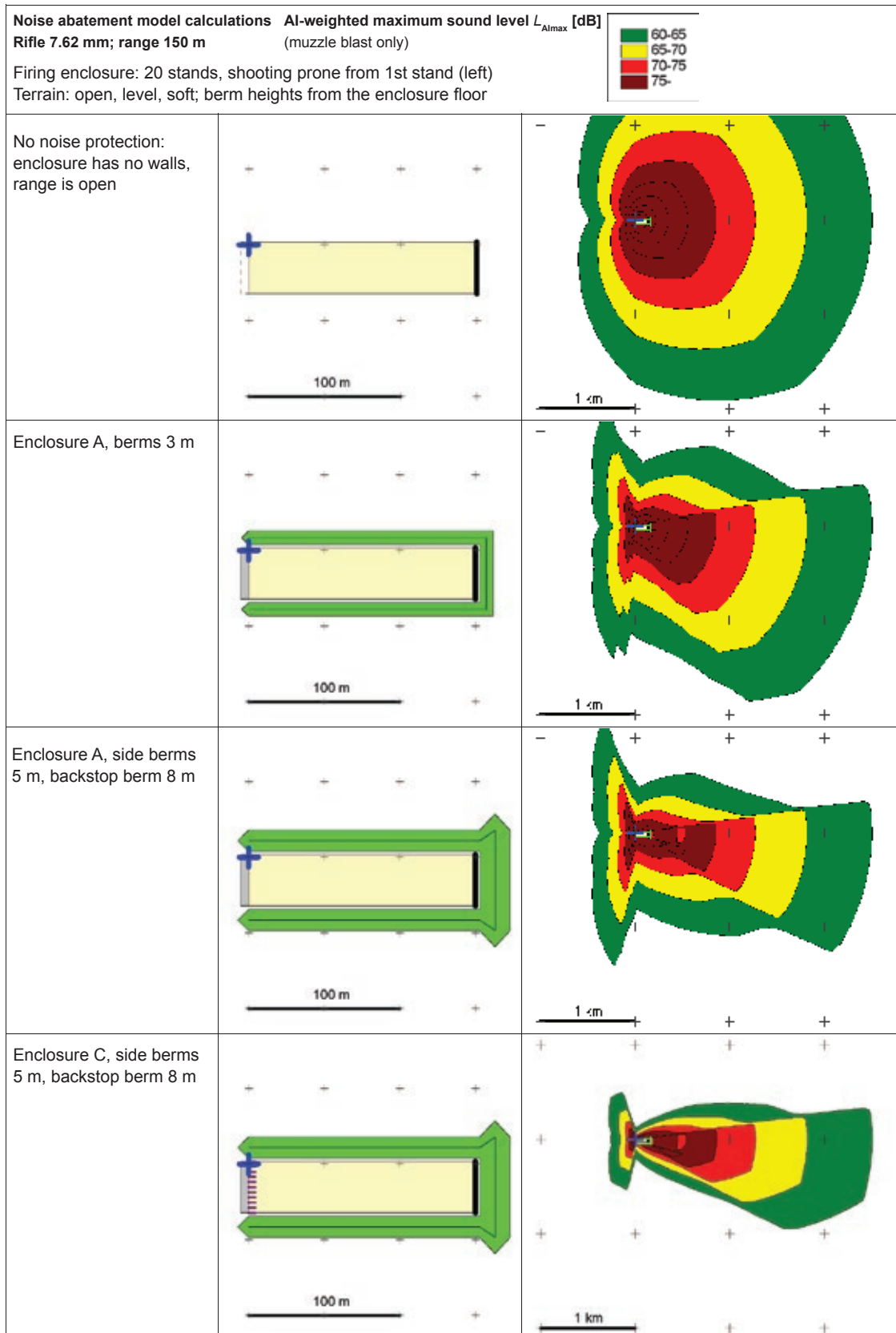


Noise screen, absorbing

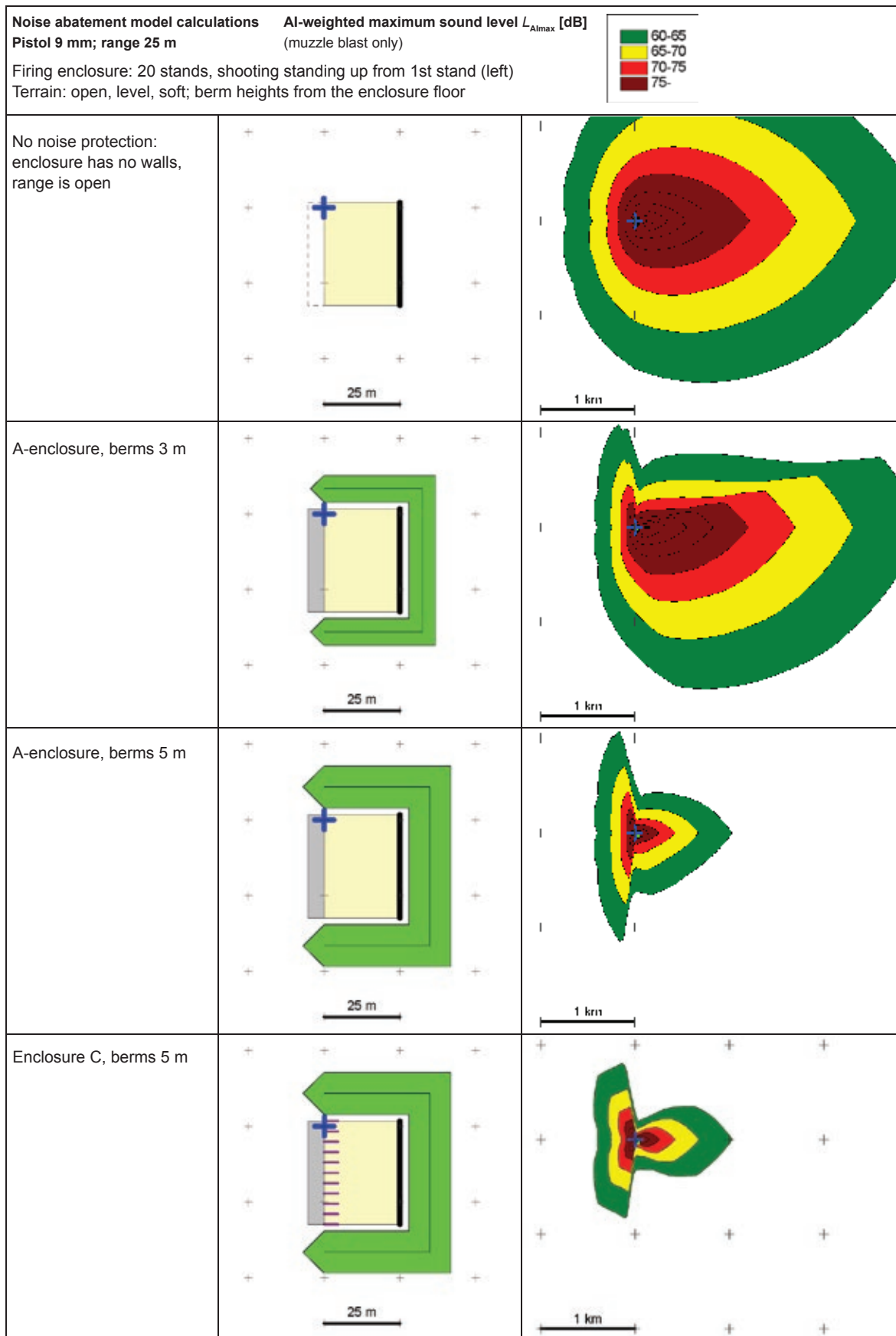


Appendix K. Effect diagrams for the abatement measures

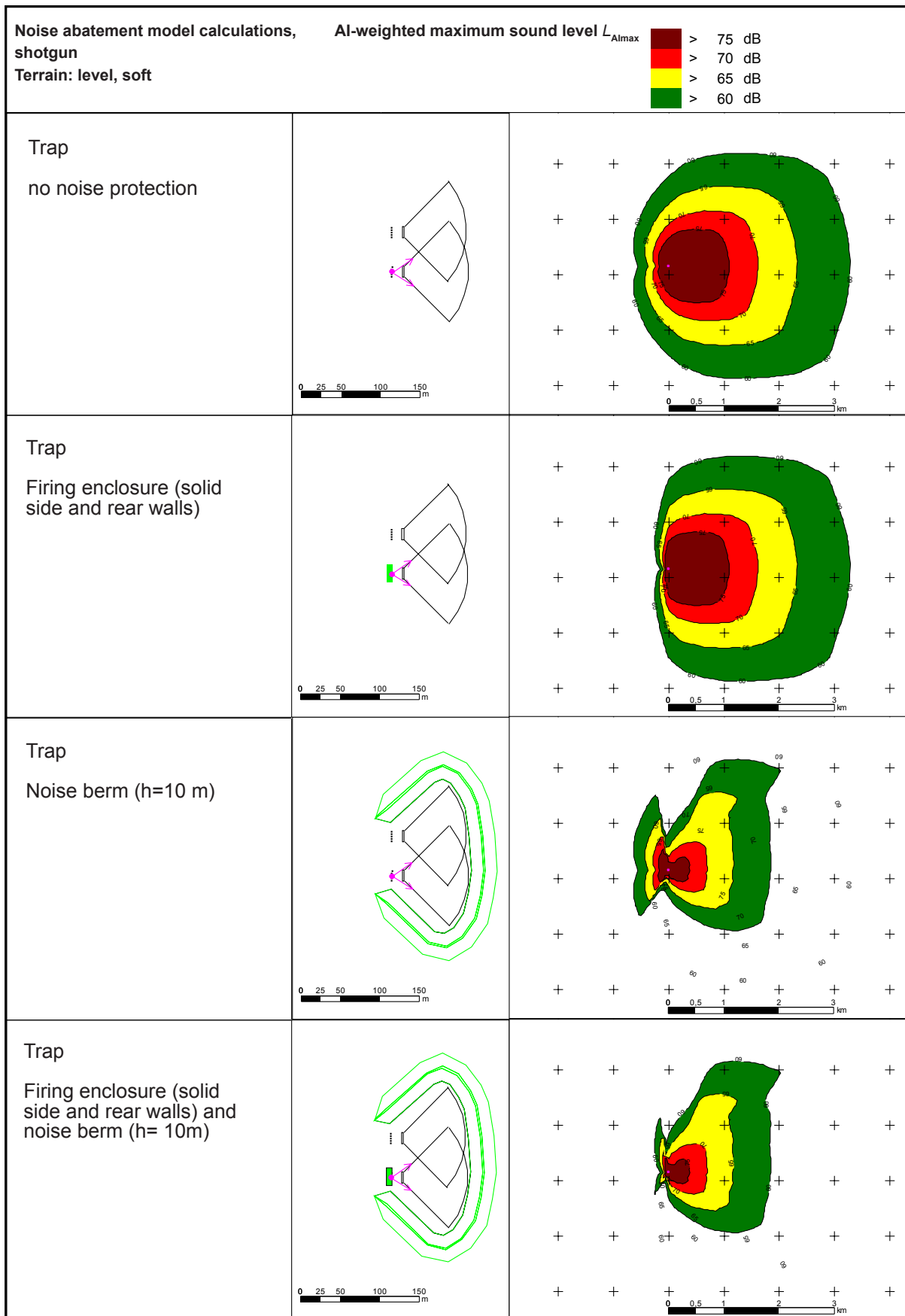
K1.1 Rifle



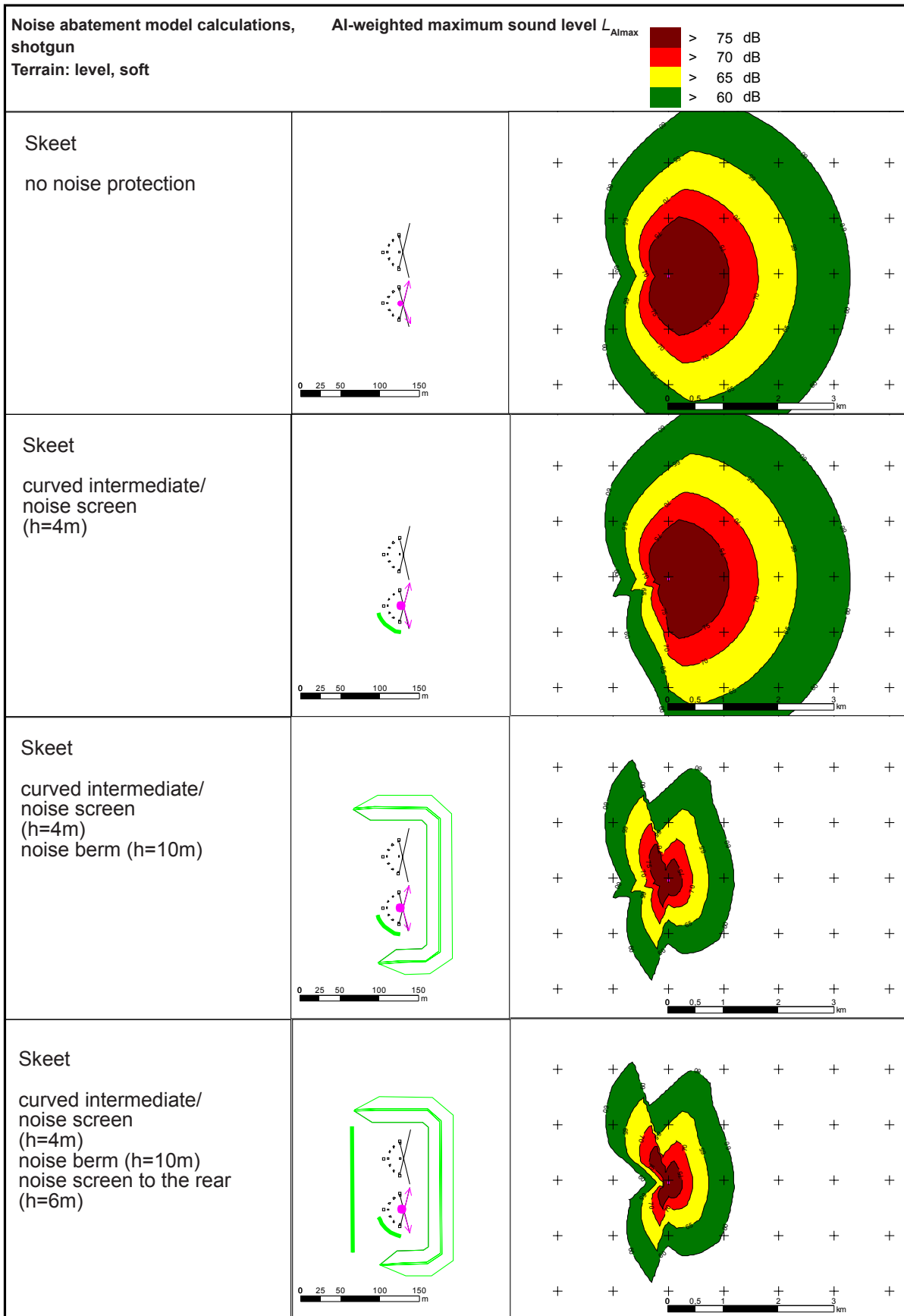
K1.2 Pistol



K2.1 Trap



K2.2 Skeet



KUVAILULEHTI

Julkaisija	Ympäristöministeriö	Julkaisu-aika Elokuu 2014		
Tekijä(t)	Sara Kajander ja Asko Parri (toim.)			
Julkaisun nimi	Ampumaratojen ympäristövaikutusten hallinta – Paras käyttökelpoinen tekniikka (BAT)			
Julkaisusarjan nimi ja numero	Suomen ympäristö 4/2014			
Julkaisun teema	Ympäristönsuojelu			
Julkaisun osat/ muut saman projektin tuottamat julkaisut	Julkaisu on saatavana myös internetistä: www.ym.fi/julkaisut			
Tiivistelmä	<p>Ampumaratojen ympäristövaikutuksia ovat haitallisten aineiden, pääasiassa metallien, mahdollinen leviäminen ympäristöön sekä melu. Vuonna 2010 käynnistettiin eri viranomais- ja toiminnanharjoittajatahojen yhteistyönä hanke, jonka tavoitteena oli määritellä ulkona sijaitseville ampumarakenteille paras käyttökelpoinen tekniikka (BAT). Tässä hankkeen loppuraportissa on esitelty käytössä ja osin vasta kehitteillä olevia, mahdollisesti potentiaalisia menetelmiä luotiase- ja haulikkoampumaratojen ympäristövaikutusten hallintaan sekä arvioitu niiden tehokkuutta ja soveltuvuutta eri ratatyypeille sekä kustannuksia ja taloudellista toteuttamiskelpoisuutta. Raportissa on lisäksi arvioitu ympäristövaikutusten hallinnan tarvetta erityyppisillä ampumarakenteilla ja erilaisissa ympäristöissä sekä annettu ohjeistus kohdekohtaisen arvioinnin tekemiseen.</p> <p>Selvitystyön johtopäätöksenä esitetään parhaat käyttökelpoiset tekniikat ja käytännöt ampumaratojen haitta-aine- ja melupäästön hallintaan, sekä ohjeelliset linjaukset kohdekohtaisesti soveltuvimman menetelmän valintaan. Parhaiksi arvioiduista tekniikoista on laadittu ohjeellisia tai periaatteellisia mallityöselityksiä ja rakennekuvia.</p> <p>Tämän kansallisen BAT-raportin on tarkoitus toimia ohjeena ympäristölupahakemusten laatijoille ja käsittelijöille.</p>			
Asiasanat	Ampumaradat, ympäristövaikutukset, paras käyttökelpoinen tekniikka, haitta-aineiden hallinta, meluntorjunta			
Rahoittaja/ toimeksiantaja	Ympäristöministeriö			
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	Sivuja 297	Kieli Suomi	Luottamuksellisuus Julkinen	Hinta (sis. alv 8 %)
Julkaisun myynti/ jakaja	Suomen ympäristökeskus (SYKE), neuvonta PL 140, 00251 Helsinki Sähköposti: neuvonta.syke@ymparisto.fi			
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PRESENTATIONSBLAD

Utgivare	Miljöministeriet	Datum August 2014		
Författare	Sara Kajander och Asko Parri (red.)			
Publikations titel	Ampumaratojen ympäristövaikutusten hallinta – Paras käyttökelpoinen tekniikka (BAT) (Begränsande av skjutbanors miljöpåverkan – Bästa tillgängliga teknik (BAT))			
Publikationsserie och nummer	Miljön i Finland 4/2014			
Publikationens tema	Miljövård			
Publikationens delar/ andra publikationer inom samma projekt	Publikationen finns tillgänglig också på internet: www.ym.fi/julkaisut			
Sammandrag	<p>Skjutbanors miljöpåverkan består i huvudsak av utsläpp av skadliga ämnen, främst metaller, samt buller. År 2010 påbörjades ett samarbetsprojekt mellan olika myndigheter och verksamhetsutövare för att fastställa bästa tillgängliga teknik (BAT) för skjutbanor utomhus. I denna slutrapport för projektet presenteras olika metoder för att begränsa miljöpåverkan av skjutbanor för finkalibriga vapen och jaktsskytte. En del av metoderna är beprövade och tillgängliga, medan en del fortfarande är under framtagande men anses potentiella. De olika metodernas effektivitet och lämplighet för olika typer av skjutbanor, samt kostnader och ekonomisk genomförbarhet har bedömts. I rapporten har man också granskat behovet av miljökrav på olika typer av skjutbanor i varierande miljö.</p> <p>Som slutsats av den genomförda utredningen framförs bästa tillgängliga teknik och bästa miljöpraxis för att begränsa skjutbanors metallutsläpp och bullerpåverkan. Därtill ges riktlinjer för miljökrav och val av lämpligaste metod för olika typer av skjutbanor och situationer. Principiella eller vägledande modellritningar och arbetsbeskrivningar har utarbetats för de tekniker som bedömts vara bäst.</p> <p>Denna nationella BAT-rapport är ämnad som vägledning både för dem som skriver och dem som behandlar miljötillståndsansökningar för skjutbanor.</p>			
Nyckelord	Skjutbanor, miljöpåverkan, bästa tillgängliga teknik, BAT, begränsande av metallförorening, bullerbekämpning			
Finansiär/ uppdragsgivare	Miljöministeriet			
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<i>Publication series and number</i>	The Finnish Environment 4/2014			
<i>Theme of publication</i>	Environmental protection			
<i>Parts of publication/ other project publications</i>	The publication is available on the internet: www.ym.fi/julkaisut			
<i>Abstract</i>	<p>The main environmental impacts of shooting ranges are contamination by heavy metals and noise. In 2010, a project for defining the best available techniques (BAT) for outdoor shooting ranges was started in co-operation with environmental authorities and range operators. In this report, a variety of methods for managing the environmental impacts of small arms and shotgun ranges is presented. Some of the methods are well-known and available, whereas others are emerging technologies with recognised potential. The environmental efficiency and suitability for different types of ranges as well as the costs and economic feasibility of the presented methods have been assessed. Furthermore, the environmental protection requirements for different types of ranges in different settings have been considered.</p> <p>As a result of the study, best available techniques and best practices for contamination and noise management on shooting ranges are introduced, as well as guidelines for determining the most suitable solutions for different situations. Indicative plans and drawings have been produced of the best techniques.</p> <p>This national BAT report is designed as a tool for environmental permit applicants and permit authorities.</p>			
<i>Keywords</i>	Shooting ranges, environmental impacts, best available techniques, BAT, pollutant management, noise management			
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