

Swiss Lake Decontamination
(Bomb Run Team)

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Group Project
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Abstract

This report details the steps taken to derive a new process for retrieving munitions from shallow lake waters in Switzerland. An introduction to the scale of the issue is explored, the roles the author undertook to fulfil their role in the activity, how the team worked together in collaboration and an implementation of a systems engineering approach to ensure that the task was fulfilled in an effective, safe and environmentally sustainable manner with reflections on how the process could be improved. The team also presented their findings to a panel of explosive industry experts and the feedback from which is also covered in this report too.

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1.0 Introduction

The Swiss Government put out an announcement in the news asking for people to come up with a solution to dispose of munitions dumped in various lakes in Switzerland during the 20th century. The author and a team of engineers have created a well thought out design solution to mitigate this extremely damaging problem effectively while being safe/environmentally conscious.



Figure 1 Munitions being dumped into a Swiss lake

To give some further insight into how much of an issue this is, it is estimated that there are 3,300 tonnes of munitions in Lake Lucerne and another 4,500 tonnes in Lake Neuchatel which has been used as a bombing practice range up to 2021 [1]. The munitions continue to leak harmful chemicals into the soil and pose a risk to life due to the unstableness of the fuzes/explosive compositions. While there are multiple lakes to recover munitions from, the team were tasked as the “Bomb run team” and therefore looked at shallow water recovery, (around 6 or 7 meters deep). The team were tasked with researching 3 different types of munitions that fit the profile of being found on the lakebed, each one being significantly different from the other which therefore required detailed analysis before deciding on a final recovery solution. It should be noted that a systems engineering approach was taken to prioritise areas such as environmental factors, safety, cost etc.

The team also presented their findings/solution to a panel of explosives industry experts and were given feedback which was considered and reflected on to ensure that the designs were as functional as possible.

1.1 Roles

The team was made up of 4 different people, all of which had different backgrounds in terms of their work with explosives. The authors role specifically was that of “munitions specialist” due to their greater exposure to a variety of ordnance, munitions and explosives (OME). As a munitions specialist they were responsible for researching all necessary background information regarding the tasked bombs, it should be noted that this is a significant role as the data gathered was then relayed to the rest of the team to help influence the rest of the decisions. This role in the team was outlined as a requirement from the very beginning which gave the author a great deal of clarity as to what work had to be undertaken.

Whilst undertaking the planning of the proposal the authour suggested that on shore inspections should be undertaken for several reasons including determining the conditions of the munitions and feeding this information back to the recovery/transportation/disposal teams in real time to further their decision making and enhancing safety. Another reason included photographing for archive purposes as it still is entirely possible that more UXO may be found in other lakes around the world and by having an archive of evidence, certain munitions can be identified with greater ease. Finally, the damage assessment from the onshore inspections can be analysed and put into the public domain for NATO defence companies to use when designing new ordnance, as areas such as material degradation in water can be considered during a new design process.



Figure 2 Munition on a shore

The rest of the team were split up into roles that best suited their areas of expertise which included, transport, environmental factors, safety, disposal techniques, recovery and water survey. It should be noted that team members generally took on more than one role as did the author.

1.2 Team collaboration/communication

During the development of the project, it became clear from the beginning that a reliable/consistent method of communication between the team was imperative to ensure the deadline for the final presentation was met. Without this it would have been entirely possible to lose track of progress/ideas and make it harder to collaborate altogether.

The preferred method of communication was done in three forms, email, WhatsApp group chat and a weekly scheduled team's call taking place on a Friday for around an hour. Most of the research sent between the team was done through email as it was the authors/team's favourite way to store information straight into the SharePoint. Other less formal communication occurred on WhatsApp as this gave the ability to speak to one another for advice or any other query's outside of normal working hours. This combined with a weekly camera on video call where we would track progress on each team members section ensured a constant level of discourse was taking place.

MEETING MINUTES 29/09/2025

FINAL SOLUTION CHOSEN – PSB for the step by step process of the solution

- Locate munitions (x-ray/sonar)
- Water Survey (close to munitions and away from munitions) testing for toxins
- Diving bell/one man risk to x-ray each munition to determine what state they're in
- Survey of Area (for metallic components)

IF MUNITION IS SAFE TO MOVE:

- Float to surface using flotation devices
- Tow to the shore using a small ship
- Dispose on shore OR transport to disposal site

IF MUNITION IS UNSAFE TO MOVE:

- Low order all munitions where they stand

If there are any questions on the chosen solution or any changes you'd like to propose, please reach out to the group on the WhatsApp group chat.

TALKING POINTS FOR PRESENTATION – The chosen solution has been broken up into talking points for the presentation. If your initials are next to a talking point, you must research that point in preparation for the next Uni block. PSB the talking points

- Location and Introduction (JB)
- Munitions Discussion (TG)
- Sonar to Locate and Why (JH)
- Water Survey and Why (JH)
- X-ray (how to use / what model / hazards/risks involved) / Diving Bell (and one man risk) risks (JH, JB)
- Low order and Techniques (HT)
- Removal using Flotation Devices (JB)
- Disposal on Shore (HT)
- Transport (JB)

PLEASE NOTE – These are NOT necessarily the points you will be talking about during the presentation, you're just researching them in preparation for creating the presentation during the next Uni block.

If there are any questions on a talking point you're researching, please reach out to the group on the WhatsApp group chat.

IMPORTANT DATES

- Meeting with Dave Holley Thursday 25th September @ 1500hrs (OME lab)
- Weekly Dropin Session will be at 1000hrs Friday 5th September

Figure 3 Weekly progress meeting minutes email

The figure above evidences a typical email that one of the team members would send out after concluding a weekly meeting. Each email would be dated to allow for tracking back progress, current final solution plans, changes to said solution against requirements, team roles (as they would occasionally be modified for some people) and updates made to the deliverable presentation. It should also be noted that the meeting minutes would be sent out in a separate email chain to keep clarity high.

Overall, the team managed to stay on top of communication with one another, and this attributed to success in their final proposals.

2.0 Design/Requirements

When deriving the requirements for the final solution many ideas were initially discussed. It became clear that a holistic approach must be undertaken to ensure a safe/robust munition recovery design. The holistic approach essentially looks at the problem as a whole instead of individual parts and where multiple roles are being undertaken such as this instance, this is required to allow effective collaboration and ultimately ensure the rapid changes in each area affect other areas positively [2].

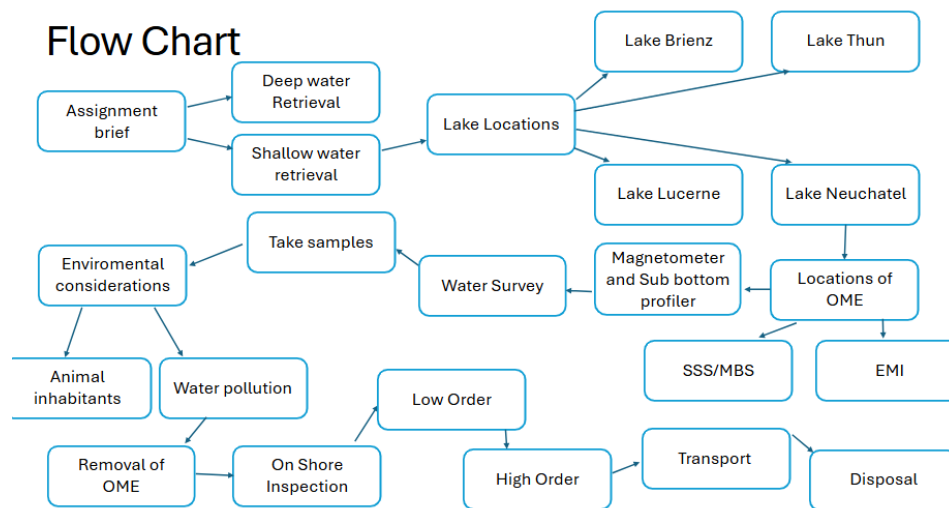


Figure 4 Design process using systems approach

The team felt that creating an in-depth flow chart with the basic requirements for the project would be the most effective solution in the planning phase. By clearly outlining the stakeholder needs and then creating sections that match up with the roles and responsibilities of team members allowed for a clear- and thought-out approach to the design process.

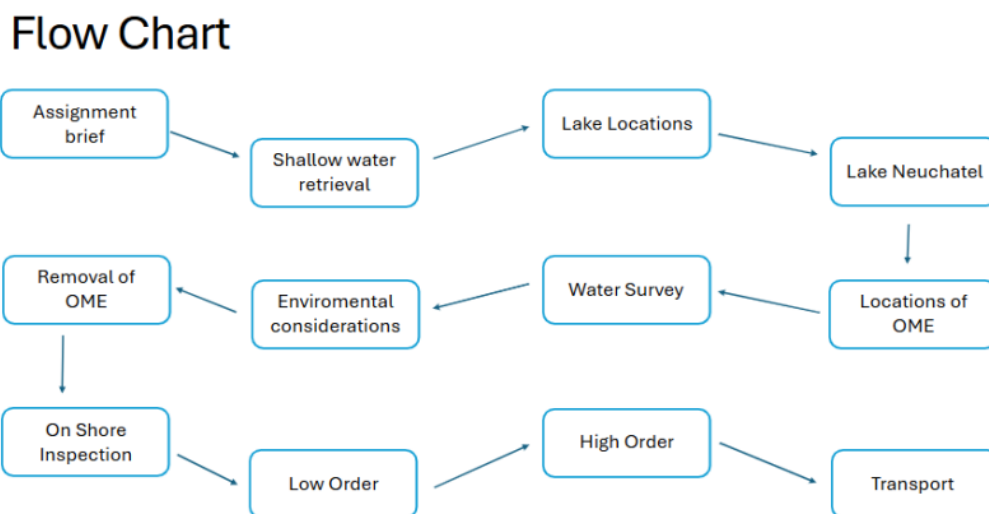


Figure 5 Revised flow chart

Once a clear set of requirements were thought out, the previous flow chart was then condensed into a simpler version for the team to follow. Each section of the revised flow chart covers all roles for the team members. By having this critical piece of planning material, the team then had greater clarity when undertaking their respective roles as it made it easier to understand how their area of the project affected someone else's.

It should be noted that when deriving the initial requirements, many conversations on how to balance the explosive safety, environmental factors and efficiency took place and the author along with the team spent a large amount of time researching this area.

2.1 Research

This section of the report details the specific research that the author brought to the team for the project. Areas such as the munition design, challenges in research and other areas of their role are documented. Also note that the final delivered presentation slides have been included into their respective areas.

Munitions

As for mentioned, the bomb run team were tasked with the removal/disposal of three different types of munitions. As the role of the author was munitions specialist, they collated all the research regarding said munitions and fed this into the team to help with their decision making on certain processes.

BL755 Cluster bomb

Overview

The BL755 was developed primarily by a company called hunting engineering and then entered service around 1972 with British forces. The munition was designed to be dropped from a low altitude and deploy several submunitions in a cluster manner onto the intended target area giving it its name. Due to this, the bomb was very effective at area denial and destroying armoured vehicles [3].

Munition Design

The full system of the BL755 has an estimated all up weight of 270kg once loaded with all 147 of it's submunitions also known as "bomblets". The munitions length is 2,451 mm in length and 419 mm in diameter [3].

Submunition Design

The Submunitions for the BL755 were designed with maximum damage in mind. Each of it's 147 use a HEAT warhead (High explosive anti-tank), this is achieved using a shaped charge and can penetrate up to 250mm of armour. The bomblet is 350mm in length, 88.9mm in diameter and also wound in tessellated square wire which generates 200,000 pieces of fragmentation and therefore makes the bomblets HEDP (High explosive dual purpose), the fragmentation is mostly effective against infantry personnel [4].

Explosive Specifications

While it is not documented accurately it is estimated that each bomblet has an NEQ (net explosive quantity) of 0.8kg and an overall weight of 1.18kg. This therefore makes the AUR NEQ approximately 117.6kg. It should also be noted that most variants used Composition B as the explosive compound, which is a melt castable HE (High explosive) made up of around 60% RDX and 40% TNT plus a small amount of desensitizing wax for safety purposes [5] [6].

Safety Features

The munition has a variety of safety features to ensure successful functioning while not becoming a danger to the user. The main safety feature of the BL755 is in the safety arming unit (SAU). This is in the nose of the munition casing and essentially acts as the “brains”, it completes a series of checks to understand the state the bomb is in before allowing the release of the submunitions. The five main checks the SAU does before functioning the gas generator is release (ensure the bomb has been dropped), fall time (is it far enough away from the airplane), orientation (what way up is the munition?), altitude (is it the correct time to deploy submunitions) and finally an electronic fault check is completed just to make sure everything will function as intended. Failure for any of these requirements to be met will result in the submunitions staying inside the casing and not detonating which then creates an Unexploded Ordnance (UXO) risk [7] [4].

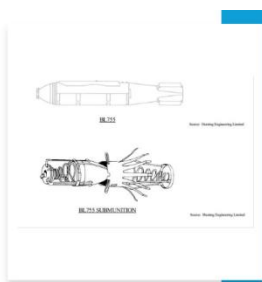
Submunition Functions

Once the gas generator has activated, removed the case doors and ejected the submunitions, a new arming sequence starts to ensure the proper functioning of the submunitions. Upon ejection a ribbon is pulled on each bomblet, this deploys the parachute to slow it's fall time and allow for proper impact. The forward end telescopic probe then extends which in turn arms the fuze and gives the shaped charge effective standoff (1 to 3 charge size diameters). Again, let it be known that if any of these steps fail the UXO risk increases dramatically as the submunitions are extremely sensitive. Most failures come from improper impact, and this is generally due to the low altitude delivery method. The risk the UXO creates was used as part of the reason the munition was banned under international law as it can indiscriminately target civilians [7].

Upon impact with the ground the explosive train begins as the telescopic probe collapses inwards onto the impact fuze which in turn initiates the detonator then the booster charge and finally functioning the main shaped charge [3].

Overview of BL755

- Development and History
- Munition Design
- Submunition Design
- Explosive Specifications



BL755 Functions

- SAU (Safety Arming Unit)
- Release, fall time, orientation, altitude, faults
- Submunition Arming
- Arming ribbon, Probes, Parachute
- Failure can create UXO



In depth overview of Submunition

- Impact, probe collapse, impact fuze, Explosive train
- Functionality of main charge
- HEDP, Shaped charge + Frag
- UXO from low altitude or improper landing



Figure 6 Slides used for BL755 in Presentation

1000Lb Bomb (MC Variant)

Overview

The 1000Lb bomb is an extremely effective air dropped blast munition that is still used in modern day service. Multiple variants have been designed/developed over the years however the tasked variant specified (torpex filled), during the authors research it became clear that the likely version that would be in the lake is the medium capacity (MC) variant as it was usually was torpex filled and fit the time scale of when it would have been dumped in the lakes.

The MC variant was developed in 1942 to replace the general purpose (GP) model. It is also estimated that 17,000 were produced in 1943 and 203,000 in 1944, manufactured by multiple companies to keep up with wartime demand [8].

Munition Design

The munition has a total length of 1840mm with a diameter of 450mm [9]. The intended targets were usually fortified structures and the blast produced was generally effective against this. The safety features of the munition pretty much were all contained in the fuzes that were fitted before flight.

Explosive specifications

While it is nearly impossible to understand what exact explosive composition was contained within the MC variant, it is generally agreed that a combination of RDX, TNT and Torpex was used which made the bomb function well against ships and docks, due to the efficient blast properties of the torpex [10]. The estimated NEQ for the MC variant is 184kg.

Safety Features

Generally, fuzes wouldn't be fitted to the bomb until the it was ready to be fitted to the aircraft as the fuze option may have to change depending on the needed application, therefore a transit fuze was usually fitted to ensure safety. It should also be known that a fuze pin blocker would be fitted to the munition right up until the aircraft was ready to take off however this could rust underwater and make the fuze sensitive to functioning which had to be considered during the removal process research.

Multiple fuzes could be used depending on the desired target, the most common included the No. 44 nose fuze, which was designed for long delay, by using pyrotechnic delays it could allow the bomb to stay undetonated for days which created not only a UXO risk but psychological warfare against the enemy who may try to defuse it. This fuze also had anti disturbance features meaning vibrations from the footsteps of nearby personal or the moving of it could trigger a detonation [11]. If this fuze is found on a munition in the lake extra precautions must be taken due to the sensitive nature. In 2008 a 1000lb bomb with this type of fuze was found in London docklands and had to be functioned in place by an explosive ordnance disposal (EOD) regiment [12].

Another commonly used fuze was the No. 27 nose fuze, this was designed to detonate the munition upon impact, it uses inertia and a spinning vane to arm itself once a certain number of rotations were completed. The team are less worried about finding a 1000lb bomb with this fuze attached to it as it is less sensitive than the No. 44 [11].

The less common “tail pistol” fuzes such as the No. 30 were also occasionally fitted, these allowed for safer transport and sat at the rear of the munition. This allowed for a more reliable penetration into a structure before detonating [11].



Figure 7 Slides used for 1000lb MC bomb in Presentation

3kg Practice bomb

The final munition that the author researched was the 3kg practice bomb, this was developed to allow pilots to practice bombing runs without having to use a HE munition. There is no high explosive fill in the practice bomb, however there is a pyrotechnic composition (SR800 and Magnesium) to give off the flash and smoke effect upon impact which shows the pilot an impact signature. While this munition carries the lowest risk in the removal process, it should be treated with utmost due diligence as pyrotechnic compositions can be just as if not more sensitive/dangerous than HE compositions in the right environment. This is not commonly known and has caused a damaging myth in the explosives industry that just because something is “only a pyro” certain safety measures can be overlooked [13] [14].

Other design features include being painted blue to make it identifiable as a practice round as per the NATO standards. This will aid the recovery process as identifying it will be easier. The munition also uses internal fuzes and basic boosters to complete an explosive train [14].

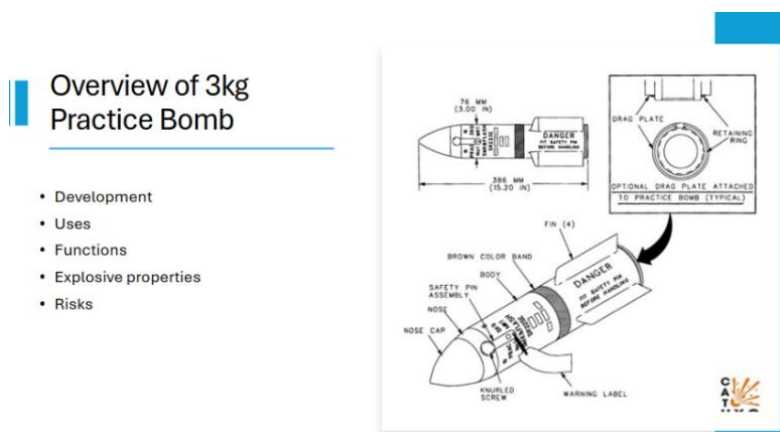


Figure 8 Slide used for 3kg Practice bomb in Presentation

2.2 Output to the team

Following on from the previous research section of the report, it is important to understand how the authors analysis of munitions contributed to team's overall work.

The idea for the final solution was to use a range of tried and tested disposal techniques such as high/low ordering. To do this an in depth understanding of said munitions must be conducted in the first place. The author was able to make informed recommendations to the recovery/disposal team members as to the potential hazards of removing certain munitions. Specifically, the author managed to persuade the team that the BL755 cluster bomb was too dangerous to remove and disposed of on shore and should be high ordered in the lake to ensure all of it's bomblets functioned properly. Furthermore, the author made final decisions as to what munitions would be brought to the shore and low ordered (1000lb and 3kg) but also noted that this was fuze dependant as anti-disturbance fuzes on the 1000lb bomb would be too risky.

The author also created the added process of on shore inspection regarding the ordnance to aid the rest of the team in decision making before and after disposal. The justification for undertaking this extra work was agreed upon by the rest of the team as it meant further assessments of the munitions could be conducted for the disposal/transportation team, photographs for NATO archives which will aid future EOD work if the same munition is found again around the globe and analysis for future manufacture research as defence companies would be able to understand how water affects the explosive compositions and materials.

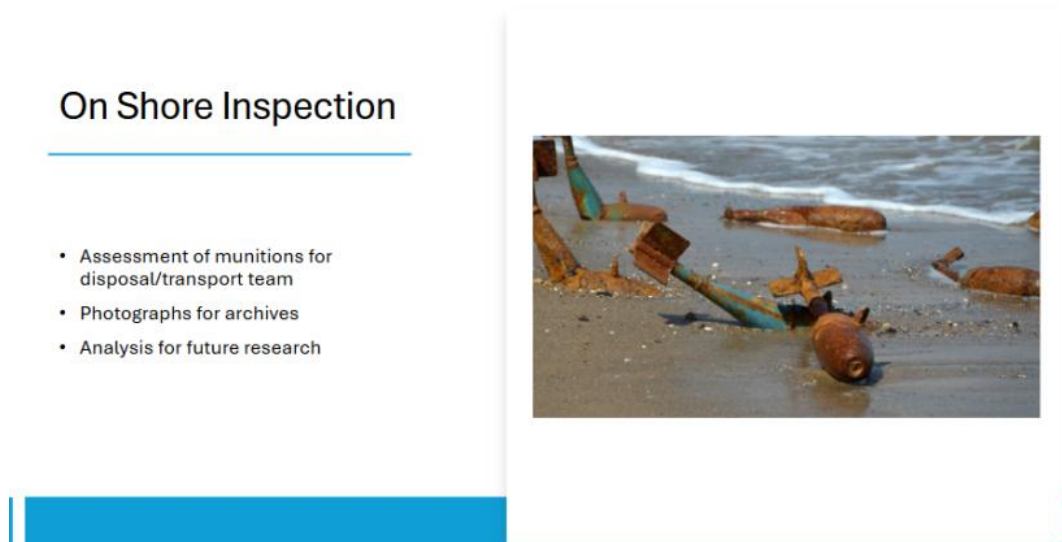


Figure 9 Slide used for on shore inspection justification

Overall, the authors contributions made a significant impact as to how the recovery process was undertaken and they feel that their work was greatly beneficial to the team.

3.0 Final solution

As this report discusses the contributions of the author to the final project the final solution to the project will be kept relatively brief.

Parts of the team conducted water surveys to understand the potential environmental implications that the project would have on the surrounding wildlife and water quality. Then by using complex sonar the team would identify where the munitions are located. Once located and identified the recovery teams would make decisions using the authors strong recommendations as to next steps. For the 3kg practice bomb and 1000lb bomb without the No. 44 nose fuze, lift bags would be attached to the munitions, floated to the surface and towed at a safe distance to the shore where they would be inspected, low ordered and transported away for final disposal, (also note fuze disruptors would be used where relevant). The BL755 and 1000lb bomb with the No. 44 nose fuze would be functioned using high order equipment to ensure the munition no longer posed an environmental/explosive risk.

This process may seem simple when discussed in this nature, however a well thought out collaborative approach was undertaken to get to the point where a simple step by step algorithm like process was able to be concluded.

Low Order Techniques

- Definition of Low order
- 1000lb Bomb
- 3kg Practice Bomb



High order of BL-755 Cluster Bomb

- Definition of High order
- How does the BL-755 Cluster Bomb work?
- Undisrupted, fused 1000lb



Post Disposal Process

- Re-burn any casings
- Samples collected
- Waste recovered



Transport

- Transportation of EOD arisings uncertified
- Transportation of FFEH and Explosive waste
- Transportation of Samples



Figure 10 Various slides used in the final proposal presentation covering other areas

4.0 Presentation/Reflection

After completing the group presentation, the author received feedback from the assessors to reflect upon.

The following questions below were posed to the author and have have been answered to the best of their ability

Assessor 1 questions

1. What are you likely to find in part functioned BL755?

Answer: If the BL755 has part functioned underwater and is discovered by the recovery team they are most likely to find the casing of the munition open with bomblets scattered around the local area of it and with some inside too. The risk really is whether the bomblets have been armed during this process. Due to this, the team decided it would therefore be safer to high order the lot in situ.

2. How is the pyro contained in the practice bomb

Answer: From what can be found using public domain research it can be concluded that the pyrotechnic is contained within a sealed unit inside the casing of the munition.

Assessor 2 questions

1. Was a risk assessment done for storing the munitions?

Answer: While storage wasn't within the authors area of the project, upon consultation with the relevant team members it was concluded that a risk assessment was done regarding storage, by doing so a better understanding of the risks was understood.

2. How did the group communicate?

Answer: Communication in a group project is always one of the most challenging aspects, however by using a multitude of messaging platforms, WhatsApp, email and teams video calls. The group managed to effectively communicate on a regular basis.

3. Is there a more environmentally friendly means of disposal?

Answer: Yes, there absolutely is, however as you increase the requirement for environmental sustainability it was evidenced that the risk factor increased, for example it would be better for the environment to not high order anything in the water however the risk of removing the BL755 from the lake to the shore would increase the danger factor significantly.

Assessor 3 questions

1. Could the 1000lb bomb with the No. 44 (sensitive) fuze fitted be deflagrated underwater instead of high ordered?

Answer: This was something the team considered briefly in the planning stages, however by choosing to high order the munition, you increase the chance of ensuring all HE material is combusted therefore allowing for a greater chance of toxic materials to not be in the lake anymore. This is something the team will consider further going forward.

Final reflections/conclusions

To give a brief after action review the project was an overall success, the feedback given from the industry professionals was mostly positive, a clear, thought out, environmentally sustainable and safe solution to a highly topical problem was reached by the author and their team while adopting a systems engineering approach. The team excelled in areas such as communication and understanding the risks that come with undertaking work such as this.

In terms of what could be improved, revised processes on underwater disposal techniques could change. To be specific, the disposal of the 1000lb bomb with a No. 44 nose fuze could be changed to deflagration rather than high ordering.

If the work had to be undertaken again the author feels covering an area of the project outside of their expertise may be beneficial to help them better understand other areas of explosive work such as transport or recovery.

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