Marine Towed Array (MTA) UXO Geophysical Survey on the Island of Culebra

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SAIC
From Science to Solutions

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1.0 Background and Logistics

During the month of July 2007 SAIC conducted a MEC Demonstration Survey in the bays surrounding Culebra using the Marine Towed Array in accordance with the Demonstration Test Plan.[1] The Test Plan called for conducting a series of transect surveys in protected shallow water areas of bays on the eastern shore of Culebra Island and similar areas around Cayo de Louis Peña. Suggested survey transects are shown in Figure 1.

During June the areas involving the suggested transects were inspected from a boat in conjunction with Mr. Andrew Schwartz of the U.S. Army Engineering and Support Center, Huntsville (Army Corps of Engineers) and several regulatory agency representatives from the Commonwealth of Puerto Rico, the National Oceanic and Atmospheric Administration, the Department of Natural Resources and the U.S. Fish and Wildlife Service. Certain areas were pointed out that support ongoing farming of endangered coral species. Other areas were suggested by the regulators to be particularly sensitive because of native populations of endangered coral in the extensive fringing reef systems associated with some of the bays with planned survey transects.

The transects suggested in Figure 1 were incorporated into a GIS system and overlaid on an electronic version of the NOAA map 25655 as shown**.** The transects were regularized, made more parallel, adjusted for more constant separation and divided into two groups. The first group of transects were in water depths of 2-10 m and were deemed appropriate for MTA survey. The remaining transects were in water depths of 1-2.5 m and were intended to be surveyed from a flat bottom skiff using sensors deployed in the bottom of the boat.

Following completion of the MTA survey in Vieques in late June 2007, the MTA equipment was demobilized and transported to Puerto del Rey Marina in Fajardo. The support vessels were also returned to this marina (home port) where minor repairs were made. On 9 July the three MTA support vessels were ferried from Fajardo to the Culebra Ferry docking area in the Bahia de Sardinas and stationed at public mooring areas. These same moorings were used for overnight stationing of the equipment throughout the Culebra demonstration operations.

On 10 July the MTA equipment was moved from Fajardo to Culebra using the Public Cargo Ferry. The sensor platform is transported on a small boat trailer. The remainder of the MTA equipment is transported (and stored in) a 14 ft box truck. The survey platform was reassembled at the dock. Because there was no boat launch facility readily accessible to this area, a backhoe was rented to launch the survey platform directly from the Ferry Dock (about 2 m above the water). This operation is shown in Figure 2. The chartered tow vessel, the Coral Queen was tied up at the dock and the sensor platform was mated with the vessel, Figure 3. All electrical and electronic equipment was tested before leaving the dock to begin surveying, Figure 4.

The Army Corps of Engineers established a new GPS control point to support this demonstration. It was high on a hill above Bahia Tarja and had almost line-of-sight communication with the MTA vessel in most of the survey areas. This was not true of the bay directly on the west side of Cayo de Louis Peña where the Cerro de Louis Peña lies directly between the base station

and the bay. RTK positioning was lost and this bay was not surveyed. The Control Point coordinates are given in Table 1.

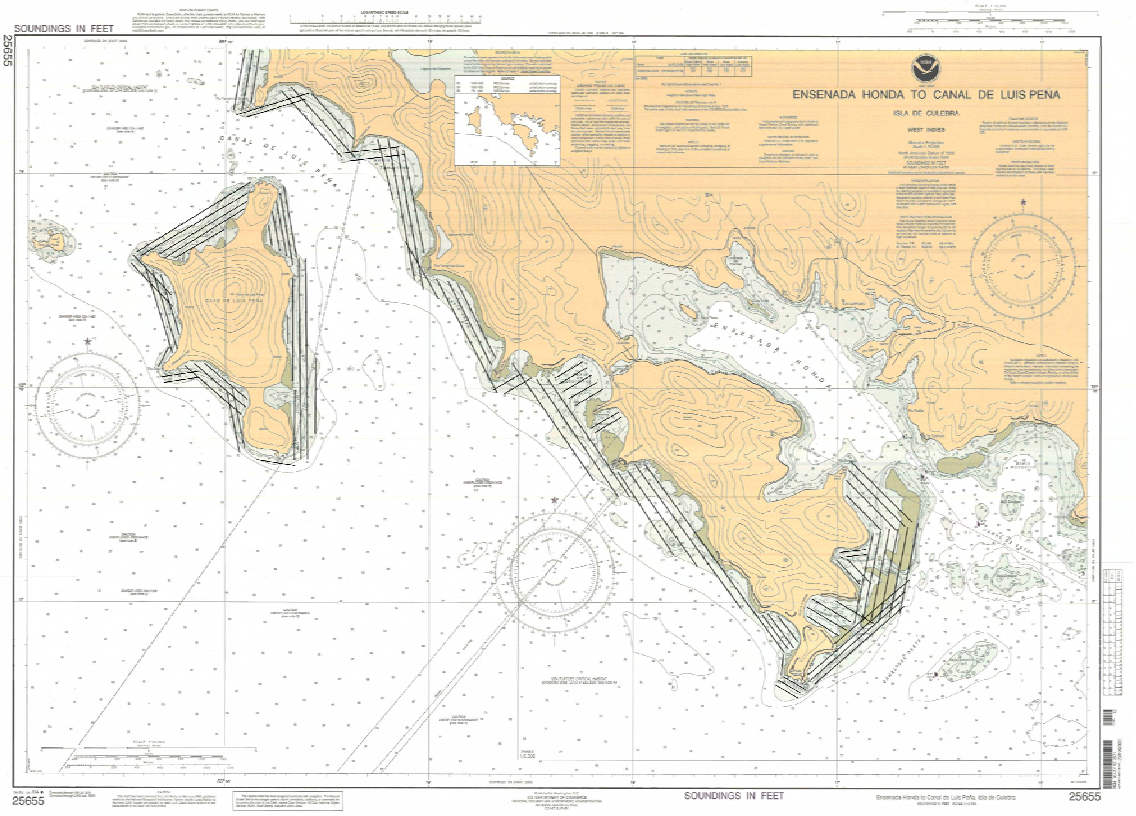

Figure 1. Suggested MTA survey transects are shown (as black lines) superimposed on the NOAA Marine Chart 25655.

Figure 2. Because there was no boat launch facility, the MTA sensor platform is being launched from the Ferry Dock using a backhoe.

Figure 3. The MTA sensor platform is mated with the Coral Queen and hot tested before leaving the Ferry Dock.

Figure 4. The Coral Queen is towing the sensor platform away from the Culebra Ferry Dock. The small skiff on the right is used for shallow area surveys and the larger vessel on the left is the chase boat that supported our survey operations.

Figure 5. The base station is set up on a new GPS control point high above Bahia Tarja (on the right). The Fajardo passenger ferry is shown in the foreground, the island of Vieques is in the distance. Position coordinates are provided in the text.

Table 1. GPS Control Point Location (UTM Zone 20N, WGS84 Datum)

Point	Latitude (deg)	Longitude (deg)	HAE (m)	Easting (m)	Northing (m)
MTA Control	18.3047009	-65.3098533	14.26	255842.83	2025443.30

2.0 The Transect Surveys

Many of the initially planned transects shown in Figure 1 were ultimately not surveyed. All transects that were planned for survey using the flat bottom skiff were deleted from the survey plan. The potential danger for damage to the fringing coral in the very shallow water could not be resolved with the regulators in the available time before beginning the demonstration.

The dozens of moorings in the Bahia de Sardinas, the constant boat traffic through the area (Ferry Dock), and the probability that there were dozens of other abandoned moorings in this bay militated against surveying in this bay. The two tiny bays immediately adjacent to Bahia de Sardinas were too shallow to conveniently survey using the MTA and coral choked off the entrances to each bay. The bays east and north of Soldado Point were also deemed to be too shallow and too encircled by coral to be appropriate for survey using the MTA.

On Wednesday 11 July and Friday 13 July the transect surveys shown in Figure 6 were completed. The survey transects are shown in red as “Course-Over-Ground” plots superimposed on the NOAA Marine Map (25655). Several recorded transits into and out of the Bahia de Sardinas are not shown in the figure. Because surveying was not done with the skiff and because numerous transects were censored from the original survey plan, the survey transects shown in Figure 6 were completed relatively quickly. Because significant survey time remained, it was decided to complete a more extensive continuous or blanket survey coverage of certain areas deemed to be of more importance by the Corps site representative. Survey grids were set up in the Bahia Tamarindo and Bahia Tamarindo Chico on a 4 m spacing. In addition, a more

extensive survey was conducted in the Soldado Point area to more comprehensively cover the Calibration Target group. We will separately discuss the Transect Surveys in Bahia Tarja and the bays around Cayo de Lois Peña because there was no blanket coverage in these areas. The transect surveys in Bahia Tamarindo, Bahia Tamarindo Chico and Bahia Soldado will be treated later in this report in conjunction with the more extensive survey coverage in these areas.

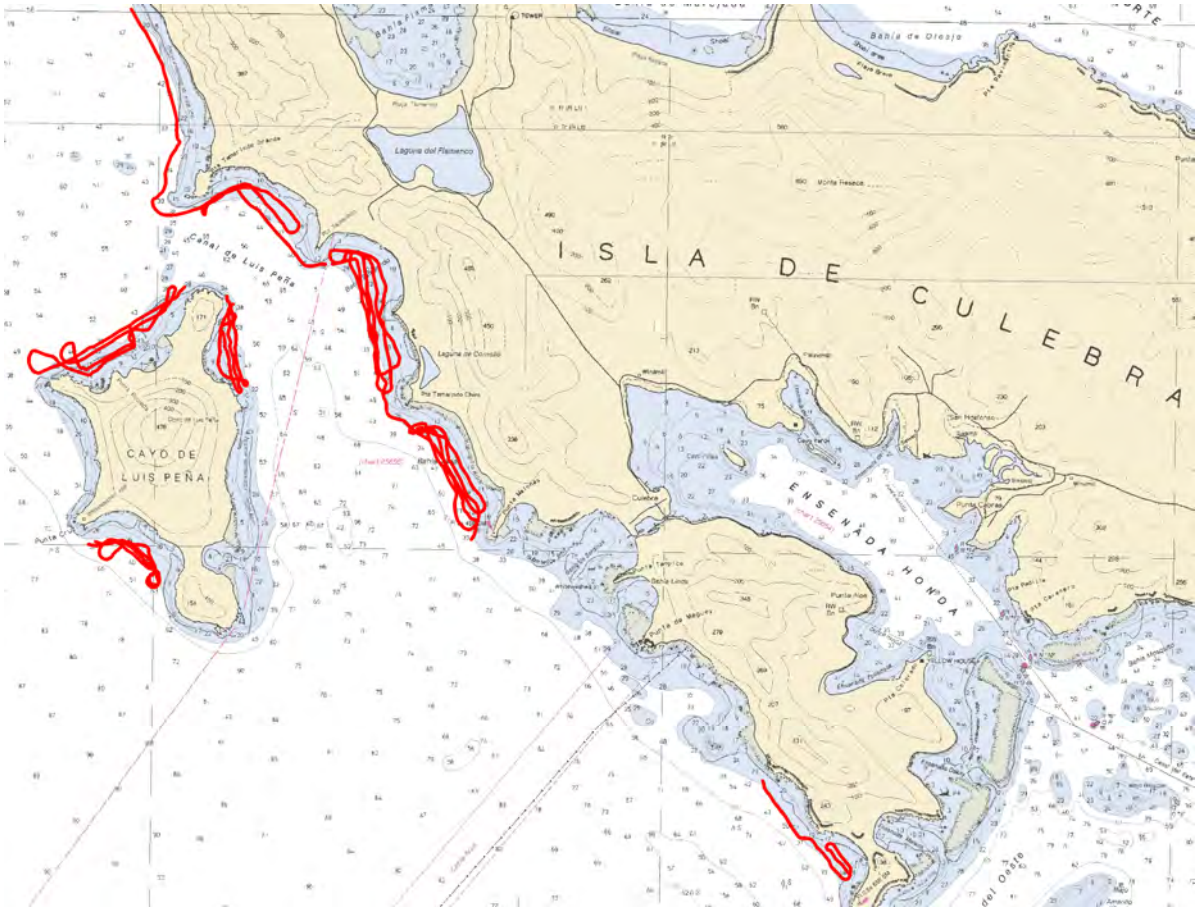

Figure 6. The Transect Surveys are shown in red as "course-over-ground" plots superimposed on NOAA chart 25655.

2.1 Bahia Tarja

The survey transects are plotted over the NOAA chart of the bay in Figure 7 and the magnetic anomaly signal from the mapped data file is shown in Figure 8. The target analysis results are shown in Table 2.

In all the target analysis tables in this report the information is presented in three groups. The first 4 columns provide the target identification number, the water depth at the position of the anomaly and the maximum and minimum signal strengths of the anomaly that the analyst has chosen to examine. The second group of columns provides the results of the target fitting process. These parameters include the fit target position (in local coordinates), the magnetic moment of the anomaly, orientation information based upon the pointing vector of the dipole signal, and the magnetic moment. The size of the target is derived (as the diameter of a cylinder

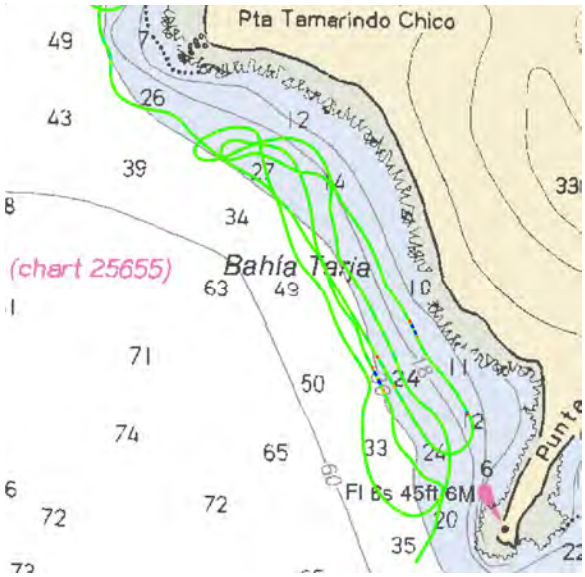

Figure 7. The measured magnetometry signal is plotted over the NOAA chart for the Bahia Tarja transect survey.

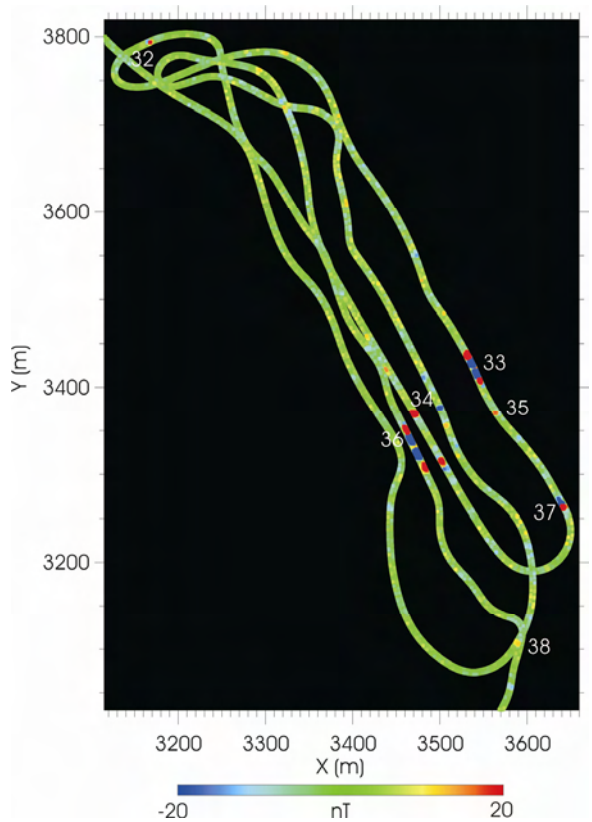

Figure 8. Magnetic anomaly image of the transect survey of Bahia Tarja. The numbers correspond to the targets reported in Table 2.

in meters) from the anomaly footprint and the magnetic moment assuming that the target is a cylinder with a length 4 times the diameter.

The target depth is calculated as the Height above Ellipsoid (in the three-dimensional fit to the three-dimensional signal). The HAE value is converted to a burial depth below the sediment surface by deconvoluting the information about the sensor platform depth, its height above the bottom, and the height of the GPS antenna above the water surface. The fit quality is a measure of the goodness of fit of the measured signal to a theoretical point dipole corresponding to a target with the generated fit parameters. The third group of information is the comment provided by the analyst observing the fit parameters of the target (often using multiple fit approaches) and observation of the signal profiles of the individual sensor readings as they pass over the target. The final four columns provide the target positioning information in Lat/Lon and UTM, Zone 20N coordinates.

Also in each of the target reports we have highlighted (light yellow) targets that we feel might be single metallic objects (e.g. potential MEC) and that are located near enough to the surface that they could be examined by a diver. In the Bahia Tarja only 2 of the 7 analyzed targets were selected as possible MEC. The other entries are almost certainly anomalies created by geological interferences. Geologically-related anomalies are responsible for the majority of the entries in all the target reports. Often the geological returns are grouped together (often extending from a point of land on shore. Their fit parameters often predict targets that are much too deep and too large to be single metallic objects (MEC or otherwise). Moreover, close examination of the individual anomaly signals often reveals a complex structure composed of many subcomponents.

2.2 Louis Peña – Northeast Bay

The survey transects are plotted over the NOAA chart of the bay in Figure 9 and the magnetic anomaly signal from the mapped data file is shown in Figure 10. The target analysis results are shown in Table 3. There were only 4 targets selected for analysis in this bay.

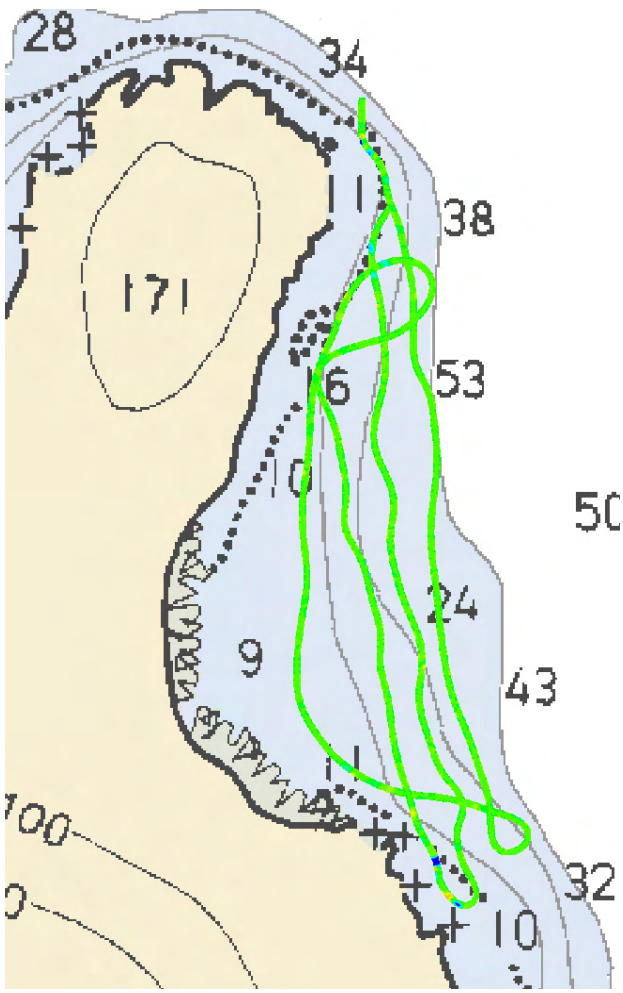

Figure 9. The measured magnetometry signal is plotted over the NOAA marine chart for the bay on the Northeast side of Cayo de Louis Peña.

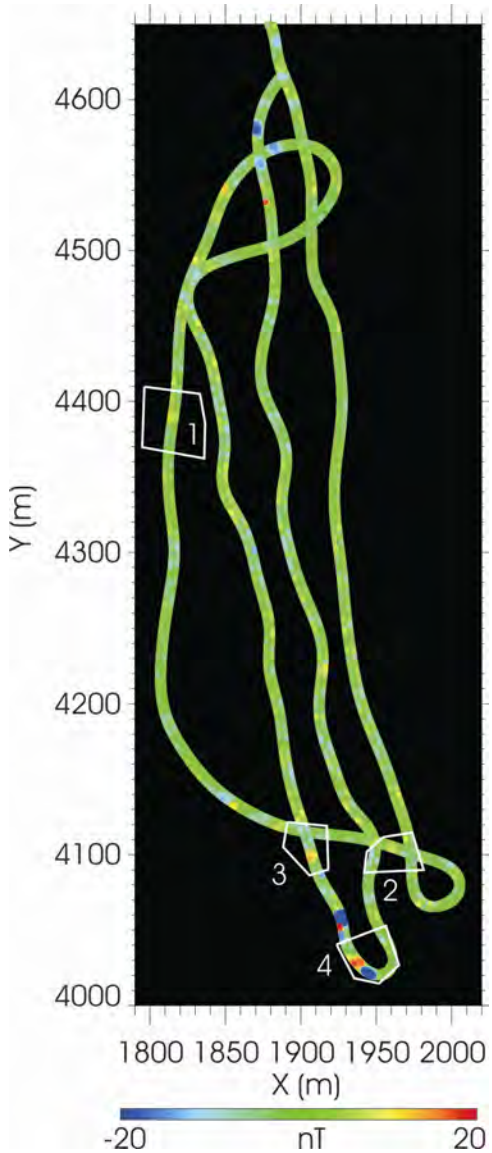

Figure 10. Magnetic anomaly image of the transect survey of the bay on the Northeast side of Cayo de Louis Peña.

2.3 Louis Peña – Northwest Bay

The survey transects are plotted over the NOAA chart of the bay in Figure 11 and the magnetic anomaly signal from the data analysis is shown in Figure 12. The target analysis results are shown in Table 4. There were 18 targets selected for analysis in this bay. Of the 18 targets in Table 4, many are associated with geological interferences that are located beyond a shoreline point at the north end of the survey. Numerous other targets were listed in the possible MEC category. Several of these may also be associated with geological interferences, e.g. "hot rocks" that have rolled down or fallen from outcrops above the shoreline. "Hot rocks" cannot be confirmed without diving on the anomalies, however.

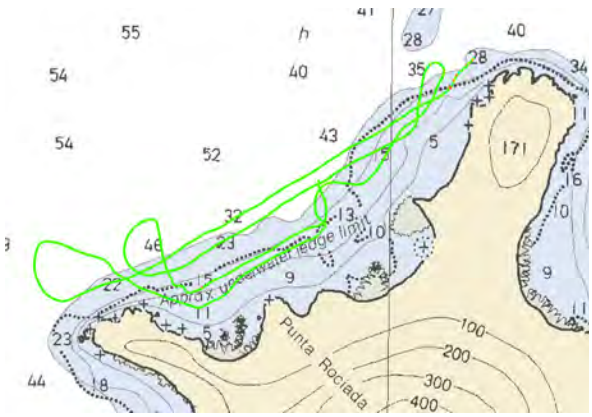

Figure 11. The measured magnetometry signal is plotted over the NOAA chart for the Northwest Bay on Cayo de Louis Peña.

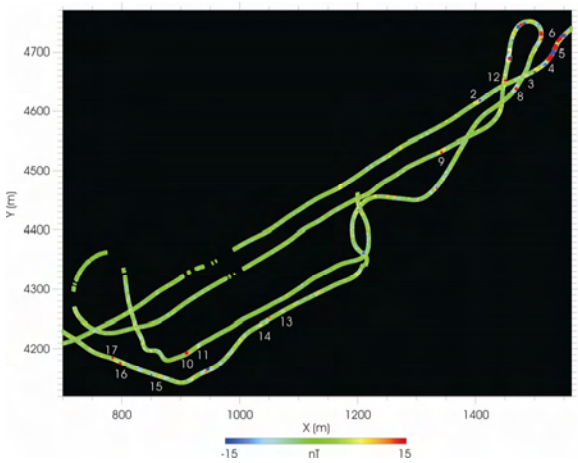

Figure 12. Magnetic anomaly image of the survey transects for the Northwest Bay on Cayo de Louis Peña.

2.4 Louis Peña – Southwest Bay

The survey transects are plotted over the NOAA chart of the bay in Figure 13 and the magnetic anomaly signal from the data analysis is shown in Figure 14. The target analysis results are shown in Table 5. There was only 1 target selected for analysis in this bay. It is geologically very quiet and there is a general absence of clutter. The one target is shallow and definitely metallic. From its size, it may well be a boat anchor.

2.5 Transect Survey Summary

Transect surveys provide at most a glimpse of the densities and types of targets in the sediment layer. However, it has been our observation that offshore surveys of land ranges that were extensively used, where the impact areas lie within a few hundred meters of the shoreline, provide conclusive evidence of target under- or over-shooting of the ranges.

The most prominent features of the transect surveys presented above are the concentrated returns from magnetically-active geological features. In most cases these occur in areas that are obvious extensions of shoreline features where outcroppings from the "Points" that define the ends of the bays. On analysis most (but not all) of these features analyze as several meters below the

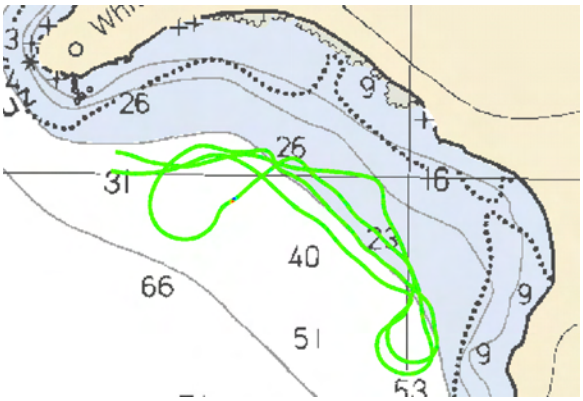

Figure 13. The measured magnetometry signal is plotted over the NOAA chart for the Southwest Bay on Cayo de Louis Peña.

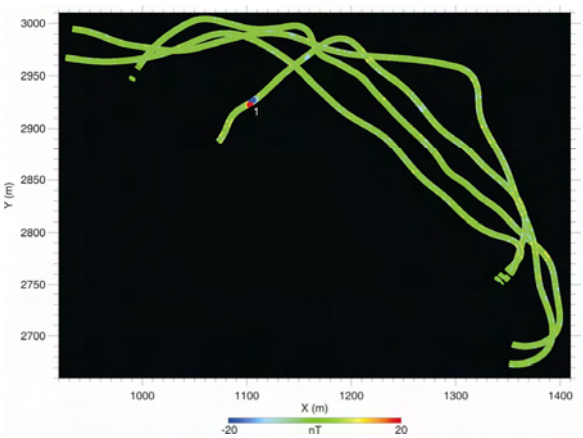

Figure 14. Magnetic anomaly image of the survey transects for the Southwest Bay on Cayo de Louis Peña.

sediment surface, making them easy to recognize. In other cases geological returns are likely associated with "hot rocks," isolated boulders that have broken off from features at the shoreline and rolled out into the bays.

There are a few (14) analyzed targets that appear to be compact metallic objects. Most, but not all of these, lie near or slightly below, the sediment surface. They are highlighted in the tables and range in size from objects that could be mortars or projectiles to large objects that could be GP bombs.

It has also been our observation in all offshore surveys that we have done that many of the features, when recovered, turn out to be culturally related. All previously studied sites are heavily populated with derelict boat anchors. Most sites have metallic features associated with fishing or boating (fish or crab traps, boat hooks, gas tanks, bait buckets, etc). Some sites are heavily populated with intentionally discarded junk (refrigerators, engines, lawn mowers, etc). All of the bays described above have relatively heavy boat traffic (divers, fishermen, pleasure boaters, etc). Only investigation of the highlighted targets will resolve their identities.

Table 2. Target Report for the Transect Survey of Bahia Tarja

Target Measured Information				Target Fit Information								Analyst Comment	Other Coordinates			
Targ ID	Water Depth (m)	Max Signal (nT)	Min Signal (nT)	Local X (m)	Local Y (m)	Burial Depth (m)	Size (m)	Moment	Incl. (deg)	Azi. (deg)	Fit Quality		UTM X (m)	UTM Y (m)	Latitude	Longitude
32	7.77	20	-14	3,166.68	3,794.83	0.01	0.187	2.6085	15	283	0.926	good anomaly on surface, check this one	255166.68	2025794.83	18.3077980	-65.3162884
33	4.59	27	-103	3,547.20	3,416.39	3.62	0.916	308.4053	-32	350	0.544	geology	255547.20	2025416.39	18.3044240	-65.3126453
34	8.14	47	-10	3,471.13	3,369.41	3.14	0.509	52.9122	31	103	0.412	geology	255471.13	2025369.41	18.3039910	-65.3133588
35	4.65	17	-10	3,563.43	3,371.13	1.61	0.229	4.8046	80	115	0.560	geology	255563.43	2025371.13	18.3040171	-65.3124864
36	8.98	61	-104	3,468.09	3,347.61	4.74	0.975	371.7853	-28	157	0.651	geology	255468.09	2025347.61	18.3037938	-65.3133849
37	3.99	114	-46	3,640.29	3,264.00	0.49	0.325	13.7152	51	4	0.744	partial signature, this might be metal	255640.29	2025264.00	18.3030585	-65.3117468
38	6.12	10	-13	3,589.16	3,109.12	1.81	0.226	4.632	36	50	0.668	geology	255589.16	2025109.12	18.3016539	-65.3122117

Table 3. Target Report for the Transect Survey of the Bay on the Northeast Side of Cayo de Louis Peña

Target Measured Information				Target Fit Information								Analyst Comments	Other Coordinates			
Targ ID	Water Depth (m)	Max Signal (nT)	Min Signal (nT)	Local X (m)	Local Y (m)	Burial Depth (m)	Size (m)	Moment	Incl. (deg)	Azi. (deg)	Fit Quality		UTM X(m)	UTM Y(m)	Latitude	Longitude
1	5.15	12.1	-5.6	1813.97	4390.00	0.52	0.149	1.319	47	92	0.501	good target, partial signature	253813.97	2026390.00	18.3130173	-65.3291501
2	8.94	8.4	-8.5	1961.79	4104.99	1.39	0.251	6.370	27	99	0.497	looks like geology	253961.79	2026104.99	18.3104604	-65.3277181
3	5.41	14.8	-9.7	1907.66	4099.81	4.35	0.401	25.885	40	95	0.708	lookslike geology	253907.66	2026099.81	18.3104074	-65.3282293
4	4.92	17.8	-35.9	1943.08	4024.34	4.69	0.596	84.884	-39	176	0.770	geology	253943.08	2026024.34	18.3097299	-65.3278852

Table 4. Target Report for the Transect Survey of the Bay on the Northwest Side of Cayo de Louis Peña

Target Measured Information				Target Fit Information								Analyst Comments	Other Coordinates			
Targ ID	Water Depth (m)	Max Signal (nT)	Min Signal (nT)	Local X (m)	Local Y (m)	Burial Depth (m)	Size (m)	Moment	Incl. (deg)	Azi. (deg)	Fit Quality		UTM X(m)	UTM Y(m)	Latitude	Longitude
1	8.92	9.9	-7.2	630.97	4186.88	0.31	0.148	1.312	10	289	0.957	small target 1 ft deep	252630.97	2026186.89	18.3110461	-65.3403109
2	4.43	9.6	-17.4	1407.22	4617.97	0.42	0.187	2.638	-20	28	0.696	likely not UXO	253407.22	2026617.97	18.3150290	-65.3330236
3	3.99	9.4	-6.8	1486.73	4661.08	0.39	0.151	1.381	14	28	0.713	low signal target, 1 ft deep, maybe UXO	253486.73	2026661.08	18.3154275	-65.3322770
4	5.99	41.1	-18.6	1527.10	4688.62	7.74	0.937	330.305	36	239	0.662	geolgoy	253527.10	2026688.62	18.3156810	-65.3318987
5	7.39	29.7	-26.2	1528.63	4707.92	3	0.680	126.361	-30	238	0.596	geology	253528.63	2026707.92	18.3158554	-65.3318866
6	7.79	35.1	-19.5	1542.96	4725.59	3.27	0.565	72.526	27	65	0.603	geology	253542.96	2026725.59	18.3160166	-65.3317532
7	7.02	81	-90.4	1457.11	4690.65	0.26	0.143	1.174	29	15	0.905	small shallow target, this is metal	253457.11	2026690.65	18.3156911	-65.3325607
8	3.88	25.8	-11	1468.73	4639.38	0.04	0.207	3.538	50	320	0.712	target on surface	253468.73	2026639.38	18.3152295	-65.3324446
9	5.26	22.1	-8.8	1342.11	4531.96	0.25	0.095	0.345	87	352	0.482	small target shallow, with clutter around	253342.11	2026531.96	18.3142448	-65.3336288
10	4.59	87	-5.6	909.72	4193.88	-0.69	0.206	3.518	85	90	0.608	serious target, poor fit above ground	252909.72	2026193.88	18.3111416	-65.3376762
11	4.42	7	-7.9	930.45	4204.84	0.17	0.160	1.653	3	1	0.951	target shallow, low signal	252930.45	2026204.84	18.3112430	-65.3374815
12	4.74	16.6	-4.3	1449.82	4652.44	0.09	0.142	1.151	59	231	0.633	looks like clutter on surface	253449.82	2026652.44	18.3153452	-65.3326250
13	4.37	11.9	-7.8	1073.00	4263.02	0.16	0.125	0.786	36	339	0.909	shallow target, looks like clutter	253073.00	2026263.02	18.3117849	-65.3361407
14	4.19	8.3	-4.2	1034.64	4240.17	-0.01	0.109	0.514	46	260	0.852	on surface, looks like clutter	253034.64	2026240.17	18.3115741	-65.3365006
15	4.51	10.5	-5.2	866.04	4154.11	0.29	0.147	1.278	25	94	0.831	small shallow target	252866.04	2026154.11	18.3107774	-65.3380843
16	5.93	13.5	-15.6	797.23	4175.90	0.01	0.142	1.154	9	310	0.317	small target on surface, poor fit	252797.23	2026175.90	18.3109662	-65.3387376
17	6.63	16.4	-5.9	785.19	4184.46	-0.26	0.116	0.631	5	131	0.778	small target on surface, partial signature	252785.19	2026184.46	18.3110421	-65.3388525
18	9.51	7.1	-3.9	571.64	4159.78	-0.1	0.118	0.659	5	349	0.823	small surface target, just above background	252571.64	2026159.78	18.3107945	-65.3408686

Table 5. Target Report for the Transect Survey of the Bay on the Southwest Side of Cayo de Louis Peña

Target Measured Information				Target Fit Information								Analyst Comment	Other Coordinates			
Targ ID	Burial Depth (m)	Max Signal (nT)	Min Signal (nT)	Local X (m)	Local Y (m)	Burial Depth (m)	Size (m)	Moment	Incl. (deg)	Azi. (deg)	Fit Quality		UTM X(m)	UTM Y(m)	Latitude	Longitude
1	0.24	35.2	-52.8	1104.00	2926.17	0.24	0.393	24.2994	-2	19	0.939	large target near the surface	253104.00	2024926.17	18.2997156	-65.3356857

3.0 Extended Coverage Surveys

In three areas, more extensive survey coverage was undertaken. On Bahia Tamarindo and Bahia Tamarindo Chico an attempt was made to comprehensively survey the available areas within the bays. On Bahia Soldado we carried out an extended survey to map out the area that included the calibration targets previously installed by the Army Corps of Engineers. These extended survey areas are shown overlaid on the NOAA marine chart in Figure 15.

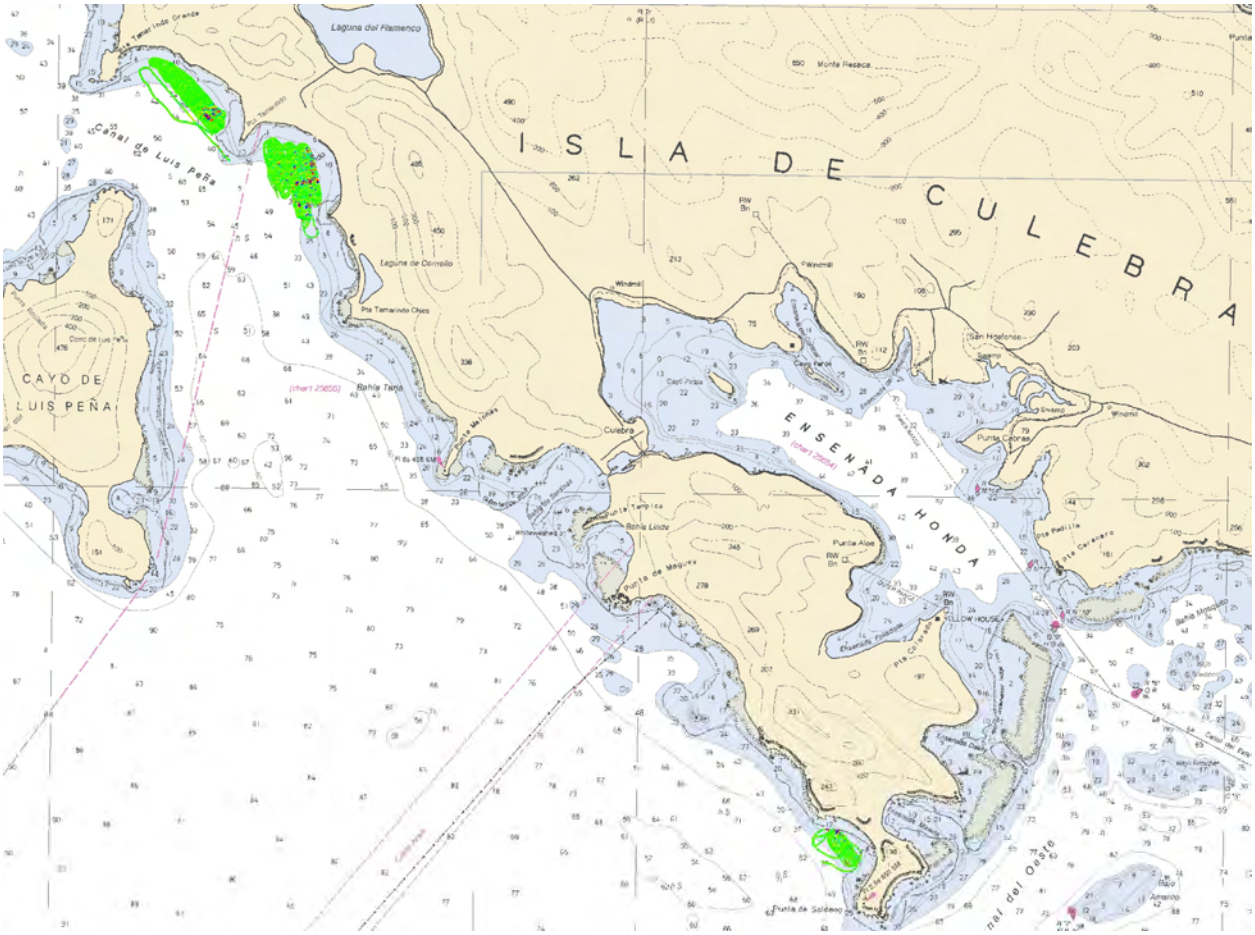

Figure 15. The extended survey areas are shown as magnetic mapped data file overlaid on the NOAA marine chart.

3.1 Bahia Tamarindo

The survey grid set up with survey lines separated by 4 m is shown in Figure 16 overlaid on the NOAA marine chart. The grid contains more than 80 relatively short survey lines. The magnetic anomaly image map from the comprehensive survey is shown in Figure 17.

The target report is presented in Table 6. This table also includes the targets that appeared in the transect survey that proceeded the grid survey shown in Figure 17. The common targets are noted in the Analyst Comments section of Table 6. Targets suggested for investigation are highlighted in yellow.

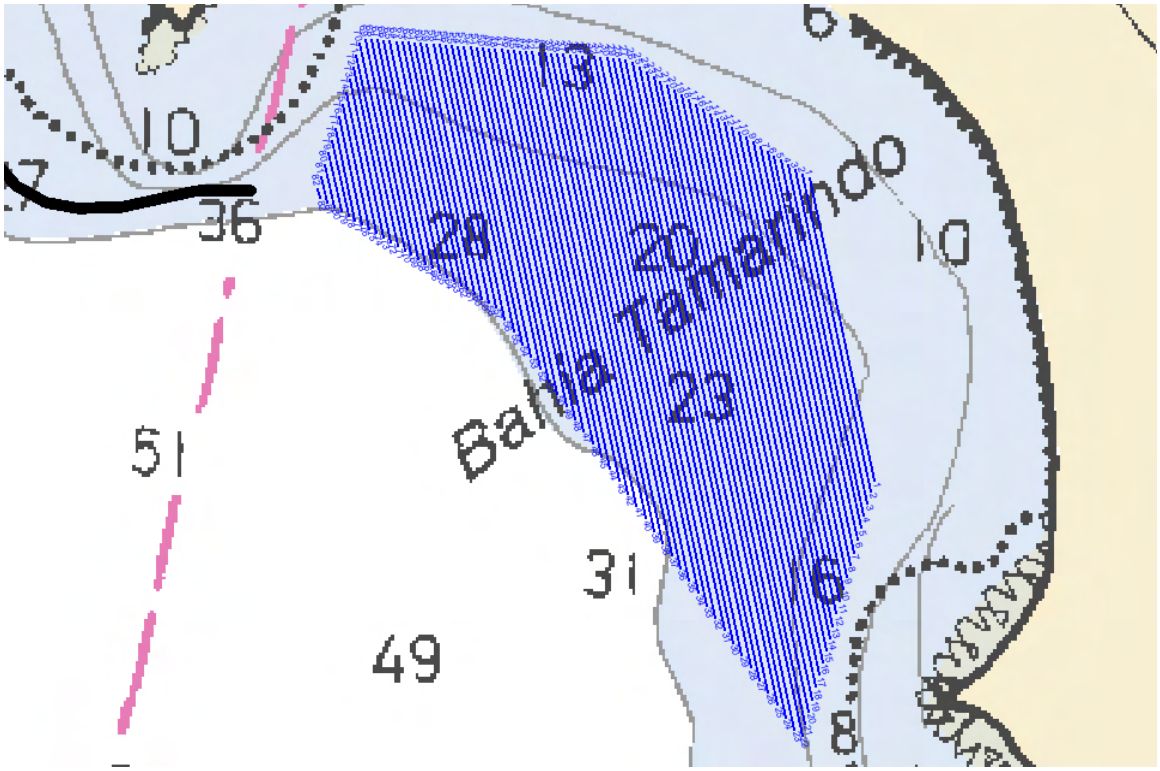

Figure 16. The planned survey grid for Bahia Tamarindo is shown overlaid on the NOAA marine chart.

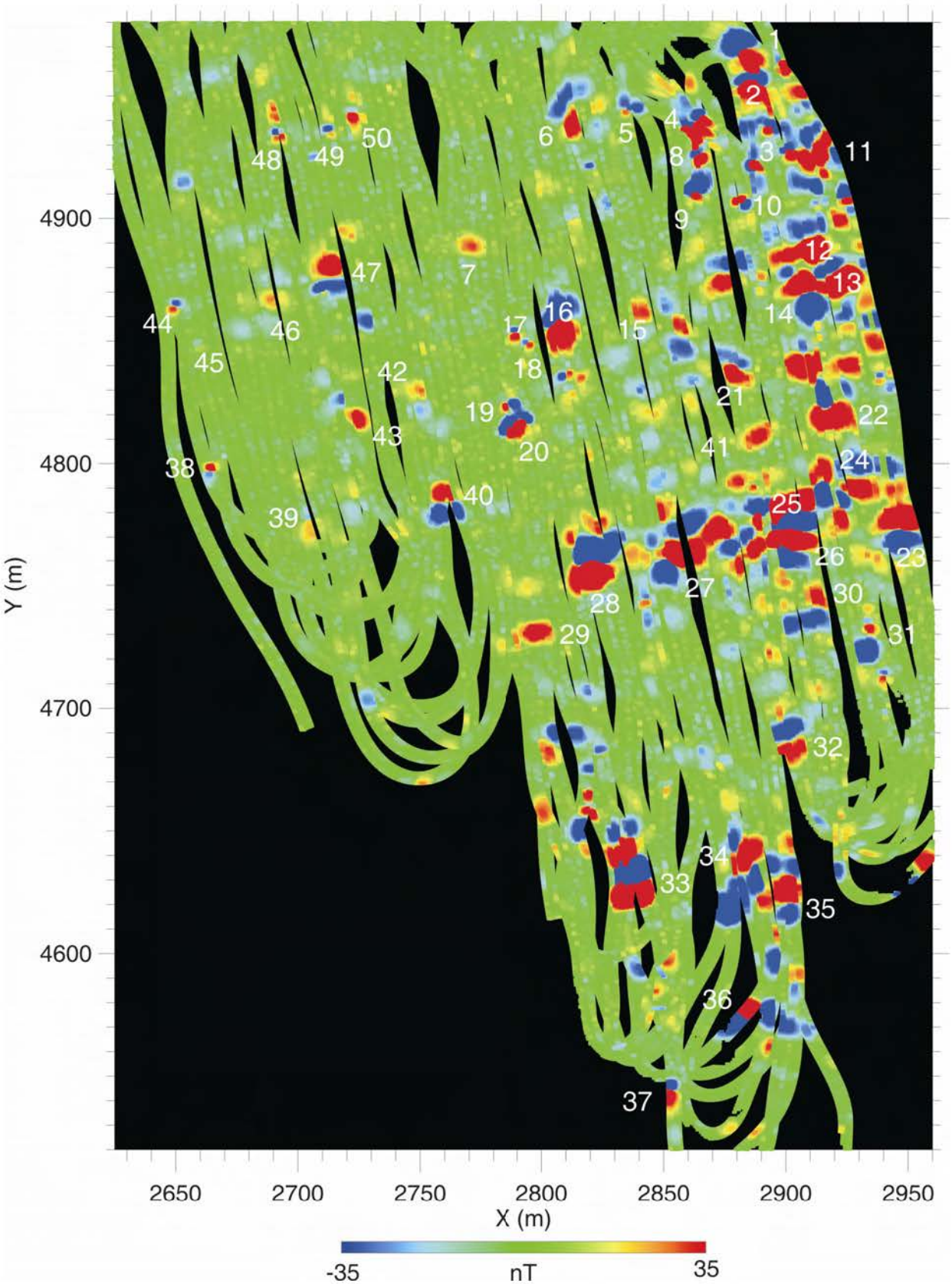

Figure 17. Magnetic anomaly image of the Bahia Tamarindo survey. Analyzed targets shown in the Target Report (Table 6) are superimposed on the image.

Table 6. Target Report for the MTA survey of Bahia Tamarindo

Target Measured Information				Target Fit Information								Analyst Comments	Other Coordinate Systems			
Targ ID	Water Depth (m)	Max Signal (nT)	Min Signal (nT)	Local X (m)	Local Y (m)	Burial Depth (m)	Targ Size (m)	Moment	Incl. (deg)	Azi. (deg)	Fit Quality		UTM X(m)	UTM Y(m)	Latitude	Longitude
1	3.54	110.9	-116.8	2881.09	4970.11	3.50	0.795	201.552	-7	330	0.787	poor fit, too many passes, too deep to dig	254881.09	2026970.11	18.3183791	-65.3191301
2	3.91	215.0	-183.7	2886.23	4956.06	0.60	0.531	59.899	23	27	0.807	very large target with clutter	254886.23	2026956.06	18.3182528	-65.3190797
3	4.49	55.2	-102.3	2893.58	4937.59	-0.02	0.324	13.680	-2	47	0.921	good target, on surface, Transect targ No. 2	254893.58	2026937.59	18.3180868	-65.3190081
4	4.27	60.9	-64.5	2865.17	4941.34	0.73	0.339	15.597	18	315	0.809	good target, poor fit, too many passes	254865.17	2026941.34	18.3181175	-65.3192772
5	4.45	29.4	-32.8	2834.44	4945.13	1.09	0.285	9.311	15	17	0.659	may be geology	254834.44	2026945.13	18.3181481	-65.3195682
6	5.45	46.1	-43.3	2809.93	4943.87	6.10	0.813	215.526	17	314	0.703	6m deep, geology	254809.93	2026943.87	18.3181339	-65.3197998
7	6.54	32.4	-12.0	2769.65	4887.63	4.94	0.558	69.657	20	192	0.917	5m deep, geology, Transect Targ No. 7	254769.65	2026887.63	18.3176214	-65.3201739
8	4.11	79.2	-52.0	2864.05	4925.60	1.47	0.344	16.370	36	308	0.863	deep target, may be UXO	254864.05	2026925.60	18.3179752	-65.3192859
9	4.48	46.5	-146.5	2863.29	4911.95	1.86	0.486	46.094	-18	353	0.795	all negative and deep, likely geology	254863.29	2026911.95	18.3178518	-65.3192914
10	4.29	64.8	-72.4	2882.04	4907.25	0.50	0.314	12.472	-2	121	0.926	partial signature	254882.04	2026907.25	18.3178116	-65.3191135
11	4.50	85.3	-77.7	2901.41	4927.79	0.53	0.325	13.806	11	327	0.863	good target, Transect targ. No. 8	254901.41	2026927.79	18.3179992	-65.3189329
12	4.80	157.0	-42.4	2910.15	4889.01	4.43	0.889	281.918	79	266	0.951	4.5m deep, geology	254910.15	2026889.01	18.3176500	-65.3188455
13	4.66	110.0	-55.1	2920.21	4878.05	4.45	0.878	271.544	27	321	0.796	4.5m deep, geology, Transect targ. No. 9	254920.21	2026878.05	18.3175522	-65.3187491
14	4.92	139.7	-90.1	2908.08	4870.71	4.12	0.934	326.379	-7	162	0.854	4 m deep, geology	254908.08	2026870.71	18.3174845	-65.3188629
15	6.01	32.8	-19.7	2840.65	4860.48	4.94	0.625	98.068	19	179	0.873	5m deep, geology	254840.65	2026860.48	18.3173844	-65.3194993
16	6.16	202.9	-406.8	2805.98	4857.95	1.58	0.671	121.132	2	324	0.905	this is metal, too large for UXO?	254805.98	2026857.95	18.3173576	-65.3198268
17	6.69	38.5	-36.2	2788.79	4853.39	0.84	0.265	7.481	28	350	0.890	good target, too deep to dig	254788.79	2026853.39	18.3173144	-65.3199888
18	6.61	32.0	-30.6	2794.13	4849.16	0.11	0.189	2.703	14	300	0.828	good target, on surface	254794.13	2026849.16	18.3172768	-65.3199377
19	7.29	57.0	-58.8	2786.97	4824.38	0.20	0.283	9.124	1	73	0.837	partial signature, shallow, Transect targ. No 11	254786.97	2026824.38	18.3170522	-65.3200025
20	7.19	88.2	-159.7	2787.67	4815.80	1.20	0.501	50.433	11	297	0.856	complex target, likely not UXO, Transect targ. No. 12	254787.67	2026815.80	18.3169748	-65.3199948
21	5.44	67.4	-37.5	2878.86	4839.85	3.42	0.612	92.101	27	27	0.858	3.6m deep, geology, Transect Targ. No. 13	254878.86	2026839.85	18.3172024	-65.3191354
22	5.25	80.9	-118.8	2917.09	4825.15	5.42	0.968	363.518	11	340	0.648	5.5m deep, geology	254917.09	2026825.15	18.3170741	-65.3187722
23	4.83	140.2	-91.7	2948.21	4774.54	4.80	1.065	483.905	-9	195	0.938	5m deep, geology, Transect targ. No. 14	254948.21	2026774.54	18.3166206	-65.3184719
24	5.35	137.6	-128.1	2911.64	4787.82	3.51	0.885	278.098	-6	73	0.890	3.5m deep, geology	254911.64	2026787.82	18.3167364	-65.3188193
25	5.63	223.1	-215.2	2899.46	4779.83	3.64	0.999	400.314	-20	130	0.863	geology	254899.46	2026779.83	18.3166628	-65.3189335
26	5.65	278.6	-223.2	2900.73	4767.64	3.26	1.006	408.759	4	206	0.882	geology	254900.72	2026767.64	18.3165529	-65.3189201
27	7.08	142.9	-93.9	2853.82	4761.48	4.69	1.066	485.889	6	219	0.922	4.7m deep, geology	254853.82	2026761.48	18.3164919	-65.3193629
28	7.49	205.8	-335.8	2821.59	4761.77	4.83	1.343	971.354	-6	3	0.949	4.8m deep, geology	254821.59	2026761.77	18.3164907	-65.3196676
29	8.55	56.1	-3.0	2797.10	4730.67	4.96	0.628	99.173	48	188	0.911	5m deep, geology, Transect targ. No. 15	254797.10	2026730.67	18.3162071	-65.3198954
30	5.67	46.3	-48.4	2912.53	4741.99	6.28	0.876	269.866	-12	209	0.708	6.3m deep, geology	254912.53	2026741.99	18.3163225	-65.3188053
31	4.88	45.1	-23.0	2933.77	4733.47	0.90	0.255	6.687	59	309	0.865	looks like geology	254933.77	2026733.47	18.3162481	-65.3186035
32	5.85	37.3	-60.7	2902.67	4689.34	4.47	0.737	160.795	2	343	0.805	geology	254902.67	2026689.34	18.3158460	-65.3188922
33	8.39	244.5	-533.1	2837.34	4631.40	3.95	1.390	1076.161	-17	346	0.856	very complex signature, too big and deep for UXO, Transect targ. No. 23	254837.34	2026631.40	18.3153152	-65.3195030
34	5.78	83.4	-47.5	2882.05	4642.54	5.79	0.836	234.041	51	281	0.709	geology	254882.05	2026642.54	18.3154210	-65.3190816
35	4.94	86.6	-60.8	2900.33	4622.23	5.22	0.849	245.605	-8	168	0.733	geology	254900.33	2026622.23	18.3152396	-65.3189063
36	6.67	182.1	-156.4	2882.25	4576.11	-0.12	0.617	94.048	5	221	0.666	data artifact	254882.25	2026576.11	18.3148210	-65.3190716
37	7.62	79.3	-78.6	2850.63	4544.95	2.21	0.639	104.767	29	43	0.726	Likely too big for ordnance	254850.63	2026544.95	18.3145360	-65.3193669
38	10.32	53.3	-24.7	2664.01	4797.79	0.63	0.286	9.369	7	200	0.962	Very good target, 2 ft deep	254664.01	2026797.79	18.3167979	-65.3211619
39	10.11	23.9	-22.4	2704.71	4775.19	4.12	0.468	41.129	73	300	0.723	4m deep geology	254704.71	2026775.19	18.3165985	-65.3207744
40	8.55	62.1	-57.6	2759.45	4784.72	5.09	0.723	151.688	-20	184	0.708	5m deep geology	254759.45	2026784.72	18.3166908	-65.3202580
41	6.45	15.9	-17.8	2864.96	4798.81	3.42	0.462	39.483	-10	113	0.916	inverted signal, 3.5m deep, geology	254864.96	2026798.81	18.3168303	-65.3192620
42	8.02	29.9	-23.0	2749.55	4827.16	5.16	0.572	75.171	-11	159	0.803	5m deep, geology	254749.55	2026827.16	18.3170730	-65.3203566
43	8.74	57.3	-32.1	2722.47	4821.94	5.74	0.675	123.200	50	308	0.757	5.7m deep, geology	254722.47	2026821.94	18.3170228	-65.3206121
44	9.41	32.8	-34.9	2649.48	4864.70	0.46	0.264	7.415	8	32	0.965	very good target, 18" deep	254649.48	2026864.70	18.3174005	-65.3213074
45	9.50	11.1	-12.2	2659.50	4848.72	0.12	0.160	1.646	11	322	0.903	looks like clutter - hot rocks	254659.50	2026848.72	18.3172574	-65.3212107
46	8.56	27.4	-19.4	2690.69	4871.90	4.95	0.579	77.691	29	12	0.859	5 m deep, geology	254690.69	2026871.90	18.3174703	-65.3209186
47	8.02	77.5	-73.8	2713.42	4878.84	4.69	0.797	202.783	10	179	0.864	geology	254713.42	2026878.84	18.3175355	-65.3207045
48	6.98	35.1	-50.4	2691.90	4934.67	0.01	0.227	4.713	20	335	0.808	partial signature, good target on surface, = No. 6 in transe	254691.90	2026934.67	18.3180372	-65.3209147
49	6.65	24.2	-41.6	2712.51	4936.26	0.27	0.220	4.252	-12	327	0.920	shallow target, very inverted, Transect targ.No. 5	254712.51	2026936.26	18.3180540	-65.3207200
50	6.28	56.3	-22.0	2722.05	4942.47	1.28	0.309	11.808	55	342	0.863	multiple maxima, likely geology	254722.05	2026942.47	18.3181111	-65.3206306

3.2 Bahia Tamarindo Chico

The survey grid was set up with survey lines separated by 4 m. The magnetic anomaly image map is shown in Figure 18. The target report is given in Table 7. This table also includes the targets that appeared in the transect survey that proceeded the grid survey shown in Figure 18. The common targets are noted in the analyst comments section of Table 7. Targets suggested for investigation are highlighted in yellow. The shallow targets near the north end of the bay are candidates for investigation. They are shown at a more sensitive scale in Figure 19. Effectively all the anomalies at the south end of the bay are the result of geological returns from formations that extend beyond the Point Tamarindo Grande.

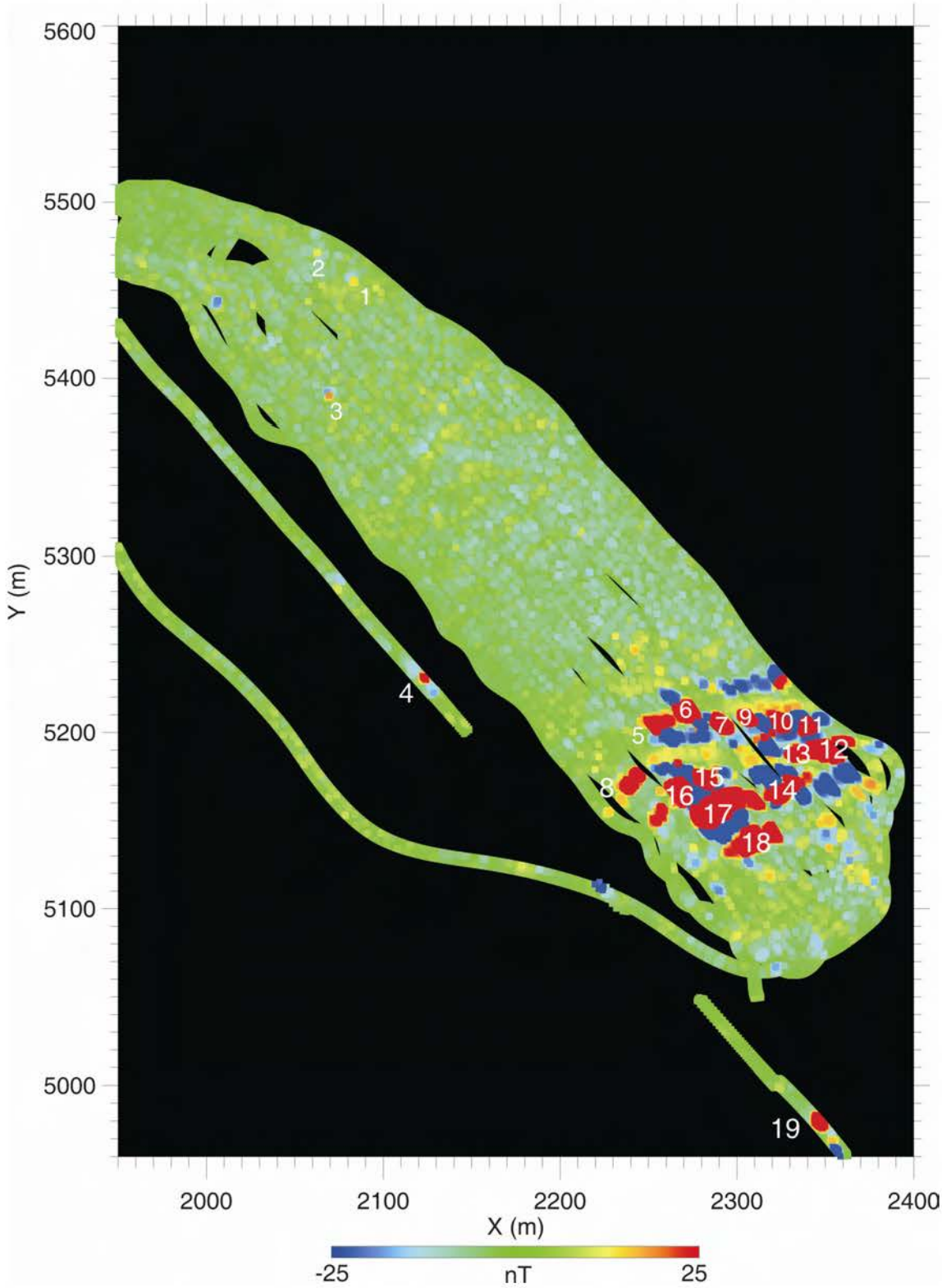

Figure 18. Magnetic anomaly image of the Bahia Tamarindo Chico survey.

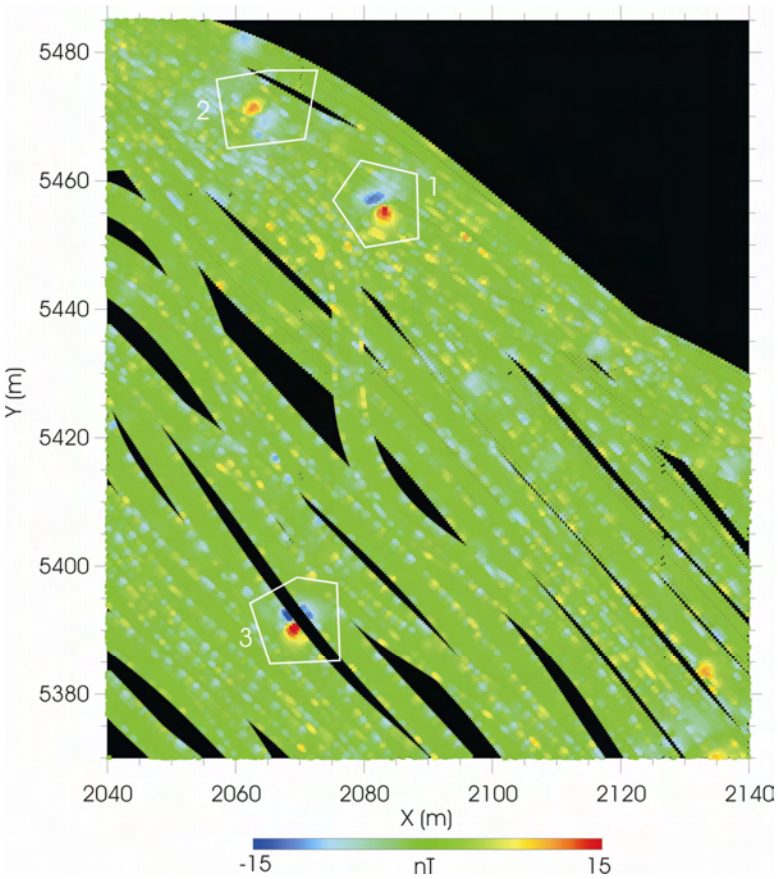

Figure 19. A portion of the Tamarindo Chico survey is shown that highlights the three small targets.

Table 7. Target Report for the MTA Survey of Bahia Tamarindo Chico

Target Measured Information				Target Fit Information								Analyst Comments	Other Coordinates			
Targ ID	Water Depth (m)	Max Signal (nT)	Min Signal (nT)	Local X (m)	Local Y (m)	Burial Depth (m)	Size (m)	Moment	Incl. (m)	Azi. (m)	Fit Quality		UTM X(m)	UTM Y(m)	Latitude	Longitude
1	5.12	15	-13	2082.73	5456.62	-0.04	0.172	2.052	17	339	0.902	Good small target on surface	254082.73	2027456.62	18.3226808	-65.3267377
2	4.47	11	-10	2063.26	5470.82	0.18	0.148	1.313	4	135	0.777	good small shallow target, almost lost in noise	254063.26	2027470.82	18.3228068	-65.3269235
3	7.23	19	-17	2069.44	5392.06	0.16	0.186	2.581	-10	3	0.893	small shallow target	254069.44	2027392.06	18.3220962	-65.3268556
4	8.59	32	-17	2122.20	5234.23	1.49	0.315	12.547	45	322	0.305	partial signal, likely artifact	254122.20	2027234.23	18.3206770	-65.3263377
5	7.95	58	-91	2258.82	5202.46	4.29	0.742	163.877	-20	141	0.703	4m deep, likely geology	254258.82	2027202.46	18.3204058	-65.3250420
6	8.02	96	-29	2269.15	5215.79	5.85	0.803	207.814	43	303	0.574	6m deep, geology	254269.15	2027215.79	18.3205274	-65.3249459
7	7.92	118	-28	2290.95	5203.58	4.19	0.817	218.795	34	179	0.879	4m deep geology	254290.95	2027203.58	18.3204196	-65.3247383
8	8.75	48	-20	2243.82	5170.87	6.81	0.736	159.853	4	120	0.542	geology	254243.82	2027170.87	18.3201188	-65.3251800
9	7.30	88	-23	2305.83	5207.04	2.71	0.528	59.075	18	188	0.746	geology	254305.83	2027207.04	18.3204526	-65.3245981
10	7.23	218	-238	2320.35	5206.69	2.68	0.929	321.501	1	269	0.688	geology	254320.35	2027206.69	18.3204511	-65.3244607
11	6.22	247	-182	2337.35	5205.35	2.71	0.738	161.448	23	298	0.730	geology	254337.35	2027205.36	18.3204410	-65.3242998
12	7.19	180	-29	2350.22	5191.39	6.03	1.042	454.285	75	104	0.566	6m deep, geolgoy	254350.22	2027191.39	18.3203164	-65.3241765
13	7.09	56	-21	2330.74	5189.84	2.99	0.448	36.171	40	293	0.715	geology	254330.74	2027189.84	18.3203001	-65.3243605
14	7.75	83	-104	2322.31	5174.82	5.69	1.031	438.957	-9	317	0.577	geology	254322.31	2027174.82	18.3201635	-65.3244383
15	8.43	160	-210	2275.17	5176.12	7.05	1.291	862.586	6	286	0.620	7m deep, geology	254275.17	2027176.12	18.3201698	-65.3248842
16	8.52	185	-62	2265.85	5165.59	6.87	1.109	546.309	83	182	0.598	Geology = Transect Target 19	254265.85	2027165.59	18.3200736	-65.3249711
17	8.59	1646	-2359	2281.98	5162.60	3.38	2.349	5197.022	-1	319	0.892	one giant hot rock buried 3m deep	254281.98	2027162.60	18.3200485	-65.3248182
18	8.27	102	-51	2308.45	5140.93	8.35	1.137	589.200	72	138	0.775	geology	254308.45	2027140.93	18.3198558	-65.3245653
19	8.35	59	-9	2345.70	4980.73	4.39	0.637	103.701	41	235	0.941	likely is geology	254345.70	2026980.73	18.3184134	-65.3241937

3.3 Bahia Soldado

The Army Corps provided the coordinates of a set of Calibration Targets that were installed in June 2005. The coordinates are provided in Lat/Lon coordinates in Table 8. The UTM coordinates were converted to Zone 20 North. A grid of 7 lines with a 4 m spacing was set up encompassing the targets. It is shown in Figure 19. These grids were all surveyed in a South-to-North direction. Much of the remainder of the bay was surveyed while circling around to next grid line. The magnetic anomaly image of the survey is shown in Figure 20. Figure 21 shows a closer view of the area containing the calibration targets. The target report is provided in Table 9.

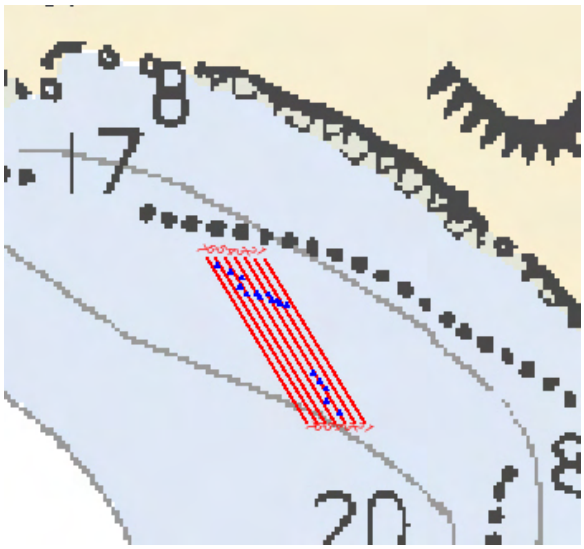

Figure 19. The ACE Calibration Target positions are shown as blue triangles. Seven planned survey grid lines with 4 m separations are shown.

Table 8. Calibration Target Positions Provided by the Army Corps of Engineers

Cal Target ID	Latitude	Longitude
COE-19	18ø16'52.25254"N	65ø17'16.22313"W
COE-29	18ø16'54.00824"N	65ø17'17.28259"W
COE-30	18ø16'53.97021"N	65ø17'17.23086"W
COE-28	18ø16'54.01913"N	65ø17'17.36951"W
COE-27	18ø16'54.10847"N	65ø17'17.41835"W
COE-31	18ø16'53.94797"N	65ø17'17.11091"W
COE-21	18ø16'54.45868"N	65ø17'18.03834"W
COE-22	18ø16'54.36886"N	65ø17'17.85485"W
COE-25	18ø16'54.12774"N	65ø17'17.60580"W
COE-26	18ø16'54.05729"N	65ø17'17.54916"W
COE-24	18ø16'54.11086"N	65ø17'17.77845"W
COE-23	18ø16'54.22289"N	65ø17'17.89336"W
COE-20	18ø16'54.56659"N	65ø17'18.26121"W
COE-16	18ø16'52.75183"N	65ø17'16.55194"W
COE-15	18ø16'52.87921"N	65ø17'16.65251"W
COE-17	18ø16'52.62749"N	65ø17'16.44783"W
COE-18	18ø16'52.43656"N	65ø17'16.42489"W

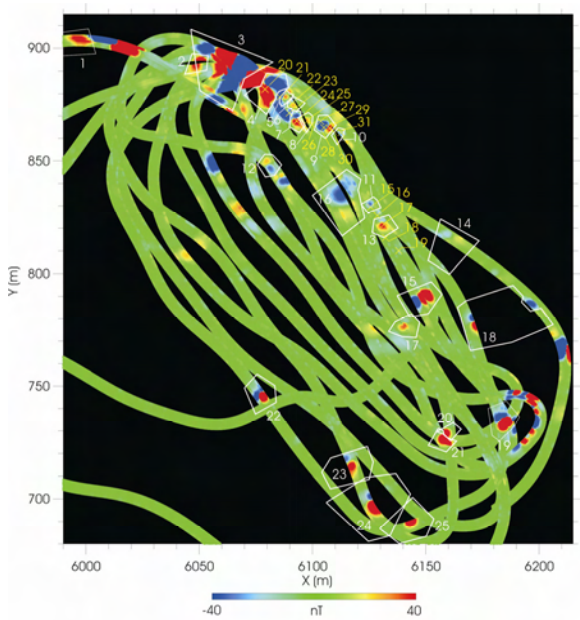

Figure 20. Magnetic anomaly image of the bay adjacent to Soldado Point.

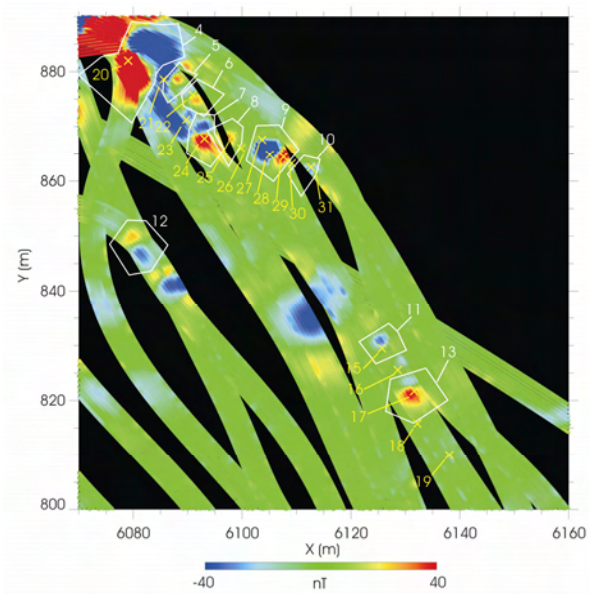

Figure 21. Closer view of the Bahia Soldado survey showing the Calibration Targets. The reported Calibration Target positions are landmarked as yellow X's and the target numbers are identified. The analyzed target numbers and analysis areas are noted in white.

Table 9. Target Report for the MTA Survey in Bahia Soldado

Target Measured Information				Target Fit Information								Analyst Comments	Other Coordinates			
Targ ID	Water Depth (m)	Max Signal (nT)	Min Signal (nT)	Local X (m)	Local Y (m)	Burial Depth (m)	Size (m)	Moment	Incl. (deg)	Azi. (deg)	Fit Quality		UTM X(m)	UTM Y(m)	Latitude	Longitude
1	7.47	45	-49	5999.77	907.16	0.49	0.413	28.226	-23	38	0.670	large target, single pass	257999.77	2022907.16	18.2820424	-65.2891587
2	6.84	54	-35	6050.36	894.59	1.52	0.349	17.037	37	110	0.607	likely geology	258050.36	2022894.59	18.2819346	-65.2886789
3	6.50	96	-209	6065.63	895.42	3.01	0.824	224.017	-30	126	0.623	Geology, Also Transect Targ. No. 1	258065.63	2022895.42	18.2819438	-65.2885347
4	6.28	96	-95	6081.49	883.03	2.19	0.612	91.811	4	49	0.837	COE Target #20	258081.49	2022883.03	18.2818337	-65.2883833
5	6.20	32	-29	6088.44	878.70	0.02	0.170	1.978	47	169	0.775	COE Target #21	258088.44	2022878.70	18.2817954	-65.2883171
6	6.04	29	-19	6091.15	875.83	0.45	0.202	3.324	42	310	0.879	COE Target #22	258091.15	2022875.83	18.2817697	-65.2882911
7	6.19	50	-39	6092.88	868.89	0.42	0.271	7.968	26	2	0.862	COE Target #24	258092.88	2022868.89	18.2817073	-65.2882740
8	6.19	30	-19	6096.35	868.42	0.36	0.206	3.512	68	271	0.741	COE Target #25, Partial Signature	258096.35	2022868.42	18.2817034	-65.2882411
9	6.13	45	-126	6105.53	865.81	0.98	0.365	19.544	-23	302	0.928	COE Target #28 or #29	258105.53	2022865.81	18.2816809	-65.2881539
10	6.01	8	-27	6111.02	861.66	-0.53	0.161	1.676	-40	22	0.781	COE Target #31?	258111.02	2022861.66	18.2816440	-65.2881016
11	6.00	11	-33	6126.00	831.23	-0.10	0.173	2.073	-36	293	0.901	COE Target #15	258126.00	2022831.23	18.2813709	-65.2879563
12	6.61	29	-27	6080.76	848.50	0.67	0.237	5.338	-25	167	0.790	may be multiple targets	258080.76	2022848.50	18.2815218	-65.2883861
13	5.95	40	-23	6131.04	822.23	0.63	0.241	5.593	51	354	0.856	COE Target #17	258131.04	2022822.23	18.2812902	-65.2879076
14	5.31	19	-23	6160.39	817.65	1.05	0.397	25.131	-15	290	0.682	geology	258160.39	2022817.65	18.2812522	-65.2876296
15	5.87	154	-106	6147.59	790.21	1.83	0.532	60.432	9	238	0.641	Big Target, Deep, likely is metal	258147.59	2022790.21	18.2810029	-65.2877474
16	6.09	22	-43	6113.22	834.33	5.44	0.708	142.510	-17	330	0.751	5.5mdeep, geology	258113.22	2022834.33	18.2813975	-65.2880776
17	6.17	34	-13	6139.62	776.14	1.21	0.269	7.824	47	212	0.770	multiple clutter targets or geology	258139.62	2022776.14	18.2808750	-65.2878211
18	5.73	62	-51	6172.29	779.33	0.50	0.352	17.437	23	353	0.885	good target, partial signature	258172.29	2022779.33	18.2809075	-65.2875126
19	5.85	159	-52	6184.33	735.16	1.51	0.383	22.450	47	321	0.384	poor fit, passes in turns	258184.33	2022735.16	18.2805099	-65.2873935
20	6.39	93	-12	6159.19	730.42	-0.37	0.171	2.011	63	348	0.422	poor fit, overlaying passes in turns	258159.19	2022730.42	18.2804643	-65.2876306
21	6.49	107	-9	6157.18	726.63	0.94	0.280	8.833	59	263	0.551	poor fit, overlaying passes in turns	258157.18	2022726.63	18.2804299	-65.2876492
22	8.59	180	-72	6077.14	746.13	0.03	0.319	13.019	31	271	0.972	good target on surface, look at this anchor	258077.14	2022746.13	18.2805969	-65.2884082
23	7.95	46	-34	6115.79	716.40	1.47	0.387	23.279	17	321	0.914	good target, partial signature	258115.79	2022716.40	18.2803327	-65.2880392
24	7.91	127	-46	6126.58	697.80	1.48	0.440	34.071	59	260	0.541	Great target, partial signature	258126.58	2022697.80	18.2801660	-65.2879350
25	7.56	140	-6	6143.24	690.96	0.33	0.301	10.927	86	141	0.704	Good target on surface, partial signature, look	258143.24	2022690.96	18.2801061	-65.2877767
26	7.26	20	-66	6058.15	847.96	3.33	0.586	80.925	-18	346	0.847	3 m deep, geology	258058.15	2022847.96		

4.0 Discussion of the Extended Area Surveys

4.1 Bahia Tamarindo

Almost the entire area of Bahia Tamarindo is dominated by strong geological returns. Note the relatively course scale that is used in the presentation in Figure 17. Fifty anomalies were chosen for analysis. More than 35 of them are clearly geological in origin. Scattered among the geological interference targets are 11 that are highlighted in Table 6, which more closely

resemble compact metallic objects. Half of the highlighted targets are buried shallow enough that they might be able to be investigated by divers. To gain a better differentiation of the potentially metallic targets one could either (1) lower the magnetometer array as close to the bottom as possible (to improve the signal-to-noise of the shallow metallic targets), (2) conduct a survey with and EM array, or (3) deploy a magnetometer array in a gradiometer configuration. The latter approach would also improve the differentiation between deep geological returns and shallower metallic objects. Option (1) runs the risk of damaging coral on the bottom. Options (2) and (3) improve discrimination, but at the loss of absolute detection sensitivity.

4.2 Bahia Tamarindo Chico

The southern 20% of the bay is dominated by geological returns very similar to those in Tamarindo Bay. The remainder of the bay is geologically quiet. Three anomalies near the north end of the bay are identified as likely compact metallic objects. Their visualization is improved in Figure 19. Target 2 is somewhat diffuse and has an inverted signal (remnant moment). It is less likely to be MEC. Targets 1 and 3 are worthy of investigation.

4.3 Bahia Soldado

The northern part of this survey area is dominated by geological interferences. These extend into the northern parts of the area where the seed targets area located. Some of the seed targets appear to be associated with obvious anomalies. Some are undetectable, even at much more sensitive presentation scales. We have noted in Table 8 the anomalies that most likely can be associated with the reported positions. Four anomalies are highlighted in Table 8. Three of the 4 have only partial signatures, and the same 3 are predicted to be buried 1-1.5 ft deep. They are large, however, and may be identifiable by divers from the surface or with small hand tools.