White Paper: Worst Case Environmental Scenario for Explosives Residues at SAAB Munitions Assembly Plant, Grayling, MI

Author: Dr. Bonnie Packer, Strata-Geo, LLC, Arlington, VA 22205

SAAB intends to build a munitions assembly manufacturing center in Grayling, MI. At the request of the Grayling township, this paper is intended to explore the environmental consequences of a bunker explosion on the groundwater, and potentially surface water, if any impacted groundwater reaches local surface water. While, it is not possible to know with certainty what the consequences would be, there is a local analogue on Camp Grayling that can be used for comparison.

<u>Before exploring this scenario, several factors bear repeating, so that the focus on this one issue makes sense:</u>

1) Transportation issues local to the Grayling community come down to how close shipments into and out of Grayling come to citizens. The building of a dedicated road into and out of the assembly plant that connects to State Route 75, eliminates the majority of explosive safety risk (e.g. proximity * duration of exposure). Some local transportation of munitions will occur from the assembly plant to Camp Grayling ranges for lot acceptance testing (see below) and will occur in appropriate vehicles per the Department of Transportation. I note here that such transport of munitions to the various Camp Grayling ranges already occurs in Grayling Township for military training purposes.
2) Sealed explosive components will come into Grayling Township. No 'melt and pour' or packing of explosives and /or propellants will occur at this assembly plant (private communications with SAAB, November 2024). Therefore, no process water with primary explosives (initiator explosive), secondary explosives (main charge) or propellant is planned or envisioned. The design of the assembly facility reflects this, and therefore, does not include sump pumps or floor drains.
3) Assembly will consist of bolts, screws, epoxies and glues applied to sealed munitions components. SAAB plans to apply single use or very small containers of epoxy and glues, and therefore envisions little waste. Final assembled products will be placed in stackable crate-like containers and then placed in specially designed "igloos," or "bunkers," or sometimes called "magazines." SAAB plans for earth covered magazines for added safety.
4) Igloo designs focus on a maximum net weight of explosives (per the Defense Explosive Safety Board requirements). Due to the stackable crates that take up a large volume of the Igloo, it's nearly impossible to have that maximum weight of explosive in an Igloo. Due the bulk volume of the packing crates, the maximum net explosives weight will be 50-60% of the maximum allowable net explosive

weight in the scenarios chosen. Additionally, igloos are designed such that if an explosion happens in one igloo, the igloo implodes, and the explosive shock wave does not propagate to other adjacent storage igloos.

5) SAAB is required to have an Explosives Site Safety Plan (all uses of explosives in the US of explosives must have such a plan). SAAB will submit this plan to the Defense Contract Management Agency (DCMA). Further, per SAAB's contract with the US Defense Department, the DCMA will audit and /or inspect the facility annually as well as prior to issuing award of any new contract. Additionally, an audit or inspection will occur prior-to or during any first testing of a new munition (First Article Testing).
6) This testing of munitions is called "lot acceptance testing." The testing of munitions will not occur on the grounds of the assembly plant, but rather it will occur within the confines of Camp Grayling where the appropriate explosives safety (fragmentation distances) for the munitions system exists. Any manufactured lots that do not meet specifications, will have disassembly elsewhere in the United States, in a facility that is specifically designed for demilitarizing (disassembly) of the munitions (SAAB personal communication, November 2024). No munitions washout is planned or envisioned to occur (SAAB personal communications, November 2024).

Example contents of munitions at the SAAB facility

For the GLSDB (Ground Launched Small Diameter Bomb), themaximum net explosive weight in a single magazine will be approximately 53,000 pounds, consisting of:

- Propellant igniter MG-Tfe- Magnesium with PTFE- less than 12 pounds)
- Booster (primary) PBXN-5 (less than 4 pounds) HMX explosive with a matrix for reduced shock sensitivity
- Rocket Propellant (approx. 36,000 pounds of Aluminized HTPB composite)- main fuel is aluminum powder with binder – less than 50% ammonium perchlorate (AP) by composition
- Secondary explosive (main charge-AFX-757, the PBX-based with aluminum powder (approx. 6,500lbs)

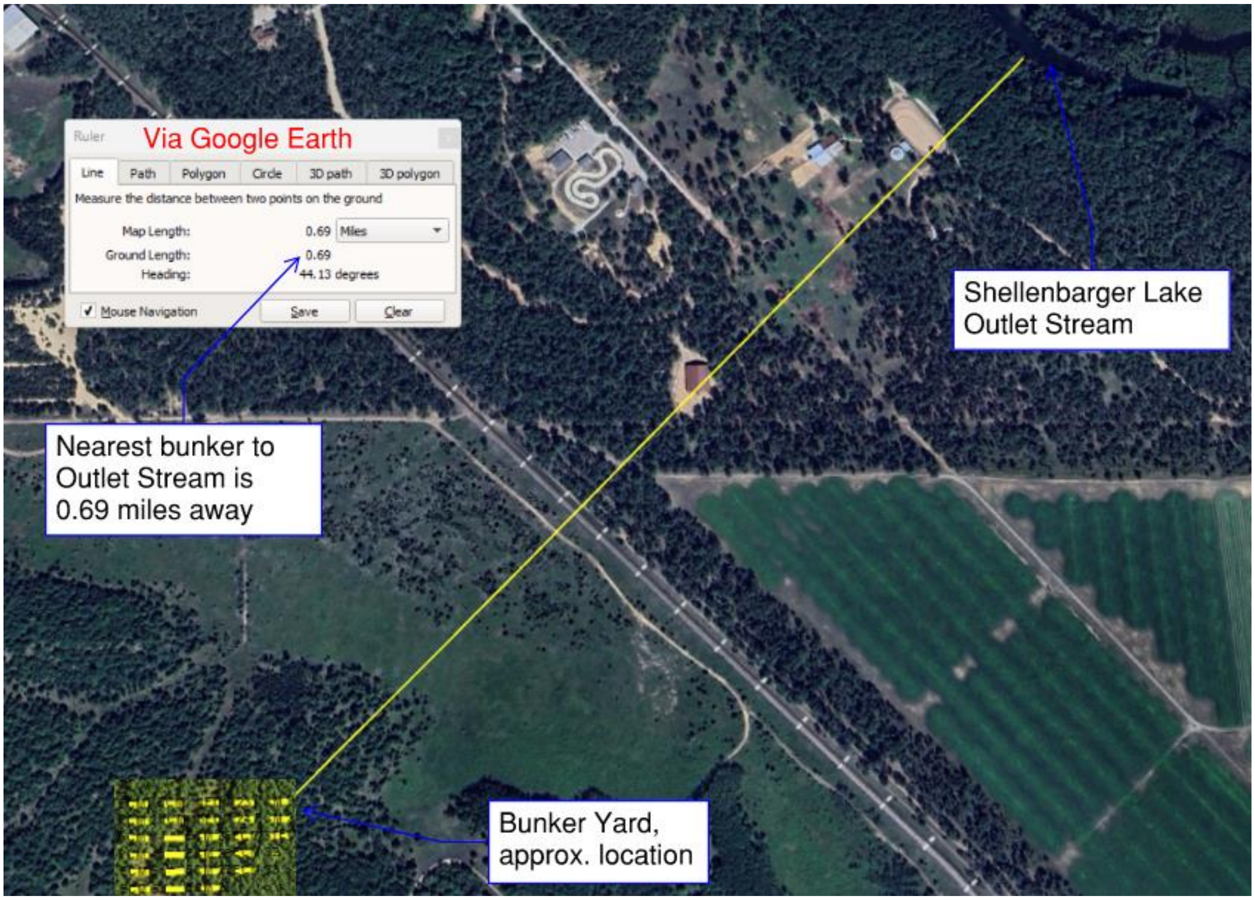
For the AT-4 family of munitions, a man-portable, shoulder fired anti-armor weapon, the maximum net explosive weight in a single magazine will be approximately 5,500 pounds, consisting of:

- Propellant igniter: similar to a primer in a bullet (less than 200 pounds)

- Boosters: a HMX explosive with a matrix for reduced shock sensitivity (less than 130 pounds)
- Propellant: NK 1287 to ignite the booster (less than 2 pounds)
- Primary: PBXW-11- similar to a fuse to detonate the secondary explosive (less than 1 pound)
- Secondary: PAX-47- DNAN (Dinitroanisole)+RDX (Royal Dutch Explosive)+HMX (approx. 7000 pounds)

<u>Why it is unlikely that a bunker explosion will affect surface water in Grayling:</u>

First, an explosion would be a one-time event, unlike a location where rounds are repeatedly detonated (munitions disposal area-Open Burning/Open Detonation). Only some small percent of the particulate explosives will leave the bunker location and spread through the explosive arc for that bunker (it's not possible to know exactly how much). Then based upon what we know about how explosives adsorb to soils, only half or so of the mass of the explosive will make its way to the water table. Additionally, after this one-time event it will take months for millimeter sized explosives particles to dissolve and the explosives will be spread over the entire explosives arc for that bunker, diluting the concentrations in groundwater. As the groundwater moves away from individual particles and 0.69 mile to the north-east where a stream lies, it will become diluted to the point of laboratory non-detection by the time it reaches any surface water (see figure below). Affects in groundwater will be relatively short lived, as these explosives degrade in the environment (unlike PFAS).



<u>How we know a single event would not create an environmental impact: a local Grayling analogue</u>

In 1997 an administrative order shut down training at the Massachusetts Military Reservation, due to detections of explosives in a sole source aquifer, at the range boundary with the community. It was then, that the military embarked on a program to sample ranges to ensure military ranges nation-wide. DoD did not find systemic contaminated groundwater and surface water leaving its operational ranges. This author was the program manager for the Army Guard's program to sample ranges nation-wide. As it turns out, after a decade sampling over 100 Army National Guard installations, Massachusetts Military Reservation (MMR) was only installation with explosives leaving it Army Guard's operational ranges. Two other installations with glacial till and outwash aquifers, and medium to high caliber munitions use, with seemingly similar conceptual site models were Camp Grayling, MI and Camp Ripley MN. Neither installation had similar issues with explosives leaving the ranges. The reason MMR is the anomaly turns out to be the very slow movement of groundwater at MMR relative to any other installation (over an order of magnitude difference in groundwater velocity). The few centimeters a year groundwater flow rate (nearly flat-water table) at MMR allowed groundwater concentrations to buildup to very high concentrations as rainwater moved through the sandy soils to the water table. Even so, it was the Open Burning/Open Detonation areas at MMR that showed the highest concentrations because it is at these locations where munitions are blowup with strapped on explosives and do not detonate as intended. These detonations, where explosives only partially detonate are called low order detonations. The research organization Environmental Research and Development Center at Cold Regions did extensive sampling and research to determine what creates explosive residues on ranges (see summary publication ERDC TR 06-13).

While high order detonations oxidize (combust) 99.999 percent of the explosives compounds in munitions, low order detonations can leave millimeter sized particles on soils. As much as 50 percent of the original mass of explosives can be left on soils. Therefore, it is these unintended explosions that can create the most significant residues on soils. ERDC tested munitions over snow covered ranges to determine the level of residues left from both high order and lower order detonations.While some of the explosives listed above include traditional explosives, such as HMX, it appears that the explosives are primarily newer insensitive explosives and propellants. DNAN is a relatively new insensitive explosive (less sensitive to shock and temperature) and is readily soluble in water. When these compounds are part of a formulation, their dissolution will depend not only on their individual solubility and dissolution rates but also on the fraction of each component exposed to water. Both the extent of soil sorption and the mechanisms involved are not yet fully known for DNAN.

Accurate dissolution kinetics for explosives and for explosives formulations are key to describing the fate and transport of explosives residues from firing ranges into groundwater and surface water. A particle that is millimeters in size can take weeks to many months to dissolve via rainwater. Once dissolved some explosives adsorb readily to soils, particularly soils with carbon. DNAN more strongly adsorbs to soils than TNT, up to 50 percent retardation in soils (column studies: Dontsova et al, 2014), making it less mobile than TNT in soils.

<u>So what did the operational Range Program find for the open burning/open detonation area at Camp Grayling?</u>

If any spot were likely to show a high concentration of explosives in groundwater that might affect the environment, it would be the open burning/open detonation area at Camp Grayling due to decades of explosives use and many low order detonations. The 2013 report (not releasable) evaluated/sampled for explosives (and metals):

- Cyclotetramethylenetetranitramine (HMX), cyclotrimethylenetrinitramine
- (RDX), trinitrotoluene (TNT), pentaerythritoltetranitrate (PETN), 2,4-dinitrotoluene
- (DNT), 2,6-DNT, and nitroglycerin (NG)
- Metals: antimony (Sb), copper (Cu), lead (Pb), zinc (Zn)
- Perchlorate

Directly from the report: The Phase II assessed three areas identified as “worst-case” MCOC source areas: Range Complex B, Range Complex C, and the light demolition ranges. The groundwater pathway is considered to be the “worst-case” scenario, as MCOC would first need to migrate through the soil column to reach groundwater prior to discharging to off-installation surface water to reach potential surface water receptors. Since the Camp Grayling range soils are predominantly sandy soil that are well drained, overland flow from the range areas is not expected to reach off installation surface water bodies. Therefore, only groundwater samples were collected for the Phase II field activities. Groundwater samples were collected at 15 locations, including eight existing monitoring wells at Range Complex B, four newly installed monitoring wells at Range Complex C, and three newly installed wells at the demolition ranges. Four independent groundwater sampling events were conducted over an eight-month period. Groundwater samples were analyzed for metals [antimony (Sb), copper (Cu), lead (Pb), and zinc (Zn)], explosives MCOC, and perchlorate.”

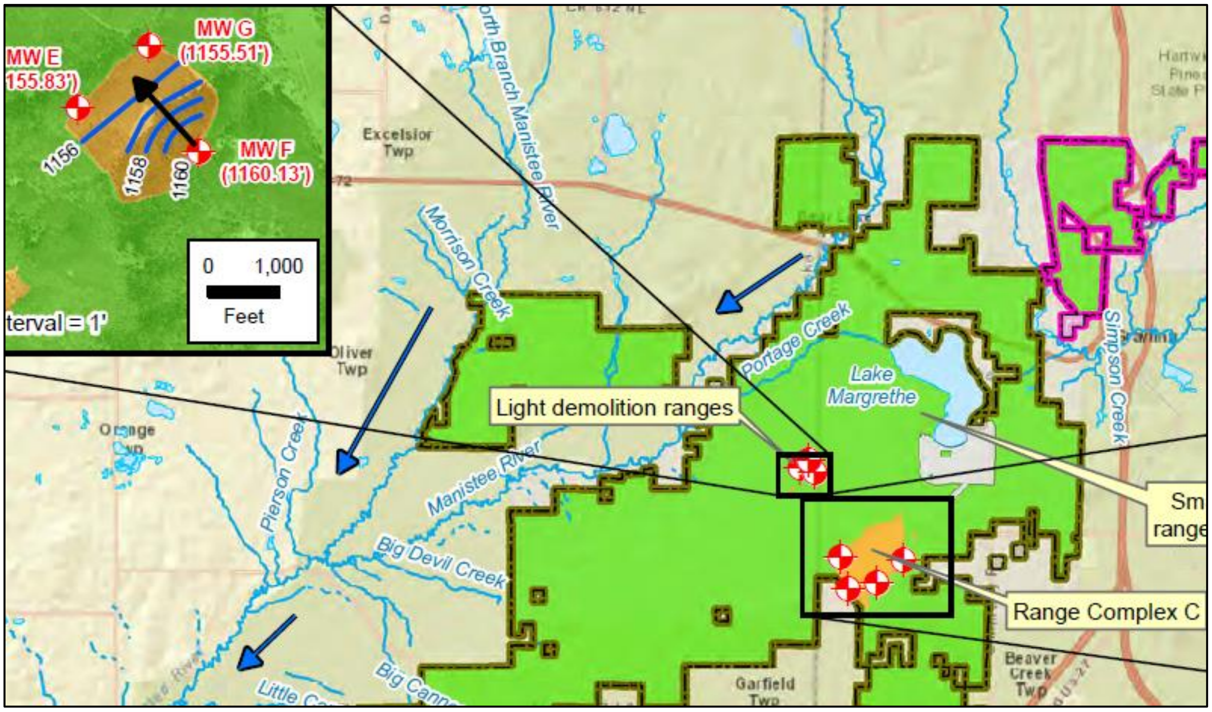


Table 3-1: Camp Grayling Project Action Limits

	Human Receptor Drinking Water PALs (µg/L)	Ecological Receptor Surface Water PALs – (µg/L)
Metals		
Antimony	6	30
Copper	620	9.0[(a)]
Lead	4[(b)]	2.5[(a)]
Zinc	2,400[(b)]	120[(a)]
Explosives		
1,3,5-Trinitrobenzene	460	11
1,3-Dinitrobenzene	1.5	20
2,4,6-Trinitrotoluene	2.2	90
2,4-Dinitrotoluene	0.2	44
2,6-Dinitrotoluene	15	42
2-Amino-4,6-Dinitrotoluene	30	20
2-Nitrotoluene	0.27	---
3-Nitrotoluene	1.3	750
4-Amino-2,6-Dinitrotoluene	30	---
4-Nitrotoluene	3.7	1,900
HMX	780	150
Nitrobenzene	0.12	270

Nitroglycerin	1.5	138
Pentaerythritol Tetranitrate (PETN)	16	85,000
RDX	0.61	190
Tetryl	63	---
1,3,5-Trinitrobenzene	460	11
1,3-Dinitrobenzene	1.5	20
Perchlorate		
Perchlorate	15	9,300

Figure and Table above from the Phase II Operational Range report for Camp Grayling (2013) show the location for the demolition area as well as the project action limits.

Directly from the 2013 Camp Grayling Operational Assessment Report: “Explosives MCOC and perchlorate were not detected in any groundwater samples collected at the light demolition ranges. Total antimony and total lead were detected in at least one of the four samples collected at MW-E, MW-F (up-gradient well), and MW-G. Total zinc was detected at MW-E in one of the four samples collected. All of the total antimony, total lead, and total zinc detections were well below the PALs. Total copper was not detected in any of the groundwater samples collected at the light demolition ranges.”

The worst case for Camp Grayling is a demolition area that is repeatedly used and is likely to have numerous low order detonations annually (a heavy and consistent load of munitions constituents to soils). In less than a half a mile (1000 feet) from the center of the source area, no detections were found of explosives in groundwater. Given that RDX, commonly used for decades at the open burning/open detonation area on Camp Grayling, and more soluble than DNAN was not found in groundwater, it is unlikely that DNAN would be found in groundwater after a single event. Said another way: if the consistent loading of explosives did not show any releases to groundwater, then it is unlikely that a one-time explosive release of particles, would impact local surface water a half a mile from the bunker in a worst-case explosion.

References:

Katerina Dontsova, Susan Taylor, Rose Pesce-Rodriguez, Mark Brusseau, Jennifer Arthur, Noah Mark, Marianne Walsh, James Lever, and Jiri Šimůn, “Dissolution of NTO, DNAN, and Insensitive Munitions Formulations and Their Fates in Soils,” Sept 2014, ERDC/CRREL TR-14-23.

Judith C. Pennington, Thomas F. Jenkins, Guy Ampleman, Sonia Thiboutot, J. M. Brannon, Alan D. Hewitt, Jeff Lewis, Sylvie Brochu, Emmanuela Diaz, Michael R. Walsh, Marianne E. Walsh, Susan Taylor, Jason C. Lynch, Jay Clausen, Thomas A. Ranney, Charles A. Ramsey, Charolett A. Hayes, Clarence L. Grant, Charles M. Collins, Susan R. Bigl, Sally Yost and Katerina Dontsova, “Distribution and Fate of Energetics on DoD Test and Training Ranges: Final Report” November 2006, ERDC TR 06-13.

URS and Arcadis, for USACE Baltimore on behalf of the Army National Guard, “Operational Range Phase II Assessment Report Camp Grayling, Michigan” June, 2013.