

# AN ACCESSIBLE SEEDED FIELD for Humanitarian Mine Action Research

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## MOTIVATION

The detection of buried and surface explosive remnants of war (ERW) is a critical task in the land release process.<sup>1</sup> The goal of this project is to create a long-term study site and benchmark to accelerate humanitarian mine action (HMA) research for the detection of buried ERW, including unexploded ordnance (UXO), landmines, and improvised explosive devices (IEDs). A crucial step in transitioning experimental detection techniques from the lab to the field is conducting rigorous field testing in a realistic and safe environment.<sup>2,3,4</sup> With most academic institutions lacking access to stockpiles of inert ERW to conduct testing and prioritizing scientific publications over real-world field applicability, this step is too often neglected. The result is that most HMA studies lack sufficient benchmarking among detection variables such as depth of burial, size and diversity of ERW, and environmental context, making it nearly impossible to objectively compare the effectiveness of different instruments and sensors. Consequently, the humanitarian demining community is less willing to accept novel methods and instead relies largely on traditional approaches.



**FIGURE 1.** Orthomosaic of the initial field on 7 March 2023 (1) next to the same field on 13 June 2023 (2) processed in Pix4DMapper.  
*All graphics courtesy of the authors.*



Military munitions response (MMR), an industry focused on clearing UXO from formerly used defense sites, differs from HMA in that it has strict industry standards and protocols for testing and evaluating new instruments and methods on ground-truthed seeded fields with known geophysical signatures and depths of burial.<sup>5</sup> Unfortunately, access to these fields are restricted and

the results of the benchmark tests are rarely released to the scientific community. Additionally, MMR focuses almost exclusively on larger, buried metal UXO, while HMA deals with clearance of landmines, UXO, and IEDs which can include plastic or low-metal content objects that are present on the surface and at depth.<sup>6</sup>

## OVERVIEW

To address this issue, the Demining Research Community,<sup>7</sup> (a US-based nonprofit organization whose mission is to advance the field of HMA through bridging academic research in accordance with demining organizations), in partnership with the Global Consortium for Explosive Hazard Mitigation at Oklahoma State University (OSU), have seeded a comprehensive field with 143 diverse items including landmines, submunitions, UXO, and IEDs

located at OSU's Center for Fire and Explosives, Forensic Investigation, Training and Research (CENFEX) range in Pawnee, Oklahoma. This field was initially seeded in March 2023 and was reseeded at a permanent location in June 2023. The permanent site will be open to the broader mine action community to test equipment and methods for detecting and mapping ERW.

## INITIAL TEST SITE

**Environment.** The topsoil of the burial site is a silt loam for the A horizon 0–18 cm and a silty-clay loam 18–30 cm for the Bt1 horizon. It is categorized dominantly as a RenC2-Renfrow silt loam by the Web Soil Survey (WSS) from the US Department of Agriculture.<sup>8</sup> The field is oriented approximately north-south in the long

**Burial grid.** We buried 143 items in total (including control holes) in a grid pattern that covered 10 x 40 m for an area of 400 m<sup>2</sup>. The grid consists of six columns (labeled A–F) spaced 2 m apart, each with 25 rows (labeled 1–25) spaced 1.5 m apart (Figure 2). We placed six ground control points (GCPs), one at each corner and two inside of the

**TABLE 1.** Class and quantity of buried items.

CLASS	QUANTITY
Control Hole	8
Clutter	11
Projectile	25
AP landmine	27
AT landmine	2
Grenade	18
40mm grenade	13
Submunition	9
IED	7
3D printed ERW	10
TNT stick	1
Shells & casing	10
Empty	9
<b>Total</b>	<b>150</b>

direction. It is located on an explosive test range and is therefore littered with small metal fragmentation. The field is relatively flat with no strong gradients that were visually apparent. There was no vegetation at the time of burial 7 March 2023, but after three months, knee-height weeds in the northern end of the field grew (Figure 1). We can expect vegetation growth as time passes depending on the time of year.

**FIGURE 2.** Top panel shows an oblique angle of the initial field oriented from south (bottom) to north (top) showing columns A–F. Bottom panel shows an oblique angle of the permanent field oriented from east (bottom) to west (top) showing columns A–F.



grid. The Northwest corner of the grid is A1 with the southeast corner being F25. The buried items are a diverse set of ERW. We categorize each item into broad classes consisting of *Control hole, Clutter, Projectile, Anti-personnel (AP) mine, Anti-tank (AT) mine, Hand grenade, 40mm grenade, Submunition, Improvised Explosive Device (IED), 3D printed ERW, Shells & Casings, and Empty* (nothing buried in this location). The quantity of each class is shown in Table 1 and the specific type of ERW along with its weight, size, ferrous or nonferrous metal content, and related notes are available in Table 4. The items were buried organized into columns by class and in some cases physical properties and appearance.

Figure 3 shows all the items in a condensed grid for visualization purposes. Column A contained six larger metal projectiles, one AT mine, and six IEDs, with smaller 3D-printed ERW and empty spaces placed between the larger metal items to minimize magnetic interference

between objects during data acquisition. Column B contains eighteen hand grenades, one landmine, and six projectiles. Column C contains thirteen 40mm grenades, three projectiles, and nine submunitions. Column D contains only AP mines. Column E contains thirteen projectiles, one landmine, ten shells or casings, and two IEDs. Column F contains two munition cases, one filled with fuzes and the other with shrapnel, one plastic AT mine, and ten pieces of clutter that include cell phones, a copper pipe, aluminum cans, and metal shrapnel.

**FIGURE 3.** Condensed grid for visualization of placement of each item, produced from structure-from-motion photogrammetry. Columns A–E are accurate in terms of placement and order in the buried grid, and F is accurate in order of items, but there is offset of item placement. The exact placement and corresponding names of the items are available in Table 2 and 4.



## EXPERIMENTAL DESIGN

The diversity of ERW and the structure of the field was designed to allow scientists and researchers to tackle numerous questions related to ERW detection. This involves deciphering which sensors are most useful for detection of which types of ERW.<sup>9</sup> Each grouping of items as described previously were buried at different depth

intervals to explore how different geophysical signatures of the ERW attenuate with depth. The depth for each item was carefully determined based on the likely field deployment and depth of penetration for the specific ERW. Larger projectiles are prone to penetrate deeper into the ground, whereas submunitions and scatterable



**TABLE 2.** Placement and depth of each item in the grid.

	A	Depth (cm)	B	Depth (cm)	C	Depth (cm)	D	Depth (cm)	E	Depth (cm)	F	Depth (cm)
1	Pressure cooker <sup>1</sup>	8	M228 <sup>5</sup>	0	M385 <sup>7</sup>	0	PFM-1 <sup>6</sup>	0	M69 <sup>3</sup>	10	Shrapnel cache <sup>10</sup>	12
2	Plastic projectile <sup>2</sup>	2	M228 <sup>5</sup>	2	M385E4 <sup>7</sup>	0	PFM-1 <sup>6</sup>	0	M69 <sup>3</sup>	10	Control hole <sup>11</sup>	14
3	M6A1 <sup>3</sup>	20	M228 <sup>5</sup>	4	M385 <sup>7</sup>	0	PFM-1 <sup>6</sup>	0	60mm mortar <sup>3</sup>	8	Fuze cache <sup>10</sup>	14
4	Plastic projectile <sup>2</sup>	2	M228 <sup>5</sup>	6	M385 <sup>7</sup>	0	PFM-1 <sup>6</sup>	0	Inert warhead <sup>3</sup>	8	Control hole <sup>11</sup>	15
5	M6A1 <sup>3</sup>	16	M18 <sup>5</sup>	8	Undesignated drill <sup>7</sup>	2	PFM-1 <sup>6</sup>	0	M49A3 <sup>3</sup>	6	VS-1.6 <sup>4</sup>	12
6	Plastic projectile <sup>2</sup>	4	M228 frag <sup>5</sup>	0	M918 <sup>7</sup>	2	PFM-1 <sup>6</sup>	0	M81A1 <sup>3</sup>	6	Control hole <sup>11</sup>	15
7	M83 <sup>3</sup>	12	Mk1 <sup>5</sup>	2	Drill round <sup>7</sup>	2	PFM-1 <sup>6</sup>	0	M2A3 <sup>6</sup>	4	Aluminum can <sup>10</sup>	2
8	Plastic projectile <sup>2</sup>	4	M228 frag <sup>5</sup>	4	40mm 203 shrapnel <sup>7</sup>	4	PFM-1 <sup>6</sup>	0	Projectile <sup>3</sup>	4	Control hole <sup>11</sup>	17
9	Al pipe Bomb <sup>1</sup>	8	M228 frag <sup>5</sup>	6	M385	4	PFM-1 <sup>6</sup>	0	M55A <sup>3</sup>	2	Aluminum can <sup>10</sup>	4
10	Plastic OZM <sup>2</sup>	2	M228 frag <sup>5</sup>	8	40mm dummy <sup>7</sup>	4	PFM-1 <sup>6</sup>	0	M715 <sup>3</sup>	2	Control hole <sup>11</sup>	20
11	Al pipe bomb <sup>1</sup>	6	M213 <sup>5</sup>	0	M715 <sup>7</sup>	6	PFM-1 <sup>6</sup>	2	Drill round <sup>3</sup>	0	Shrapnel <sup>10</sup>	0
12	Plastic OZM <sup>2</sup>	4	M213 <sup>5</sup>	2	M427 <sup>7</sup>	6	PFM-1 <sup>6</sup>	2	20mm <sup>3</sup>	0	Control hole <sup>11</sup>	17
13	M6 <sup>3</sup>	4	M228 frag <sup>5</sup>	4	M918 <sup>7</sup>	6	PFM-1 <sup>6</sup>	4	KSF-cap <sup>8</sup>	0	Shrapnel <sup>10</sup>	2
14			M228 frag <sup>5</sup>	6	Drill round <sup>3</sup>	8	PFM-1 <sup>6</sup>	4	KSF-casing <sup>8</sup>	0	Control hole <sup>11</sup>	20
15	M65A1 <sup>3</sup>	2	M228 frag <sup>5</sup>	8	Drill round <sup>3</sup>	8	PFM-1 <sup>6</sup>	6	KSF-casing <sup>8</sup>	0	Copper pipe <sup>10</sup>	4
16			Riot grenade <sup>5</sup>	0	Drill round <sup>3</sup>	8	PFM-1 <sup>6</sup>	6	KSF-cap <sup>8</sup>	2	Control hole <sup>11</sup>	30
17	M65A1 <sup>3</sup>	0	M18 <sup>5</sup>	2	M42 <sup>6</sup>	0	PFM-1 <sup>6</sup>	8	KSF-casing <sup>8</sup>	2	Shrapnel <sup>10</sup>	6
18			Hand grenade 343d	4	M46 <sup>6</sup>	2	PFM-1 <sup>6</sup>	10	KSF-casing <sup>8</sup>	2		
19	PVC pipe <sup>1</sup>	8	POMZ2M <sup>6</sup>	6	M42 <sup>6</sup>	4	VPMA <sup>2</sup>	0	TNT <sup>9</sup>	12	Shrapnel <sup>10</sup>	8
20			PGU-24 <sup>3</sup>	0	M42 <sup>6</sup>	6	VPMA <sup>2</sup>	2	Tipman tank <sup>1</sup>	20		
21	Propane tank <sup>1</sup>	16	M793 <sup>3</sup>	2	M38 <sup>6</sup>	0	VPMA <sup>6</sup>	4	MK 2/2 <sup>8</sup>	16	Huawei phone <sup>10</sup>	2
22			M793 <sup>3</sup>	4	BLU-26 (D-1)/B <sup>6</sup>	2	PMN <sup>6</sup>	6	40 mm shell <sup>8</sup>	2		
23	PVC pipe <sup>1</sup>	8	M220 <sup>3</sup>	0	BLU-42/B <sup>6</sup>	4	PMN <sup>2</sup>	8	40 mm shell x2 <sup>8</sup>	2	HTC phone <sup>10</sup>	4
24			M220 <sup>3</sup>	2	BLU-42/B <sup>6</sup>	6	TS-50 <sup>6</sup>	0	40 mm shell x3 <sup>8</sup>	2		
25	M12 <sup>4</sup>	12	M220 <sup>3</sup>	4	BLU-42/B (D-1)/B <sup>6</sup>	8	TS-50 <sup>2</sup>	2	40 mm shell x4 <sup>7</sup>	2		

**LEGEND**

1. IEDs	6. Scatterable and AP mines
2. 3D printed ERW	7. 40 mm grenades
3. Projectiles	8. Shells, fuze, or casing
4. AT mine	9. TNT
5. Grenade	10. Metal clutter
	11. Control hole

landmines are placed on the surface and may become shallowly buried with time.<sup>10</sup> For example, in B1–B5, five nearly identical hand grenades were placed at different depths: one placed on the surface, one at 2 cm, 4 cm, 6 cm, and 8 cm respectively. Grenades are likely to be found on or close to the surface, so they were buried at shallow depths in increments of 2 cm up to a final depth of 8 cm. This will allow researchers to examine the signal attenuation with depth for future thermal, magnetic, and ground penetrating radar (GPR) surveys.

The burial depths ranged from the surface to 20 cm. Tables 2 and 4 have all the depth information per item. Additionally, control holes were dug at various depths and filled with the goal of decoupling a signature resulting from soil displacement or disturbance from one resulting from the items themselves. This may be especially relevant for LiDAR and depth sensors that look at soil subsidence.<sup>11</sup> Similarly, the clutter items will help determine if the signatures of the ERW are unique and if they can be distinguished from metal and electronic clutter. The non-unique signature problem



**FIGURE 4.** Permanent seeded field map displayed as an orthomosaic on a satellite map. The blue square shows the location of the IVS relative to the field. There is a pavillion for field operation logistics and gravel road access to the site.

is particularly difficult for certain sensor modalities, and we hope that the presence of clutter in our seeded field will help researchers identify ways to reduce false positive detections.<sup>12,13</sup>

There are plastic, low metal, and metal (ferrous and non-ferrous) ERW buried in the seeded field. This will allow researchers to compare the viability of different sensor modalities for different material properties. For example, we have the metal American M-12A1 anti-vehicle (AV) landmine and the plastic Italian VS-1.6 AV landmine both buried at 12 cm depth.

Over time (months to years), natural environmental emplacement and equilibriums will be reached, providing us with a realistic field that is usually only found in confirmed hazardous areas. This time-since-seeded variable is often unaccounted for in other HMA geophysical studies and is especially relevant for datasets that rely on realistic resettling of the ground or a thermal equilibrium to be reached.<sup>14,15,16,17</sup> Lastly, while weeds and light vegetation are present, there are no large trees or bushes in the field site to prevent testing of unmanned aerial vehicles (UAVs) and ground-based methods.

## LIMITATIONS

Given one test location, studies using this field cannot address the effect of differing environmental factors such as soil type and vegetation biodiversity on detectability of ERW. Landmines and UXO are found in sixty countries and territories around the world in diverse environments ranging from the tropical rainforests of Southeast Asia to the deserts of the Sahara, thus not all the geophysical tests on this field will provide transferable knowledge for

ERW detectability in all regions of the world.<sup>18</sup> Despite this, it is necessary to constrain environmental variables to allow for a clear, objective comparison of detection rates for different geophysical sensors. Other environmental parameters such as soil moisture, temperature, and humidity, which affect GPR and thermal imagery, change daily and must be considered and recorded.<sup>19,20</sup>



**FIGURE 5.** Instrument verification strip, ISO buried at recorded depths of 6 inches (15.2 cm), 13 inches (33.0 cm), and 20 inches (50.8 cm) respectively.

## BENCHMARK SURVEYS

From 12–16 June 2023, the Demining Research Community with affiliate researchers from OSU, the Department of Geological Sciences at Binghamton University and University of Maryland, and Lamont-Doherty Earth Observatory at Columbia University collected the first major datasets on the seeded field.

Among the datasets collected were thermal, visual, magnetic, GPR, stereoscopic, and LiDAR surveys with both UAV- and ground-based platforms (cart and handheld) over the field site. Once processed, these datasets and the subsequent analysis will be made freely available to the HMA community, providing the first comparative dataset on this seeded field for future studies.

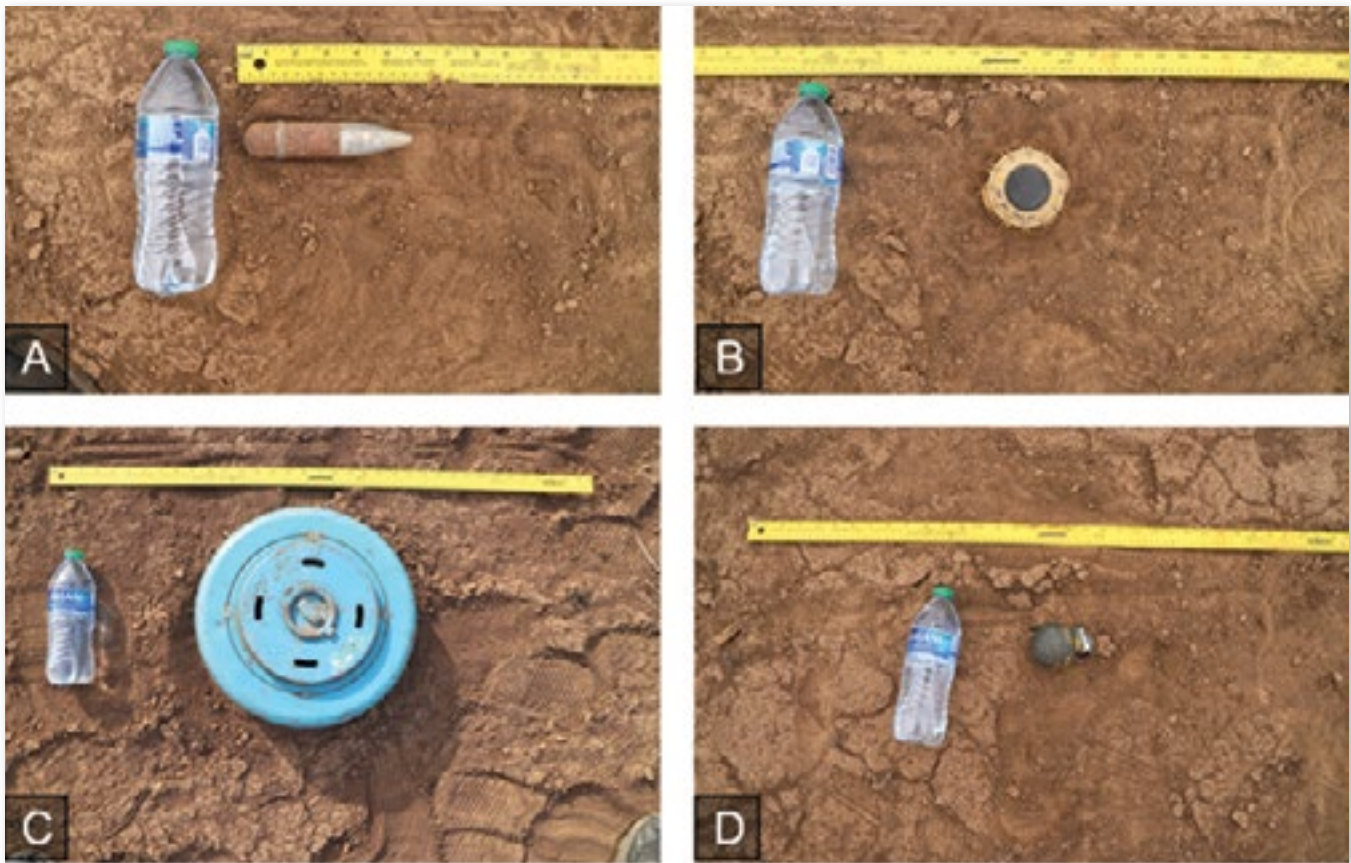
## PERMANENT SITE

On 15 June 2023, after the benchmark surveys on the initial field were conducted, the items were unburied and reseeded in a new permanent site. The ongoing burial is meant to simulate real-world conditions where UXO and mines need to be detected months to years after a conflict has ended.

The permanent site has the same seeding pattern and burial depths as the original field. The primary difference

is that the twenty-five rows are spaced 1 m apart instead of 1.5 m in the previous field due to a space constraint. The dimensions of this field are 10 m x 25 m with a total area of 250 m<sup>2</sup> (Figure 4). This field is about 150 m from the initial site and oriented approximately east-west lengthwise. The soil layers vary slightly from the initial field with the first 6–8 cm consisting of silty loam and 8–30 cm depth consisting of a dense silty-clay that is difficult to dig





**FIGURE 6.** Scaled pictures of A) 20mm projectile, B) TS-50 AP mine, C) M12 AT mine, D) M213 grenade.

through. Wooden popsicle sticks were placed to mark the locations of the buried items so as not to interfere with future magnetic surveys. There is a minimal amount of small metal fragmentation in this site compared to the initial site.

An instrument verification strip (IVS) was installed near the permanent site. The IVS has items with known shapes, sizes, and magnetic signatures that serve to calibrate instruments, especially magnetometers. The IVS contains four industry standard objects (ISO) 3 m apart as shown in Figure 4 to include two small, one medium, and one large ISO (Figure 5). The two small ISOs were buried horizontally at 6 inches, the medium ISO was buried horizontally at 13 inches, and the large ISO was buried horizontally at 20 inches. Each ISO was made from black steel pipe nipples, with the exception of one small ISO. The first small ISO is a heavy hex head bolt, 2 inches long. The second small ISO is Schedule 40, 1 inch straight pipe nipple and is 4 inches long. The medium ISO is Schedule 40, 2 inch straight pipe nipple and is 8 inches long. The large ISO is a Schedule 40, 4 inch straight pipe nipple and is 12 inches long.

Six ground control points (GCPs) were placed at the permanent site: one at each corner of the grid and two in the center. The NW-center GCP is located between

columns B and C and rows 16 and 17 and the SE-center GCP is located between columns D and E and rows 8 and 9. The placement of each ISO and GCP was recorded using a handheld Trimble Geo7x with accuracy of  $\pm 5$  cm. Coordinates of the GCPs and ISOs are provided in Table 3.

**TABLE 3.** Locations of GCPs and ISOs as measured from the Trimble Geo7x.

GCP/ISO	LATITUDE	LONGITUDE
GCP NE	36.3531001	-96.856893
GCP NW	36.3531111	-96.857171
GCP SE	36.3530033	-96.8569
GCP SW	36.3530164	-96.857078
GCP NW-center	36.3530772	-96.857078
GCP SE-center	36.3530375	-96.856996
ISO 20mm	36.3531296	-96.857243
ISO small	36.3531282	-96.857263
ISO medium	36.3531299	-96.857285
ISO large	36.3531283	-96.857306



**FIGURE 7.** The left image shows the technique used to measure burial depth. The right image shows the digging process.

## METHODS

**Pre-burial data collection.** Prior to burial, each item was weighed, measured (length and diameter), photographed with and without a scale, and underwent a ferrous metal test. The workflow for taking these measurements followed a systematic process. First, we organized the ERW into a condensed grid in the arrangement in which they would be buried (Figure 3). Next, each item was weighed on a small food scale accurate to 1 g. A small portion of the larger items (such as the pressure-cooker and metal AT mine) were too heavy for the small scale and were weighed using a digital luggage scale accurate to 100 g. Next, we used a ruler to measure the length and diameter of each item in place. Then we conducted a ferrous metal test, placing a magnet on each item and recording if the item was composed of a ferrous or non-ferrous material. Finally, we placed the items next to a water bottle and a ruler for scale and took bird's eye view pictures. Figure 6 shows examples of the scaled pictures. The collected data for each item can be found in Table 4. These measurements were collected prior to seeding the initial test site.

## CONCLUSION

We seeded a well-documented test field consisting of 143 diverse inert ERW in a grid pattern at depths ranging from 0 to 20 cm equipped with an instrument verification strip. This field is intended to serve as a benchmark to the HMA community, allowing researchers to thoroughly test the

**Burial techniques.** After each item went through several measurements, we transported them to their designated burial location. After all the items were placed, we conducted a thermal and visual light drone survey over the field. The processed visual surveys are shown in Figures 1 and 4. Next, we dug burial holes for each item and placed the item into its hole. We tried to dig holes to the proper depth to mitigate soil disturbance. In some instances, the hole was deeper than intended and we had to remove the item, infill it, and then replace the item. In other instances, we needed to continue digging to make the hole the intended depth. After the item was placed into the hole, two rulers were placed, one horizontal on the soil surface and one vertical resting on the uppermost surface of the item. We then recorded the depth to the center of mass of the object based on the intersection of these rulers (Figure 7). For this method, we estimate an error of  $\pm 1$  cm. Once an item was buried, the hole would be filled until level with the surface and the soil was not manually compacted.

methods and instruments they develop with transparency and uniformity. The first iteration of this field was seeded on 7 March 2023 and remained in place for three months. Before the initial site was unburied, our team along with university and industry partners, collected the first aerial



**TABLE 4.** The specific type of ERW buried along with its weight, size, ferrous or nonferrous metal content, and related notes.

ID	Item	Class	Depth	Weight (g)	Length (cm)	Diameter (cm)	Ferrous (1) or NF (0)	Country	Reference	Notes
A1	Pressure Cooker	IED	8	3800	20	23	0	Afghanistan, India, and Pakistan		Empty at burial, mostly non ferrous, handles ferrous
A2	Plastic Projectile	3D Printed	2	90	16.8	4	0			
A3	M6A1	Rocket	20	1500	54	6.8	1	US	OP 1664	2.36 inch bazooka
A4	Plastic Projectile	3D Printed	2	90	16.8	4	0			
A5	M6A1	Rocket	16	1500	54	6.6	1	US	OP 1664	2.36 inch bazooka
A6	Plastic Projectile	3D Printed	4	90	16.8	4	0			
A7	M83	Projectile	12	1108	36.6	6.4	1	US	OP 1664	60mm Illum
A8	Plastic Projectile	3D Printed	4	90	16.8	4	0			
A9	Aluminum Pipe Bomb	IED	8	1318	35.2	5	1			
A10	Plastic OZM	3D Printed	2	200	12	7.2	0			
A11	Aluminum Pipe Bomb	IED	6	1019	25.4	5	1			
A12	Plastic OZM	3D Printed	4	200	12	7.7	0			
A13	M6	Rocket	4	1400	55	6	1	US	OP 1664	2.36 inch bazooka
A14										
A15	M65AI	Projectile	2	922	21.2	6				White projectile that's dented in
A16										
A17	M65AI	Projectile	0	922	21.2	8.4				White projectile
A18										
A19	PVC Pipe	IED	8	870	37	8.8	0			Wide PVC pipe
A20										
A21	Propane Tank	IED	16	1290	29.4	13	1			Empty black propane tank
A22										
A23	PVC Pipe	IED	8	760	45.6	5.4	0			Longer PVC, mostly nonferrous, with ferrous handle
A24										
A25	M12AI	Anti-tank mine	12	4200	12.8	33	1	US	OP 1664	Practice M12 landmine
B1	M228	Grenade	0	482	11	6	1			
B2	M228	Grenade	2	499	11	6	1			
B3	M228	Grenade	4	492	11	6	1			
B4	M228	Grenade	6	401	11	6	1			
B5	M18	Grenade	8	294	11	6	1	US	60E-2-2-27	Israeli version
B6	M228 Frag	Grenade	0	621	11.2	5.8	1			
B7	Mk1	Grenade	2	501	11.2	5.8	1	US	OP 1664	
B8	M228 Frag	Grenade	4	483	11.2	5.8	1			
B9	M228 Frag	Grenade	6	474	11.2	5.8	1			
B10	M228 Frag	Grenade	8	452	9	5.8	1			
B11	M213	Grenade	0	397	8.8	6.5	1			
B12	M213	Grenade	2	456	8.8	6.5	1			
B13	M228 Frag	Grenade	4	490	11.2	5.8	1			
B14	M228 Frag	Grenade	6	525	11.2	5.8	1			
B15	M228 Frag	Grenade	8	584	11	5.8	1			
B16	"Rusty" Aluminium	Grenade	0	303	12	6	0			Rusty aluminium

ID	Item	Class	Depth	Weight (g)	Length (cm)	Diameter (cm)	Ferrous (1) or NF (0)	Country	Reference	Notes
B17	M18	Grenade	2	157	12	6	1	US	60E-2-2-94	Purple smoke
B18	Handgranate 343d	Grenade	4	147	12	6	1	Germany	60E-6-2-4	German concussion grenade
B19	POMZ-2M	Anti-personnel frag	6	1198	10.5	6	1	Russia	60H-1-1-1	
B20	PGU-24	Projectile	0	490	22	4	1	US	60D-2-2-293	20mm projo
B21	M793	Projectile	2	243	22	4	1	US	60D-2-5-16	25mm TP-T
B22	M793	Projectile	4	243	22	4	1	US	60D-2-5-16	25mm TP-T
B23	M220	Projectile	0	227	18.2	3	1	US	60D-2-2-28	20mm TP
B24	M220	Projectile	2	227	18.2	3	1	US	60D-2-2-28	20mm TP
B25	M220	Projectile	4	225	18.2	3	1	US	60D-2-2-28	20mm TP
C1	M385	40mm	0	246	7.5	4	0	US	60D-2-2-303	Practice 203mm grenade
C2	M385E4	40mm	0	251	7.5	4	0	US	60D-2-2-303	Practice 203mm grenade
C3	M385	40mm	0	245	7.5	4	0	US	60D-2-2-303	Practice 203mm grenade
C4	M385	40mm	0	245	7.5	4	0	US	60D-2-2-303	Practice 203mm grenade
C5	Undesignated drill	40mm	2	165	10	4	0	US	UNKN	Rubber 40mm 203 round
C6	M918	40mm	2	190	10.4	4	1	US	60D-2-2-23-11	40mm prac with spotting charge
C7	Drill Round	40mm	2	103	11	4	0	US		40mm drill 203
C8	40mm 203 shrapnel	40mm	4	116	6.2	4	1			Projectile
C9	M385	40mm	4	304	10.4	4	0	US	60D-2-2-303	40mm prac solid
C10	Undesignated 40mm dummy	40mm	4	105	10	4	0	US		40mm dummy 203
C11	M715	40mm	6	92	7.6	4	0	US	60D-2-5-28	Green smoke 40mm 203
C12	M427	Fuze	6	203	9.8	4	0	US	60F-2-3-32	2.75 inch rocket fuze
C13	M918	40mm	6	238	8.5	4	1	US	60D-2-2-23-11	40mm prac with spotting charge
C14	Drill Round	Projectile	8	384	11.2	4	0	US		40mm frill 203, ferrous casing, body NF
C15	Drill Round	Projectile	8	319	11.2	4	0	US		40mm drill 203
C16	Drill Round	Projectile	8	335	11.2	4	0	US		40mm drill 203, ferrous casing, body NF
C17	M42	Scatterable	0	211	7.4	4	1	US	60T-2-2-12	HEAT submunition
C18	M46	Scatterable	2	209	7.4	4	1	US	60T-2-2-12	HEPD submunition
C19	M42	Scatterable	4	213	7.4	4	1	US	60T-2-2-12	HEAT submunition
C20	M42	Scatterable	6	214	7.4	4	1	US	60T-2-2-12	HEPD submunition
C21	M38	Scatterable	0	130		4	0	US	60C-2-1-2	Golf ball
C22	BLU-26 (D-1)/B	Scatterable	2	413		6	1	US	60C-2-1-2	Prac baseball submunition




ID	Item	Class	Depth	Weight (g)	Length (cm)	Diameter (cm)	Ferrous (1) or NF (0)	Country	Reference	Notes
C23	BLU-42/B	Scatterable	4	314		6	1	US	60B-2-2-36	Baseball submunition Halfshell X2
C24	BLU-42/B	Scatterable	6	304		6	1	US	60B-2-2-36	Baseball submunition Halfshell X2
C25	BLU-26 (D-1)/B	Scatterable	8	406		6	1	US	60C-2-1-2	Prac baseball submunition
D1	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D2	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D3	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D4	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D5	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D6	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D7	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D8	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D9	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D10	PFM-1	Scatterable Anti-personnel	0	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D11	PFM-1	Scatterable Anti-personnel	2	72	11.8	6.2	1	Russia		Training, Missing wing
D12	PFM-1	Scatterable Anti-personnel	2	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D13	PFM-1	Scatterable Anti-personnel	4	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D14	PFM-1	Scatterable Anti-personnel	4	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D15	PFM-1	Scatterable Anti-personnel	6	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D16	PFM-1	Scatterable Anti-personnel	6	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D17	PFM-1	Scatterable Anti-personnel	8	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D18	PFM-1	Scatterable Anti-personnel	10	72	11.8	6.2	1	Russia		Training, fuze is ferrous, body is not
D19	VPMA	3D Printed	0	87	3.2	10.5	0			
D20	VPMA	3D Printed	2	87	3.2	10.5	0			
D21	VPMA	Anti-personnel Blast	4	126	3.5	10.5	0			
D22	PMN	Anti-personnel Blast	6	248	5	8	1			
D23	PMN	3D Printed	8	167	6.5	11	0			
D24	TS-50	Anti-personnel	0	135	4.5	9	1			
D25	TS-50	3D Printed	2	88	4.5	9	0			
E1	M69	Projectile	10	1850	19.4	6	1	US	OP 1664	Practice 60mm mortar/ no fuze well
E2	M69	Projectile	10	1900	19.4	6	1	US	OP 1664	Practice 60mm mortar
E3	60mm Mortar	Projectile	8	1260	21	5.5	1			Rusted 60mm Mortar
E4	Inert Warhead	Rocket	8	1148	21	7	1	US		2.75 inch factory inert warhead, 60mm
E5	M49A3	Projectile	6	1000	23	7	1	US	60D-2-2-262	60mm mortar
E6	M81A1	Projectile	6	881	17	3.5	1	US	OP 1664	
E7	M2A3	Landmine	4	840	15.4	6.4	1	US	60A-2-1-12	Bounding frag
E8	Unknown	Projectile	4	558	18.8	8.6	1			

ID	Item	Class	Depth	Weight (g)	Length (cm)	Diameter (cm)	Ferrous (1) or NF (0)	Country	Reference	Notes
E9	M55A	Projectile	2	217	17	3	1	US	60D-2-1-12	20mm TP
E10	M715	Projectile	2	860	12.2	3.8	1	US	60D-2-5-28	Green smoke 40mm 203
E11	Drill Round	Projectile	0	865	16.4	3.8	1	US		
E12	20mm	Projectile	0	275	13.8	3.4	1			20mm projo with rounded base
E13	KSF-cap	Casing	0	61	6.6	5.8	1	Russia		
E14	KSF-casing	Casing	0	154	20.5	6.2	1	Russia		
E15	KSF-casing	Casing	0	105	23	5	1	Russia		
E16	KSF-cap	Casing	2	82	6.8	6	0	Russia		
E17	KSF-casing	Casing	2	153	20.5	6.2	1	Russia		
E18	KSF-casing	Casing	2	106	23	5	1	Russia		
E19	TNT	TNT	12	482	18	4.6	0			Small ferrous component
E20	Tipman Tank	IED	20	1376	28	9	0			
E21	MK 2/2	Projectile	16	216	22	5	0	British	60D-2-3-36	2 inch Illum mortar
E22	40mm Shell	Shell	2	49	4.5	4	0			
E23	40mm Shell x2	Shell	2	98	4.5	4	0			x2
E24	40mm Shell x3	Shell	2	146	4.5	4	0			x3
E25	40mm Shell x4	Shell	2	241	4.5	4	0			x4
F1	Shrapnel Cache	Clutter	12	5100			1			
F2	Hole	Control Hole	14							
F3	Fuze Cache	Clutter	14	9200			1			
F4	Hole	Control Hole	15							
F5		Anti-tank mine	12	2698	10.5	22	0			
F6	Hole 12cm	Control Hole	15							
F7	Aluminum Can	Clutter	2	14	12.5	6	0			Partially filled with dirt
F8	Hole 13cm	Control Hole	17							
F9	Aluminum Can	Clutter	4	14	12.5	6	0			Partially filled with dirt
F10	Hole 18cm	Control Hole	20							
F11	Shrapnel	Clutter	0	457	12	8	1			
F12	Hole 15cm	Control Hole	17							
F13	Shrapnel	Clutter	2	493	12	9	1			
F14	Hole 20cm	Control Hole	20							
F15	Copper Pipe	Clutter	4	107	24	2.5	0			
F16	Hole 30cm	Control Hole	30							
F17	Shrapnel	Clutter	6	418	9	4.1	1			
F18										
F19	Shrapnel	Clutter	8	393	10	4	1			
F20										
F21	Huawei Phone	Clutter	2	136	12	5.6	0, 1			Has some ferrous components
F22										
F23	HTC Phone	Clutter	4	129	11.2	5.5	0, 1			Has some ferrous components
F24										
F25										



and ground-based magnetic, GPR, thermal, visual, and LiDAR surveys that will serve as the baseline datasets for this field. The same field of 143 items was reseeded at a nearby location on 15 June 2023 at a permanent site. To our knowledge, this is the most diverse field of

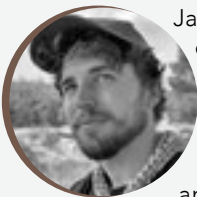
inert munitions seeded for HMA testing purposes. This resource will help bridge the gap between academia and HMA by offering researchers a realistic field to assess ERW detection methods and HMA operators a framework through which to compare them. 

*See endnotes last page*

### **Acknowledgements**

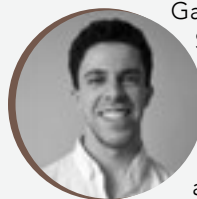
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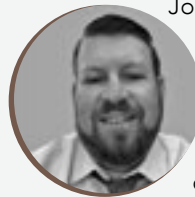
Jasper Baur is the co-founder and President of the non-profit organization Demining Research Community and the Lead Scientist at Safe Pro AI. Baur is a PhD candidate at Columbia University studying remote sensing applied to explosive hazard mitigation ranging from detecting small anti-personnel landmines to monitoring Alaskan volcanoes. He graduated from Binghamton University in 2020 with a Bachelor of Science in Geological Sciences, and a master's from Columbia University in 2022 in physical volcanology. He has received numerous awards for his work in landmine detection and is always striving to innovate in the humanitarian mine action space. He is an FAA 107 certified UAS remote pilot and has months of fieldwork experience in remote environments.

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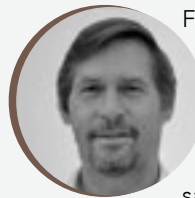
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For the past three years, Anthony Brinkley has been associated with Oklahoma State University, School of Forensic Sciences. Having earned his Master of Science in Forensic Sciences from OSU in spring of 2023, he is currently pursuing a PhD in the same field. Brinkley has over thirty-five years of experience with UXO beginning in the US Navy, where he served for twenty-five years in roles such as Salvage Diver, Salvage Diving Officer, and Special Operations/EOD Officer. Since retiring from the US Navy in 2013, Brinkley has remained committed to the EOD community overseeing and conducting numerous munitions and explosives removal projects. Currently, he serves as Vice President of Pacific Rim Services, Guam LLC, where he plays a crucial role in supporting the US Marine Corps buildup in the Pacific region. In addition, he provides UXO support for Ukraine.

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