Appendix H
Advanced Processing Techniques

Testing of Procedures to Remove False Positives During Data Processing

A Geophysical prove out (GPO) was completed using the ODDS (Ordnance Discrimination and Detection Study) plots in May 2006. The purpose was to demonstrate Shaw's ability to detect buried ordnance similar to that found at Fort Ord and to apply the technologies and methodologies used to Multi Range Area 16. It was determined (by the previous contractor) that using a vehicle towed array of EM61's is the most effective and cost-efficient way. During the GPO data processing and reduction, it was also determined that using a sum of responses from all four time gates (sum4) would be best used for target detection. The previous contractor used Channel 3 only. However, our experience with the Sum 4 data set from the known plots is that the detection rates were higher than just using Channel 3 (irrespective of filtering etc.). This resulted in high detection rates but also higher false positive and/or false alarm percentages. Shaw geophysicists applied various techniques in an effort to reduce these percentages. These techniques and conclusions are summarized in the following sections.

The first step was to determine which anomalies are more likely to be false positives and which items are not of interest. These would include various metal fragments and scrap. This was accomplished by reacquiring targets in one of the known plots using a single EM61 and Schonstedt fluxgate Magnetic Locator. As was expected, higher amplitude targets were easily reacquired (higher amplitude targets should be excluded from any filtering/removal process unless they are clearly the result of cultural features or data spikes). Of the targets that were not successfully reacquired, the average sum4 gridded value was 15 mV. Of those successfully reacquired, the average sum4 gridded value was 32 mV. Therefore, any target with a response of 30 mV or higher should remain on any final pick list and should not be filtered out. The results for the rest of the targets were also used in the analysis of target selection routines.

Filtering

Two filtering techniques were applied. The goal was to remove any high frequency targets that could be either noise or surface scrap. The results are qualitatively summarized in table 1 below.

Low Pass Filter	Non Linear Filter
a. Used various filter lengths ranging from 2.5 points to 12 points on both the sum and	a. Good for removing spikes (mostly in magnetic data) but not filtering out

channel 3. This process removes many targets but the only way to preserve all seed items is to use 2.5 point filter which is basically the same as not using a filter at all. b. Leaves artifacts in the data (at least geosoft's implementation does). These must be accounted for in any target picking routine. It worked well in Known Plot 2 but eliminated one seed item in Known Plot 1.	possible targets. b. Need a larger filter width but that essentially results in a low pass. No artifacts, but removes too much (including targets).

***Table 1**. Results from using a low pass and non-linear filter.*

Using Later Times

Using a different method than the 4 channel sum was also investigated. Two different techniques were applied. The first was using a later time gate (channel 3). The second was eliminating the earliest time gate (channel 1) and summing channels 2 and 3 (sum2). Seed item 605 was used for a baseline threshold since it had the lowest amplitude of the detectable known seed items. It was assumed that using this as a benchmark would result in detection rates that were similar to the original rates. The results are outlined in table 2.

Plot	Method	Total Targets	Seeds Detected	P_D	FP
k1	Ch3 (3mV)	55	23	74	58
k2	Ch3 (3mV)	74	25	74	66
k1	Ch3 (2.2 mV)	98	26	84	73
k2	Ch3 (2.2 mV)	116	26	76	77
k1	sum4 (14 mV)	108	26	84	76
k2	sum4 (14 mV)	120	26	76	78
k1	sum2_3 (5.5 mV)	123	25	81	80
k2	sum2_3 (5.5 mV)	143	27	79	81

***Table 2.** Results from various picking schemes. P_D = percent detected, FP = False Positives, Thresholds are in parenthesis.*

The results from the above analyses indicate that either the original 14 mV threshold sum4, or using a **2.2 mV** threshold channel 3, produce the highest detection rates on both known plots. The false positive rates are slightly better for the channel 3 method. This was noted at the early stages of the GPO data processing task and it was decided that using a 2.2 mV threshold on channel 3 would result in an even larger number of false positives in real field conditions. However, this must be understood before production work begins.

Field Strength Decay Rates

This method has been used in previous Shaw projects and exploits the fact that metallic UXO type items behave differently from natural earth materials. A few different techniques can be used but are all based on differences in response at different time intervals. Here we chose to examine the decay rates (response normalized by the time interval). One benefit of this method is the fact that the higher amplitude targets tend to have a higher decay rate. If we only select targets with a decay above a certain threshold decay, the higher amplitude targets will remain in the final pick list. Figure 1 shows the response at each time gate for seed item 605 and two initial targets that were considered false positives following the anomaly reacquisition of known plot 1. It is clear in this case that the decay rate is initially much higher with a more "normal" decay curve for the seed item. There is also a striking difference in the decay between the later times (660 μs and 1266μs). However, this isn't always the case and this method is not 100% reliable in that there are probably a few false positives that meet the decay criteria.

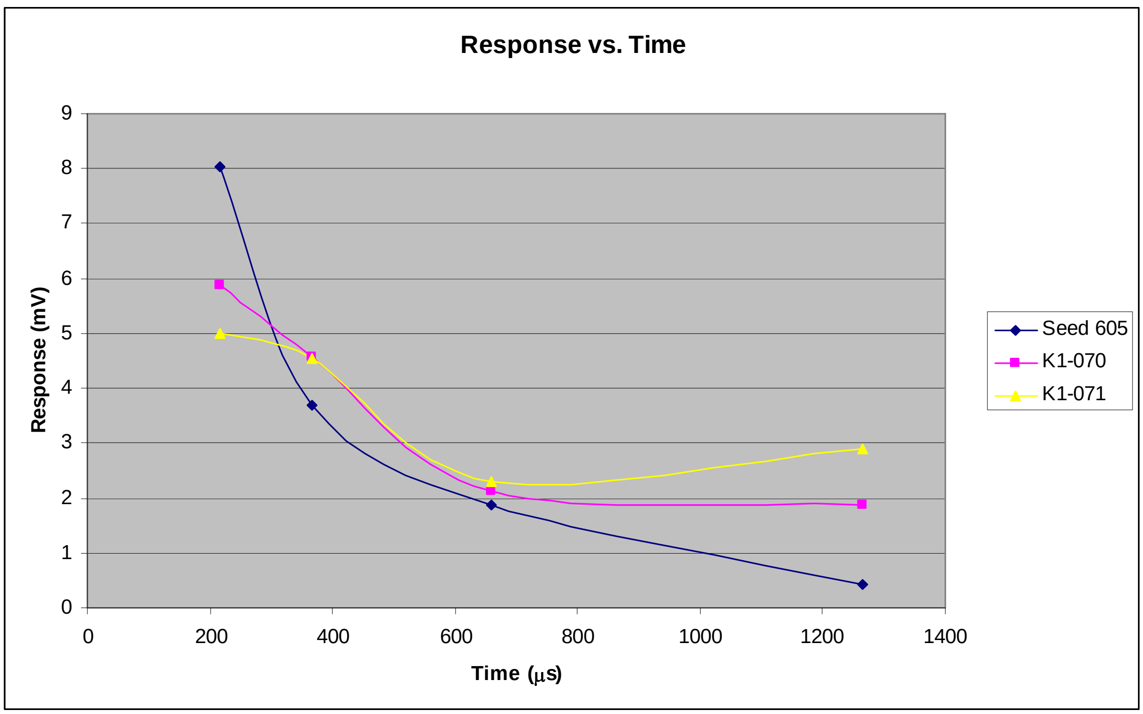

Figure 1. *Response versus time. Three items were chosen for this plot based on similar sum results and are all near the 14mV threshold.*

Anomaly Footprint

Another method previously used by Shaw is to check the data values on either side of the target peak. This method is feasible when line spacing is small enough that smaller targets show a response on adjacent lines. For this project, the line spacing is two feet which is small enough. Figure 2 shows and example (seed item 607) where there is a response on adjacent lines.

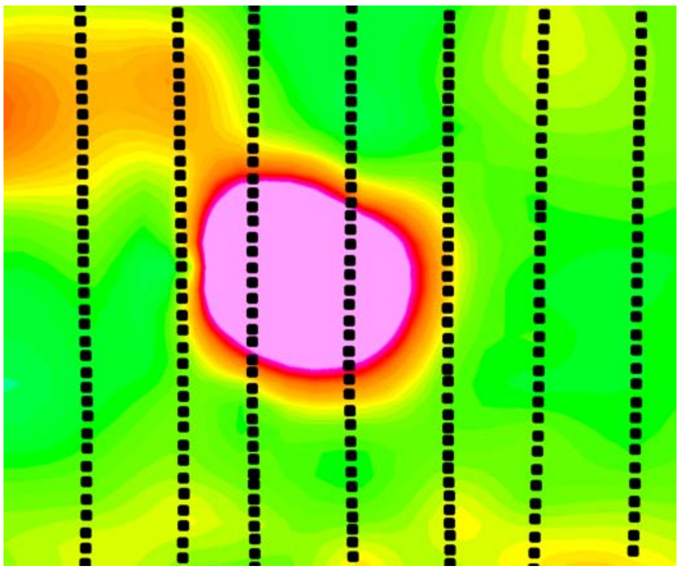

Figure 2. *Seed item 607 visible on multiple survey lines. Dotted lines represent survey paths.*

All detected seed items exhibit this behavior. At this time this method is the most labor intensive as far as target selection.

Other Methods

Other methods were also considered. One of these was using anomaly widths. This method is based on the idea that smaller, near surface, items have a shorter wavelength than deeper and larger sub-surface items (considering upward and downward continuation). This is basically the same as using a low pass filter but without altering the data. Therefore you do not run the risk of filtering out the targets that are near the base threshold. This method was attempted, but did not result in a significant reduction in smaller amplitude anomalies.

Another method involves the use of specialized algorithms developed by third party vendors. Shaw has attempted to use Hunter Ware's Chi Square Analysis but are still awaiting results from a previous project. This technique is supposed to provide a way to filter out non-metallic targets. When there is a more definitive answer, Shaw will respond and determine how appropriate it will be for later use.

One simple method is to raise thresholds. However, this reduces the detection rate and is simply a way to reduce the number of targets. However, our goal is to reduce false positives.

Shaw geophysicists also attempted various tweaks on the above methods. The results were inconsistent in most cases.

Various leveling techniques were also considered, but didn't yield any appreciable results that were usdable..

Conclusions/Recommendations

Our goal was to reduce the number of false positives in an efficient and effective way. Of all methods investigated, the decay appears to be the most robust and consistent. Removing targets with a decay rate of .02 mV/μs or less from (1) below removes a number of targets but does not reduce the detection rate. It also has the benefit of being simple to incorporate and will have negligible affect on data processing costs.

$$Rate(dV/\mu s) = \frac{Channel1 - Channel2}{150\mu s} \tag{1}$$

Examining anomaly footprints should also be incorporated. At this time, this method does increase processing time. However, Shaw geophysicists are working at methods to automate this task. The extra time required is also insignificant (in most cases) compared to the time and manpower required to reacquire targets.

Using the decay rate method, **the original increased detection rates (using the sum of 4 channels – Sum4) in the known plots remain the same**. At the same time we see a decrease in the total number of targets (excluding seed items – hence unknown items) by 24 percent in known Known Plot 1, 16 percent in Known Plot 2, and 15 percent in Unknown Plots 1 and 2. Since the actual seed data for Unknown Plots 1 and 2 is unknown, a true number for the false alarm rate cannot be calculated. If we assume that the targets removed are false positives, then the false positive percentage in Unknown Plot 1 falls from 41 percent to 26 percent, and, falls from 50 percent to 34 percent in Unknown Plot 2.

The two combined methods (combined with diligent processing) will reduce the number of probable false positive targets. Shaw also realizes that this is an iterative process and as our knowledge base grows so will the accuracy. Shaw will also explore new approaches as they become available.

Eliminating False Positive Anomalies Using Decay Curve Analysis at Ft Ord ODDS GPO Known Plot 1

During the data collection, processing, and target picking at Known Plot 1 of the ODDS GPO at Ft Ord numerous targets were detected. Shaw originally picked 108 targets using the Sum 4 (sum of all 4 EM61 MK2 channels). This was utilized to increase the detection rate of seed items. Shaw originally reviewed and used the previous contractor's protocol for picking anomalies. The previous contractor used channel 3 EM61 MK2 data with a threshold of 3 mV. That approach generated 58 percent false positives but detected only 23 seed items. Shaw tested and utilized a variety of different processing techniques which is outlined in a white paper titled "Testing of Procedures to Remove False Positives During Data Processing". In that paper, Shaw looked at a significant variety of techniques that increased the detection rate significantly but also created more "false positives". The purpose of this paper is to refine the processing and target selection criteria that Shaw utilized to reduce the "false positives".

The attached spreadsheet summarizes the results of this process. Shaw used the Sum 4 values for each anomaly because it significantly increased the detection rate of the seed items (threshold 14 mV) and reduced the signal to noise ratio. The spreadsheet shows all original 108 target picks with the original anomaly sum 4 value in column 4 (GV). Known Plot 1 had a total of 27 seed items. These are indicated in the last column of the spreadsheet under the seed item title. There were also 27 anomalies whose reacquisition values were significantly greater than 14 mV (threshold value Sum 4). These were valid metal objects that could easily be MEC items. They may be blind seeds.

The first task performed was to go back to Known plot 1 and reacquire all anomalies that were seed and non-seed items. The reacquired values are shown in column 10. The purpose of this task was to verify the existence of metallic objects at all possible locations.

The next step was to use a decay curve analysis using channels 1 and 2 from the EM61 MK2 data. Shaw has successfully done this on other projects to eliminate items that are insignificant and false positives. The analysis consists of retaining anomalies with a decay rate greater than .02 mV/µs. This step immediately eliminated 27 anomalies. These anomalies are indicated by the pink shading shown on the attached spreadsheet for Known Plot 1. The original population was now reduced from 108 picks to 81 picks.

After using the decay curve analysis there were 14 anomalies that remained whose original anomaly values were above 14 mV. These 14 anomalies can be considered false positives or insignificant items. It should be noted that the reacquisition values for all of the 14 anomalies was below 14 mV (originally they were above 14 mV). All of the other anomalies had reacquisition values above 14mV and should be considered targets. Hence, if the 14 anomalies that remained whose reacquisition values were below 14 mV are considered false positives (or insignificant items) the false positive percent was reduced to 17 percent.

It should be noted that the 14 anomalies considered to be false positives may be insignificant metal objects. However, they would not be considered MEC targets for excavation. Shaw believes this is a valid approach for the data processing and target selection criteria for MRS-16 at the Ft Ord Site.

Table 1
Target Reacquisition Decay

ID	X	Y	GV	ch1	ch2	ch3	ch4	offset	Reac sum	sch	Notes	Reac over 14 mV	Decay Rate > .02 mV/µS	Seed Item
K1-001	5744512.00	2115008.00	59.6	29.5	15.9	10.2	5.8	1.5 N	61.4			Y	Y	
K1-002	5744515.25	2115074.25	68.1	50	38	23	11	1 N	122	Y		Y	Y	
K1-003	5744521.00	2115040.00	20.9	12.6	6.8	3.6	1.7	.5 N	24.7	Y	Another response 2 feet W	Y	Y	
K1-004	5744528.00	2115016.00	38.2					0	34	Y		Y	Y	589
K1-005	5744529.52	2115026.47	52.0					1 W	45	Y		Y	Y	588
K1-006	5744529.50	2115060.50	39.5	36	24	11	3.5	1.5 N	74.5	Y		Y	Y	
K1-007	5744530.50	2114995.00	38.8					1.5 NW	31	Y		Y	Y	590
K1-008	5744531.46	2115051.69	27.5	18	11	5	1	2 W	35	Y		Y	Y	
K1-009	5744531.00	2115055.50	42.6	17	10	5	2	1 N	34	Y	2 Peaks, Schondstet 1 foot S	Y	Y	
K1-010	5744531.00	2115083.50	20.3	14	9	4	2	2 N	29	Y		Y	Y	
K1-011	5744536.50	2115068.00	31	10	2	4	1.5	1 N	17.5	Y		Y	Y	
K1-012	5744536.88	2115024.19	72.7	52	38	24	11	1 W	125	Y		Y	Y	
K1-013	5744541.00	2115073.50	117.7	54	40	25	12	1.5 W	131	N		Y	Y	
K1-014	5744544.50	2115058.50	19.6	16	9	4.3	2	.5 S	31.3	Y		Y	Y	
K1-015	5744546.00	2115006.00	20.0					1.5 NW	16	Y		Y	Y	591
K1-016	5744546.00	2115019.00	19.4	10	5	2	0.5	2 NW	17.5	Y		Y	N	
K1-017	5744548.00	2115008.00	19.2	8.5	4.8	2.1	0.5	0	15.9			Y	Y	
K1-018	5744548.30	2115036.88	42.4					1.5 N	42	Y		Y	Y	593
K1-019	5744550.00	2115019.50	24.9					.5 W	20	Y		Y	Y	592
K1-020	5744550.00	2115075.50	19	5	4	3	2	0	14	N		Y	Y	
K1-021	5744557.00	2114995.00	24	11.4	4.6	1.3	0.4	2.5 N	17.7			Y	N	
K1-022	5744564.00	2115057.00	23.4	11.3	7	3.5	1	1 WNW	22.8	Y		Y	Y	
K1-023	5744565.74	2115030.36	98.6					1 NW	89	Y		Y	Y	594
K1-024	5744568.50	2114995.00	19.1					0	17	Y		Y	Y	596
K1-025	5744568.87	2115009.80	90.7					.5 N	85	Y		Y	Y	595
K1-026	5744577.08	2115036.54	20.7	15	9.3	4.6	1.4	2 N	30.3	Y		Y	Y	
K1-027	5744587.00	2115075.50	20.1	8	3	1	0.5	1.5 NW	12.5	Y		N	Y	
K1-028	5744590.00	2115001.50	20.8	17.2	7.5	3.2	1.5	.5 N	29.4			Y	Y	
K1-029	5744589.51	2115006.58	75.4					.5 NE	95	Y		Y	Y	597
K1-030	5744596.50	2114993.50	35.4	0	0	0	0	0	0		maybe 3 feet north	N	Y	
K1-031	5744597.00	2115074.00	28.8	11	5	3	1	.5 NW	20	Y		Y	Y	
K1-032	5744598.50	2115034.50	33.7	22	11	5	2	0	40	Y		Y	Y	
K1-033	5744599.50	2115016.50	24.7	16.4	8	4	2	1 W	30.4	Y		Y	Y	
K1-034	5744601.50	2115084.00	88.3	36	23	11	3	1.5 NW	73	Y		Y	Y	
K1-035	5744603.50	2115011.50	20.9	16	6.2	2	0.3	1.5 N	24.5			Y	Y	
K1-036	5744604.50	2115060.50	26.1	10	6	4	2	.5 NW	22	Y		Y	Y	
K1-037	5744606.50	2115014.00	91.9					0	84	Y		Y	Y	602
K1-038	5744612.00	2114995.00	27.3	18	8.8	2.5	0.1	1.5 N	29.4			Y	Y	
K1-039	5744612.00	2114998.50	48.3					1.5 N	62	Y		Y	Y	603
K1-040	5744616.00	2115007.50	20.9	12.5	6.6	3.1	0.9	1.5 NW	23.1			Y	Y	
K1-041	5744619.00	2115069.00	131.2	89	67	41	19	1 NW	216	Y	Schondstet hit 1 foot S	Y	Y	
K1-042	5744624.00	2115084.50	194.7	83	70	51	33	1 NW	237	Y	Schondstet hit 1 foot S	Y	Y	
K1-043	5744633.25	2115009.25	53.0					.5 NW	69	Y		Y	Y	607
K1-044	5744639.02	2115030.36	94.4					0	119	Y		Y	Y	606
K1-045	5744640.00	2114993.00	23.1					.5 NW	15	Y		Y	Y	608
K1-046	5744651.00	2115007.00	24.7					1 NW	22	Y		Y	Y	609
K1-047	5744652.47	2115015.64	31.9					1 E	51	Y		Y	Y	610
K1-048	5744651.50	2115038.50	27.6					.5 NW	30	Y		Y	Y	616
K1-049	5744659.25	2115076.75	63.7	46	34	21	10	1 NW	111	Y		Y	Y	
K1-050	5744660.00	2115006.50	18.5	14.8	5.6	2.4	1.2	2.5 NW	24			Y	Y	

Table 1
Target Reacquisition Decay

ID	X	Y	GV	ch1	ch2	ch3	ch4	offset	Reac sum	sch	Notes	Reac over 14 mV	Decay Rate > .02 mV/µS	Seed Item
K1-051	5744665.50	2115084.50	80.5	30	22	14	6	.5 NW	72	Y		Y	Y	
K1-052	5744667.03	2115012.51	100.9					1 S	121	Y		Y	Y	612
K1-053	5744669.74	2114995.41	65.5					1 W	88	Y		Y	Y	611
K1-054	5744670.00	2115030.00	84.4					1.5 NW	120	Y		Y	Y	615
K1-055	5744671.50	2115082.00	72.8	30	20	13	6	.5 NW	69	Y		Y	Y	
K1-056	5744674.50	2115029.00	59	25	13.2	9	4.2	0	51.4			Y	Y	
K1-057	5744677.50	2115063.50	109	62	48	34	21	0	165	Y		Y	Y	
K1-058	5744680.06	2115015.64	21.8	0	0	0	0	0	0		Larger Response 3 feet NW	N	Y	
K1-059	5744679.00	2115020.50	46.8					.5 SW	49	Y		Y	Y	613
K1-060	5744680.57	2115001.34	52.8					0	43	N		Y	Y	586
K1-061	5744686.83	2115032.65	40.5					0	42	N		Y	Y	614
K1-062	5744687.50	2115080.00	20.5	4	2	1	0.6	0	7.6	Y	Schondstet hit .5 feet SW	N	Y	
K1-063	5744545.76	2115048.64	16.8	12	9	6	3	1 W	30	Y	Schondstet response .5 SW	Y	Y	
K1-064	5744620.91	2115029.69	16.7					1.5 NW	22	Y		Y	Y	600
K1-065	5744554.06	2115078.43	17.3	3.5	2.5	1.5	0.5	0	8	N		N	N	
K1-066	5744686.38	2115025.98	16.5	21	16	8.5	3	.5 W	48.5			Y	Y	
K1-067	5744526.14	2115046.46	14.6	8	5	2.5	0.8	1 W	16.3	Y		Y	Y	
K1-068	5744542.06	2115001.35	13.9	16	8	3.5	1.5	1.5N	29			Y	N	
K1-069	5744530.41	2115001.24	13	7	3	0.5	1.5	0	12		High readings 3 feet south	N	N	
K1-070	5744528.68	2115002.62	12.4	7	3	1	0.5	0	11.5			N	N	
K1-071	5744526.49	2114998.70	13	7	3	1	0.5	0	11.5			N	N	
K1-072	5744538.83	2115064.92	12.9	6	3	1	0.6	0	10.6	Y	Another response 3 feet W	N	Y	
K1-073	5744540.91	2115068.15	11.9	5.5	3.2	2	0.5	1 NW	11.2	N		N	N	
K1-074	5744532.83	2115068.04	13	5	4	2.5	1.5	1 W	13	Y		N	Y	
K1-075	5744546.56	2115070.11	12.7	1	0	8	0	0	9	N		N	Y	
K1-076	5744544.37	2115076.23	16.5	2	2	1	1	0	6	N		N	Y	
K1-077	5744560.06	2115048.65	15.2	4	2	0.7	0.2	0	6.9	N		N	Y	
K1-078	5744562.14	2115053.15	13.4	5	2	1	0.3	1 W	8.3	Y		N	N	
K1-079	5744566.29	2115048.08	12.2	4	2	1	0.3	0	7.3	N		N	N	
K1-080	5744551.75	2115009.43	13.6	6.3	3.8	1.5	0.4	0	12			N	N	
K1-081	5744564.21	2115004.81	14.7	4	1.2	0.5	0.1	0	5.8			N	Y	
K1-082	5744580.71	2115003.66	13.9	19.2	8.5	2.6	0.6	1.5 SW	30.9			Y	Y	
K1-083	5744585.90	2114991.09	11.5	13.5	5.1	2	0.5	0	21.1			Y	Y	
K1-084	5744584.29	2115042.89	12.7	5	3	1	0	1 W	9			N	N	
K1-085	5744594.21	2115044.73	15	3	2	0.7	0	0	5.7	N		N	Y	
K1-086	5744596.29	2115047.27	11.9	3	2	1	0.2	2 N	6.2	N		N	Y	
K1-087	5744598.02	2115049.81	13.9	5	3	1	0.5	0	9.5	N		N	N	
K1-088	5744623.40	2115015.43	11.0					0	18	N		Y	Y	605
K1-089	5744626.51	2115042.77	10.4	9	6	4	2	1 W	21	Y		Y	N	
K1-090	5744601.13	2115006.78	13.3	7.8	1.5	0.5	0.3	0	10.1			N	Y	
K1-091	5744598.48	2115028.93	13.1	2	1	0.5	0	1 N	3.5	N		N	N	
K1-092	5744594.21	2115037.35	12.8	5.5	3.8	1.6	0.6	.5 N	11.5	N		N	N	
K1-093	5744660.20	2115031.35	14.5	10.2	5.8	2.8	1.2	0	20			Y	Y	
K1-094	5744659.97	2115020.85	14.4	9	4.5	1.9	0.8	0	16.2			Y	Y	
K1-095	5744662.05	2115015.89	13.2	15.5	8.2	3.7	1.2	0	28.6			Y	N	
K1-096	5744666.66	2115050.15	14.4	4.5	2.6	1.4	0.8	0	9.3	N		N	Y	
K1-097	5744676.01	2115075.65	16.1	3	0	0	0	0	3	N		N	N	
K1-098	5744678.20	2115079.23	13.2	6.5	3.9	2	0.8	.5 N	13.2	Y		N	N	
K1-099	5744601.48	2115063.77	12.3	13	8	4	1	1 N	26	Y		Y	Y	
K1-100	5744610.71	2115084.07	14	4	2	1	0.5	0	7.5	Y	Schondstet hit 1 foot S	N	N	

Table 1
Target Reacquisition Decay

ID	X	Y	GV	ch1	ch2	ch3	ch4	offset	Reac sum	sch	Notes	Reac over 14 mV	Decay Rate > .02 mV/µS	Seed Item
K1-101	5744575.75	2115071.04	14.4	5	3	2	0.5	1.5 NW	10.5	Y		N	N	
K1-102	5744625.11	2115048.95	14	7	5	3	1	1.5 N	16	N		Y	N	
K1-103	5744601.50	2115046.79	14.4	5	2.5	1	0.4	0	8.9	N	Larger response 3 feet east	N	N	
K1-104	5744611.55	2115024.76	14.0					2 W	1	Y	Something wrong with seed item	N	Y	601
K1-105	5744603.60	2115049.38	13.9	6	4	2	0.5	1 NW	12.5	Y		N	N	
K1-106	5744520.81	2115002.60	17.2	12	11	6	3	1.5 W	32			Y	N	
K1-107	5744603.60	2114999.14	16.1	0	0	0	0	0	0			N	N	
K1-108	5744606.91	2115037.45	16.9	8	5	3	2	.5 N	18	N	Wooden Stake visible	Y	N	