PYROTECHNICAL RISK ASSESSMENT

Site specific RA – Kommune Porsgrunn

V.01 – 30/11/2021

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1 RELATED DOCUMENTS

[1]	23/10/1987	Geotechnical Report: H227B-1 Hovedvegnettet i Grenland – Kultangen-prosjektet – Orientering om grunnforhold
[2]	13/08/2021	Historical UXO Research, Nedre Frednes in Porsgrunn (Norway)
[3]	20/05/2021	Offer ADEDE: UXO Desktop Study and Risk Analysis
[4]	26/11/2014	Sektor Gruppen AS – Grunnundersokelser Porsgrunn, Down Town
[5]	March 2021	Statens Vegvesen – Grunnundersokelser RV36 E18 Skyggestein utdrag

2 PROJECT LOCATION & SCOPE OF WORKS

Porsgrunn Kommune (Norway) plans in Nedre Frednes the construction of a social complex including apartment buildings, underground parking, office areas, stores, a park etc. (figure 1). As the project area lies in vicinity to the in 1943 bombed peninsula Herøya, the project area is likely contaminated with unexploded ordnance (UXO). A historical study of the war actions by ADEDE [2] concludes that the project area has a very high potential to be contaminated with unexploded 500 lb aerial bombs and a high potential to be contaminated with 3-inch rockets, 1000 & 2000 lb sea mines and 8.8 - 10.5 cm artillery in the project area. This UXO risk assessment gives a better insight in the risks such types of UXO pose during groundwork.

The following aspects are covered in this UXO risk assessment:

- General information on risk assessment studies
- UXO-risk calculations
    - Overview of UXO and potential occurrence in the project area
    - UXO-risk calculation per type of ammunition
    - Impact & safety perimeters for each UXO
- Prevention and mitigation measures
- Advise concerning the Risk mitigation strategy

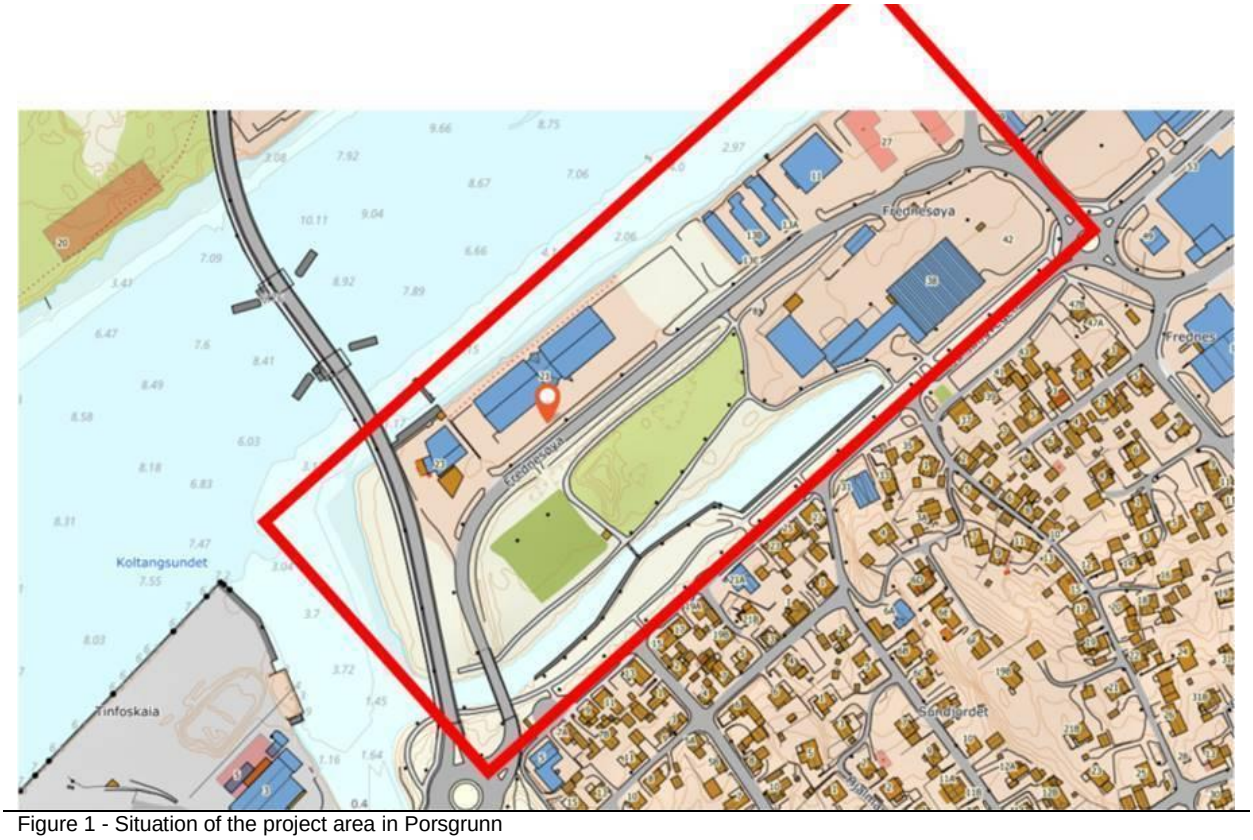

Figure 1 - Situation of the project area in Porsgrunn

3 RISK ASSESSMENT STUDY

3.1 INTRODUCTION

An UXO risk assessment evaluates, quantifies, and compares the effects and risks of UXO when (1) no extra mitigation measures are taken (section 3.3) and (2) advised safety measures are incorporated to eliminate or reduce the high risks to an acceptable level (section 3.4). A semi-quantitative interpretation of UXO risks is needed and can be obtained based on sets of pre-defined parameters using the Fine and Kinney method:

Risk = Probability x Exposure x Severity
R = P x E x S

The pre-defined parameters correspond with indicative values ranging from 'very low' to 'very high':

- Probability with values ranging from 0.1 = 'unthinkable' to 10 = 'to be expected,
- Exposure with values ranging from 0.1 'very rarely' to 10 = 'continuously',
- Severity with values ranging from 1 = 'light wounds' to 100 = 'catastrophic'.

It is important to underline that an UXO Risk Assessment (RA) differs from a Project Risk Assessment (PRA) or a general Task Risk Assessment (TRA). Table 1 explains the, sometimes subtle, differences between RA, PRA and TRA studies. Clear and unambiguous definitions with correct descriptions and examples are essential for a correct interpretation of the risk assessments.

Symbol	Definition	Example of estimations
R_{uxo} (this study)	Estimated risks for the different types of UXO expected at the project area during project work	$R_{uxo} = P_{uxo} \times E_{uxo} \times S_{uxo} = C_{uxo} \times S_{uxo}$ (C = Chance) Example: How dangerous will the 500 lb bombs dropped during WW2 be for the project?
R_p	Estimated risk of UXO-related accidents due to unsafe project decisions, actions and/or situations	$R_p = P_p \times E_p \times S_p$ Example 'Incorrect project planning': How dangerous can excavation work be in a high UXO-risk area without taking mitigation measures?
R_t	Estimated work-related risks of all tasks, actions, decisions, and situations.	$R_t = P_t \times E_t \times S_t$ Example: How dangerous is it to work next to an excavator?

Table 1 – Definitions and examples of several types of risk assessments. This document inventories and evaluates R_P for project decisions, actions and/or situations.

3.2 UXO RISK PARAMETERS

The definitions of used pre-defined risk parameters for this RA are described in table 2. To fully understand the UXO risks and effects of an explosion, several factors influencing the risk parameters must be considered. The most important 'influencers' are:

- Type and explosive content of UXO,
- Caused effects when UXO explodes (impact range, heat, shockwave, ...),
- Condition and orientation of UXO / fuse,
- Potential occurrence and depth of UXO in subsoil,
- Magnitude and type of groundwork.

Most of the factors can be derived from a preliminary historical study, military databases and mathematical models. However, some of the influencing factors are difficult to estimate and will stay uncertain until the UXO is exposed (f.e. the condition of UXO depends on the type of material, subsoil redox potential, etc.). This risk assessment will define these uncertain parameters as if in a 'worst case scenario' to anticipate on the largest threat. This does not reflect an over-estimation of risk parameters. The highest risk and most common error are simply neglecting the UXO risks.

More, a single explosion of UXO causes multiple effects that must be considered in a risk analysis. The magnitude of these effects depends on the type of ammunition. The expected effects are:

- Shock wave through air (supersonic) with destructive effects on people and infrastructure
- Ground shock (supersonic) with destructive effect on people and infrastructure
- Dispersion of fragments (fast-flying shards and splinters) both from the UXO itself as from nearby materials. Dispersion of fragments under water is limited.
- Sound pressure with damaging effect on people and infrastructure
- Underwater shock wave with destructive effect on people and floating/solid infrastructure

- Underwater bubble jet effect with destructive effects on nearby infrastructure
- Explosion heat
- Chemical aerosols (smoke and gas)

Symbol	Description	Values	
R_{uxo}	Estimated risk of UXO-related accidents due to the presence of UXO in the project area	**R < 21**	**Slight risk; acceptable**
		21 ≤ R < 71	**Small risk; attention required**
		71 ≤ R < 201	**Moderate risk; apply simple measures**
		201 ≤ R < 401	**High risk; apply large measures immediately**
		401 ≤ R	**Risk is too high; stop activities / operations**
P_{uxo}	Probability of triggering an UXO explosion during project work: depends on condition of UXO and type/orientation of UXO/fuse	0,5	Highly unlikely, but conceivable
		1	Unlikely, but possible in the long term
		3	Unusual (but possible)
		6	Possible
		10	To be expected
E_{uxo}	Exposure to the UXO-dangers: depends on occurrence/depth of UXO and type/magnitude of groundwork	0.5	Seldom exposed
		1	Rarely
		2	Sometimes
		3	Often
		6	Frequently
		10	Constantly exposed
S_{uxo}	Severity of injury and damage after an UXO explosion: depends on type/content of UXO and caused effects (impact range, heat, shock wave, …)	1	Slight effect; injury without absence
		3	Important; injury with absence
		7	Severe, lasting injury
		15	Very severe, lasting disability
		40	Disaster, a fatal casualty
		100	Major disaster, multiple fatal casualties

Table 2 – Description of UXO risk parameters

3.3 UXO RISKS AT NEDRE FREDNES

Based on the historical preliminary investigation [1], several geotechnical studies [2, 4, 5], and a thorough UXO knowledge, it is possible to evaluate the risks of the different types of UXO at Nedre Frednes correctly. The historical study [1] concludes a high to very high potential to encounter next types of UXO in the project area of Nedre Frednes:

- Allied 500 lb drop-off bombs
- Allied 3-inch rockets – RP-3
- Allied 1000 and 2000 lb naval mines
- German 8.8 and 10.5 cm anti-aircraft grenades

Modelled penetrating depths are derived from a.o. historical military data (drop-off flight altitude or firing speed) and UXO-intrinsic data (All up weight, Net explosive equivalent weight, shape) combined with geological/geotechnical data [2,4,5]. Those last studies point out that the subsoil of this area consists mainly of loose sediments (fine sand, silty clay to clayey

silt) up to 20-25 MBGL. There is no indication of a shallow hard-rock massif which influences the penetration depths and UXO risks.

An important note when dealing with UXO: all ammunition is designed with a single goal, to create as much damage to people or infrastructure as possible. This explains the often maximum scores of 100 for the S_p-parameter.

3.3.1 ALLIED 500 LB DROP-OFF BOMBS

Based on the described factors in table 4 and calculated impact ranges in table 5 for 500 lb drop-off bombs, an estimation of UXO risk parameters for groundwork, without UXO mitigation measures, is made for this project area. The 500 lb bombs have a high potential to be found in the project area [2] up to a depth of 7 m below the WW2 ground level. During all types of groundwork up to 7 m below ground level (MBGL), and activities generating heavy vibrations, people and infrastructure will be exposed frequently to explosion danger (E_{uxo} = 6). An accidental explosion can be expected due to the potential bad condition, type and orientation of the fuse and bomb. In other words, there is a very high triggering potential during groundwork (P_{uxo} = 10). An accidental explosion has a very high potential to create a catastrophe (S_{UXO} = 100).

Probability - P_{UXO}	**Exposure - E_{uxo}**	**Severity - S_{uxo}**	**Risk - R_{uxo}**
10	6	100	**6000**

Table 3 – UXO risk of drop-off bombs at project area – R_{uxo} without UXO mitigation measures

The calculated risk for these types of bombs equals 6000. Groundwork and activities causing heavy vibrations cannot be allowed. Work can only start when thorough UXO mitigation measures are implemented (see chapter 4). The severity of explosions tends to decrease with increasing depth but remains far from safe (R_{uxo} will remain > 2400).

Type of ammunition	▪ 500 lb General Purpose M43 & MC allied drop-off ammunition
Potential occurrence	▪ Very likely to occur in the subsurface of the entire project area ▪ Not in the soil along the banks brought in after the war. The subsoil under this post-war package remains prone to bomb contamination.
Explosive content	▪ 127 kg TNT or amatol explosives
Major effects	▪ Shock wave with very destructive effect on people and infrastructure ▪ Dispersion of fragments in a wide area. Actual radius decreases with depth of bomb explosion ▪ Ground shock with destructive effect on people and infrastructure ▪ Sound pressure damaging people and infrastructure ▪ Explosion heat
Condition	▪ Potentially very dangerous condition: bombs and fuses are exposed for ca. 80 years to oxidation (since 1944).
Depth in subsurface	▪ Up to 7 MBGL: bombs were designed to penetrate the subsurface. They were dropped at high altitude (15 350 feet or 4680 m). This implies a high kinetic energy of the bomb when reaching the surface, able to penetrate the subsurface.

Orientation in subsoil	▪ Very dangerous orientation of fuse: these types of drop-off bombs move, while penetrating the subsurface, in a parabolic way due to increasing friction with depth. This implies a 'turn' at their greatest depth in the subsoil, and move up again, fuse upwards directed.
Dangerous project activities	▪ All groundwork up to 7 MBGL: drilling, excavating, milling asphalt/pavements, … ▪ All activities which cause heavy vibrations (heavy transport, excavation and demolition work).

Table 4 – Factors needed to estimate the risk parameters of allied 500 lb drop-off bombs

	Location of explosion	Explosion effect	Impact class	Modelled radius (m)
Impact ranges of a 500 lb drop-off bomb	Explosion on surface	Shock wave	50% chance on mortality / destruction of infrastructure	25
			Severe injuries / damage to infrastructure	40
			Important injuries / damage to infrastructure	75
			Light injuries / damage to infrastructure	111
			Minor or no injuries / damage to infrastructure	221
		Dispersion of fragments	Harmful dispersion radius	1103
			Maximum dispersion radius	1430
		Ground shock	Harmful ground shock radius	139
			Max. distance of ground shock	361
		Sound pressure	Harmful impact radius	290
	Under water explosion	Shock wave	Max. distance of shock wave	2367
			Destructive Impact radius on infrastructure	23

Table 5 – Impact ranges of a 500 lb drop-off bomb

3.3.2 RP-3 ROCKETS

Based on the described factors in table 7 and the calculated impact ranges in table 8 for RP-3 rockets, an estimation of UXO risk parameters for groundwork, without UXO mitigation measures, is made for this project area. The rockets have a very high potential to occur in the project area [2] up to 2 MBGL. During all types of groundwork up to 2 MBGL, and during activities generating heavy vibrations, people and infrastructure will be exposed frequently to explosion danger (E_{uxo} = 6). An accidental explosion is possible due to the potential bad condition of fuses and rockets as well as the unknown orientation of the fuse (P_{uxo} = 6). An accidental explosion has a very high potential to create a catastrophe (S_{UXO} = 100).

Probability - P_{UXO}	Exposure - E_{uxo}	Severity - S_{uxo}	Risk - R_{uxo}
6	6	100	**3600**

Table 6 – UXO risk of RP-3 rockets at the project area – R_{uxo} without UXO mitigation measures

The calculated risk for RP-3 rockets equals 3600, which is unacceptable high. Groundwork and activities causing heavy vibration cannot be allowed. Work can only start when thorough UXO mitigation measures are implemented (see chapter 4).

Type of ammunition	▪ RP-3 – Rocket projectile 3 inch
Occurrence	▪ Very likely to occur in the total project area. Will not occur in post-WW2 dumped sediments (e.g., banks of Porsgrunn Selva).
Explosive content	▪ 60-pound (27.4 kg) warhead with 5.44 kg TNT or amatol 60/40 explosives
Major effects	▪ Shock wave with destructive effect on people and infrastructure ▪ Destructive ground shock ▪ Sound pressure damage ▪ Explosion of RP-3 rockets leaves wide impact craters ▪ Explosion heat ▪ Dispersion of fragments with catastrophic effects
Condition	▪ Potentially dangerous condition: rockets and fuses are exposed during 80 years to oxidation (since 1944).
Depth in subsurface	▪ Up to 2 MBGL: RP-3 rockets are 'fired' at low altitude (100-200 ft or 30-60 m) with dive bombers at a speed of 300 miles/h.
Orientation in subsoil	▪ Unknown orientation of explosives = dangerous situation.
Dangerous project activities	▪ All groundwork up to 2 m: drilling, excavating, milling asphalt/pavements, drilling, … ▪ All activities which cause heavy vibrations (heavy transport, excavation and demolition work).

Table 7 – Factors needed to estimate the risk parameters of allied 3-inch rockets

	Location of explosion	Explosion effect	Impact class	Modelled radius (m)
Impact ranges of a RP-3 rocket explosion	Explosion on surface	Shock wave	50% chance on mortality / destruction of infrastructure	9
			Severe injuries / damage to infrastructure	14
			Important injuries / damage to infrastructure	26
			Light injuries / damage to infrastructure	39
			Minor or no injuries / damage to infrastructure	77
		Dispersion of fragments	Harmful dispersion radius	771
			Maximum dispersion radius	841
		Ground shock	Harmful ground shock radius	29
			Max. distance of ground shock	75
		Sound pressure	Harmful impact radius	136
	Under water explosion	Shock wave	Max. distance of shock wave	828

			Destructive impact radius on infrastructure	8

Table 8 – Estimated impact ranges of an RP-3 rocket explosion

3.3.3 ALLIED 1000 AND 2000 LB NAVAL MINES

Based on the described factors in table 10 and calculated impact ranges in table 11 for 1000 and 2000 lb naval mines, an estimation of UXO risk parameters for groundwork, without UXO mitigation measures, is made for this project area. The naval mines have a high potential to occur near the surface (parachute drop-off) in the navigable waterways within the project area [2]. During all types of groundwork near the surface, and during activities generating heavy vibrations, people and infrastructure on or near the waterways will be exposed often to explosion danger (E_{uxo} = 3). On the land side, naval mines are seldom encountered during groundwork (E_{uxo} = 0.5). An accidental explosion can be expected due to the potential bad condition of fuses and mines as well as the very dangerous orientation of the fuses and thus high triggering potential during groundwork (P_{uxo} = 10). An accidental explosion has a very high potential to create a catastrophe (S_{UXO} = 100).

Probability - P_{UXO}	**Exposure - E_{uxo}**	**Severity - S_{uxo}**	**Risk - R_{uxo}**
10	3 – waterways	100	**3000**
10	0.5 – land side	100	**500**

Table 9 – UXO risk of drop-off naval mines at project area – R_{uxo} without UXO mitigation measures

The calculated risk for naval mines equals 3000 for work on or near the navigable waterways (Porsgrunn Selva) and 500 for groundwork on the land side. In both cases, groundwork and activities causing heavy vibrations cannot be allowed. Work can only start when thorough UXO mitigation measures are implemented (see chapter 4).

Type of ammunition	▪ 1000 lb British A-MK V and A-MK VII parachute drop-off mines ▪ 2000 lb British I-IV and I-VI parachute drop-off mines
Potential occurrence	▪ Likely to occur near ground level in waterways at the project area (Porsgrunn Selva) ▪ Can be covered by soils along the banks brought in after the war. ▪ Rarely found on the land side but a small possibility remains (drifting parachutes, bad aiming of pilots, …).
Explosive content	▪ 1000 lb MK bombs hold 600 lb (272 kg) of explosives ▪ 2000 lb I bombs hold 950 lb (321 kg) of explosives
Major effects	▪ Underwater shock wave with extreme destructive effect on people and infrastructure on or nearby the waterway (partial flooding of project area, destruction of bridges, ships and quays, …) ▪ Shock wave with very destructive effect on people and infrastructure ▪ Underwater bubble jet effect with destructive effect on nearby infrastructure
Condition	▪ Potentially dangerous condition: bombs and fuses have been exposed for 80 years to oxidation and weathering/current erosion (since 1944).

Depth in subsurface	▪ Near-surface depths: mines were dropped using parachutes at low altitude (100-200 ft or 30-60 m).
Orientation in subsoil	▪ Very dangerous orientation of fuse: these mines were dropped with parachutes. Fuses are pointing upwards.
Dangerous project activities	▪ All near-surface groundwork: drilling, dredging, excavating, … ▪ All activities which cause heavy vibrations (heavy transport, excavation & dredging work).

Table 10 – Factors needed to estimate the risk parameters of allied naval mines

	Location of explosion	Explosion effect	Impact class	Modelled radius (m) - 1000 lb mine	Modelled radius (m) – 2000 lb mine
Impact ranges of 1000 & 2000 lb naval mines	Explosion on surface	Shock wave	50% chance on mortality / destruction of infrastructure	25	33
			Severe injuries / damage to infrastructure	39	54
			Important injuries / damage to infrastructure	74	100
			Light injuries / damage to infrastructure	109	147
			Minor or no injuries / damage to infrastructure	217	295
		Dispersion of fragments	Harmful dispersion radius	1215	1380
			Maximum dispersion radius	1408	1901
		Ground shock	Harmful ground shock radius	135	213
			Max. distance of ground shock	351	33
		Sound pressure	Harmful impact radius	382	519
	Under water explosion	Shock wave	Max. distance of shock wave	2323	3153
			Destructive impact radius on infrastructure	22	30

Table 11 – Estimated impact ranges for 1000 and 2000 lb naval mines

3.3.4 8.8 AND 10.5 CM ARTILLERY AMMUNITION

Based on the described factors in table 13 and the calculated impact ranges in table 14 for 8.8 and 10.5 cm German artillery ammunition, an estimation of UXO risk parameters for groundwork, without UXO mitigation measures, is made for this project area. The anti-aircraft grenades have a high potential to occur in the project area [2] up to 4 MBGL. During all types of groundwork up to 4 MBGL, and during activities generating heavy vibrations, people and infrastructure will often be exposed to explosion danger (E_{uxo} = 3). An accidental explosion during groundwork up to 4 m below ground level, or caused by heavy vibrations, is possible due to the potential bad condition of the detonation mechanism (P_{uxo} = 6). An accidental explosion can cause a disaster (S_{UXO} = 40).

Probability - P_{UXO}	**Exposure - E_{uxo}**	**Severity - S_{uxo}**	**Risk - R_{uxo}**
6	3	40	**720**

Table 12 – UXO risk of 8.8 and 10.5 cm artillery ammunition at project area – R_{uxo} without UXO mitigation measures

The calculated risk for 8.8 and 10.5 cm FLAK grenades equals 750. Groundwork and activities causing heavy vibration cannot be allowed. Work can only start when thorough UXO mitigation measures are implemented (see chapter 4).

Type of ammunition	▪ 8.8 and 10.5 cm German anti-aircraft grenades (FLAK grenades)
Potential occurrence	▪ Likely to occur in project area, including in post WW2 dumped sediments from nearby areas. The project area lies in the proximity of two WW2 German anti-aircraft batteries, and movable canon batteries may have been present.
Explosive content	▪ 8.8 cm grenade – 0.68 to 1 kg TNT or amatol 60/40 ▪ 10.5 cm grenade – 1.55 kg TNT or amatol 60/40
Major effects	▪ Shock wave with destructive effect on people and infrastructure ▪ Ground shock with destructive effect on people and infrastructure ▪ Damaging sound pressure wave ▪ Explosion heat ▪ Dangerous dispersion of fragments
Condition	▪ Potentially dangerous condition: ammunition is exposed for 80 years to oxidation (since 1944).
Depth in subsurface	▪ Up to max. 4 MBGL: ammunition is fired giving the grenades high speed. This implies a high kinetic energy of the grenades when reaching the surface, able to penetrate subsurface.
Orientation in subsoil	▪ Orientation of unexploded grenades is most likely with the nose downwards. ▪ The grenades were designed with a preset time detonation. Touching unexploded grenades can trigger the fuse to detonate.
Dangerous project activities	▪ All groundwork up to 4 MBGL: drilling, excavating, milling asphalt/pavements, … ▪ All activities which cause heavy vibrations (heavy transport, excavation and demolition work).

Table 13 – Factors needed to estimate the risk parameters of German anti-aircraft grenades

	Location of explosion	Explosion effect	Impact class	Modelled radius (m)
Impact ranges of a 10.5 cm grenade explosion	Explosion on surface	Shock wave	50% chance on mortality / destruction of infrastructure	6
			Severe injuries / damage to infrastructure	9
			Important injuries / damage to infrastructure	17
			Light injuries / damage to infrastructure	25
			Minor or no injuries / damage to infrastructure	51
		Dispersion of fragments	Harmful dispersion radius	682
			Maximum dispersion radius	698
		Ground shock	Harmful ground shock radius	15
			Max. distance of ground shock	40
		Sound pressure	Harmful impact radius	90
	Under water explosion	Shock wave	Max. distance of shock wave	545
			Destructive radius on infrastructure	5

Table 14 – Estimated impact ranges of a 10.5 cm German grenade explosion

4 PREVENTION AND MITIGATION MEASURES

4.1 UXO RISK MITIGATION MEASURES

All risk calculations point out that UXO risk mitigation measures must be implemented before any groundwork, or vibration-generating activities, can start. Table 15 shows the risk calculation, first without UXO mitigation measures as calculated and explained in sections 3.3.1 to 3.3.4. A list of precautionary actions and the re-evaluated risks after implementing mitigation measures which eliminate or minimise one or more risk parameters (P, E, S):

UXO	P_{uxo}	E_{uxo}	S_{uxo}	R_{uxo}	Mitigation measures	P_{uxo}	E_{uxo}	S_{uxo}	R_{uxo}
500 lb drop-off bombs	10	6	100	**6000**	▪ Emergency and intervention plan when UXO is found ▪ Evacuation and coordination plan ▪ Known safety perimeters per type of UXO (see chapter 4.2) ▪ All (sub)contractors need to implement these UXO risks in their Task Risk	3	0.5	40	60

RP-3 Rockets	6	6	100	**1800**	Assessment ▪ Informing, training, and testing (sub) contractors/personnel about working in an area with a very high UXO risk ▪ EOD contact number is known by all personnel in case explosives are accidentally found ▪ Preliminary geophysical bomb detection of project area by experienced EOD experts ▪ Surface detection in areas where groundwork is limited to 2 MBGL ▪ Intrusive detection in areas where groundwork exceeds 2 MBGL ▪ UXO clearance by a team consisting of senior EOD experts and excavator operators with EOD experience ▪ Supervising groundwork by EOD experts with mine detectors / bomb locators ▪ Supervising drilling activities by geophysicist with EOD experience and intrusive magnetometers ▪ Stop all activities on project area when UXO is found. An EOD expert can advise correct safety perimeters and remove UXO to a safe location ▪ Work is only allowed when areas are made 'clear of UXO' ▪ All water-based excavations must be supervised by senior EOD experts ▪ Installing anti-explosion infrastructure when UXO is found (hanging protective screens, installing containers, …) ▪ Installing trenches (mutes explosion energy) ▪ Preparing a nearby lying secured area where coordinated explosions of non-transportable UXO can be performed	3	0.5	40	60
1000 and 2000 lb naval mines in waterways	10	3	100	**3000**		3	0.5	40	60
1000 and 2000 lb naval mines on land	10	0.5	100	**500**		3	0.5	40	60
8.8 and 10.5 cm anti-aircraft grenades	6	3	40	**720**		3	1	40	120

Table 15 – RA of UXO in project area

4.2 SAFETY PERIMETERS

When discovering an UXO, it is of utmost importance to avoid any (further) manipulation of the explosive. Taking immediate distance from the UXO is the first preventive measure. Further emergency coordination and actions can then be organized from a safe distance. There are three types of safety perimeters when encountering explosives. The indicative values for UXO at Nedre Frednes Porsgrunn are given in chapters 4.2.1 to 4.2.4.

Note that in-field UXO knowledge is necessary during groundwork in this area, so a correct evacuation and shelter perimeter can be calculated by the national demining service. The evacuation and shelter perimeters given here are purely indicative. Values given here do not consider extern factors (wind speed and direction, presence of local barriers which can direct explosion energy towards a certain area, …). It is the task of the national Norwegian demining service to calculate these perimeters.

- The reflex perimeter indicates the area that needs an immediate evacuation if UXO is found, in order to avoid triggering the UXO to explode. All persons must leave this area as quickly as possible, and incoming traffic must be stopped. Equipment within this perimeter must be left behind. The local authorities and national emergency or demining service are informed. An EOD expert or the national demining service will identify the UXO and take further precaution measures (installing evacuation and shelter perimeter, installing bomb sheets, …).

- The evacuation perimeter indicates the area that could be impacted by a possible explosion and the associated shock wave. All residents or persons present who are not part of the operational emergency or security services must leave this area as quickly as possible and incoming traffic must be stopped. The national Norwegian demining service decides the effective perimeter.

- The shelter perimeter indicates the area on top of an evacuation perimeter within which shrapnel could fall after a possible explosion. Traffic within this perimeter (water, air and land) should therefore be shut down and all residents will be asked to stay indoors, away from doors and windows until after the UXO has been neutralized. The national Norwegian demining service decides the effective perimeter.
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4.2.1 SAFETY PERIMETERS – 500 LB DROP-OFF BOMBS

Safety perimeters	Reflex perimeter	100 m
	Evacuation perimeter	225 m
	Shelter perimeter	1430 m

4.2.2 SAFETY PERIMETERS – RP-3 ROCKETS

Safety perimeters	Reflex perimeter	50 m
	Evacuation perimeter	80 m
	Shelter perimeter	845 m

4.2.3 SAFETY PERIMETERS – 1000 & 2000 LB NAVAL MINES

Safety perimeters	Reflex perimeter	100 m	150 m
	Evacuation perimeter	220 m	300 m
	Shelter perimeter	1410 m	1905 m

4.2.4 SAFETY PERIMETERS – 8.8 AND 10.5 CM GRENADES

Safety perimeters	Reflex perimeter	50
	Evacuation perimeter	55
	Shelter perimeter	700

5 ADVISE

All the past WW2 actions in Porsgrunn point out that any groundwork, on land and in the navigable waterways, are subject to a very high UXO risk. Thorough UXO mitigation measures, as shown in table 15, must be taken before and during the project's work. We strongly advise the cooperation with EOD experienced companies specialised in a.o. (1) underground and underwater detections (up to 7 m below ground level), (2) UXO clearance, and (3) EOD supervision of groundwork.

All the UXO risks described in this document must be made very clear to all actors, from workmen to project managers, emergency services and the local authority. A specific UXO coordination by EOD experts is advised. A clear emergency and evacuation plan with safety perimeters is required to move all persons as quickly as possible to a safe distance from the UXO risks if UXO is found. To lower the impact ranges, and thus the exposure of persons and infrastructure to UXO found during groundwork, the use of protective sheets (bomb blankets) is advised.

The emergency, security and/or coordination plans must at least cover:

- The results of this RA
- The safety perimeters
- Project planning phase per phase
- Emergency enter and exit points per phase
- A clear circulation plan
- Communication schema with all numbers of actors
- A plan of underground infrastructure (cables, pipelines, sewer system and their 'exit' points) is necessary for the national demining service and the EOD experts.

- A list of locations of nearby chemical storage facilities (including artificial fertilizers),
- A list of location of vulnerable people and infrastructure (hospitals, elder people, schools, disabled people etc) living inside the given safety perimeters.
- A safe location nearby the project area where the national demining service can, if needed, perform controlled explosion of UXO which is in very bad condition (transport to dismantling facility is not possible due to the very high risk of such UXO).