Technical Appendix S11

Marine archaeologist review of suitability of survey methods to identify submerged maritime heritage for the Ichthys Gas Field Development Project, Northern Territory, Australia

Marine Archaeologist Review of Suitability of

Survey Methods to Identify

Submerged Maritime Heritage

For the Ichthys Gas Field Development Project

Northern Territory, Australia

INPEX DOCUMENT NUMBER: C036-AH-REP-0109 REV 1

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March 4, 2011

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EXECUTIVE SUMMARY

Background

INPEX Browse, Ltd. (INPEX) has proposed to construct a natural gas pipeline and LNG Plant within Darwin Harbour as part of the Ichthys Gas Field Development Project. The proposed project has the potential to impact submerged cultural heritage protected by Northern Territory and Australian cultural heritage law and by United States (U.S.) laws, in the case of sunken military craft originally of U.S. origin.

The project area consists of a gas pipeline construction corridor, LNG harbour facilities development areas, and the offshore spoil disposal area. It is divided into nine survey blocks, denoted Blocks 1 through 9 and Dredge Spoil Area. Blocks 1 through 5 are located near or adjacent to Blaydin Point, Block 6 extends west from the Wickham Point shoreline. Block 7 slightly overlaps Block 6 and comprises the majority of the pipeline route as it exits Darwin Harbour. Block 8 crosses the Middle Arm between Middle Arm Peninsula and the Cox Peninsula, and Block 9 extends outward from Point Margaret on the Cox Peninsula. The Dredge Spoil area is located 12 km north of Darwin Harbour.

Objectives

In accordance with cultural heritage laws, INPEX commissioned URS Australia Pty Ltd. (URS) to conduct a marine archaeologist's review of the suitability and limitations of the maritime remote sensing survey methods employed within the Project's nearshore and inshore development footprint to identify marine heritage places and artifacts. This review focuses on the remote sensing instruments' ability to discern low amplitude shipwrecks, and identify where additional survey may be required. INPEX also requested a review of current shipwreck inventories and a re-analysis of previous survey data from the project area. This re-analysis will serve to identify any potential cultural heritage items not previously noted during the original data review. A maritime context for Darwin Harbour was also prepared to provide a chronology of vessels likely to be encountered in the project area, their common construction materials and methods, their preservation potential in Darwin Harbour, and the geophysical signatures expected from each.

Methods

URS reviewed a series of remote sensing survey reports (seven total) and related remote sensing data collected by contractors for INPEX. This review included documenting the various techniques employed, delineating the results of those surveys in a Geographic Information System (GIS), and re-analyzing the data provided using marine archaeologist techniques. The GIS allowed URS to compare the results of different surveys conducted over the course of several years. An explanation of the capabilities of each remote sensing technique to recognize or image submerged cultural heritage was prepared to supplement the discussions of survey techniques.

To address the question of whether any submerged cultural heritage resources were not recognized during previous surveys, URS developed a cultural context on maritime activity in Darwin Harbour. This context derived from on a review of secondary sources related to the history of the Northern Territory. URS developed an assessment of the likelihood that various maritime resource types would be recognized using various remote sensing techniques. URS also reviewed online sources related to shipwrecks in Darwin Harbour and its approaches.

Results

A variety of remote sensing data techniques were employed by INPEX' contractors for the project, which included side scan sonar, multi-beam echo sounder and multibeam pseudo backscatter side scan sonar, single beam echo sounder, sub bottom profiler, magnetic gradiometer, and seismic refraction profiling. These geophysical methods recorded 80 acoustic anomalies and 242 gradiometric anomalies within the INPEX project areas.

URS' re-analysis of the geophysical data added one additional acoustic anomaly URSAA1, which measures 14 m by 8 m, in the proximity of five reported shipwrecks in the Australian National Shipwreck Database. Analysis of the gradiometric data did not record any potential new targets, but two anomalies (URSM1 and URSM2), may represent portions of the World War II anti-submarine nets that crossed Darwin Harbour. These targets may be heritage places, although they retain minimal capacity to inform on the defense of Darwin during the War; INPEX should discuss the need to minimize impacts to these targets with NRETAS.

Conclusions

The remote sensing techniques employed for the Ichthys Gas Field Development Project were adequate to identify any marine cultural heritage places or objects, given the local setting, cultural history, and geological conditions. Based on the research carried out for this project, it is thought that there is a low potential for low amplitude vessels not being imaged and reported on, within the INPEX project areas. There is a low probability that there are moderate to large scatters of significant cultural heritage materials located outside of the buffers that INPEX' project designers have put around the known or identified shipwrecks, aircraft, and other maritime heritage items reported in, or directly adjacent to the pipeline construction corridor right-of-way, or within the areas of potential effect as reported by INPEX.

There are nine known or reported shipwrecks in Darwin Harbour that have not been located with precision to date and had their locations confirmed by marine archaeologists. The techniques used for the geophysical surveys were adequate to have identified these potential shipwrecks. None of these wrecks were recognized during the current re-analysis of remote sensing data for the project and therefore are not likely to be in the project area.

Recommendations

No further remote sensing surveys are warranted to identify submerged cultural heritage for the Ichthys Gas Field Development Project. INPEX should discuss the presence of the remnants of the World War II anti-submarine nets with the Natural Resources, Environment, the Arts and Sport (NRETAS). However, given the poor state of preservation of these damaged net remnants, and the fact that the anti-submarine nets were recovered and stored at the close of WWII, it does not appear that these fragmentary portions of the net have a high research value, or will likely add to the what is already known of Darwin Harbour's anti-submarine defenses and the personnel that manned the nets during the war years.

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1.0 INTRODUCTION

INPEX Browse, Ltd. (INPEX) has proposed to construct a natural gas pipeline and LNG Plant within Darwin Harbour as part of the Ichthys Gas Field Development Project. The proposed project has the potential to impact submerged cultural heritage protected by Northern Territory and Australian cultural heritage law and by United States (U.S.) laws, in the case of sunken military craft originally of U.S. origin.

In accordance with these laws, INPEX commissioned URS Australia Pty Ltd. to conduct a marine archaeologist review of the suitability and limitations of the survey methods employed within the Project's nearshore and inshore development footprint to identify marine heritage places and artifacts. This review will focus on the remote sensing instruments' ability to discern low amplitude shipwrecks and identify where additional survey may be required, if necessary. INPEX also requested a review of current shipwreck inventories and a re-analysis of previous survey data from the project area. This re-analysis will serve to identify any potential cultural heritage items not previously noted during the original data review. A maritime context for Darwin Harbour was also prepared to review a chronology of vessels likely to be encountered in the project area, their common construction materials and methods, their preservation potential in Darwin Harbour, and the various geophysical signatures expected from each.

The project area consists of the gas pipeline construction corridor, LNG harbour facilities development areas, and the offshore spoil disposal ground outside of Darwin Harbour (Figures 1-1 to 1-8). The project area is divided into nine survey blocks, denoted Blocks 1 through 9, and a dredge spoil area. Blocks 1 through 5 are located near or adjacent to Blaydin Point, Block 6 extends west from the Wickham Point shoreline. Block 7 slightly overlaps Block 6 and comprises the majority of the pipeline route as it exits Darwin Harbour. Block 8 crosses the Middle Arm between Middle Arm Peninsula and the Cox Peninsula, and Block 9 extends outward from Point Margaret on the Cox Peninsula. The Dredge Spoil area is located 12 km northeast of Darwin Harbour. Blocks 8 and 9 considered the alignments of an optional pipeline crossing of Middle Arm and landfall site on the Cox Peninsula, respectively. These options are no longer considered a part of the project.

This study was undertaken between December 1 and December 22, 2010. Ian Baxter and Merome Wright of URS Australia Pty Ltd. In Perth coordinated the project with INPEX. Christopher Polglase served as Project Manager for this task order and co-Principal Investigator. JB Pelletier served as co-Principal investigator and senior remote sensing analyst. Anthony Randolph conducted historic research and contributed to the report. Bridget Johnson served as remote sensing analyst and GIS specialist, and Justin Bedard provided ancillary support.

Following this introduction, this report is divided into six sections, including: Natural Setting, Cultural Context, Research Design, Results and Conclusions, Summary and Recommendations, and References Cited. Figures are attached as an addendum. Appendix A contains the Qualifications of Investigators, Appendix B contains the Table of Side Scan Sonar Anomalies, and Appendix C contains the Table of Gradiometric Anomalies.

2.0 NATURAL SETTING

This natural settings section provides a framework for the description and analysis of the benthic environment of the Ichthys Gas Field Development project areas. The project area is located in the Anson-Beagle bio-region, which consists of all inshore waters of the western Top End coast (INPEX Browse, Ltd. 2009). This region is characterized by a monsoon-tropical climate, and experiences high rainfall between November and March. Cyclones, or Pacific hurricanes, occur with low to moderate frequency. Offshore currents have a minimized influence on the region, due to the presence of the continental shelf (INPEX Browse, Ltd. 2009). Tides range from 6 to 8 meters on average, and monsoons produce more turbulent wave activity during the rainy season.

The geomorphology of the region is characterized by ria shorelines, which are drowned river valleys formed by a rise in sea level in Darwin and other nearby harbours (INPEX Browse, Ltd. 2009). Rocky reefs and shoals are scattered throughout the region. Coral fringing reefs and patch reefs are distributed sparsely, and are frequently associated with rocky coastal outcrops.

Three geological units have been identified in the area of Darwin Harbour. These consist of Recent Marine, Burrell Creek Formation, and Undifferentiated Granite. Sediments in the East Arm, north of Blaydin Point, are typically unconsolidated sediments over the phyllites and sandstones of the Burrell Creek Formation (INPEX Browse, Ltd. 2009). There are several meters of unconsolidated mud and sediment east of Blaydin Point, which overlay weathered phyllite and other residual soils. The most prevalent seabed material west of the Middle Arm Peninsula is residual soil sloping to weathered phyllite and sandstone (INPEX Browse, Ltd. 2009).

Soils in the project area, between KP 706 and KP 862 are mostly featureless clay-silt sands with some regions of megaripples. Sand waves in the Darwin area typically run northeast to southwest in bands. They vary in height and length, with average heights being 0.5 to 1.0 meters and wavelengths between 10-25 meters (INPEX Browse, Ltd. 2009). These sand waves are mobile and overlie flat lying sandy silt and bedrock.

The sediments in and around the Darwin Harbour area have been divided into four different types: “terringenous gravels, which occur primarily in the main channel; calcareous sands with greater than 50% biogenic carbonate, which are among or close to the small coral communities at East Point, Lee Point, and Channel Island; terringenous sands [are found] on beaches and spits with 10-50% carbonate, [which are] largely derived from mollusks. This type of sediment is predominantly quartz and clay; mud and fine sand [found] on broad, gently inclined intertidal mudflats occur in areas characterized by low current and tidal velocities, such as Kitchener Bay” (Michie 1988 in INPEX Browse, Ltd. 2009). Coarser material is typically found in the central channels of tributaries and the main portion of the harbour.

Water depth is typically between 11 and 70 meters offshore (URS 2009). The maximum depth of the Darwin Harbour channel is 36 meters, with an average between 15 to 25 meters. The channel runs closer to the eastern side of the harbour; broader, shallower areas of the channel are on the western side of the harbour (INPEX Browse, Ltd. 2009). The harbour is specifically characterized by strong currents produced by tidal action. Currents can peak at speeds of 2 to 2.5 meters per second.

Darwin Harbour and the surrounding areas are home to an array of flora and fauna. The mangrove communities located throughout the harbour, especially around Blaydin Point, contain a rich biological community. There are 123 different types of hard corals indigenous to Darwin Harbour, along with 50-65 types of soft corals and sea whips (INPEX Browse, Ltd. 2009). Fish in the region are abundant, and include trevallies (*Caranx* spp.), grunter (*Pomadasys kaakan*), mackerel (*Scomberomorus semifasciatus*), salmon (*Eleutheronema tetradactylum*) and barramundi (*Lates calcarifer*) (INPEX Browse, Ltd. 2009). Barramundi is especially important to both commercial and recreational fishermen in the region. There are several species of jellyfish and two species of box jellyfish prevalent in the region during the wet season. Sponges of 56 different types are also found.

Seagrass is found in patches around Weed Reef. Seagrass types include *Halophila. Halodule uninervis* and *Halophila decipiens* are also sparse at Wickham Point (INPEX Browse, Ltd. 2009). Other species of seagrass found in the general area include *Cymodocea rotundata* and *Halophila ovalis.*

A number of protected marine species are also found in the Darwin Harbour and its surroundings. These species include the blue whale (*Balaenoptera musculus*), Humpback whale (*Megaptera novaeangliae*), loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), freshwater sawfish *(Pristis microdon*), whale shark (*Rhincodon typus*), flat-faced seahorse (*Hippocampus planifrons*), and hedgehog seahorse (*Hippocampus spinosissimus*). Other creatures in the region include dolphins, dugongs, waterbirds and seabirds, sea snakes, and the saltwater crocodile (*Crocodylus porosus*; INPEX Browse Ltd, 2009).

3.0 CULTURAL CONTEXT

This maritime cultural context for Darwin and its approaches provides a framework for the description and analysis of the submerged cultural resources that may be encountered within the INPEX project areas. It also serves as a basis for evaluating the potential for these vessel types to have been identified using the remote sensing equipment used by INPEX' contractors for this project.

The context will be divided into five historical periods. These periods are defined by broad (pre)historical themes that have contributed to, and in some cases defined, the maritime development of Darwin and the surrounding region. The periods reviewed in this chapter are: Darwin and the Northern Territory Prior to 1606, European and Asian Colonial Interests (1606-1791), The Rise of Port Darwin (1839-1939), Darwin during World War II (1939-1945), and Darwin Today (1945-2010). Each period will be reviewed for broad maritime themes, the vessel types that might be expected during each era, relevant vessels listed on the ANSD by period, and the likelihood that these vessels would survive in a marine environment to the present day.

All ANSD and FUGRO (2008) data referenced in this chapter is compiled in Table 3-1. There are discrepancies between positional data gathered by FUGRO and that listed in the ANSD for certain shipwrecks. Shipwrecks with positional discrepancies have both sets of coordinates listed in Table 3-1.

Table 3-1. Shipwrecks in Darwin Harbour (ANSD and FUGRO [2008])

ANSD Number	Vessel Name	Identification	Latitude	Longitude
3363	*Africa*	Vessel lost in 1915.	12.66666	130.85
3366	*Ark*	Foundered in Darwin Harbour on 06/01/1897.	12.66666	130.85
3367	*Arnhem T*	Vessel wrecked in Frances Bay, Darwin Harbour on 25/12/1974.	12.66666	130.85
3368	*HMAS Arrow*	Vessel wrecked at Iron Ore Wharf in 1974.	12	130
3370	*Ataluma*	Vessel wrecked at Dudley Point, Darwin Harbour in 1974.	ANSD: 12.81666	130.41333
3376	*Bear Sing*	Vessel foundered in 1886.	12.66666	130.85
3377	*Bell Bird*	Steel hulled motor vessel built in 1971, lost in Cyclone Tracey in 1974.	ANSD: 12.46816 FUGRO: 12.4689	ANSD: 130.8365 FUGRO: 130.835
3381	*Betty Joan*	Wooden vessel lost in Cyclone Tracey in 1974 in Frances Bay, across from Sokes Hill power station.	12.48333	130.866667
3383	*Black Jack*	Vessel foundered on 06/01/1897.	12.66666	130.85
3384	*Blue Bird*	Steel hulled motor vessel built in 1971, lost in Cyclone Tracy at Iron Ore Wharf in 1974.	12.47333	130.8425

3386	*Booya*	Steel Schooner sailing vessel built in 1917. Lost in Cyclone Tracey in 1974. 5 crewmen reported killed.	ANSD: 12.65 FUGRO: 12.3897	ANSD: 132.016667 FUGRO: 130.771
Fish Finder 2005 (Fugro 2008)	*Bottlewasher*	Unknown	FUGRO: 12.3023	FUGRO: 130.863
3388	*Brisbane*	Lugger sailing vessel wrecked on 06/01/1897.	12.66666	130.85
3389	*British Motorist*	British steel hulled, screw propelled steamer built in 1924. Sunk by Japanese during air raid on Darwin Harbour on19/02/1942. 2 crewmen reported killed.	ANSD: 12.49766 FUGRO: 12.4828	ANSD: 130.81933 FUGRO: 130.839
NT	*Buffalo Amphibian*	Unknown	FUGRO: 12.438	FUGRO: 130.798
3392	*Cameo*	Foundered in Darwin Harbour on 08/03/1919.	12.48333	131.85
3402	Carina	Motor vessel lost in Cyclone Tracey at Stokes Hill Wharf, Darwin Harbour in 1974.	12.48	130.84333
3403	*Chang 1028*	Steel hulled vessel built in France. Scuttled at mooring at Reichardt Creek, Darwin Harbour in 1978.	12.47083	130.89916
3405	*Charles Todd*	Steel hulled, diesel driven vessel lost in Cyclone Tracey in 1974, 350m off Iron Ore Wharf. 1 crewman killed.	12.49	130.85833
3407	*Chinta*	Yacht wrecked under Stokes Hill Wharf, Darwin Harbour in 1974.	12.48833	130.86833
3408	*Con Dao 3*	Vietnamese wooden fishing vessel scuttled by crew in East Arm, Darwin Harbour on 19/05/1978.	12.505	130.90333
3409	*Coral*	Unknown vessel type lost in Darwin Harbour in 1932.	12.48333	131.85
3412	Darwin Harbour Chinese fishing boat 1	Chinese fishing boat lost on 31/08/1888.	12.66666	130.85
3416	Darwin Harbour unidentified wreck 1	No information available.	12.46833	130.85833
3417	Darwin Harbour unidentified wreck 2	No information available.	12.48333	130.83333

3418	*Darwin Princess*	Australian built steel hulled, twin diesel motor vessel. Lost in Cyclone Tracey in 1974. 1 crewman killed.	ANSD: 12.638332 FUGRO: 12.3982	ANSD: 131.01833 FUGRO: 130.765
3421	*Dawn*	Vessel of unknown type blown ashore with lugger *Yampi Lass* during gale in 1943.	12.58333	130.94999
3422	*NR van Dieman*	Steel hulled motor vessel built in 1970. Sank in 1978	ANSD: 12.42666 FUGRO: 12.4266	ANSD: 130.75333 FUGRO: 130.765
3426	*Dsac Barge*	Barge scuttled in 1988 1 km off Dudley Point to create an artificial reef.	12.42666	130.81966
3427	East Arm barge 2	Barge lost in 1945.	12.48078	130.90688
3428	East Arm barge	Barge lost in 1945.	12.48209	130.90656
3429	East Arm Vietnamese refugee boat 1	Vietnamese refugee boat stranded in 1976.	12.51111	130.9227
3430	East Arm Vietnamese refugee boat 2	Refugee vessel stranded in the East Arm, Darwin Harbour in 1976.	12.48133	130.90491
3433	*Edwina May*	Steel hulled, diesel driven vessel lost in Cyclone Tracy off of Stokes Hill Wharf in 1974.	12.48833	130.86833
3435	Elizabeth River unidentified wreck	No information available.	12.53655	130.95666
3436	*Ellengowan*	Steel hulled steamboat built in Norway in 1866. Sank at its moorings while at Channel Island on 27/04/1888.	12.538	130.86799
3441	*Evangel*	Unknown vessel type wrecked at Night Cliff, Darwin Harbour in 1901.	12.38333	130.84166
3447	*Flowerdale*	Schooner stranded in Darwin Harbour in 1899	12.48333	130.83333
3448	*Flying Cloud*	Wooden cutter built in Australia in 1870. Lost in a storm in Frances Bay, Darwin Harbour in 1894.	12.55	130.93333
3450	*Gertrude*	Vessel of unknown type lost in 1896.	12.48333	130.86666

3456	*Gulnare*	Wooden schooner scuttled and filled with stones to make a jetty near Fort Hill, Darwin Harbour in 1872	12.48666	130.86166
3458	*Ham Luong*	Steel hulled Vietnamese fishing boat sunk in the middle of Darwin Harbour as artificial reef	ANSD: 12.49333 FUGRO: 12.4747	ANSD: 130.815 FUGRO: 130.802
3459	*Hankow*	Vessel of unknown type used as naval target practice due west of East Point. Sunk in 1932.	12.63833	130.01833
3460	Harbour tug	Vessel in tow from Darwin foundered in 1942.	12.63733	131.0165
3464	*Hibernia*	Wooden ketch built in 1857, lost in 1882.	12.66666	131.03333
3471	*Jack*	Vessel of unknown type lost in 1896.	12.48333	130.83333
	Japanese Submarine KRS 1-124	World War II era submarine	12.1188	130.108
3473	*Jenny Wright*	Steel hulled vessel lost in Cyclone Tracey in 1974 off of Iron Ore Wharf.	12.4765	130.8495
3474	*John Holland* Barge	Steel barge scuttled in 1982 in the middle of Darwin Harbour to form part of an artificial reef.	ANSD: 12.49 FUGRO: 12.4747	ANSD: 130.8175 FUGRO: 130.802
3476	*Kathleen*	Unknown vessel type capsized of Emery Point, Darwin Harbour in 1873. 2 crewmen killed.	12.53833	130.89666
3477	*Kelat*	Iron hulled clipper type vessel constructed in 1888. Sunk in 1942 during Japanese air raid.	ANSD: 12.51666 FUGRO: 12.4987	ANSD: 130.895 FUGRO: 130.878
3478	*L. Ann*	Vessel wrecked at Mandorah.	12.44666	130.765
3479	Landing Barge	Steel barge.	ANSD: 12.5 FUGRO: 12.4859	ANSD: 130.86166 FUGRO: 130.845
3481	*Leichhardt*	Steam powered vessel. Caught fire while being refitted ashore. Stranded wreck type.	12.48833	130.86833
3483	Lighter No. 2	Vessel of unknown type built in 1885. Reported lost by enemy action near Darwin in 1943	12.66666	131.03333
3487	Ludmilla Creek unidentified refugee boat	Refugee boat.	12.41333	130.84166

3492	Mandorah unidentified wreck 1	No information available.	12.44666	130.765
3493	Mandorah unidentified wreck 2	No information available.	12.44666	130.765
3494	*Mandorah Queen*	Steel hulled vessel sunk off Mandorah Jetty, Darwin Harbour by Cyclone Tracey in 1974	ANSD: 12.45966 FUGRO: 12.4427	ANSD: 130.79599 FUGRO: 130.778
3498	*Marchart 3*	Steel hulled, diesel powered motor vessel built in 1969. Scuttled in 1988 at Fenton Patches to create an artificial reef.	12.19333	130.69333
3500	*Margaret*	Unknown vessel type lost in 1888	12.48333	130.83333
3503	*USAT Mauna Loa*	Screw propelled steamboat built in 1919 in San Pedro California. Sunk during a Japanese air raid in 1942. 5 crewmen killed.	ANSD: 12.49766 FUGRO: 12.4969	ANSD: 130.81933 FUGRO: 130.819
3505	*USAT Meigs*	American steel hulled, screw propelled steamer built in 1921. Sunk during Japanese air raid on Darwin Harbour in 1942. 2 crewmen killed.	ANSD: 12.48766 FUGRO: 12.4878	ANSD: 130.81833 FUGRO: 130.818
Darwin Dive Ventre (Fugro 2008)	*Medkahnun 3*	Unknown	12.4785	130.802
3509	Middle Arm wreck	No information available.	12.538	130.868
3510	*Midge*	Vessel of unknown type stranded in Darwin Harbour in 1907.	12.48333	130.83333
3517	*MV Neptuna*	German built steel hulled, twin screw steamer built in 1924. Sunk off Stokes Hill Wharf during Japanese air raid of Darwin Harbour in 1942. 45 crewmen reported killed.	ANSD: 12.47066 FUGRO: 12.4717	ANSD: 130.84983 FUGRO: 130.849
3519	*Nimrod*	Wooden motor yacht lost off Stokes Hill Wharf during Cyclone Tracey in 1974.	12.48833	130.86833
3523	*Olga*	Wooden vessel of unknown type, stranded near Darwin in 1926.	12.58333	130.94999
3524	*Olive*	Vessel of unknown type lost in 1897.	12.5	130.86666

3531	*USS Peary*	American steel hulled, screw propelled steamer built in 1920. Sunk during Japanese air raid on Darwin Harbour in 1942. 92 crewmen killed.	ANSD: 12.475 FUGRO: 12.4754	ANSD: 130.82916 FUGRO: 130.83
3536	*Pinafore*	gale 4.2 kilometers (2.5 miles) out of Fannie Bay. 1 crewman killed.	12.13833	131.01833
3548	*Rachel Cohen*	Australian built wooden barquentine built in 1871. Burned with a cargo of crude oil in 1924.		
3549	*Rasta*	Vessel of unknown type lost on 24/12/1974.	12.48333	130.83333
3552	*Revenge*	Vessel of unknown type lost in 1897.	12.48333	130.83333
3555	*Roebuck*	Vessel of unknown type lost in 1897.	12.48333	130.86666
Fish Finder 2005 (Fugro 2008)	Sandbar barge	Barge	12.4484	130.81
3559	*S.F. Hersey*	Vessel of unknown type lost on 16/12/1886.	12.48333	130.86666
3563	*Scallywag*	Vessel of unknown type lost on 25/12/1974.	12.48333	130.85
3564	*Scout*	Vessel of unknown type lost in 1896.	12.48333	130.86666
3569	*Song Saigon*	Steel hulled Vietnamese fishing boat scuttled to form an artificial reef in 1982.	ANSD: 12.49133 FUGRO: 12.4747	ANSD: 130.81783 FUGRO: 130.802
3570	*Spray*	Unknown vessel type foundered during a cyclone in 1915.	12.48833	130.86833
Fish Finder 2005 (Fugro 2008)	Steel Barge	Barge	12.4891	130.873
3577	*Triumph*	Unknown vessel type sank while under tow on the way to *HMAS Condamine* on 13/07/1954.	12.66666	131.03333
3584	Vietnamese refugee boat Pk76	Wooden vessel of unknown form.	12.45983	130.83283
3585	*Waihoi*	Vessel of unknown type ran onto a sand bank and grounded amidships in 1974.	14.86666	134.25

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3588	*Warrego*	British built compound engine hulk built in 1883. Hulked and buried for land fill in 1919 at the Stokes Hill Power Station site.	ANSD: 12.48333 FUGRO: 12.466	ANSD: 130.86666 FUGRO: 130.865
3592	*Yampi Lass*	Wooden lugger sailing vessel blown ashore and destroyed by gale in 1943.	12.63483	131.00316
3595	*Yu Han 22*	Wooden fishing built in Taiwan. Scuttled on Weed Reef for illegal fishing	ANSD: 12.5175 FUGRO: 12.5167	ANSD: 130.82166 FUGRO: 130.817
3596	*Zealandia*	Steel hulled twin screw steamer built in the United Kingdom in 1910. Sunk during Japanese air raid in 1942. 3 crewmen killed.	ANSD: 12.48333 FUGRO: 12.4814	ANSD: 130.85083 FUGRO: 130.851
3598	*Zulieka*	Vessel of unknown type lost in Middle Arm, Darwin Harbour in 1897.	12.53333	130.86666

3.1 DARWIN AND THE NORTHERN TERRITORY PRIOR TO 1606

Australia was first inhabited by the ancestors of modern Aboriginal Australians, who arrived at least 40,000 year ago from New Guinea and the southeastern Asian islands of Malaysia, Singapore, and Indonesia. It is estimated that between 600 and 700 different tribes of Aboriginal Australians developed from the original migration(s). Survival in Australia required vast knowledge of the many micro-environments within the continent, and aboriginal peoples mastered the Australian landscape over the ensuing millennia (Knight 1992). The Indigenous Australians who occupy the Darwin Harbour region are the *Larrakia* or *Gulumirrgin*, which translates from the Larrakian language as *salt water people*. As their name implies, the Larrakian culture are heavily reliant on marine protein sources including fish, crab, shellfish, dugong, and turtles (Tindale 1974). Before contact with Europeans, the Larrakia harvested the bay and sea using bark and dugout canoes and wooden rafts (Barlow 1994).

Aboriginal Australian watercraft were of simple construction and were fashioned from materials that were readily available. Rafts were of either single or double fan construction, and were composed of one or two rows of between 7 and fourteen mangrove poles fastened with *liminidi* wood dowels. A single fan raft would stand alone, while a double fan would be comprised of two single fans overlapping and pinned with *limnidi* wood in at least two places. The top of the raft was often lined with grass and leaves (Ackerman 1975).

Bark canoes were also commonly used and were constructed from one or two sheets of thick bark, often from box or red gum trees. The sheets were shaped and formed into a canoe shape by soaking and heating, and the extremities were secured with plant fiber twine to prevent leakage. Seams were occasionally caulked with sticky, resinous plant materials. There were many variants of the bark canoe made throughout Australia; the above description is a distillation of the most common construction techniques (Berndt 1941).

Aboriginal dugout canoes were usually constructed from sycamore trees that had been shaped and hollowed by hand. Dugouts were more stable that the lighter bark canoe, and were used to transport heavy prey items such as dugong and turtle. Dugouts were not constructed before the early seventeenth century, because they could not be made without an iron axe, which was one of the earliest trade goods introduced to Australia (Thomas 1905).

Aboriginal watercraft were simply constructed of natural materials. Aboriginal tribesmen considered them to be disposable commodities that were discarded when they became worn or damaged. The only environment conducive to the preservation of an ancient aboriginal watercraft is a stable, anaerobic burial matrix with non-acidic, clay, or silty clay sediments. The highly volatile conditions of Darwin Harbour would obliterate these delicate craft, leaving no mark on the geophysical record. The only hope to encounter such a craft intact is buried in the dense sediments of the swampy mangrove margins that surround portions of the harbour (Table 3-2).

Table 3-2. Probability of Detection Using Remote Sensing by Vessel Type and Date

Date Range	Construction Materials and Power	Boat Type	Magnetic Intensity	Acoustic Reflectivity	Probability of Detection
Before 1606	Natural materials (no iron)	Aboriginal Raft	None	Extremely Limited	Low
		Aboriginal Bark Canoe	None	Extremely Limited	Low
1606-1839	Wooden hulls with iron components-Sail	Barque	High	Moderate	High
		Galleon	High	Moderate	High
		Carrack	High	Moderate	High
		Fluyt	High	Moderate	High
		Prau	Low	Low	Low
1839-1900	Wooden hulls with iron components-Sail	Schooner	High	Moderate	High
		Ketch	High	Moderate	High
		Barquentine	High	Moderate	High
		Brig	High	Moderate	High
		Cutter	Moderate	Moderate	Moderate
		Lugger	Moderate	Moderate	Moderate
	Wooden hulls with iron components-Steam	Schooner	High	High	High
		Ketch	High	High	High
		Barquentine	High	High	High
		Small Steam Powered Vessel	High	High	High
	Iron/Steel hulls-Steam	Various types and sizes	High	High	High
1900-1936	Wooden hulls with iron components-Sail	Schooner	High	High	High
		Ketch	High	High	High
		Barquentine	High	High	High
		Brig	High	High	High
	Wooden hulls with iron components-Sail	Cutter	Moderate/High	Moderate/High	Moderate to High
1900-		Lugger	Moderate/High	Moderate/High	Moderate to

Date Range	Construction Materials and Power	Boat Type	Magnetic Intensity	Acoustic Reflectivity	Probability of Detection
1936					High
	Wooden hulls with iron components-Steam/Gas/ Diesel	Schooner	High	High	High
		Ketch	High	High	High
		Barquentine	High	High	High
		Small Powered Vessel	High	High	High
	Iron/Steel hulls-Steam/Gas/Diesel	Various types and sizes	High	High	High
1936-2010	Wooden/Fiberglass hulls with iron components-sail	Large vessels	High	High	High
	Wooden/Fiberglass hulls with iron components-Sail	Medium sized to small vessels	High	Moderate to high	High
	Wooden/Fiberglass hulls with iron components-Steam/Gas/ Diesel	Various types and sizes	High	High	High
	Iron/Steel hulls-Steam/Gas/ Diesel	Various types and sizes	High	High	High

3.2 EUROPEAN AND ASIAN COLONIAL INTERESTS (1606-1839)

During the Age of Discovery, European maritime powers dispatched explorers and merchant fleets to scour the ever-expanding planet in search of new commodities and land. The two most aggressive nations in exploration of southeast Asia and Oceania were the Spanish and Dutch. Iberian Luiz Baez de Torres and his crew were likely the first Europeans to view Australia in 1606. Under command of the carracks *San Pedro* and *Los Tres Reyes*, de Torres crossed the eponymous Torres Straits and sailed very near Cape York, Queensland. It is unclear if de Torres progressed further west toward what would later become the Northern Territory. Torres either did not realize that he had discovered a new continent, or he failed to convince the Spanish Crown to take interest in this new land (Knight 1992).

Enterprising Dutch trading houses had been sailing to southeast Asia since 1595 to establish a spice trade with Java, Indonesia, and Malaysia. The danger and length of the voyage prohibited single houses from gaining a reliable foothold in the region; this was remedied with the founding of the Dutch United East Indian Company (VOC) in 1602 (Wilkins 2006). This company became one of the great maritime merchant empires of the seventeenth and eighteenth centuries, and successfully completed over 4,800 voyages to Asia between 1602 and 1795 (Wilkins 2006).

The main interest of the VOC was the islands to the west of Australia's northwestern coast. Vessels were eventually sent further east in search of new resources and in 1605 Captain Willem Jansz was commissioned to explore New Guinea and the lands beyond (Wilkins 2006; Heath 2005). In command of the barque *Duyfken*, Jansz briefly landed on the western edge of Queensland near Cape York, and became the first European to land on Australia's shore. Jansz's discovery encouraged a series of explorers to brave uncharted Australian waters to both map and colonize the continent. Between 1607 and 1644, explorers called Hartog, Houtman, Carstensz, Dewitt and Pelsaert captained vessels that included *Eendracht, Amsterdam, Leeuwin, Pera, Arnhem, and Batavia* around the northern and western coastline, searching for potential landing sites (Wilkins 2006; Heath 2005). The area around Darwin was first discovered in 1644 by Abel Tasman and Jacobsen Visscher (Knight 1992).

Tasman was commissioned in 1642 by Anthony van Deimen, then governor of the Dutch East Indies, to sail *Heemskerk* and *Zehaen* from Mauritius down the Australian coastline. During this journey, he identified what is today called the Dundas Strait and Melville Island. No promising trade possibilities were identified and the area was hastily mapped and abandoned (Heath 2005; Knight 1992). Dutch interest in the region waned until 1705, when England began to prowl the coast of Australia. The Dutch sent two final expeditions to the Northern Territory coastline between 1705 and 1755, but eventually abandoned the region to others.

The Northern Territory coastline was not devoid of foreign influence during the eighteenth century. *Makassar* fishermen from Indonesia arrived in the early eighteenth century to harvest and process *trepan* (sea cucumber), which was used as a medicine and aphrodisiac in China. They arrived in fleets of up to 60 wooden hulled boats, called *prau*, and spent each rainy season interacting and trading with the *Larrakia*. They introduced new technologies and goods to the local indigenous populations during these stays, including iron tools, cloth, *arak* liquor, and the dugout canoe. *Trepan* fishing continued unabated until 1906, when the Australian government halted the practice through the levy of a large export tax. Archaeological evidence of *trepan* processing has been documented along the coastlines near Port Darwin and Port Essington (Knight 1992).

Vessels employed by Spanish and Dutch explorers and merchants between 1606 and 1755 were called barque, galleon, carrack and *fluyt* (Unger 1994). The construction of these ships has been well documented and they share similar characteristics. They maintained an elevated forecastle and aftcastle, rounded hulls, and a length to breadth ratio between 2.8 and 3.1 to 1. Waterline length varied between 20 and 45 meters (65.6 and 147.6 feet; Steffy 1994). These ships generally maintained between two and four masts and were either square or lateen rigged. These traits resulted in slow, seaworthy ships of massive tonnage. These vessels were often heavily armed because they were too slow and unwieldy to outsail predators. *Batavia*, the 650 ton Dutch fluyt that sank off the western Australian coast in 1628, is a prime example of such a ship. She boasted three masts and was 186 feet in length with a 34 foot beam and a 17 foot draught. She was crewed by 341 men and carried 24 caste iron cannon on one deck (Godard 1993).

Smaller European vessels were not commonly used for exploration during this time period, and there are no confirmed landings near or within Darwin Harbour until 1791. Small ships boats may have landed to gather water or food, but these vessels were rarely left behind. The most common small vessels that would have venture into or near to the area were the *prau* of the Makassar fishermen. *Prau* are lightly constructed sailing vessels with a sharp entrance and exit, shallow draft, and one or two masts with lateen or gaff rigged fore-and-aft sails.

Ocean going *prau*, like those used to harvest *trepan* in Australia, were upwards of 18 meters (60 feet) in length (Knight 1992).

Although the Australian coast was within the orbit of Dutch explorers and merchants for 150 years, their presence was extremely rare and unscheduled. There have been no reported losses of these vessel types in the vicinity of Darwin Harbour project area. In the event that a large ship of discovery had been lost, there would be wreckage left to document the sinking, particularly large iron objects, including cannon and cannon ball, chain, and anchors. Other elements such as ballast piles, brass hardware, cargo casks, and wooden vessel remains would likely also be present. The harsh conditions of Darwin Harbour could not completely erase a vessel of that size, and the sediments in the harbour are rarely deep enough to conceal such a wreck. Remains of vessels of this size and date have been found all over the world in similar environments, as evidenced by *Batavia* in Australia, *Belle* in the United States, *Mary Rose* in England, and *Vasa* in Sweden. A well conducted, systematic remote sensing survey of the harbour bottom should readily identify this type of wreck site. The currents and general volatility of the channels and channel margins in Darwin Harbour would eventually fragment even large wooden vessels, and would scour artifacts by weight in a distinctive pattern that mimicked the general current flow (Table 3-2).

Smaller boats, particularly the *prau* employed by *Makassar* fishermen, were very lightly constructed and contained very little iron. *Prau* lost in Darwin Harbour in the historic past would have been quickly broken and dispersed by the first storm event after sinking. Due to their relatively light construction, it is highly unlikely that the wreckage would sink in a given location and stay there. A more likely scenario would have the wreck fragmented and pitched ashore during one of the many mistrals that plague the Northern Territory coastline. *Prau* remains located in the project area would likely not be recognized during a systematic remote sensing survey because of the lack of iron, and the expected fragmentary nature of the wreck (Table 3-2).

3.3 THE RISE OF PORT DARWIN (1839-1939)

The English crown began to slowly chart the Northern Territory coastline during the early nineteenth century. Four previous attempts to settle along that coastline failed miserably between 1824 and 1866, and the early foothold gained at nearby Port Essington was tenuous at best. Captain Wickham of the *HMS Beagle* was sent from Port Essington in 1839 to further detail the coastline to the east and north. He became the first known European to land at Port Darwin in September of that same year (Carment 1996). Upon arrival at Darwin, Wickham was immediately struck by the protected harbour, and what he coined “a splendid stretch of water” (Hordern 1989). Wickham was prompted to name the new harbour Darwin, after the famed naturalist Charles Darwin, with whom he had sailed on *Beagle* between 1831 and 1836 (Carment 1996).

The development of Darwin was slow and laborious. After a failed attempt to settle east of Port Darwin at Escape Cliffs, George Goyder surveyed the east side Darwin Harbour in 1868 as a suitable location for a town. The municipality was called Palmerston, and it was soon staffed with 44 civil servants and acting Governor JS Millner (Carment 1996). Palmerston’s economy was buoyed by a new rail line, telegraph service, and massive calm water port. New industries sprang up, included gold mining, pearling, fishing, and cattle ranching. By 1890, the *Larrakia* had to share their ancestral land with Englishmen along with enclaves of Chinese, Malays, and Japanese (Carment 1996; Mitchell 2005; Roberts 2005).

Despite setbacks caused by a series of devastating cyclones, Palmerston's economy steadily grew. The Northern Territory was ceded from South Australia to the Commonwealth of Australia in 1911, and Palmerston officially became Darwin. Municipal growth continued in Darwin until a widespread depression slowed the economy in 1929.

The Palmerston/Darwin maritime economy between 1870 and 1930 was dominated by large steam ships. Cattle ranchers fenced their land and fed their cattle with wire and corn brought by these boats (North Australian 1883). Stores like Adcock Brothers, Jolly and Luxton Importers, and D.B. Tenent, constantly boasted of new stock that had arrived on steamers called *Suez*, *Arcadia*, and *Athol*. Large cargo steamers also shipped from Palmerston/Darwin, carrying tin ore, timber, cattle, passengers, and mail to Sidney and beyond (North Australian 1883).

There are two steamboats from this time period that have wrecked in or near Darwin Harbour. The first is the harborship/coaster *SS Ellengowan* (ANSD 3436). She was a small, steel-hulled, screw propelled steamboat that was 89 feet in length, 17 feet in breadth, with a carrying capacity of 36 tons. She was built in Norway in 1866 under the name *SS Nokken*, but was renamed *SS Ellengowan* in 1874. Much like the other steamers of Darwin Harbour, she served as a supply vessel, mail packet, and ferry on the coast and on the Roper and McArthur rivers. The vessel sunk in Darwin Harbour in 1888 and was abandoned without salvage (Fugro 2008a).

The second example is a much larger, ocean going cargo vessel called *SS Brisbane* (ANSD 3387, Figure 3-1). She was a massive, 891 ton steel-hulled, screw propelled steamboat that boasted four boilers, six wooden boats, three auxiliary masts, and first, second, and steerage class accommodations. *Brisbane* was 282 feet in length and 32 feet in breadth. She was built in Scotland in 1874 by A&J Inglis and regularly ran between Hong Kong and Melbourne. Port Darwin was one of 12 stops on her itinerary. *Brisbane* carried passengers, meat in cold storage lockers, and ornaments and other fineries from Asia. She was used to transport immigrants during her final years. *Brisbane* ran aground on October 10, 1881 on Bathurst Island, just outside Darwin Harbour. She was salvaged and her cargo sold at auction in Darwin two months later (Steinberg 2005).

Many types of moderate to large sailing craft were employed in Darwin Harbour between 1839 and 1939. These were multipurpose vessels that were used in the fishing and pearling industry, as cargo carriers, and personal pleasure craft. Many of these craft were equipped with steam and sail power combined. The vessels in this class reviewed below are the types represented in the ANSD, and include brigs, schooners, ketches, and barquentines (Table 3-1). Vessels reported lost in Darwin Harbour during this time period include the schooners *Gulnare* (ANSD 3456) and *Flowerdale* (ANSD 3447), the brig *Flying Dutchman* (ANSD 3449), ketches *Hibernia* (ANSD 3464) and *Good Intent* (ANSD 3451), and the barquentine *Rachel Cohen* (ANSD 3548). A third schooner not listed in ANSD is *Huddersfield*, which was lost in Darwin Harbour in 1928. It has been theorized that the Frances Bay Wreck, which was documented by Flinders University in 2010, may represent *Huddersfield*, *Flowerdale* or *Rachel Cohen* (McKinnon et al. 2010).

Schooners and ketches maintained a relatively bluff bow, long waterline, and broad waist with two fore and aft rigged masts, with the occasional topsail (Chapelle 1935, 1967). These boats were designed to be very sharp and fast, and differed only in sail plan. They ranged between 12 and 33 meters (40 – 110 feet) in length, 3 and 7 meters (10 - 25 feet) in breadth, with length to breadth ratios ranging between 2.5 and 5 to 1. Brigs and Barquentines were built on a larger scale than schooners and ketches. Brigs boasted two large square rigged masts, while barquentines maintained a single square rigged foremast and up to three additional fore and aft rigged masts. These ships ranged up to 52 meters (170 feet) in length and 480 tons in size (Chapelle 1935; Gardiner 1992).

Smaller boats, both sail, steam, and diesel powered, were also vital to Darwin's economic success. The pearling industry in Darwin began in 1884 when the sailing schooner *Sree Pas Sair* first recovered pearl shell from Darwin Harbour (Carment 1996). Pearling immediately became a boom industry, and the lugger became the most common vessel used during the pearl shell harvest (Figure 3-2). Luggers were bluff-bowed sailing vessels that ranged between 10 and 20 meters (35 - 65 feet) in length with a 3 to 1 length to breadth ratio. They supported two to three masts rigged with lug-sails, and were considered weatherly and dry (Chapelle 1951). Luggers were used in many other capacities around Darwin Harbour and the nearby rivers until very recently and served as inshore traders, lighters, and fishing vessels (Figure 3-3; Roberts 2005). The lugger *Brisbane* (ANSD 3388) was reported lost in Darwin Harbour in 1897.

The other small vessel common to historic Darwin was the cutter (Roberts 2005). Cutters were relatively small, single masted sail boats with a gaff-rigged mainsail (Figure 3-4; Chapelle 1935, 1951). They were much the same size as luggers, and were very valuable for navigating rivers and embayments that deeper drafted vessels could not reach. Cutters were often used to supply outlying river towns and farms (Roberts 2005). The cutter *Flying Cloud* (ANSD 3448) was lost in a gale in Darwin Harbour in 1894.

Fifteen additional wrecks of undetermined type were also lost between 1839 and 1939 (Table 3-1). These are *Ark* (ANSD 3366), *Africa* (ANSD 3363), *Black Jack* (ANSD 3383), *Cameo* (ANSD 3392), *Evangel* (ANSD 3441), *Gertrude* (ANSD 3450), *Hankow* (ANSD 3459), *Jack* (ANSD 3471), *Kathleen* (ANSD 3476), *Margaret* (ANSD 3500), *Midge* (ANSD 3510), *Olga* (ANSD 3523), *Olive* (ANSD 3524), *Spray* (ANSD 3570) and *Warrego* (ANSD 3588).

All manner of sail, steam, and early diesel/gas powered vessels plied Darwin Harbour between 1839 and 1939. The preservation of wrecked ships in the harbour, and the relative likelihood that they will be detected with a geophysical survey, is based largely on the construction elements of the individual craft, date of loss, and the benthic (sedimentalogical, biological, and turbic) environment in which they reside (Table 3-2). Evidence of large, iron hull steam vessels such as *Ellengowan* and *Brisbane* will linger in almost any environment, due to the amount of metal in, and mass of, the craft. These ships will be readily detected by most, if not all, sonar arrays and magnetometers. In fact, *SS Ellengowan* was positively identified by a geophysical survey conducted for INPEX in 2008 (Fugro 2008a).

The preservation and ability to detect wooden hulled vessels is dependent on the date of deposition, metal content, and depositional environment. Wooden hulls, even those of the larger barquentines and brigs, can be quickly broken by the violent currents endemic to the harbour channel. Even though there are thousands of pound of iron within even moderately sized wooden vessels, the fragmentation of the hull will greatly reduce the intensity of its magnetic signature and will make it harder to identify acoustically. Wrecks that lie exposed on the bottom, as opposed to those completely buried in sediment, will be reduced the fastest by current and will also be susceptible to sustained attack from aquatic wood borers.

The magnetic and acoustic signature of all wrecks will also be reduced through time, because the currents have had longer to tear the hull apart and the elemental composition of the iron components have been reduced through oxidation. The signatures of sailing vessels are also much more ephemeral than steam or diesel/gas powered craft, because the metal engines and associated hardware greatly enhance their magnetic signature, and also serve to stabilize the hull after sinking.

The craft from this time period that are most likely to be poorly preserved and overlooked during a geophysical survey are small, vernacular sailing craft lost between the mid-nineteenth and early twentieth centuries (Figure 3-5). These include cutters, luggers, small rowing dories, single masted runabouts, and small schooners and ketches. These vessels were often lightly constructed with less iron components, and are more likely to be hidden in the relatively shallow sediments of Darwin Harbour. Their magnetic signatures would also be reduced by oxidation, and they would have a greater likelihood of being severely fragmented by storm events and general current flow. These factors could result in a shipwreck with a dispersed, low to moderate amplitude magnetic signature that might be almost invisible acoustically (if buried or severely fragmented).

3.4 DARWIN DURING WORLD WAR II (1939-45)

The location of Darwin has been considered strategically valuable from a military standpoint since the nineteenth century (Carment 1996). The rise of Japan as a realistic threat to Australian national security in the 1930’s prompted the Australian government to construct a number of fortifications along East Point, including the installation of two, four, and six-inch gun emplacements and a series of machine gun posts. Army barracks were constructed in the Darwin suburb of Larrakeyah between 1937 and 1942, as was a Royal Australian Air Force (RAAF) base at nearby Winnellie (Carment 1996). Darwin Harbour itself was also protected against attack. Defenses included a six kilometer-long anti-submarine boom net, an underwater sonar system, and a signal station (Forster 2010).

The population of Darwin just before 1939 was estimated at roughly 6,000 people. Civilians were slowly evacuated and the community became a military town of 2,000 inhabitants shortly after war was declared. American and Australian naval ships and large merchant vessels and frequented the harbour, along with troop transports, cargo carriers, landing craft, and many different types of small boats (Frame 2009).

Allied military activity in Darwin attracted the attention of the Japanese Imperial Command during their massive push through the Pacific, and as a result Darwin was brutally bombed on February 19, 1942. A total of 242 Japanese aircraft attacked Darwin in three waves, the first beginning just before 10 AM. This sortie, which included bombers and Zero fighters, focused on land-based targets around Darwin, as well as the few aircraft that were able to mobilize against the attackers. The second sortie of 81 Kate torpedo bombers then concentrated on shipping in Darwin Harbour. A third sortie of 54 Nell and Betty bombers later attacked the nearby RAAF airfield. The attacks completely devastated Darwin, Darwin Harbour, and nearby towns. There is considerable debate as to the number of Allied dead, with estimates ranging between 250 and 1,100. Most historians number the dead at around 320, and the wounded between three and four hundred (Fugro 2008a; Frame 2009; Lockwood 1992). Twenty-three aircraft were also lost in the raid, including three United States Air Force (USAF) Catalina seaplanes that were sunk at their moorings.

Eight ships were sunk during the attack, including USS Peary, USAT Meigs, MV Neptuna, Zealandia, HMASD Mavie, SS Mauna Loa, MV British Motorist, and Kelat. The remains of all but HMAD Mavie still reside at the bottom of Darwin Harbour. MV Neptuna (ANSD 3517) was a 5,952 ton steam trader that exploded when a bomb ignited the 200 depth charges that she was carrying; 45 crewmen lost their lives in the blast. SS Zealandia (ANSD 3596) was a second steam trader that exploded when a bomb ignited her hold, instantly killing two crew. HMAD Mavie was 19-ton Royal Australian Navy (RAN) patrol boat that was sunk by a near miss; her crew of four survived. USS Peary (ANSD 3513) was a destroyer class naval vessel that was sunk when a Japanese bomb detonated near the forward magazine, instantly killing 80 sailors. British Motorist (ANSD 3389) was an English tanker that was in the process of refueling USS Peary when the raid started. USS Meigs (ANSD 3505) was an American transport that sunk when struck by two Japanese incendiary bombs. Kelat (ANSD 3477) was a steel-hulled clipper type sailing vessel that was serving as a coal carrier when sunk. Eleven of her crew were lost. USAT Mauna Loa (ANSD 3503) was a screw propelled steamboat of 5,436 tons. She was carrying a cargo of heavy vehicles, motorcycles, and armaments when she was sunk; five crewmen were killed.

In addition to the seven shipwrecks associated with the attack on the 19th of February, there are six other shipwrecks in Darwin Harbour from this time period, along with the remains of six Catalina aircraft not listed on the ANSD (Table 3-3). The two positively identified shipwrecks are Dawn (ANSD 3421) and the lugger Yampi Lass (ANSD 3592), which were lost in a gale in 1943. The remaining vessels are unnamed, including two steel barges lost in 1945 (ANSD 3427 and ANSD 3428), a harbour tug lost in 1942 (ANSD 3460), and a wreck called Lighter Number 2 (ANSD 3483), which was reportedly sunk by enemy action near Darwin in 1943.

The six Catalina aircraft in Darwin Harbour include the three American planes destroyed during the February 19th attack, and three RAAF seaplanes lost later during the war (Table 3-3). These aircraft are identified as two USAF PBY-4s (Catalina 5 and 6), a USAF 28-5MNE (Catalina 4), an RAAF PBY-5 (Serial Number A24-1), an RAAF PBY-5A (Catalina 2; Serial Number A24-69), and an RAAF PB2B-1 (Catalina 3; Serial Number A24-206).

Due to the high metal content and recent date of deposition of World War II era ships (and beyond) and aircraft, there is a very low likelihood that they would be missed by a systematic geophysical survey (Table 3-2). Geophysical surveys conducted for the INPEX project identified all six Catalina aircraft, along with Kelat and USAT Mauna Loa (Fugro 2008a).

Table 3-3. Aircraft Wreckage in Darwin Harbour (1939-1945)

Name	Identification	Description	Longitude	Latitude
Catalina 4	28-5MNE (#41)	A United States aircraft sunk during a Japanese air raid on February 19, 1942	130 53.897’	12 30.620’
Catalina 5	PBY-4 (#4 or #8)	A United States aircraft sunk during a Japanese air raid on February 19, 1942	130 54.169’	12 30.641’
Catalina 6	PBY-4 (#4 or #8)	A United States aircraft sunk during a Japanese air raid on February 19, 1942		
Catalina 3	PB2B-1 (A24-206)	RAAF seaplane sunk in 1945 by own depth charge, 2 killed	130 54.518’	12 29.791’
Catalina 2	PBY-5A (A24-69)	RAAF seaplane sunk at mooring in 1945	Unknown	Unknown
RAAF Catalina	PBY-5 (A24-1)	RAAF seaplane crashed in Darwin Harbour in 1945	130 31.148’	12 55.748’

3.5 DARWIN TODAY (1945-2010)

Darwin was almost completely destroyed by the raid on the 19th of February 1942. The rebuilding effort took years. The economy of Darwin shifted heavily towards mining in the decades after World War II, and became a major producer of gold, zinc, bauxite and uranium. It remains a vibrant mining community to the present day, with annual earning exceeding 2.5 billion dollars. The population of Darwin increased along with the development of mining and the municipal infrastructure. The population was below 3,000 in 1947, increased to almost 16,000 by 1961, jumped to 62,000 by 1981, and was over 120,000 by 2009. Darwin was granted city status in 1959, and is currently the largest city in, and capital of, the Northern Territory (Darwin City Council 2010).

The most significant event in the history of post-war Darwin was the destruction of the town by Cyclone Tracy on Christmas Eve in 1974. The cyclone battered the city with Category 4 winds, and was the most violent and compact storm to ever affect the Australian Basin. Tracy destroyed between 70 and 80 percent of the structures in the city, killed 71 people, and sunk an undetermined number of vessels. 30,000 of the 43,000 inhabitants were airlifted out of the city in the days following the storm (Bureau of Meteorology 2010). The reconstruction of the city took several years and millions in government funding. The second reconstruction in thirty years has made Darwin the most modern capital in Australia.

Fifteen shipwrecks lost during Cyclone Tracy rest in Darwin Harbour (Table 3-1). These are the *Arkham T* (ANSD 3367), *Bell Bird* (ANSD 3377), *Betty Joan* (ANSD 3381), *Blue Bird* (ANSD 3384), *Booya* (ANSD 3386), *Carina* (ANSD 3402), *Charles Todd* (ANSD 3405), *Chinta* (ANSD 3407), *Darwin Princess* (ANSD 3418), *Edwina May* (ANSD 3433), *Jenny Wright* (ANSD 3473), *Mandorah Queen* (ANSD 3494), *Nimrod* (ANSD 3519), *Rasta* (ANSD 3549), *Scallywag* (ANSD 3563), and *Waihoi* (ANSD 3585). *Nimrod*, *Chinta*, and *Edwina May* were detected during a survey conducted for the INPEX project in 2008 (Fugro 2008a). The *Chinta* (ANSD 3407), *Edwina May* (ANSD 3433), and *Nimrod* (ANSD 3519) were detected during surveys completed for INPEX in 2008 for the current project.

Shipping in modern Darwin Harbour has increased steadily since the war. All manner of vessels frequent the harbour every day, from massive, ocean-going container ships to small day-sailers and recreational fishing boats. There are thirteen shipwrecks dating between 1945 and 2010 documented in Darwin Harbour not associated with Cyclone Tracy (Table 3-1). These are *HMAS Arrow* (ANSD 3368), *Ataluma* (ANSD 3370), *Chang 1028* (ANSD 3403), *Con Dao 3* (ANSD 3408), *NR Diemen* (ANSD 3422), *Dsac* Barge (ANSD 3426), *John Holland* Barge (ANSD 3474), *Marchant 3* (ANSD 3498), *Song Saigon* (ANSD 3569), *Triumph* (ANSD 3577), an unnamed Chinese fishing boat (ANSD 3412), and two Vietnamese refugee boats (ANSD 3429 and 3430).

4.0 RESEARCH DESIGN

4.1 OBJECTIVES

The main objective of this study is to analyze and assess of the suitability of the survey methods employed within the project areas/development footprint to identify marine heritage places and artifacts and to assess if it is likely that marine heritage places were missed during geophysical surveys for the Ichthys Gas Field Development Project. These objectives were met through the completion of three tasks. The first task was to conduct an assessment of the suitability of each remote sensing instrument employed within the Project's nearshore and inshore development area for detection and identification of marine heritage sites and artifacts. The second task was a review of current shipwreck inventories to determine if there are any vessels reported lost in the vicinity of the project areas (and the Darwin Harbour region) that are not mentioned in the Draft EIS or other reports. This inventory contributes to a general maritime context of Darwin that reviews the most likely vessel types to be lost in the project areas by historical period, general ship construction materials, and also offers a basic assessment shipwreck preservation potential, based primarily on the geomorphological setting of Darwin Harbour. The third task is the re-analysis and evaluation of all available marine geophysical survey data to locate and identify, if possible, any potential cultural heritage resources not identified earlier. This re-analysis will help identify areas where additional geophysical survey is needed, if necessary.

The Ichthys Gas Field Development project is comprised of nine separate survey parcels, which are denoted as Blocks 1 through 9 (Table 4-1; Figures 1-1 to 1-8). These blocks encompass the portions of the pipeline within Darwin and the areas that will be impacted by the LNG Plant development on Blaydin Point. Blocks 8 and 9 considered possible alternative routing for the pipeline. The remote sensing data related to those two blocks are considered here for completeness reasons. The combined size of these survey parcels is 3,250 hectares (8,032 acres). These blocks are located within Darwin Harbour and its approaches.

Table 4-1. Fugro Hazard Survey Blocks

Block	Size (Hectares/Acres)	Corner Point	Easting (AMG 1984 Zone 52)	Northing (AMG 1984 Zone 52)
Block 1	585/1,445	North	703148	8619433
		East	707165	8616293
		South	706034	8615654
		West	702411	8618486
Block 2	476/1,176	North	709021	8618226
		East	709795	8616940
		South	707136	8615344
		West	706365	8616630
Block 3	200/494	North	709795	8616940
		East	710824	8615225
		South	709968	8614711
		West	708937	8616424
Block 4	49/122	Northeast	707448	8615532
		Southeast	707694	8613535
		Southwest	707446	8613505
		Northwest	707215	8616424

Block	Size (Hectares/Acres)	Corner Point	Easting (AMG 1984 Zone 52)	Northing (AMG 1984 Zone 52)
Block 5	16/40	Northeast	707028	8615530
		Southeast	706519	8614645
		Southwest	706390	8614721
		Northwest	706940	8615390
Block 6	255/630	Northeast	703817	8613847
		Southeast	703694	8612854
		Southwest	701211	8613161
		Northwest	701334	8614153
Block 7	1062/2,625	North 1	689984	8628243
		North 2	690379	8628550
		East 1	696025	8621283
		East 2	696945	8619412
		East 3	697795	8617219
		East 4	699373	8614143
		South 1	701303	8613905
		South 2	701242	8613409
		West 1	699049	8613679
		West 2	697338	8617014
		West 3	696486	8619210
		West 4	695599	8621016
Block 8	425/1,050	North	706229	8609112
		East	706694	8608433
		South	702388	8605485
		West	701924	8606163
Block 9	182/450	North	669207	8624628
		East	672077	8622415
		South	671771	8622019
		West	668902	8624232

The offshore disposal area is located approximately 15 kilometers north of Darwin Harbor. The block proposed as the disposal site measures approximately 7.0 by 3.0 kilometers, in size or approximately 2,070 hectares (5,115 acres). The approximate corner points of the disposal area are (based on AMG 1984 Zone 52):

- North (697821.12, 8649413.92)
- Northeast (700006.78, 8647317.19)
- South (695152.83, 8642254.20)
- Southwest (692997.45, 8644334.63)

4.2 METHODS

4.2.1 Cultural Context and Shipwreck Inventory Research

The purpose of background research is to develop cultural contexts for identifying and evaluating maritime cultural heritage items encountered within the project area. Background research was also conducted to development a current list of shipwrecks in Darwin Harbour.

Research was conducted at the National Archives in Washington, D.C. Reports of previous maritime cultural resources investigations within Darwin Harbour were obtained from INPEX and reviewed. Other sources were obtained from the URS Maritime Archaeology Library in Gaithersburg, Maryland. Research for the shipwreck inventory was conducted online by contacting the following:

- The Register of the National Estate
- National Heritage List
- Commonwealth Heritage List
- World Heritage List
- Northern Territory Heritage Register
- Archaeological Sites Register Database
- Australian National Shipwrecks Database
- Northern Territory Shipwreck Database
- Admiralty and US Naval Shipwreck and Magnetic Anomaly Database

The only online database that yielded data regarding shipwrecks currently resting in Darwin Harbour was the Australian National Shipwreck Database. The Northern Territory Shipwreck Database was not accessible and/or functioning during the current research. The results of that research are found in Table 3-1.

4.2.2 Remote Sensing Instrument Suitability Assessment

Marine geophysical survey data obtained from Fugro, EGS, INPEX, and URS was reviewed and five environmental and geophysical reports were reviewed to assess the suitability and limitations of the survey methods. The instruments to be reviewed for this assessment of survey system applicability are multi-beam bathymetry, side scan sonar, magnetometer, sub bottom profiler, and other high resolution shallow seismic methods. As a part of the assessment, each remote sensing method used was reviewed to address the type of data created, the data resolution, frequency, range settings, beam angle, and the appropriateness of these instruments for recording potential shipwrecks and other maritime heritage resources. The assessment will take into account the efficacy of all methods used to adequately identify low amplitude/relief shipwrecks.

The remote sensing suitability assessment also addressed the recorded or suspected shipwrecks identified in the database research, particularly the likelihood that these resources would have been recognized using the different remote sensing arrays employed during the Project remote sensing surveys. The reports reviewed during this task are:

- Report on the Ichthys Field Development, Darwin Harbour, Geophysical Site Surveys 2008. Volume 1A: Results (Fugro 2008a)
- Report for the Ichthys Field Development, Darwin Harbour, Geophysical Site Surveys 2008. Volume 2: Survey Operations (Fugro Survey Report No. P0804; Fugro 2008b)
- Report on the Seismic Refraction Survey Ichthys Gas Field Development, Darwin Harbour, Northern Territory. Volume 1: Results (Fugro Survey Report No. P0916; Fugro 2009a)
- Report on the Offshore Pipeline Route Unexploded Ordnance (UXO) Survey, Volume 1: Survey Results (Fugro Survey Report No. P1049; Fugro 2009b)

- 2009 URS Dredge Material Disposal Area Survey: Side Scan Sonar and Echosounder Survey Final Report (EGS 2009 [for URS])
- Neptune Report Nearshore Unexploded Ordnance and Debris Survey 2010 (Report No.: 10A541-RR-001-R0)

4.2.3 Remote Sensing Re-Analysis

URS then completed a re-analysis of the Fugro Hazard Survey data to locate potential cultural heritage places and objects not identified earlier. The boundaries of the survey areas were then evaluated in comparison to the proposed footprint of the Project to identify areas where additional survey may be needed to minimize the potential to encounter submerged cultural heritage items during the construction phase.

The majority of digital survey data was managed via Geographic Information System (GIS). Data layers were required from the existing project GIS to accomplish the re-analysis tasks. Geospatial data were be kept in the existing project projection.

4.2.4 Side Scan Sonar Analysis

A visual field examination of side scan sonar data was conducted to look for anomalous and/or angular returns, reflective surfaces, and sediment textural variation that may represent a potential cultural heritage places or objects. Images of any such items were captured along with positioning data. The anomalies were then assigned an anomaly designation and were listed in an acoustic anomaly table, along with all relevant data.

4.2.5 Magnetic Data Analysis

Two types of magnetic data re-analysis was conducted during this portion of the study. Gradiometric data was reviewed in terms distance and time to determine if any magnetic anomalies could represent a potential cultural heritage place or object. The second type of analysis reviewed whole earth readings, which included identifying discrete magnetic anomalies and evaluating their potential to represent cultural heritage places or objects based on a defined set of criteria. The magnetic anomalies were evaluated based on the change in magnetic gradient away from the center of the anomaly, the amplitude of the total magnetic field nanoTeslas (nT), and magnetic signature. Magnetic signatures were denoted as dipoles, monopoles, or multi-components.

Positive and negative monopoles refer to one half of a dipolar perturbation, and usually indicate an isolated magnetic source located some distance from the sensor. Monopoles produce either a positive or negative deflection from the ambient magnetic field. The polar signature depends on whether the positive or negative pole of the object is oriented toward the magnetometer sensor. Dipolar signatures display both a rise and a fall from the ambient field, and they are generally associated with single source anomalies located directly under the magnetic sensor. Multi-component magnetic perturbations represent several, randomly scattered ferrous objects with different magnetic orientations. Anomalies with these signatures are likely associated with man-made objects, possibly shipwrecks. The last two criteria are the location of the anomaly center, and the distribution and patterning of anomalies within the survey area.

5.0 RESULTS AND CONCLUSIONS

INPEX commissioned URS Australia Pty Ltd. to conduct a review of the suitability and limitations of the survey methods employed within the Project's nearshore and inshore development footprint to identify marine heritage places and artifacts. The main goal of this review was to determine each remote sensing instruments' ability to discern low amplitude shipwrecks, and identify where additional geophysical survey may be required. INPEX also requested a re-analysis of previous survey data from the project area. The main goal of this re-analysis was to identify potential cultural heritage places and objects not previously noted during the original data review. The results of these separate tasks are reviewed below. Results of the remote sensing instrument suitability assessment are presented first, followed by the findings of the data re-analysis effort.

5.1 REMOTE SENSING INSTRUMENTS SUITABILITY ASSESSMENT

Ten remote sensing instruments were reviewed during this suitability assessment. All of these instruments were used during the remote sensing hazard surveys as reported in the five geophysical reports submitted to URS (Fugro 2008a, 2008b, 2009a, 2009b, and EGS 2009). Instrument types reviewed include Global Positioning Systems (GPS), motion reference units, single beam echo sounders, sound velocity meters, multi-beam echo sounders, multibeam pseudo backscatter side scan sonar, side scan sonar, sub-bottom profilers, gradiometers, and seismographs. These will be divided into navigation instruments and geophysical instruments.

5.1.1 Navigation Instruments

Global Positioning System

Geophysical surveys collect data that are corrected for position by recording antenna and transducer positions on the survey vessel, and by calculating the location of the data through global positioning satellite systems (GPS). These systems calculate the position of the vessel in real time by measuring the arrival time of radio signals from geostationary satellite constellations. Each satellite transmits a signal that includes the position, along with that of the other satellites in its constellation. The GPS receiver onboard the survey vessel receives time signals from several satellites and calculates a best fit position. Several high resolution corrections are made to the position based on the position of other fixed radio beacons and time stamps (Starfix differential beacons; Jones 1999). Offset measurements to all sensors used in the survey are measured from the reference antenna in both the horizontal and vertical plane; these are used to correct the sensor position via computer integrated navigation and data collection software. Accuracies of these systems have reached centimeter resolution in real time, and allow geophysical data to be collected with very high position resolution and repeatability in severe weather.

Motion Referencing Units

Ship navigation and the geophysical sensor positions in the X, Y, and Z axis (heave, pitch, roll and yaw) have to be corrected during marine geophysical surveys because they are conducted on moving vessels that are affected by wave motion. This is achieved with motion reference units (MRUs) and gyroscopes. MRUs operate by measuring the acceleration in all three planes through combinations of accelerometers and gyroscopes placed over the sensors and onboard the vessel. Vessel movements are recorded by these devices and sent to the data collection computer for integration with sensor data. Data collection software take the MRU positioning and correct the antenna position and collected data by subtracting the motion (time and direction) from the data sets (US Army Corps. of Engineers 2002). Gyroscopes are used to calculate heading by measuring changes in angular momentum based on the location of true north. Mechanical gyroscopes are being replaced by duel high precision GPS units that can make corrections based on satellite corrections and fixed distances between antennas.

The quality of positioning during all phases of the INPEX surveys is considered to be sub-meter. All of the equipment was state-of-the-art, with multi layer redundancy. Complete discussions regarding each individual positioning instrument are found in the following reports:

- Report on the Ichthys Field Development, Darwin Harbour, Geophysical Site Surveys 2008. Volume 1A: Results (Fugro 2008a)
- Report for the Ichthys Field Development, Darwin Harbour, Geophysical Site Surveys 2008. Volume 2: Survey Operations (Fugro Survey Report No. P0804; Fugro 2008b)
- Report on the Seismic Refraction Survey Ichthys Gas Field Development, Darwin Harbour, Northern Territory. Volume 1: Results (Fugro Survey Report No. P0916; Fugro 2009a)
- Report on the Offshore Pipeline Route Unexploded Ordnance (UXO) Survey, Volume 1: Survey Results (Fugro Survey Report No. P1049; Fugro 2009b)
- 2009 URS Dredge Material Disposal Area Survey: Side Scan Sonar and Echosounder Survey Final Report (EGS 2009 [for URS])
- Neptune Report Nearshore Unexploded Ordnance and Debris Survey 2010 (Report No.: 10A541-RR-001-R0)

5.1.2 Geophysical Instruments

Single Beam Echo Sounder

One of the oldest marine geophysical instruments used to investigate the seafloor is the single beam echo sounder (SBES). This instrument transmits an acoustic pulse that travels down to the seafloor and reflects back to the transducer, which calculates the pulse signal strength and first arrival (E1; Lawrence et al. 2002). Frequencies used by these units can vary in spectrum from a few kilohertz (kHz) to megahertz (MHz). A general rule used in acoustic surveys is that image resolution increases as frequency increases, but the distance or penetration of the acoustic energy decreases as it moves away from the transducer. This simple rule governs how all acoustic geophysical instruments work.

The average speed of sound traveling through water is measured at approximately 1,500m/s (Jones 1999). This speed changes based on factors of water temperature, salinity, and pressure. The depth to bottom is calculated as half of the total travel time, as corrected for transducer depth, salinity, and the effects of temperature.

The area beneath the transducer that is ensonified by the echo sounder is cone shaped. The area of this ensonified cone is calculated by taking the tangent of the transducer beam angle (Φ) multiplied by the measured water depth. If the echo sounder records 20 m of water with a beam angle of 10 degrees, the total area ensonified would measure (Tan 10 degrees) = 0.176 x 20 m = 3.2 m. The acoustic returns from this area are averaged to a single depth value. The typical resolution for an echo sounder using a 10 degree transducer with a frequency of 210 kHz is 10 cm, which means the beam has the ability to discern two objects spaced 10 cm apart. The quality of resolution is also based on the number of times the bottom is sonified while the survey vessel moves forward. This is determined by the number of times the transducer transmits an acoustic pulse (Ping Rate) and the depth range settings of the echo sounder. The typical ping rate for shallow water survey using a frequency of 210 kHz, and a 10 degree transducer set with a 50 m range is 15 pings per second. This is used to calculate the data density collected by a vessel traveling between 4 and 4.5 knots (±2.0 - 2.4m/sec), which would yield 2.4m/s ÷ .25Hz = 1 reading for every 0.16 m (16 cm) horizontally traversed by the survey vessel.

Duel frequency single beam echo sounders use low frequency acoustic transducers usually around 33 kHz, and a 20 degree beam angle to measure beneath flocculent sediments on the seafloor to reflect the depth of the shallowest cohesive sediment layer. The high frequency transducer is used in conjunction with the low frequency transducer to record the surface of the flocculants. The thickness of flocculants as well as the true sea floor depth is then calculated. The overall resolution of the systems used for these surveys are on the order of 10 – 16 cm, given the likely average speed of 2.0 - 2.5 m/s.

Sound Velocity Meters

All acoustic survey methods depend on sound speeds as transmitted through water. The ideal speed is calculated at 1,500 m/s, but variances in salinity, temperature, and pressure can change the speed and induce errors that must be filtered and correct.

To account for these variables, a sound velocity meter is used to measure the time it takes a sound pulse with a known frequency and wavelength to travel across a known distance. The device is lowered into the water column and a velocity measurement is taken at set intervals until a complete table of velocities versus depth has been created. These data are then averaged, which creates an averaged water velocity (US Army Corps of Engineers 2002). This process is called “taking a cast.” The average water velocity is then entered into the survey equipment to correct for local variation. The speed correction is then validated by use of a bar check. Bar checks mechanically block the acoustic pulse at fixed depths by suspending a metal plate beneath the transducer and recording the depths (US Army Corps of Engineers 2002). If the bar check does not reflect the measured depth beneath the sensor, then the velocity measurements need to be repeated until both coincide.

Sound velocity meters are also used to calibrating all other acoustic instruments, including multi-beam echo sounder, side scan sonar, interferometric (pseudo side scan backscatter) side scan sonar, sub bottom profilers (pingers or chirp) and towed seismic system (boomers). This ensures highly precise beam angle measurements and arrival times.

Multi-Beam Echo Sounder

Multibeam echo sonar (MBES) can be thought of as several hundred individual single beam echo sounders working in unison tens of times per second to measure individual data points along the seafloor in a cross fan pattern. Travel time estimates are converted first into slant ranges and then to depths by applying beam angle and sound velocity profile data (US Army Corps of Engineers 2002). Beam spacing for interferometric multibeam systems usually fall between 0.5 and 3.0 degrees. Smaller beam angles result in greater resolution.

The ensonifinied swath is then visualized as thousands of points that are defined by their respective signal characteristics (amplitude, frequency, slope angle, and phase). Each point reflects the physical nature of the seafloor surface (US Army Corps of Engineers 2002). The MBES software can process this data into a point cloud bathymetric map, or use the data to create output that is commonly referred to as pseudo side scan sonar.

Interferometric, or phased array, MBES systems work on the principle of beam direction as measured by the time it takes for the beam to be detected by the different receiving staves of the MBES head. The phased difference is calculated by the equation: Sin Φ = C/FD * Θ/360°, where C = acoustic velocity, D = array stave spacing, F = signal frequency, and Θ = the phase shift between arrival times on two different staves (US Army Corps of Engineers 2002). This equation is used to calculate thousands of phase shifts per signal. Phasing is then converted to an angle relative to a perpendicular, while also recording the physical properties of the seafloor. The processor software then converts phase differences into beams. There are no physical beams in a phase system, but phased data is collected from all directions and processed simultaneously. The theoretical swath coverage of the Geoacoustic system is 240°, with a range measuring 12 times the water depth.

The strength of an interferometric system is that there is little outer beam distortion, which is commonly found with other non-phase systems. Beam angles can also be steered via software processing to compensate for vessel motion and beam spread. Depth resolution is limited by the computational limits of the hardware (US Army Corps of Engineers 2002). The weakness of the interferometric phased MBES is that phase tracking processing can become overloaded and unstable, which causes anomalous data and resolution (US Army Corps of Engineers 2002). The first issue can be address by the use of an SBES to track the bottom depths and cross check the validity of the phase angle depth calculation. This method was used during the first part of the harbour survey to monitor and validate incoming data. The second issue will be addressed as computer processing speeds and dynamic data storage increases with time.

Once the depth point cloud data is collected, it is processed to create digital terrain maps (DTM) that are usually thinned (binned) to one meter squares by averaging all point data within each square. This reduction in data boosts computational speed, visualization, and also removes redundant data points (US Army Corps of Engineers 2002) at the expense of resolution. The selection of bin or cell size is based on terrain irregularity or the amount of topographic change over the seafloor. Binning at 1.5 m or more cell size may reduce the resolution of the DTM beyond usable scales for locating marine cultural heritage sites or objects. The multibeam echo soundings collected for this project were binned using a 1.0 meter square cell size. A 0.5 m cell size was employed around reported wrecks or obstructions. This renders the overall DTM resolution to 1.0 meter cells, which in turn are averaged to the shallowest depth within a few centimeters elevation.

Multibeam Pseudo Backscatter Side Scan Sonar

Early multibeam pseudo backscatter side scan sonar was not thought to be as effective as towed side scan sonar sensor for the recording of shadows. In part because the frequencies used by backscatter units were not as high as those used for high-resolution side scan surveys. This was due to the hull mounting of phase array systems, which led to a high grazing angle that creates poor comparable sensor geometry. The modern interferometric side scan systems used for this survey (Geoswath 250 kHz) produced a 6.7 cm resolution at 2.0 m/s, but it is assumed that this is along the center portion of the theoretical beam spread, which increases to 13.3 cm along the outer margins of the beam. These resolutions are adequate for resolving the overall bathymetric elevation changes associated with potential shipwrecks or other partially buried cultural heritage items, and also creates adequate side scan coverage.

Side Scan Sonar

Side scan sonar is an acoustic imaging system that dates to World War II. Like MBES, it is another acoustic method of imaging the seafloor by pulsing acoustic energy in a band or swath to either side of a transducer.

Acoustic energy travels at an angle based on the sensor height above the seafloor; it is then reflected back specularly. This means that the angle of the incoming acoustic pulse is reflected back on the same, coplanar angle as the transducer. The distance the beam travels to the seafloor is the slant range, while the distance from directly beneath the sonar along the seafloor to the intersection is the ground range (Blondel and Murton 1997). Like pseudo side scan sonar, the total distance that is ensonified is known as the swath width. The range of each channel is one half the total swath distance. The beam angle is measured both in the horizontal and vertical. In the case of the Geoacoustics Model 159D and the Edge Tech FS 4200, both were operating at 410 kHz, with similar horizontal angles at 40 degrees and vertical beams at 0.3 and 0.4 degrees respectively. The main beam axis is looking down between 10 and 20 degrees, which means that the greatest portion of the acoustic pulse is focused at that angle towards the seafloor. Side scan sonar resolution is a function of an object's location as it relates to the across track distance and the along track direction of from sonar, and acoustic frequency used (410 kHz). If the object is near the transducer where beam spread is minimal, two objects can be easily differentiated, but if the objects are near the edge of the swath, sonar beam spreading may cause objects to be recorded as a single mass (Fish et al. 1990). The ping rate of the sonar system will determine the area between two pings in relation to the forward movement of the transducer. Complete coverage of the seafloor depends on the transducer length, vessel speed and the ping rate at the selected range (Jones 1999). The maximum ping rates for both the Geoacoustics 159D and the Edgetech FS 4200 are between 40 - 50 pings per second, which would allow the complete ensonification of the selected range at vessel speeds of over 6 m/s.

The geometry of the side scan transducer to the seafloor is extremely important; it ensures that resolution is optimized for image recordation. Optimal geometry for side scan systems is described as 10 – 20 percent of the range above the seafloor as measured from the center of the main acoustic lobe (Jones 1999). Beam focus and reflection are adversely affected by vessel motion translated through the tow cable. This is corrected by the use of MRUs to calculate the surface vessel motion and apply the corrections to the incoming side scan sonar data.

The resolution of the Geoacoustics Model 159D side scan sonar array yielded approximately 10 – 13 cm, given the frequencies used and the speed at which it was recorded. The EdgeTech FS 4200 has a 0.6m resolution along track, and a 2.0 cm resolution across track. These resolution ranges are more than adequate for imaging buried cultural heritage items where the size of the smallest item is between the 2 to 10 cm limits.

The ability of side scan sonar to record sediment hardness (E2) and reflectivity (E1) through back scatter also allows reviewers to discern changes in sediment composition (Collier 2005). The change in bottom roughness is based on sediment grain size. The bottom roughness acts to scatter the acoustic pulse in all directions with a small portion reflected back to the sonar unit (Mazel 1985). The strength of the returning signal is a function of bottom roughness and angle of incidence. The back scatter can be used to map textural changes where grazing angles fall between 20 and 40 degrees (Collier 2005). These data can discern changes in sediment grain size with high spatial resolution and, in conjunction with other geophysical instruments (magnetometer and high frequency sub bottom profilers). This method was used to aid in the mapping of sediment textural changes that occurred in the survey areas, and was assessed for potential anomalous sediment changes that could be associated with buried cultural materials.

Sub Bottom Profilers

The Sub Bottom Profiler (SBP) is an instrument that produces acoustic images of high resolution seismic data for use in sub-surface exploration. SPBs were developed in the early 1960s by Dr. Harold Edgerton at the Massachusetts Institute of Technology (MIT). Edgerton was working with the principles of echo sounders and acoustic impedance of sound waves as they intersect with various media. SBPs typically use vertically arranged sound beams with frequencies ranging between 10 - 200 kHz. The sound pulse travels to the seafloor, and is reflected back to the surface like an echo sounder. The low frequency of the acoustic energy causes a portion of the sound pulse to travel through the sediment package, and reflects a portion of the energy as it crosses new sediment layers/interfaces where there are sufficient variations in acoustic impedance. Acoustic impedance is related to the density of the sonified material, and the speed at which sound travel through it. When the SBP fires an acoustic pulse, the receiving transducers/ hydrophones activate and begin to record the travel time and amplitude of each echo (Jones 1999). A greyscale image is then assembled that measure changes of acoustic impedance, and displays these changes as sediment layers or strata.

The resolution of SBP is determined by acoustic energy output, pulse length, and sound frequency. Good acoustic images that display structure within the sediment are created where the acoustic power (in joules ([j]) is high enough to drive the signal into the sediment. The employment of too strong a pulse will reflect the majority of energy back from the surface only and will overwhelm the returning acoustic signals in reverberations or multiples. The acoustic pulse length also controls the resolution of the image. Long pulse lengths push greater energy into the sediment, but long pulse lengths will not resolve strata thinner than one forth the pulse length ($\lambda/4$). Reflectors are clearly recorded when their thickness exceeds $\lambda/4$ (Jones 1999). Resolution is also affected by the frequency of the sound pulse. Lower frequency sound can penetrate deeply into the sediments, but loses the ability to discern small features due to wave form. Unfortunately, high frequency sound energy is quickly absorbed by marine sediments, so only the shallowest 20 meters of sediments can be reliably imaged. Horizontal resolution is a function of shot interval/ping rate, the distance between hydrophones in the receiving array, and the sound frequency. Shorter hydrophones spacing will yield higher resolution with high frequency sound waves (Jones 1999).

For archeological purposes, medium to high frequency (2 – 30 kHz) acoustic energy is a good range for resolving the top 4-5 meters of sediment, where marine cultural heritage is likely to be found. The INPEX surveys used an Applied Acoustics boomer system to create high resolution sub bottom profile images throughout the Darwin Harbour survey areas.

The Applied Acoustics SBP consisted of a CSP-1500 surface control box used to set the projection range of the returning data (2 – 100m), the rate of pinging (250ms) and the energy (100 joules) used to create the acoustic sound pulses of the boomer plate. The AA301 boomer plate can operate between 50 – 350 j, with a frequency range of 500 Hz – 6.0 kHz. The boomer was tested at 100 j during survey mobilization and recorded a 0.175ms pulse length (λ). The hydrophone array that recorded the returning echoes was a 20 element (hydrophone), single channel string with a sensor spacing of 120 mm, and a frequency response of 145 Hz – 7.0 kHz.

The assumed velocity of sediments in the harbour was 1600 ms, based on sediment sampling and down core velocities. Given this velocity, the SBP would have recorded normal variations in velocity associated with unconsolidated marine sediment comprised of siliciclasts with velocities of 1,518 – 1,800 ms (Jackson et al. 2007). Anomalously high speeds from cultural materials such as iron (5,131ms) or wood (3,300 – 3,600ms, Witten 2006) would have been recorded when the sensor passed over them.

This SBP system, using the settings described in the geophysical report (Fugro 2008b), would have had a vertical resolution of 15 – 20 cm, with a ping every 0.5m. Given this resolution, the SBP system would be able to record sediment speed variations with high enough resolution to record buried elements of a shipwreck.

Gradiometer

Magnetometers are used to measure the strength and direction of magnetic fields. The use of marine magnetometers did not begin until the mid 20th century, when British and American scientist began to develop boat-towed magnetometers that were used in conjunction with acoustic instruments to locate enemy submarines. From these early designs, magnetic surveying instruments have been developed that can measure minute amounts of ferrous material while traversing the seafloor. The theory behind magnetic survey is based on the earths' magnetic field generated by its metallic core (Jones 1999:162). The output of this metallic core is measured to determine the strength of the Earth's total magnetic field (F) in comparison to other material that generate a magnetic field. Since there are several axes of force, magnetic intensity (which is measured in nanoTesla, nT) is a product of the sum of all the force vectors acting on the two interacting dipoles (Jones 1999:162).

Standard magnetometers only record the total field value of the magnetic field as it is affected by several factors. The Earth's magnetic field is affected by the sun's magnetic field when there are sun spots and solar geomagnetic storms. These events can cause the Earth's magnetic field to shift as much as 1,000 nT for periods of seconds to hours (Witten 2006:86). Magnetic diurnal variation is caused by the charged particles that comprise solar wind, which impinge the Earth's magnetic field by creating current flow and inducing a radical magnetic field shifts (Whitten 2006:86). These shifts increase and decrease as the earth rotates in relation to the magnetic pole. The mineralogical makeup of basement rocks and marine sediments is another source of magnetic disturbance. Sediments and bedrock composed of ultra basic or metamorphic materials have greater amounts of minerals that can induce magnetic field shifts. Areas comprised of shale and sandstone with stratigraphic folding create layers of metamorphic minerals such as gneiss. These mineral groupings can also create magnetic field deflections.

Sedimentary rocks composed of material that have been sorted by wave and currents could have pockets of magnetic minerals deposited on the lee side of sand waves or in ripple troughs. As the magnetic sensor passes over these areas, change in magnetic susceptibility would create an undulating magnetic field. All of the aforementioned magnetic field disturbances must be filtered from the raw data to ensure that the data being analyzed reflects pure shifts in the Earths' magnetic field resulting from the presence of cultural objects, and not those that have been induced by natural processes. Other problems that occur using a single magnetometer are changes in sensor altitude and orientation in relation to the seafloor, which can cause an increases or decreases in the earth magnetic field.

The use of gradiometers reduce or completely remove the majority of these deflections and allow for greater accuracies is magnetic mass and location calculations. Gradiometers are comprised of multiple magnetometers arrayed so that the magnetic force vectors are recorded in the horizontal (X), longitudinal (Y) and vertical (Z) axis for each magnetic sensor and summed to create a total gradient value (Pozza et al. 2003:5).

The fundamental operation of the gradiometer is to measure the magnetic field in each magnetometer, and subtract the recorded magnetic field to arrive at a gradient value. The gradient value is not affected by solar storms or diurnal variation. Most magnetic interference can be removed when calculating gradients, but the effects of sediment composition cannot be fully isolated, due to the nature of weathering and mineral deposition.

These factors can mask small ferrous objects when the magnetic field is shifting with every reading. Fortunately, lateritic deposits tend to form highly cemented beds where materials deposited on them stand out in the visual field and can be easily recorded by acoustic methods.

A SeaQuest 4 sensor marine gradiometer was used by Fugro during their surveys of Block 7 to identify potential unexploded ordinance (UXO) from several Japanese attacks on Darwin Harbour during World War II and other naval training actions within the project footprint. This system consisted of four magnetometers mounted in an array that measured the horizontal, vertical, and longitudinal gradients simultaneously. Each sensor has a sensitivity of 0.1 nT, with a tilt and depth sensor recording the orientation of the magnetometer during each reading to facilitate precise vector calculations. The gradiometer position was tracked and position corrected by a Sonardyne Fusion Ultra Short Baseline (USBL) sonar system that measures the azimuth and distance to the center of the gradiometer with an accuracy of 1.0 meter. When the USBL data is combined with the cable out measurements and catenary angle corrections, the position of each reading is sub-meter. Since magnetic field strengths diminish proportionally to the inverse cube of distance, the gradiometer was kept at a set depth within 1.5 meters of the seafloor. To do this a clump weight was attached to the cable in front of the sensors so the required depth was maintained. The gradiometer was set to take one reading every 0.5 seconds (2 Hz), with an average vessel speed of 2 m/s. This yielded one complete gradient measurement every meter at a 0.1 nT sensitivity. This could identify ferrous objects exceeding a weight of 0.5 kg. Lane spacing was 3.0 meters across a 40 m pipeline construction right-of-way for complete coverage inside the corridor, and several meters along the corridor edge. Because the gradiometer had clump weights riding on the seafloor (this was to keep the sensors at a fixed elevation off the bottom), all wrecks and obstructions were avoided by a 50 m buffer area in order to do no damage to the wrecks and to avoid fouling.

INPEX Browse contracted Neptune Geomatics Pty LTD (Neptune) to conduct additional high resolution nearshore geophysical surveys in portions of Block 1, located between East Arm Wharf and Wickham Point (Figures 1-4 and 1-5). Block 1 will have substantive amounts of dredging to facilitate the extension of the shipping channel from the East Arm Port to the proposed product loading facilities on Blaydin Point, a turning basin for large vessels transiting to and from Blaydin Point facilities, as well as other ship birthing and associated channels.

Neptune designed their survey to encompass the areas to be dredged with some extension beyond the areas of direct effect to insure there was enough coverage to locate any potential UXO adjacent to each of the five dredge areas (Blocks A-E). The overall survey block measured approximately 2,726 m long and 340 m wide, for a total of approximately 131.5 hectares (Figure 1-5). The survey equipment used for these studies included an EdgeTech 4200-FS 410kHz sidescan sonar, Geometrics G-882 Transverse Horizontal Gradiometer (TVG), Kongsburg MST acoustic beacon, and Sonardyne Fusion USBL acoustic beacon system.

The magnetic survey was carried out using a Geometrics G882 marine gradiometer. This instrument consists of two G882 magnetometers mounted on a fixed wing with each unit recording the total earth magnetic field, altitude and depth of the sensors. Diurnal magnetic variation ranged from -10 nT to 50 nT, and was controlled by applying a magnetic correction from a fixed earth station sampling at one minute intervals. The system was operated within 2 meters of the sea floor. A 10 Hz sampling rate was selected for the survey, which yielded five full sensitivity readings per meter while the survey vessel operated at 2 m/s. The survey transect spacing for the magnetic survey was 5 m with 108 primary lines run, which yielded 166.2 km of magnetic data.

The position of the gradiometer was controlled by the use of a Sonardyne Fusion Ultra short baseline (USBL). The Sonardyne system operated with a 90 degree sensor on the vessel and an acoustic transceiver on the gradiometer array. This system has an accuracy of 1 meter at 1,000 m when operated at 2 m/s (Table 6.1).

Seismograph

Seismic refraction is another method that uses acoustic energy to measure the return time of returning echoes. A travel time versus distance graph is created from these data, and is used to measure the thickness and velocity of sediment layers. Refractive surveys measure the travel times of critically refracted (near horizontal) body waves at fixed distances along a baseline (Jones 1999:64). Hydrophone spacing allows the resolution to be corrected even as the vessel travels along the baseline. A continuous high resolution cross section can be constructed by using a high frequency sound source (small high pressure air gun) coupled with a tightly spaced hydrophone array long enough to record a complete sequence of arrival times. This type of seismic system is referred to as a continuous recording system. Fugro employs a system that they refer to as Continuous Refraction Seismic Profiling (CRiSP).

The sound source used for this survey was a 5 cu inch high pressure (1,000 psi) 250 Hz air gun that fired every 4 seconds (0.25 Hz) along transects spaced at 25 m. There were two 24 channel hydrophone arrays used, measuring 32 m and 50 m in length with equally spaced hydrophones (32 m = 1.3 m spacing, 50 m = 2.08 m spacing). Both the air gun and the sound source were towed together approximately 1.0 m above the seafloor. The towing configuration used a heavy wire rope to weight the cable in front of the air gun and hydrophone array so that they would remain at a consistent depth.

Some of the problems encountered with refractive seismic reflectivity are associated with sound propagation through sediment layers with faster surficial velocities and slower sub-surface velocities. Higher velocity surficial layers are not recorded due to velocity inversion. Some thin layers are also not recorded because they do not create enough travel time over distance to be differentiated in the time/distance layer calculations. The resolution for the Fugro's CRiSP system using Geometric's seismographs is approximately 1.3 m (using a frequency of 250 Hz), and the horizontal resolution is approximately 5.0 m. Given the potential problems of thin layer (vessel remains) resolution with a seismic system that has a maximum vertical resolution of 1.0 m, the seismic survey data may be too coarse for resolving small items. Only the largest remains would be recorded as anomalously fast, or hard structures within the sediment package. The spatial resolution of the seismic data is also very coarse, given the seismic data was collected at 25 m.

5.2 SURVEY DATA RE-EVALUATION

Six types of remote sensing data were reviewed during the re-analysis effort. These included side scan sonar and multibeam data, magnetic (gradiometric) data, sub bottom profiler data, multibeam bathymetric data, and single beam bathymetric data. These data originally were gathered in 2008 and 2009 (Fugro 2008a, 2008b, 2009a, 2009b; and EGS 2009).

5.2.1 Side Scan Sonar and Multibeam Data

Numerous acoustic anomalies were recorded within and in the vicinity of the project area (Appendix B). These anomalies were recorded by Fugro during their 2008 survey of Darwin

Harbour, by EGS during their 2009 survey of the Dredge Material Disposal Area, and by Neptune during their nearshore UXO survey in 2010. Data collected by Fugro, EGS, and Neptune were re-analyzed to identify any additional anomalies that might be cultural heritage places or objects. One additional anomaly with the potential to represent a submerged cultural resource was encountered during the re-analysis. A more detailed discussion of the acoustic anomalies in each of the 10 survey areas is presented below.

Block 1

Two side scan sonar surveys were completed on Block1. The first survey, by Fugro (2008a and 2008b) encompassed the entire block. A second survey conducted in 2010 by Neptune was focused on the identification of UXO in this area; additional side scan data were collected during that UXO survey.

Fugro identified 16 anomalies within survey Block 1 (Appendix B). These consisted of three Catalina aircraft, the tail section of a Catalina, seven shipwrecks, two mooring blocks, a small unidentified object, a rectangular steel object, and a newly identified anomaly that may represent a shipwreck. Review of acoustic data provided by Fugro confirmed the presence of a number of these anomalies, but could not confirm all of them.

The location of the three Catalina seaplanes, noted as Catalina 4, 6 and the "missing Catalina" in the Fugro reports, was confirmed at the recorded coordinates. Catalina 6 and the "missing Catalina" reside at the same coordinates and refer to the same plane. Rectangular blocks that may represent mooring blocks are located approximately 63 meters off of each wing. The previously recorded Catalina tail section was also confirmed. There also is a rectangular steel object noted as buried in the same position as the tail section. This object may be debris associated with the tail section, if it is not the tail section itself. The location and identity of the two mooring blocks identified in the Darwin Harbour survey (2008) were confirmed.

Seven shipwrecks are recorded as possibly located within Survey Block 1. *Kelat* (ANSD 3477) and a steel barge, which were located 1908 and 885 meters southeast of the northern point of Block 1, respectively, were visible. The five additional shipwrecks, *Leichardt* (ANSD 3481), *Nimrod* (ANSD 3519), *Spray* (ANSD 3570), *Chinta* (ANSD 3407), and *Edwina May* (ANSD 3433; Appendix B), are listed in the ANSD in the same location. No shipwrecks were apparent upon review of this exact location; these wrecks may be located in the general vicinity of the given location or they were plotted in this location in the ANSD as a general characterization (and not intended as an exact coordinates). It is likely the exact location of these wrecks was not known, and an arbitrary point in the general vicinity of their suspected location was entered into the ANSD.

Anomaly URSAA1_Block1 was identified by URS during the current re-analysis of Fugro's data and is located in the vicinity of the coordinates in the ANSD that represent *Leichhardt* (ANSD 3481), *Nimrod* (ANSD 3519), *Spray* (ANSD 3570), *Chinta* (ANSD 3407), and *Edwina May* (ANSD 3433). The newly identified target is located approximately 210 meters from those coordinates. Target URSAA1_Block1 measures approximately 14 by 8 meters (46 by 26 feet). Given the regular, rectangular nature of this newly identified target, and its location in the vicinity of five previously recorded wrecks, this location should be buffered and avoided in lieu of further archaeological or geophysical investigation.

Catalina 5 was located outside of the survey block, and was situated approximately 931 meters northeast of the southern point of Block 1. The location of this previously identified seaplane is confirmed. There are also two possible mooring blocks associated with this plane positioned approximately 26 and 35 meters off of each wing.

Seven other shipwrecks identified in the ANSD are recorded outside of, but within approximately five kilometers of, Block 1. As no acoustic data was provided for these areas, their presence and exact location could not be confirmed or denied.

During the Neptune survey, the side scan sonar position was calculated by the use of an ultra-short baseline acoustic tracking system (Kongsburg MST acoustic beacon) that operates at 30kHz, with a beam spread of 90 degrees and accuracy of 1m at 1000m. An EdgeTech 4200-FS 410kHz sidescan sonar was used to acoustically image the seafloor during the survey. The side scan sonar was operated using a 60 m range with survey transect lane spacing at 50 meters. The 4200-FS side scan sonar has a resolution of 10 cm at 2 m/s (Table 6.1). A total of 11 side scan sonar transects were completed for this survey yielding 18.5 km of acoustic data. The data was used to construct a geo-referenced mosaic of the seafloor with a resolution of 0.5 m. This resolution is high enough to discern relatively small sections of shipwrecks and disarticulated elements of shipwrecks.

Block 2

Block 2 is located parallel to Blaydin Point and partially overlaps with Block 1. This survey block contains one previously identified wreck called *Con Dao 3* (ANSD 3408; Appendix B). Examination of acoustic data in the vicinity of this wreck did not reveal a submerged vessel. Further review of data provided by the ANSD and the Australian Fisheries Department suggests that the wreck was sunk as an artificial reef and is visible at low water. The wreck should not be visible at low water at the coordinates provided for the wreck. A possible wreck which meets this description was visible in aerial photographs of the region. This wreck is located east of Block 1 near the East Arm Wharf, not in Block 2 at the coordinates provided.

Three sites of potential interest were recorded outside Block 2. These are Catalina 3 (A24-206), Vietnamese Refugee Boat 1 (ANSD 3429), and an Indonesian fishing boat burning ground. The location and presence of Catalina 3 was confirmed, along with some debris that may be associated with the plane. The Indonesian fishing boat burning ground was reported to be 1609 meters northeast of the southern point of Block 2, approximately 51 meters outside of the block boundary. Review of the acoustic data shows nothing in this area. Coordinates entered into the ANSD for these sites may represent a point placed in the general vicinity of this site. The other shipwreck, called Vietnamese Refugee Boat 1 (ANSD 3429), is located outside of Blocks 2 and 3. The presence and location of this wreck could not be confirmed due to a lack of acoustic data for that area. It was recorded to reside 263 meters northeast of the western point of Block 3.

Block 3

Block 3, which is situated perpendicular to Block 2 and runs into the East Arm, contained one recorded acoustic anomaly that was detected during the 2008 Fugro survey of Darwin Harbour (Appendix B). This anomaly was later identified as a rocky ledge. Review of acoustic data confirms this assessment.

Rachel Cohen (ANSD 3548) was identified outside of Block 3, but within approximately 10 kilometers of the survey block boundary. It is located, according to the ANSD, 9,366 meters southeast of the eastern point in Block 3. There was no acoustic data recorded for this area, and its presence could not be confirmed or denied. The coordinates in the ANSD for this vessel places it approximately 1,300 meters on land; therefore, it is likely that these coordinates are incorrect.

Block 4

Block 4 extends into Lightening Creek (formerly East Catalina Creek). It does not contain any recorded or newly identified acoustic anomalies. *Leila* and *Flying Cloud* (ANSD 3448) are recorded as located within approximately five kilometers of Block 4 (Appendix B). The coordinates provided by the ANSD for these wrecks place them on the Middle Arm Peninsula; therefore, these coordinates also are likely incorrect.

Block 5

Block 5 is located along Cossack Creek (formerly West Catalina Creek) and does not contain any recorded or newly identified acoustic anomalies within the survey block and vicinity.

Block 6

Block 6 begins on the Wickham Point shoreline and then follows the proposed pipeline route. SS *Ellengowan* (ANSD 3436) is the only previously identified shipwreck in the survey block (Appendix B). This wreck is located approximately 289 meters south of kilometer posting (KP) 33.9 (old KP 879). The wreck measures approximately 25 meters long and 4.4 meters wide (82 by 14 feet). Its presence is clearly visible in the acoustic data provided. There are no other wrecks within the block or just outside the block boundaries.

Block 7

Block 7 is the longest survey block in the area, and covers the majority of the proposed pipeline corridor. This block contains seven reported anomalies including four cable crossings, two sinkers, and one reported shipwreck (Appendix B).

The four cable crossings, which are the North Telstra cable, the North Power cable, the South Power cable, and the South Telstra cable, were clearly defined by the provided acoustic data. The two objects identified as URS_SC08 and URS_SC11 in the 2009 EGS side scan sonar survey were designated as sinkers.

Ham Luong (ANSD 3458) has been identified as located in this survey block. This wreck was a steel hulled Vietnamese fishing boat that was sunk as an artificial reef. Careful review of acoustic data and information from the fisheries department and the ANSD indicates that the vessel likely rests in the general vicinity, but is not within the survey block. Review of magnetic and sidescan data do not show any magnetic anomalies larger than 2.43 kg (FA182) near the coordinates provided (Figure 5-1). The next closest magnetic anomaly (FA183) measures approximately 9 kg. Clearly, neither anomaly is large enough to represent a steel hulled vessel. These magnetic anomalies may be debris associated with *Ham Luong* (ANSD 3458), but they do not represent *Ham Luong* (ANSD 3458) herself. Therefore, URS' review of acoustic and magnetic data of the areas that surrounds the ANSD coordinates suggests the locational data for this wreck may be in error.

There are numerous acoustic anomalies identified just outside of Block 7. These anomalies include 13 shipwrecks, 16 possible sinkers or debris, a rock outcrop, and a rock pinnacle. The majority of these anomalies were identified during the 2009 EGS side scan sonar survey, while the rest are historic shipwrecks reported by the ANSD.

Shipwrecks recorded by EGS (2009) in the vicinity of Block 7 survey include *USS Maunaloa* (ANSD 3503), *USS Meigs* (ANSD 3505), *USS Peary* (ANSD 3531), and URS_SC03. These wrecks could not be positively identified from the acoustic data provided, but all of them lie outside of Block 7. Their presence has been corroborated by a number of other sources, including the ANSD. The other shipwrecks identified in the vicinity of Block 7 by the ANSD could not be positively identified because they all rest outside of the survey area.

The remaining anomalies situated outside the survey area were identified during the 2009 EGS side scan sonar survey. These anomalies, which were identified as 16 sinkers/debris, a rock pinnacle, and a outcrop/wreck, could not be verified because there is no acoustic data for these areas. URS_SC04, which was identified as an outcrop or potential wreck, is likely to be a rock outcrop because the measured dimensions for this find (34 meters long by 34 meters wide [111 by 111 feet]) are the wrong proportions for a shipwreck.

Block 8

Block 8 crosses the Middle Arm between Middle Arm Peninsula and the Cox Peninsula. URS' re-analysis of the survey block did not identify any acoustic anomalies. There is one recorded shipwreck, an unnamed lugger, located 5,153 meters east of the eastern point of Block 8 (Appendix B). The coordinates for this wreck provided by the ANSD place it on the Middle Arm Peninsula.

Block 9

Block 9 extends outward from Point Margaret on the Cox Peninsula. There are no recorded anomalies within the survey block or within five kilometers of the block boundaries.

Dredge Spoil Area

A review of government shipwreck databases and literature did not report any vessels lost in the vicinity of the proposed dredge spoil disposal area. A side scan sonar and single beam echo sounder survey was conducted across this area as part of the environmental and engineering studies associated with INPEX project. The survey lines were spaced at 100 m, with the side scan range set for 150 m, insuring 300 percent bottom coverage with overlap along the outer portions of the sonar swath for increased image resolution where beam spreading can smear the acoustic return. The side scan was operated at the 100 kHz frequency for adequate range and reflectivity values, with a ping rate controlled by vessel speed as calculated by the differential GPS navigation systems.

There are two recorded anomalies identified during the 2009 EGS Survey, Ltd., survey within the dredge spoil disposal area (Appendix B). These two anomalies, URS_SC01 and URS_SC02, each measured less than one meter in length and width and were identified as debris likely jettisoned from passing vessels.

There appears to be one long trawl or anchor drag scar that crosses the block East-West. There is no recorded depth or shadow associated with the scar, which indicates that this was done quite some time ago, and the only indication of it is recorded in the reflectivity portion (E1& E2) of the side scan sonar. This usually means that the sediment has been disturbed enough for preferential grain size sorting to take place and will slowly fade as finer grained marine sediments are mixed into the matrix and grain size distributions returns to normal. Commercial fishing gear (trawl nets, rock hoppers), use bottom dragging chains called tickle chains that churn the bottom up in front of the trawl mouth to scare the fish into the net and leave such scars. Anchor strikes and drags tend to leave a larger scar and associated bathymetric trough. There were no other recorded acoustic or bathymetric anomalies reported in the area.

The bottom appears to be smooth and devoid of any indications of cultural heritage materials in this location.

5.2.2 Gradiometer Data

Gradiometric data was gathered for Blocks 1 and 7, primarily for the purposes of identifying UXO. Twenty-five final magnetic anomalies were identified during the gradiometric survey of Block 7, these anomalies were recorded by Fugro during their 2008 survey of Darwin Harbour (Fugro 2009b; Appendix C). A total of 217 magnetic anomalies were recorded by Neptune during their 2010 nearshore UXO survey, which covered a portion of Block 1 (Neptune 2010; Appendix C). Two additional anomalies with the potential to represent a submerged cultural resource were identified during re-analysis. A more detailed discussion of the magnetic anomalies in Blocks 1 and 7 are presented below.

Block 1

Block 1 has portions of remnant lateritic bedding that outcrops, or subcrops within the survey area. This material creates areas of chaotic magnetic field shifts that can mask magnetic responses associated with disarticulated shipwrecks. Fortunately, where these laterites are found, there is usually less than a meter of sediments overtopping them and would not cover a shipwreck, so it would be clearly seen in the side scan sonar data.

A total of 156 magnetic anomalies and no acoustic anomalies were recorded in Blocks A-E. An additional 61 magnetic anomalies and 2 acoustic anomalies were recorded in the marginal areas of the survey, outside of Block A-E (Appendices B and C).

The *Kelat* is located approximately 60-70 meters from the southwestern margin of Block C. There are 11 magnetic anomalies grouped over the side scan image of the *Kelat*, showing the direct correlation between the magnetic and acoustic data sets (Appendix C and Figure 1-5). The magnetic mass calculations for these anomalies ranged from over 500 to 100 lbs., and the spatial distribution is a classic lozenge shape associated with multi-component shipwrecks (Neptune 2010:57).

There are 26 magnetic anomalies recorded in Block A with no acoustic correlations with potential ship elements (Appendix C and Figure 1-5). The spatial distribution of the center of mass for these anomalies shows no linkage, or association. The calculated mass for these anomalies range from 100 kg, to 9 kg. These anomalies likely represent modern ferrous point sources deposited from passing vessel traffic, or typhoons. No further work is recommended for these recorded anomalies.

Block B has portions of remnant lateritic bedding that outcrops, or subcrops and forms part of Walker Shoals. This material creates areas of chaotic magnetic field shifts that can mask magnetic responses associated with disarticulated shipwrecks. The margins along Walker Shoal have several areas of lateritic bedding that lack sediment cover, so any potential shipwrecks in the area would be recognizable in the side scan sonar data. The block contains 12 magnetic anomalies with no acoustic correlations that are randomly found across Walker Shoal (Appendix C and Figure 1-5). The calculated ferrous for these anomalies range from over 281 kg, to 7 kg , with no clear spatial linkage indicative of a shipwreck or other large cultural heritage items. The magnetic anomalies recorded in Block B appear to be modern ferrous material, such as UXO or modern debris deposited during storms or jettisoned by passing vessels.

Block C contains 77 recorded magnetic anomalies, which is the greatest concentration of anomalies within all the five blocks surveyed by Neptune (Appendix C and Figure 1-5). There are 10 acoustic correlations recorded with the anomalies that measure between 1-7 m long with an average width of 1m and an average height of approximately 0.5 meters. The calculated ferrous masses for these 77 anomalies range from 799 kg (M100) to 1 kg (M92).

Several of these anomalies are arrayed in a linear fashion; analysis of the magnetic data indicates a number of dipolar, or linear features with very short durations. Such data often are the result of the presence of wire rope, shots of chain, or some type of communication or power cable. MA100, which has the greatest calculated mass of 799 km, has a duration of approximately 15 m and a dipolar signature. It is located near the end of a seafloor scar, and may represent a moderate size anchor or mooring block.

One of the magnetic anomalies recorded in Block C (MA92), is located near the *Kelat*. This anomaly is dipolar with 30 nT amplitude, a duration of 3.5 m, and a calculated ferrous mass of 1kg (Neptune 2010: Appendix A). There are no acoustic correlations associated with this anomaly, and the magnetic contour map of the anomaly does not show any associated magnetic masses. While this could be some small piece of the *Kelat* that has been moved by currents, or anchoring activities in the area, there is nothing that indicates it is associated with the vessel.

Block D has 28 magnetic anomalies with one minor recorded acoustic correlation (MA196). The anomalies are for the most part scattered, with two areas of linear distributions indicative of wire rope, chains, cables, or pipe segments (Appendix C and Figure 1-5). The calculated ferrous masses ranged from a high of 509 kg (MA190) to a low of 2 kg (MA194) with short durations and simple signatures. The side scan sonar data from this area did not record any objects that resembled cultural heritage items, but does appear to show the occasional area of rubble that could be associated with rock outcrops or coral rubble. The distribution of the anomalies do not indicate the likely presence of a shipwreck.

Block E contained 13 magnetic anomalies distributed randomly across the survey area (Appendix C and Figure 1-5). The ferrous masses ranged from a high of 334 kg (MA198), located on an area of chaotic magnetic shifting to 10 kg (MA214). All of the anomalies have short durations and simple magnetic signatures. The magnetic data in this block indicate some lateritic soils near the surface, which may account for some of the anomalies. The distribution of the anomalies do not indicate the likely presence of a shipwreck, and are more indicative of scatters of ferrous materials jettisoned during commercial harbour activities or during storms.

Block 7

Block 7 is the longest survey block in the area, and covers the majority of the proposed pipeline corridor. This block contains twenty-five magnetic anomalies. Seven of these have been tentatively identified as unexploded ordinance dropped during the Battle of Darwin in 1942; five other anomalies have been attributed to Darwin Harbour cable crossings (Appendix C). The remaining 13 anomalies were unidentified in the Fugro report. The magnetic gradients of these anomalies ranged 3.98 and 497.68 nT/m, and they were buried between 0.02 and 6.7 m below the surface. A single anomaly was detected on the surface of the harbour. The estimated ferrous mass of the anomalies ranged between 1.0 and 674 kg.

The 13 unidentified anomalies identified by Fugro do not appear to have the potential to represent potential submerged cultural heritage places or objects. They lack the magnetic complexity and intensity generally associated with shipwrecks. Furthermore, the unidentified anomalies did not maintain a side scan sonar correlate, and were not spatially oriented in a pattern typically associated with shipwrecks or significant cultural resources.

Two anomalies identified during the re-analysis may represent potential cultural heritage items. Anomalies URSM1 and URSM2 are located near KP 860 (Appendix C). URSM1 was located at KP 860.92 (Easting 691833.2, Northing 8626288.8). This anomaly maintained a 40 nT/m maximum total gradient reading, and was accompanied by an acoustic image of what appeared to be a large field of debris that measured 40 by 14 m (131 by 46 ft). This anomaly may represent debris associated with the famed anti-submarine net that protected Darwin Harbour from Japanese and German submarines during World War II. URSM2 was located at KP 860.4 (Easting 691513.45, Northing 8626688.48). It maintained a 30 nT/m maximum total gradient reading, and was accompanied by an acoustic image of what appeared to be a swirl of debris that measured 40 by 50 m (131 by 164 ft). This anomaly also may represent debris associated with the anti-submarine net.

6.0 SUMMARY AND RECOMMENDATIONS

In order to determine whether or not there are any potential shipwrecks that were not recorded in the INPEX project area, each instrument was assessed for the data type and density that was collected and the precision of the associated navigation (Table 6-1). The acoustic remote sensing instruments were assessed for beam patterns, frequency of the acoustic energy, ping rate, vertical, longitudinal, and cross track resolution. The multibeam data had to be reviewed for the effects of the post processing and smoothing to understand its presentation and what would and would not be seen in the data.

For the gradiometric survey (Table 6-1), the data density and instrument sensitivity had to be considered when looking for potential shipwrecks and associated cultural material scatters. The regional geology and the effects of the lateritic outcrop and sheets had to be considered while reviewing the data in order to discern geology from cultural heritage. Where lateritic beds affected the magnetic field to the point that it became too chaotic to review magnetically, reviewers had to depend on the visual field data solely. Fortunately, the lateritic surfaces represent clear areas where there are little to no sediments to bury potential shipwrecks so they would be recorded by the side scan sonar and multibeam data.

For all of the surveys, the navigation and positioning were controlled by several combinations of highly accurate satellite navigation systems that were augmented by local ground-based differential correction stations and onboard inertial navigation systems (Table 6-1). These systems fed all of these data to computer based plotting and recording programs that corrected for vessel motion, instrument layback, and antenna locations so sub-meter accuracy was maintained throughout the complete surveys. This level of accuracy is needed when calculating all of the acoustic pings, point clouds and magnetic field shifts within the INPEX survey areas.

The single beam echo sounding systems that were used during the surveys generated good depth values with high resolutions as they relate to elevation, and for longitudinal resolution along the track line (Table 6-1). The use of a 10 degree beam transducer ensonified up to 3.5 meters, but these reading are reduced to a single value for the beam spread for each ping by the manufacturer's proprietary software. As long as the survey vessel stayed to speeds between 2 m/s – 4 m/s, the resolution of 10 – 19 cm between each data point is adequate to record low to moderate amplitude shipwrecks. The scouring and associated sediment deposition would also be recorded in the single beam echo sounder data if a wreck site was traversed. The greatest drawback of a single beam echo sounding system is the dependence on close lane spacing (15 – 20 m) to traverse a wreck site at least twice.

Geophysical methods like the sub bottom profiler (chirp or boomer) have high enough resolutions to identify objects measuring 15 to 20 cm across buried within the sediment package in the top few meters (Table 6-1). If the survey lines intersected with a shipwreck or moderately sized portions of the vessel (1- 2 m), several velocity changes would be evident in the image. Buried structure like scours would be evident in the sub bottom data, as would regions of enhanced gas trapped in the sediments as a result of wreck burial and biogenic gas generation as the wood and metals are digested by bacteria and other marine organisms. Even the cargoes would be dissimilar enough from the surrounding sediments to create velocity anomalies that could be recorded.

The drawback to these instruments is the small swath area that is recorded in relation to the survey lane spacing. Both of these instruments need lane spacing on the order of 15 – 20 m

Table 6-1. Survey Array Equipment

Survey Title	Contractor	Survey Size and Parameter	Survey Method	Instrument	Frequency	Range	Coverage	Beam Angle	Pulse Rate	Vessel Speed	Ensonification Or Resolution	Swath	Altitude
2009 URS Dredge Material Disposal Area Survey	Earth Sciences & Survey	7 km by 3 km block	Side scan sonar	GeoAcoustic 159D duel frequency	100 and 410 kHz	150 m at 100 kHz 195 ms	300% Overlap	40º by 0.3º	50 pulses/ sec	2.0 m/s	13 cm	N/A	10-20% depth off bottom
			Single beam echo sounder	Knudsen 320M dual frequency	33 and 210 kHz	50 m	N/A	20°, 10°	15 ping/ sec	1.56-2.9 m/s	10 – 19.3 cm	3.5m	N/A
			Motion referencing unit	TSS 03-05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Motion referencing unit	TSS 05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Tide gauge	Anderra WLR08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			DGPS	Sokkia Axis 3	N/A	N/A	N/A	N/A	1 Sec	N/A	N/A	N/A	N/A
			DGPS	Global Pos	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Report on the Offshore Pipeline Route Unexploded Ordnance (UXO) Survey, Volume 1 - Survey Results	FUGRO Survey Pty Ltd	Corridor 20m wide, 7 lanes at 3m spacing, 40m wide from KP650.0 onward. Added 6 lanes, 250 km long	Gradiometer with altimeter	Marine Magnetics SeaQuest 4 Sensor Overhauser	2 Hz	.1 nT	100% coverage	N/A	2Hz	1.8-2.05 m/s 3.5-4.0 knt	1 Sample per Meter	5.5m	1.5-2.0m off of bottom
			USB baseline system	Sonardyne Fusion	18-36 kHz	7000 m	90°	N/A	30/ sec	1.8-2.05 m/s 3.5-4.0 knt	1m	.1% Slant Range	Hull mount
			GPS (heading and navigation)	2 Dual Frequency Starfix 8200HP	1 Hz	N/A	N/A	N/A	N/A	N/A	10-20 cm	N/A	N/A
			Side Scan Sonar	EdgeTech FS 4200 Chirp High Frequency	120/410 kHz	50 m per channel	100% Overlap	50° Vertical, 100 kHz: 1.5°, 400	N/A	1.8-2.05 m/s 3.5-	410 kHz at 50m=10 cm	N/A	5-7m off of bottom

Survey Title	Contractor	Survey Size and Parameter	Survey Method	Instrument	Frequency	Range	Coverage	Beam Angle	Pulse Rate	Vessel Speed	Ensonification Or Resolution	Swath	Altitude
								kHz: 0.4°		4.0 knt			
Report on Ichthys Field Development Darwin Harbour Geophysical Site Surveys 2008 Volumes 1,2	FUGRO Survey Pty Ltd	Survey Lanes Spaced 50 m Pipeline Corridor 500 m	DGPS	2 FUGRO Starfix 8200HP	N/A	N/A	N/A	N/A	1Hz	N/A	.5 m	N/A	N/A
		Survey Lanes Spaced 50 m Pipeline Corridor 50 m	Side scan sonar	GeoSwath Plus Multibeam	250 kHz	60 m	120m	0.75	15 per sec	2 m/s	.13 m	N/A	N/A
			Motion referencing unit	POSMV	100 Hz	N/A	N/A	N/A	100 Hz	N/A	.3 m	N/A	N/A
			Single beam echo sounder	Odem Echotrac	200 kHz	30m	N/A	2.75	variable	2 m/s	.01m	1.5m @27m	Hull Mount
			Water velocity plate	Applied Acoustics Boomer AA300	500 Hz to 6 kHz	50 µs 75 m	N/A	N/A	.175 ms	2m/s	15-20 cm	N/A	Surface
			Seismograph	CSP 1500 surface control unit with 20 element single channel hydrophone array	1020 j/s with 145 Hz – 7 kHz (-3 dB)	N/A	N/A	N/A	6 pps max, 3 pps@350J	N/A	167dB ref1v/µPa	N/A	N/A
Report on the Seismic Refraction		Survey	DGPS	DGPS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Seismograph	2 24 elemental	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Towed 1 m off

Survey Title	Contractor	Survey Size and Parameter	Survey Method	Instrument	Frequency	Range	Coverage	Beam Angle	Pulse Rate	Vessel Speed	Ensonification Or Resolution	Swath	Altitude
Survey Ichthys Gas Field Development Darwin Harbor, Northern Territory, Volume 1 Fugro Survey 2009, Volume 1	FUGRO Survey Pty Ltd	Lanes Spaced 25 m, All wrecks and obstruction avoided by 50 meters		hydrophone array 32m and 50m									bottom
			N/A	5cu inch Air Gun@1000 psi	250 Hz	N/A	32m 50m	N/A	4 sec	N/A	N/A	N/A	N/A
			Single beam echo sounder	Odem Echotrac SBES	200kHz	30m	N/A	2.75	Variable	2m/s	0.01m	1.5m @27m	Hull Mount
			Motion referencing unit	TSS 03-05 MRU	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Motion referencing unit	TSS 05 MRU	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			N/A	Geometrics Seismic Refraction Unit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nearshore Unexploded Ordnance and Debris Survey Final Report, 26 November 2010	Neptune Geomatics PTY LTD	Sidescan transects at 50m, range 60m Magnetic Survey at 5m transect spacing	EdgeTech FS 4200 Chirp High Frequency	120/410 kHz	50 m per channel	100% Overlap	50° Vertical, 100 kHz: 1.5°, 400 kHz: 0.4°	N/A	1.8-2.05 m/s 3.5-4.0 knt	410 kHz at 50m= 10 cm	N/A	5-7m off of botto m	NA
			USB baseline system	Sonardyne Fusion	18-36 kHz	7000 m	90°	N/A	30/ sec	1.8-2.05 m/s 3.5-4.0 knt	1m	.1% Slant Range	Hull mount
			Motion referencing unit	TSS 05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Gradiometer	Geometrics G-882	N/A	N/A	N/A	N/A	10 Hz	2m/s	5 reads per meter	N/A	N/A
			GPS Nav	Veripos	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

in order to increase the likelihood that the shipwreck is crossed, or the survey lines come close enough to the site to record some of the associated geomorphic features such as motes, scours, and sediment lag deposits that can be seen formed around a mooring in the harbor (Figure 6-1).

Normally magnetic survey methods are used to locate buried or very low amplitude shipwrecks that have been flattened or buried over time. Even relatively small vernacular water craft often have enough ferrous materials associated with them that they stand out in the magnetic data. Several moderate sized vessel classes reported lost in the Darwin harbor could have rigging, auxiliary steam winches, fuel/ water tanks, chain lockers, anchors boilers, iron capstans, and any number of ferrous components that would deflect the earth's magnetic field over a broad area, and enable them to be recorded.

The major issues that one encounters with magnetic survey methods are the lateritic deposits that are recorded throughout Darwin Harbour. These naturally occurring polymetallic ore bodies mask all but the largest steel hulled vessels sitting on the seafloor above them. Gradiometric methods can remove some of the masking effect from these ore bodies, but the chaotic nature of ore genesis and weathering still creates massive fluctuations that have the potential to wipe out smaller frequency gradient shifts associated with shipwrecks. Fortunately the concreted nature of lateritic beds keeps shipwrecks or other heritage items from sinking below them. Therefore, shipwrecks would be highly visible using wide field survey methods, such as multibeam and side scan sonar.

Wide field acoustic survey systems are used to collect data in broad swaths with good resolutions. The DTMs created by the multibeam systems are used to graphically present the data in a three dimensional fashion similar to side scan sonar (Figure 6-2). Both high and low frequency side scan images of the shipwreck on Stratford Shoals (100 kHz and 500 kHz) clearly record a shipwreck, but the lower frequency unit is not capable of resolving finer details that the 500kHz side scan does. The same is true for the multibeam DTMs that record the vessel by elevation as well as the geomorphic features that are being formed as a result of current deflect and sediment deposition on the lower current side of the vessel. Both of these systems also use the E1 and E2 values returned by the acoustic reflection and are used to denote the reflectivity and hardness of the surface that the energy is bouncing off of. The multibeam DTM are not a clear in resolving the internal structures of the vessels given the cell size averaging that is used (1.0 m cell and 0.5m cell, respectively), but they clearly show the shipwreck in a fashion that is discernable both in elevation and in reflectivity values. This is similar to the DTMs of the various heritage items recorded in the greater INPEX project (Figures 6-3 through 6-6). Geomorphic features are also clearly discerned in the wide field multibeam data such as outcrops (Figure 6-7). Again, what is not resolved in structural detail is compensated by the information in the E1 and E2 data.

The side scan sonar systems used in the survey were medium frequency between 250 kHz (Kongsburg GeoSwath Plus interferometric side scan), and Edgetech 410 kHz side scan. These units produced clear seafloor imaging that were able to discern man made features from naturally occurring reefs, outcrops and seafloor bedform features (Figures 6-8 and 6-9). The sonar range (beam spread) and ping rates were optimized for survey lane spacing and vessel speeds. All of the acoustic data sets for the entire survey were corrected for wave and vessel motion (MRU and gyro corrections) to ensure high quality data with minimal image distortions.

The side scan sonar of the USS *Meigs* and *Maunaloa* clearly reflect both the elevation of portions the wrecks (shadow length), as well as the debris and cargo that was dumped to the side of the vessels during several episodes of salvage (Figure 6-8 and 6-9).

There are nine (9) shipwrecks reported lost throughout the greater INPEX project areas (Table 6-2). These vessels range from a mid to late 19th century barquentine to Southeast Asian wooden fishing vessels, to modern steel and composite hulled vessels. None of these vessels were recorded where plotted when cross checked against all of the survey data. Several of the vessels share a common position for the location they were lost. The use of a single position is indicative of the use of a generalized area of loss (e.g., Darwin Harbour); such position do not necessarily have positional voracity.

Using estimates of size and tonnage for these vessel classes reported lost in table 5-2, an estimate of potential shipwreck site size was calculated. These site estimates were then reviewed with shipwreck preservation potential based on available sediment type and depths (taken from side scan and sub bottom profiles), and bottom conditions including currents and sediment motility by examining two bathymetric studies of the same areas done a year apart. For the more modern vessels of steel, fiberglass, and wood metal composites there would have been little to no degradation and these wrecks would clearly be proud of the bottom. Given the nature of the construction materials, acoustic energy would be bounced back to the transducers with very high E2 values and clearly stand out against the sediments found in Darwin Harbor. Older wooden vessels would not have survived as well and would have been broken up and scattered by the swift currents in the harbour, unless they in areas where the shoreline or reefs protected they from currents and storm wave action. In areas where there was enough sediment available for burial, portions of these vessels may remain. Typically these would be the most massive or dense elements of the vessel and would have a high potential of partial preservation and likely would have been imaged by the side scan (Figure 6-10), or multibeam systems (Figures 6-1, 6-3 through 6-6).

When putting all of the geophysical methods of seafloor imaging and modeling that was done by INPEX for environmental and engineering assessments, it is readily apparent that there is little chance that these moderately sized vessels (9 m and up with 40 tons displacement or more) would have failed to have been imaged at least once by wide field acoustic methods. If these vessels were in the pipeline construction corridor and dredge prisms, they would have been imaged two to three times. If they were in the pipeline construction corridor, in addition to the acoustic methods they would have had magnetic gradient mapping done that was able to resolve ferrous masses below 2 kg, with 100 percent coverage of the corridor.

Based on the research carried out for this project, it is thought that there is a low potential for low amplitude vessels not being imaged and reported on, within the INPEX project areas. There is a low probability that there are moderate to large scatters of significant cultural heritage materials located outside of the buffers that INPEX' project designers have put around the known or identified shipwrecks, aircraft, and other maritime heritage items reported in, or directly adjacent to the pipeline construction corridor right-of-way, or within the areas of potential effect as reported by INPEX.

After reviewing the magnetic and side scan sonar data collected by Neptune for the Nearshore Unexploded Ordnance and Debris Survey, there does not appear to be any identified shipwrecks within Blocks A-E of Block 1, nor does there appear to be any other intact heritage materials that were recorded in the geophysical data. This finding was confirmed during UXO diving investigations by Tek Diving Services (Tek) in 2010 (Tek Diving Services 2010). Tek dove on a number of the potential UXO targets located by Fugro along the pipeline centerline right-of-way, as well as in Block 1, Blocks A-E. The divers had to work only on neap tides from April – November 2010, due to the extremely strong and dangerous tidal currents.

A total of 22 potential UXO targets were selected for review, as well as with an additional six possible cable crossings. Two pipeline centerline surveys of approximately 1,800 m also were completed. During these dives, no shipwrecks were recorded. The divers did appear to locate an unofficial naval disposal area (Site 28), where several boxes of discarded ordnance were discovered, as well as sections of discarded anti-submarine netting. Since the anti-submarine boom and nets were recovered and stored at the close of WWII (Tek Diving Services 2010: 83), these net and cable sections were thought to be damaged portions of the boom that were repaired during WWII and discarded in this area. It was common practice for naval bases to unofficially discard waste materials and munitions in isolated locations.

The remote sensing techniques employed for the Ichthys Gas Field Development Project were adequate to identify any marine cultural heritage places or objects, given the local setting, cultural history, and geological conditions. There were six classes of remote sensing data that were reviewed for this project that included side scan sonar, phased differentiated bathymetric side scan and multibeam, single beam echo sounder, sub bottom profiler, gradiometric, and high resolution continuous seismic profiling. These geophysical methods recorded 78 acoustic anomalies and 25 gradiometric anomalies within the INPEX project areas. Re-analysis of the geophysical data only added an additional acoustic anomaly URSAA1, which measures 14 m by 8 m in the proximity of five reported shipwrecks in the Australian National Shipwreck Database.

Analysis of the gradiometric data did not record any potential new targets, but two anomalies (URSM1 and URSM2), may represent portions of the World War II anti-submarine nets that crossed Darwin Harbour. These targets may be heritage places. INPEX should discuss methods to minimize impacts to these targets with the Natural Resources, Environment, the Arts and Sport (NRETAS). Given the poor state of preservation of these damaged net remnants, and the fact that the anti-submarine nets were recovered and stored at the close of WWII, it does not appear that these fragmentary portions of the net have a high research value, or will likely add to the what is already known of Darwin Harbour's anti-submarine defenses and the personnel that manned the nets during the war years.

There are nine known or reported shipwrecks in Darwin Harbour that have not been located with precision to date and/or field verified by marine archaeologists (Table 6-2). The techniques used for the geophysical surveys were adequate to have identified these potential shipwrecks, if they were present in the project area. None of these wrecks were recognized during the current re-analysis of remote sensing data for the project and therefore are not likely to be in the project area.

Table 6-2. Potentially Unaccounted for Vessel Losses within the INPEX Development Areas

Block No.	Contact Number	ANSD Number	Easting	Northing	Distance From CL	Nearest KP	Old KP	Alternate Location Information	Water Depth (m)	Dimensions (m)	Description
1	*Leichhardt*	3481	703044.43	8618730.5	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Caught fire while being refitted
1	*Nimrod*	3519	703044.43	8618730.5	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Wooden motor yacht, lost in Cyclone Tracy
1	*Spray*	3570	703044.43	8618730.5	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Unknown vessel type sunk during Cyclone Tracy
1	*Chinta*	3407	703044.43	8618730.5	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Wrecked Yacht

Block No.	Contact Number	ANSD Number	Easting	Northing	Distance From CL	Nearest KP	Old KP	Alternate Location Information	Water Depth (m)	Dimensions (m)	Description
1	*Edwina May*	3433	703044.43	8618730.5	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Steel hulled, diesel driven vessel lost in Cyclone Tracy
2	*Con Dao 3*	3408	706836.13	8616859.4	n/a	n/a	n/a	Block 2, 506 meters Northeast of Block 2 West Point	n/a	n/a	Vietnamese wooden fishing vessel scuttled by crew
2 out	Indonesian Fishing Boat Burning Ground	n/a	708512.54	8616163.5	n/a	n/a	n/a	Outside Block 2, 1609 meters Northeast of Block 2 South Point	n/a	n/a	Indonesian Fishing Boat Burning Ground
3 out	*Rachel Cohen*	3548			n/a	n/a	n/a	Outside Block 3, 9366 meters Southeast of Block 3 East Point	n/a	n/a	Australian built wooden barquentine built in 1871. Burned with a cargo of crude oil.
4 out	*Leila*	n/a	710238.03	8611302.4	n/a	n/a	n/a	Outside Block 4, 3404 meters Southeast of Block 4 Southeast Point	n/a	n/a	Lugger that was scuttled during Cyclone Tracy

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Addendum:

Figures

Appendix A:

Qualifications of Project Team

Christopher Polglase has 30 years of professional experience in archaeological excavations, research, and compliance studies. He is a Program Development Manager/Senior Principal Investigator in URS' National Capital Area Cultural Resources Group with geographically wide-ranging compliance and research experience, having managed projects and conducted investigations throughout the Continental United States, the Arctic, the Caribbean, and Europe during the course of his professional career. Mr. Polglase has provided specialized cultural resource investigations for clients requiring maritime cultural resource services for over 15 years, including the US Army Corps of Engineers, the US Navy, NASA, and the Maryland Port Administration, as well as numerous private sector clients. Among his recent work, he has worked closely with Federal and state regulators, academic specialists, and technology experts to develop appropriate techniques for identifying and assessing the significance of submerged terrestrial sites in near-shore settings. He also has directed cultural heritage studies for oil and gas industry clients in the US, the Caribbean, and in the Caucasus and southwest Asia.

Jean Bernard (J.B.) Pelletier has over 20 years experience in marine geophysics, nautical archaeology, marine and terrestrial remote sensing, remotely operated vehicle operation and maintenance, underwater photography and video, technical diving, and diving safety. He is URS' Lead Nautical Archaeologist and Marine Remote Sensing Specialist. He exceeds the Secretary of the Interior's Professional Qualification Standards for Archaeology. Mr. Pelletier is an expert in the use of side-scan sonar, sub bottom profilers, single-beam echo sounders, and marine magnetometers and gradiometers. He also has extensive knowledge of *Hypack* Version 10 software for data collection and interpretation. He has served a wide array of Federal, State, and private sector clients including the: USACE; U.S. Navy; MMS; National Oceanic and Atmospheric Administration; Delaware, Rhode Island, Florida, and Maryland DOTs; Maryland Department of Natural Resources; Maryland Port Authority; and BP. He received his M.A. in History and his B.A. in Geological Sciences from the University of Maine.

Anthony Randolph has 17 years of experience in cultural resources management, and exceeds the *Secretary of Interior Standards for Archaeology* (36CFR Part 61). Mr. Randolph has extensive experience in the management and execution of archaeological investigations. He has managed reconnaissance and investigations on prehistoric, historic and maritime sites throughout the eastern United States, Caribbean, and Europe. He also has extensive experience as an archaeological conservator through positions at Mariners Museum, and the government of Portugal. He received his Masters Degree in Anthropology from Texas A&M University in 2003 and his Bachelor's Degree in Neuroscience/Anthropology from the University of Pittsburgh in 1993.

Bridget Johnson has a broad background in historic and archaeological research. She has extensive experience in data collection and management for archaeological and historical projects. Ms. Johnson has extensive experience conducting historic research on a variety of topics and regions throughout the United States. Specialized experience includes the creation of three dimensional models of archaeological sites both terrestrial and underwater, as well as the management of archaeological collections. She received her Master's degree in Anthropology from Texas A&M University in 2008 and her Bachelor's degree in History and Archaeology from St. Mary's College of Maryland in 2006.

Appendix B:

Table of Acoustic Anomalies

Block No.	Contact Number	ANSD Number	Easting	Northing	Distance From CL	Nearest KP	Old KP	Alternate Location Information	Water Depth (m)	Dimensions (m)	Description
1	Missing Catalina	n/a			n/a	n/a	n/a	Block 1, East Arm, 1600 meters Northwest of Block 1 South Point	n/a	30.0 x 3.0 x 1.8	Missing Catalina
1	Unidentified Object	n/a	705270	8616548	n/a	n/a	n/a	Block 1, East Arm, 1176 meters Northeast of Block 1 South Point	n/a	6.8 x 3.0 x 0.6	Unidentified Object
1	Catalina 4	n/a	706282	8616273	n/a	n/a	n/a	Block 1, East Arm, 666 meters Northeast of Block 1 South Point	n/a	32.5 x 7.5 x 1.6	Catalina 4
1	Steel Rectangular Shaped Object	n/a	705926	8616317	n/a	n/a	n/a	Block 1, East Arm, 655 meters North of Block 1 South Point	n/a	buried	Steel Rectangular Shaped Object
1	Catalina Tail Section	n/a	705468	8616430	n/a	n/a	n/a	Block 1, East Arm, 953 meters Northwest of Block 1 South Point	n/a	6.0 x 4.7 x 0.7	Catalina Tail Section
1	*Kelat*	3477	704070	8617575	n/a	n/a	n/a	Block 1, East Arm, 1908 meters Southeast of Block 1 North Point	n/a	70.0 x 13.3 x 4.9	*Kelat*
1	Steel Barge	n/a	703547	8618643	n/a	n/a	n/a	Block 1, East Arm, 885 meters Southeast of Block 1 North Point	n/a	23.3 x 7.9 x 1.4	Steel Barge

1	Mooring Block 1	n/a	705609	8616547	n/a	n/a	n/a	Block 1, East Arm, 982 meters Northwest of Block 1 South Point	n/a	6.0 x 5.0 x 0.5	Mooring Block 1
1	Mooring Block 2	n/a	703449	8617920	n/a	n/a	n/a	Block 1, East Arm, 1203 meters Southeast of Block 1 East Point	n/a	3.0 x 1.5 x 0.7	Mooring Block 2
1	*Leichhardt*	3481	703044.43	8618730.45	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Caught fire while being refitted
1	*Nimrod*	3519	703044.43	8618730.45	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Wooden motor yacht, lost in Cyclone Tracy
1	*Spray*	3570	703044.43	8618730.45	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Unknown vessel type sunk during Cyclone Tracy
1	*Chinta*	3407	703044.43	8618730.45	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Wrecked Yacht
1	*Edwina May*	3433	703044.43	8618730.45	n/a	n/a	n/a	Block 1, East Arm, 682 meters Northeast of Block 1 East Point	n/a	n/a	Steel hulled, diesel driven vessel lost in Cyclone Tracy
1	Catalina 6	n/a			n/a	n/a	n/a	Block 1, East Arm, 1600 meters Northwest of Block 1 South Point	n/a	n/a	PBY-4 (#4 or #8) A US aircraft sunk during a Japanese air raid in 1942

1	URSAA1_ Block 1	n/a	702951.93	8618922.68	n/a	n/a	n/a	Block 1, East Arm, 558 meters Southwest of Block 1 North Point	n/a	14x8 m	URS 2010 Identified Acousitc Anomaly, possible shipwreck
1 out	*Jenny Wright*	3473	701006.21	8620053.96	n/a	n/a	n/a	Outside Block 1, East Arm, 2101 meters Northwest of Block 1 West Point	n/a	n/a	Steel hulled vessel lost in Cyclone Tracy but never re-located
1 out	*Bell Bird*	3377	699599.29	8620985.7	n/a	n/a	n/a	Outside Block 1, East Arm, 3795 meters Northeast of Block 1 West Point	n/a	n/a	Steel hulled motor vessel built in 1971, lost in Cyclone Tracy
1 out	*Blue Bird*	3384	700247.63	8620409.64	n/a	n/a	n/a	Outside Block 1, East Arm, 2889 meters Northeast of Block 1 West Point	n/a	n/a	Steel hulled motor vessel built in 1971, lost in Cyclone Tracy
1 out	*Carina*	3402	700333.07	8619671.41	n/a	n/a	n/a	Outside Block 1, East Arm, 2394 meters Northeast of Block 1 West Point	n/a	n/a	Motor vessel lost in Cyclone Tracy
1 out	*Chang 1028*	3403	706410.36	8620642.77	n/a	n/a	n/a	Outside Block 1, East Arm, 3467 meters East of Block 1 North Point	n/a	n/a	Steel hulled vessel scuttled at mooring
1 out	*Charles Todd*	3405	701956.02	8618553.67	n/a	n/a	n/a	Outside Block 1; 451 meters Northwest of Block 1 East Point	n/a	n/a	Steel hulled, diesel driven vessel lost in Cyclone Tracy
1 out	*Gulnare*	3456	702321.06	8618919.88	n/a	n/a	n/a	Outside Block 1; 444 meters Northwest of Block 1 East Point	n/a	n/a	Wooden schooner scuttled with rocks to make a jetty

1 and 2 out	Catalina 5	n/a	706776	8616231	n/a	n/a	n/a	Outside Block 1, East Arm, 931 meters Northeast of Block 1 South Point	n/a	17.0 x 10.5 x 1.5	Catalina 5
2	*Con Dao 3*	3408	706836.13	8616859.36	n/a	n/a	n/a	Block 2, 506 meters Northeast of Block 2 West Point	n/a	n/a	Vietnamese wooden fishing vessel scuttled by crew
2 out	Indonesian Fishing Boat Burning Ground	n/a	708512.54	8616163.47	n/a	n/a	n/a	Outside Block 2, 1609 meters Northeast of Block 2 South Point	n/a	n/a	Indonesian Fishing Boat Burning Ground
2 out	Catalina 3 (A24-206)	n/a	707419	8617799	n/a	n/a	n/a	Outiside Block 2, 1559 meters Northeast of Block 2 West Point	n/a	22.1 x 14.6 x 2.3	Catalina 3 (A24-206)
2 and 3 out	Vietnamese Refugee Boat 1	3429	708936.54	8616167.47	n/a	n/a	n/a	Outside Block 2 and 3, 263 meters South of Block 3 West Point	n/a	n/a	Boat abandoned by Vietnamese refugees in 1976
3	Rocky Ledge	n/a	709509	8615973	n/a	n/a	n/a	Block 3, 738 meters Southeast of Block 3 West Point	n/a	4.3 x 2.8 x 0.8	Rocky Ledge
3 out	*Rachel Cohen*	3548			n/a	n/a	n/a	Outside Block 3, 9366 meters Southeast of Block 3 East Point	n/a	n/a	Australian built wooden barquentine built in 1871. Burned with a cargo of crude oil.
4 out	*Leila*	n/a	710238.03	8611302.4	n/a	n/a	n/a	Outside Block 4, 3404 meters Southeast of Block 4 Southeast Point	n/a	n/a	Lugger that was scuttled during Cyclone Tracy

4 out	*Flying Cloud*	3448	710060.91	8611856.93	n/a	n/a	n/a	Outside Block 4, 2944 meters Southeast of Block 4 Southeast Point	n/a	n/a	Australian built, wooden cutter built in 1870, lost in a storm
6	*MV Ellengowan*	3436	703016	8613247	289 S	33.99	879	Block 6, 789 meters Northwest of Block 6 Southeast Point	n/a	25.0 x 4.4 x 2.8	*MV Ellengowan*
7	URS_SC08	n/a	696841.5	8618425	189.4 W	15.27	870.4	n/a	13.3	1x1x1	Sinker
7	URS_SC11	n/a	696880.8	8618213.2	215 W	15.47	870.62	n/a	11.8	1x1x1	Sinker
7	North Telstra Cable Crossing	n/a	693616	8623974	0	8.71	863.8	Block 7, 3548 meters Northwest of Block 7 West4 Point	n/a	n/a	North Telstra Cable Crossing
7	North Power Cable Crossing	n/a	693796	8623743	0	9	864.1	Block 7, 3271 meters Northwest of Block 7 West4 Point	n/a	n/a	North Power Cable Crossing
7	South Power Cable Crossing	n/a	693911	8623595	0	9.19	864.29	Block 7, 3079 meters Northwest of Block 7 West4 Point	n/a	n/a	South Power Cable Crossing
7	South Telstra Cable Crossing	n/a	694222	8623195	0	9.69	864.9	Block 7, 2584 meters Northwest of Block 7 West 4 Point	n/a	n/a	South Telstra Cable Crossing
7	*Ham Luong*	3458	697242.79	8618217.6	133 E	15.54	870.71	n/a	n/a	n/a	Steel hulled Vietnamese fishing boat sunk as an artificial reef
7 out	*USS Maunaloa_1*	3503	697710.7	8617858.3	433 E	16.06	871.28	Outside Block 7	n/a	115x18x3	Stern

7 out	*USS Maunaloa_2*	3503	697710.2	8617746.8	387 E	16.17	871.38	Outside Block 7	n/a	115x18x3	Bow
7 out	*USS Megis_1*	3505	697585	8618887	675 E	15.01	870.1	Outside Block 7	n/a	120x20x3	Stern
7 out	*USS Megis_2*	3505	697635	8618774.5	684 E	15.14	870.16	Outside Block 7	n/a	120x20x3	Bow
7 out	*USS Peary_1*	3531	698847	8620221.5	2332 E	14.26	868.53	Outside Block 7	n/a	70x13x3	Stern/Bow
7 out	*USS Peary_2*	3531	698886.5	8620164.5	2339 E	14.28	868.54	Outside Block 7	n/a	70x13x3	Bow/Stern
7 out	URS_SC03	n/a	695692	8620238	543 SW	13.06	868.4	Outside Block 7	21.1	21.5x3.5x2	Wreck
7 out	URS_SC04	n/a	695887.2	8619859.4	533 SW	13.52	868.76	Outside Block 7	14.7	34x24x7	Outcrop or Wreck (possibly boat at anchor)
7 out	URS_SC05	n/a	695904.6	8619850.2	519.9 SW	13.53	868.69	Outside Block 7	14.9	1x1x1	Debris or Sinker
7 out	URS_SC06	n/a	695716.5	8619443.5	876 SW	13.93	869.03	Outside Block 7	15.4	1x1x1	Debris or Sinker
7 out	URS_SC07	n/a	696124.5	8619558	449 SW	13.92	869.03	Outside Block 7	10.6	1x1x1	Debris or Sinker
7 out	URS_SC09	n/a	696689	8618343.5	367 W	15.34	870.48	Outside Block 7	11.6	1x1x1	Sinker
7 out	URS_SC10	n/a	696734.2	8618264.6	351 W	15.44	870.56	Outside Block 7	11.6	1x1x1	Sinker
7 out	URS_SC12	n/a	696576.6	8618258.6	506 W	15.42	870.54	Outside Block 7	10.9	1x1x1	Sinker
7 out	URS_SC13	n/a	696630.4	8618183	460 W	15.41	870.64	Outside Block 7	10	1x1x1	Sinker

7 out	URS_SC14	n/a	696861.6	8618062.5	281 W	15.57	870.78	Outside Block 7	9.7	1x1x1	Sinker
7 out	URS_SC15	n/a	696711.9	8618019.9	437 W	15.58	870.8	Outside Block 7	8.2	1x1x1	Sinker
7 out	URS_SC16	n/a	696945.4	8617883.6	267 W	15.75	870.95	Outside Block 7	8	1x1x1	Sinker
7 out	URS_SC17	n/a	696632.6	8617892.8	560 W	15.7	870.87	Outside Block 7	6.7	1x1xnmh	Debris or Sinker
7 out	URS_SC18	n/a	696908.1	8617703.2	368 W	15.93	871.13	Outside Block 7	6.5	1x1xnmh	Debris or Sinker
7 out	URS_SC19	n/a	696955.3	8617605.4	363 W	16.03	871.25	Outside Block 7	7.2	1x1xnmh	Debris or Sinker
7 out	URS_SC20	n/a	697120.4	8617532.4	239 W	16.15	871.36	Outside Block 7	10	1x1xnmh	Debris or Sinker
7 out	URS_SC21	n/a	697109.1	8617397.2	309 W	16.3	871.48	Outside Block 7	10.2	1x1xnmh	Debris or Sinker
7 out	URS_SC22	n/a	696518.4	8617437.3	831 W	16.04	871.26	Outside Block 7	2.5	5x2x2	ROCK Pinnacle
7 out	URS_SC23	n/a	697155.4	8616940.3	460 W	16.7	871.88	Outside Block 7	8	1x1xnmh	Debris or Sinker
7 out	*Mandorah Queen*	3494	695202.6	8621956.21	n/a	n/a	n/a	Block 7, 1017 meters Northwest of Block 7 West4 Point	n/a	n/a	Steel hulled motor vessel, lost in Cyclone Tracy
7 out	*USS Meigs*	3505	697609.41	8618841.46	689 NE	15.11	870.17	Outside Block 7	n/a	n/a	American steel hulled, screw propelled steamer built 1921, sunk during Japanese Air Raid on Darwin Harbor in 1942. 2 crewmen reported killed

7 out	*Neptuna*	3517	697609.41	8618841.96	689 NE	15.11	870.17	Outside Block 7	n/a	n/a	German Built steel hulled, screw propelled steamer constructed in 1924, sunk during Japanese Air Raid on Darwin Harbor in 1942. 45 crewmen reported killed.
7 out	*USS Peary*	3531	698796.84	8620235.25	n/a	n/a	n/a	Outside Block 7, 2044 meters East of Block 7 East2 Point	n/a	n/a	American steel hulled, screw propelled steamer built 1920, sunk during Japanese Air Raid on Darwin Harbor in 1942. 92 crewmen reported killed
7 out	Vietnamese Refugee Boat PK76	3584	699206.99	8621910.47	n/a	n/a	n/a	Block 7, 3249 meters East of Block 7 East1 Point	n/a	n/a	Wooden vessel of unknown form
7 out	*Yu Han 22*	3595	697949.12	8615538.96	381 W	18.29	873.48	Outside Block 7	n/a	n/a	Wooden fishing boat of Chinese origin, scuttled for illegal fishing
7 out	*DSAC Barge*	3426	697800.68	8625589.56	n/a	n/a	n/a	Outside Block 7, 4665 meters Northeast of Block 7 East1 Point	n/a	n/a	Barge sunk as an artificial reef
7 out	*John Holland* Barge	3474	697517.08	8618584.48	514 E	15.28	870.42	Outside Block 7	n/a	n/a	Steel barge sunk to form an artificial reef

7 out	*Song Saigon*	3569	697552.27	8618436.76	500 E	15.42	870.54	Outside Block 7	n/a	n/a	Steel hulled Vietnamese fishing boat sunk as an artificial reef
7 out	*British Motorist*	3389	697710.52	8617734.89	397 E	16.22	871.35	Outside Block 7	n/a	n/a	British steel hulled, screw propelled steamer built 1924, sunk during Japanese Air Raid on Darwin Harbor in 1942. 2 crewmen reported killed
7 out	*NR Dieman*	3422	691887.04	8625636.8	n/a	n/a	n/a	Outside Block 7, 3246 meters Southeast of Block 7 North1 Point	n/a	n/a	Steel hulled motor vessel built in 1970, sank in 1978
8 out	Unnamed lugger	n/a			n/a	n/a	n/a	Outside Block 8; 5153 meters East of Block 8 East Point	n/a	n/a	Wooden lugger burnt to waterline
Dredge Spoil Area	URS_SC01	n/a	694733.3	8644925.8	n/a	n/a	n/a	16946 meters Northeast of Block 7 point North2	16.7	<1x<1x<0.5	Debris
Dredge Spoil Area	URS_SC02	n/a	696335.8	8644846.5	n/a	n/a	n/a	17227 meters Northeast of Block 7 point North 2	16.8	<1x<1xnmh	Debris
D	SC218	n/a	704786.0	8617050.0	n/a	n/a	n/a	On the Margin of Block D	n/a	3.0x1.1x1.5	No magnetic anomaly observed in this location
D	SC219	n/a	704810.0	8617086.0	n/a	n/a	n/a	On the Margin of Block D	n/a	2.8x1.2x1.0	No magnetic anomaly observed in this location

Appendix C:

Table of Gradiometric Anomalies

Anomaly Number	Previous Number	Old KP	Easting	Northing	Maximum Tolerance	Comments	Estimated Burial Depth (m)	Estimated Mass (kg Fe)
FA159	A238	857.9	690110.0	8628724.0	28.81		0.57	9.7
FA160	A240	858.3	690322.0	8628429.0	18.35		0.52	7.69
FA161	A242	858.4	690388.0	8628348.0	14.47		0.45	12.05
FA162	A243	858.5	690444.0	8628284.0	8.32		1.91	23.14
FA163	A247	859	690742.0	8627932.0	73.96		0.23	2.51
FA164	A248	859	690759.0	8627873.0	3.98		3.96	120
FA165	A269	863.6	693618.0	8624241.0	59.92		0.95	41.01
FA170	A281	864.9	694353.0	8623259.0	18.53		1.74	26.44
FA171	A282	864.9	694390.0	8623205.0	70.94	Cable Crossing	0.82	7.66
FA172	A284	865.6	694811.0	8622679.0	12.25		0.53	5.75
FA173	A285	865.6	694830.0	8622642.0	4.7		3.28	252.38
FA174	A287	867.1	695675.0	8621517.0	6.05		0.02	1.68
FA175	A290	867.2	695734.0	8621412.0	33.09		No result	No result
FA176	A291	867.2	695731.0	8621395.0	4.84		4.04	176
FA177	A292	867.2	695764.0	8621368.0	35.17		0.17	8.73
FA178	A295	867.5	695888.0	8621081.0	171.93		6.72	674
FA179	A296	868.3	696233.0	8620380.0	5.33		1.42	84.86
FA180	A298	869.3	696672.0	8619481.0	70.12		1.47	75.88
FA181	A299	869.7	696796.0	8619144.0	17.44		1	10.61
FA182	A300	871	697356.0	8617987.0	n/a		1.22	2.43
FA183	A302	871.2	697422.0	8617786.0	10.2		0.6	9
FA184	A308	876	700052.0	8613870.0	4.46		1.97	26.3
URSM1	n/a	860.9	691833.2	8626288.8	n/a	Submarine Boom Net	no result	No result
URSM2	n/a	860.4	691513.5	8626688.5	n/a	Submarine Boom Net	No result	No result
MA001	n/a	n/a	702888.6	8618666.1	n/a		1.2	46
MA002	n/a	n/a	702913.4	8618653.1	n/a		3.3	104
MA003	n/a	n/a	702972.9	8618714.8	n/a		0.7	13
MA004	n/a	n/a	702943.7	8618642.4	n/a		1.2	48
MA005	n/a	n/a	702962.1	8618661.9	n/a	Disturbed seabed	1.9	58
MA006	n/a	n/a	703001.7	8618656.3	n/a		0.3	10
MA007	n/a	n/a	702972.7	8618619.4	n/a		1.2	62

MA008	n/a	n/a	702987.1	8618605.1	n/a		1.1	55
MA009	n/a	n/a	703023.3	8618596.8	n/a		0	87
MA010	n/a	n/a	703080.8	8618650.4	n/a		0.5	20
MA011	n/a	n/a	703029.1	8618562.1	n/a		1.4	63
MA012	n/a	n/a	703039.2	8618561.1	n/a		0.1	5
MA013	n/a	n/a	703103.9	8618631.9	n/a		0.1	5
MA014	n/a	n/a	703119.8	8618605.8	n/a		0.1	17
MA015	n/a	n/a	703131.5	8618596.5	n/a		0.5	9
MA016	n/a	n/a	703139.1	8618571.3	n/a		1.2	35
MA017	n/a	n/a	703105.1	8618503.5	n/a	Located in area of masking	0.2	119
MA018	n/a	n/a	703175.7	8618570.5	n/a		0.2	5
MA019	n/a	n/a	703197.9	8618538.7	n/a		0.8	15
MA020	n/a	n/a	703194.3	8618525.1	n/a		0.6	22
MA021	n/a	n/a	703159.5	8618427.4	n/a		0.5	44
MA022	n/a	n/a	703182.6	8618435.6	n/a		0.1	12
MA023	n/a	n/a	703201.9	8618457.5	n/a		1.1	48
MA024	n/a	n/a	703242.3	8618383.6	n/a	Located in area of masking	0.1	48
MA025	n/a	n/a	703459.7	8618601.8	n/a		0.1	61
MA026	n/a	n/a	703483.2	8618610.9	n/a		0.1	71
MA027	n/a	n/a	703452.7	8618556.8	n/a		1.3	43
MA028	n/a	n/a	703438.9	8618495.7	n/a		1.1	96
MA029	n/a	n/a	703475.1	8618534.5	n/a		1.4	29
MA030	n/a	n/a	703520.2	8618576.3	n/a		0.1	94
MA031	n/a	n/a	703498.8	8618541.5	n/a		0.1	5
MA032	n/a	n/a	703451.7	8618479.4	n/a		0.1	25
MA033	n/a	n/a	703527.6	8618469.6	n/a	Walker Shoal	0.1	281
MA034	n/a	n/a	703379.4	8618269.2	n/a	Located in area of masking	0.2	80
MA035	n/a	n/a	703541.3	8618456.3	n/a	Walker Shoal	0.3	228
MA036	n/a	n/a	703538.1	8618444.9	n/a	Walker Shoal	0.1	62
MA037	n/a	n/a	703547.8	8618433.9	n/a	Walker Shoal	0.1	12

MA038	n/a	n/a	703546.5	8618394.9	n/a	Walker Shoal	0.3	31
MA039	n/a	n/a	703435.0	8618234.2	n/a		0.1	7
MA040	n/a	n/a	703642.8	8618441.5	n/a	Walker Shoal	0.1	7
MA041	n/a	n/a	703461.3	8618201.8	n/a		0.1	0
MA042	n/a	n/a	703752.2	8618350.5	n/a		1.1	279
MA043	n/a	n/a	703628.2	8618162.3	n/a		0.1	8
MA044	n/a	n/a	703636.7	8618160.9	n/a		0.3	24
MA045	n/a	n/a	703758.6	8618270.0	n/a		0.1	165
MA046	n/a	n/a	703762.8	8618242.5	n/a		0.7	125
MA047	n/a	n/a	703736.7	8618165.3	n/a		1.4	23
MA048	n/a	n/a	703842.0	8618293.2	n/a		0.8	116
MA049	n/a	n/a	703753.9	8618170.4	n/a		0	29
MA050	n/a	n/a	703798.0	8618224.5	n/a		2.7	106
MA051	n/a	n/a	703670.5	8618064.2	n/a		1.4	140
MA052	n/a	n/a	703652.0	8618029.0	n/a		0.8	20
MA053	n/a	n/a	703647.9	8618022.5	n/a		1	58
MA054	n/a	n/a	703663.3	8618034.1	n/a		1.2	25
MA055	n/a	n/a	703807.6	8618210.2	n/a	Disturbed seabed	0.2	77
MA056	n/a	n/a	703662.6	8618006.5	n/a		1.3	44
MA057	n/a	n/a	703872.0	8618253.1	n/a		1.1	31
MA058	n/a	n/a	703733.4	8618051.2	n/a		0.1	184
MA059	n/a	n/a	703880.9	8618229.9	n/a		0.4	14
MA060	n/a	n/a	703843.8	8618181.4	n/a		0.5	57
MA061	n/a	n/a	703715.0	8618002.5	n/a		0.4	24
MA062	n/a	n/a	703706.6	8617973.6	n/a		1.5	291
MA063	n/a	n/a	703706.0	8617958.2	n/a		2.3	108
MA064	n/a	n/a	703930.7	8618205.5	n/a		1.1	17
MA065	n/a	n/a	703760.1	8617940.9	n/a	Located in area of masking	0.6	82
MA066	n/a	n/a	703890.7	8617970.6	n/a		0.4	30
MA067	n/a	n/a	703934.3	8617967.2	n/a		2.4	174
MA068	n/a	n/a	703901.7	8617919.7	n/a		1.4	61
MA069	n/a	n/a	703878.3	8617884.4	n/a	located at end of seabed scar	0.1	5
MA070	n/a	n/a	703861.1	8617847.9	n/a		0.1	8
MA071	n/a	n/a	703924.8	8617915.2	n/a		0.1	7

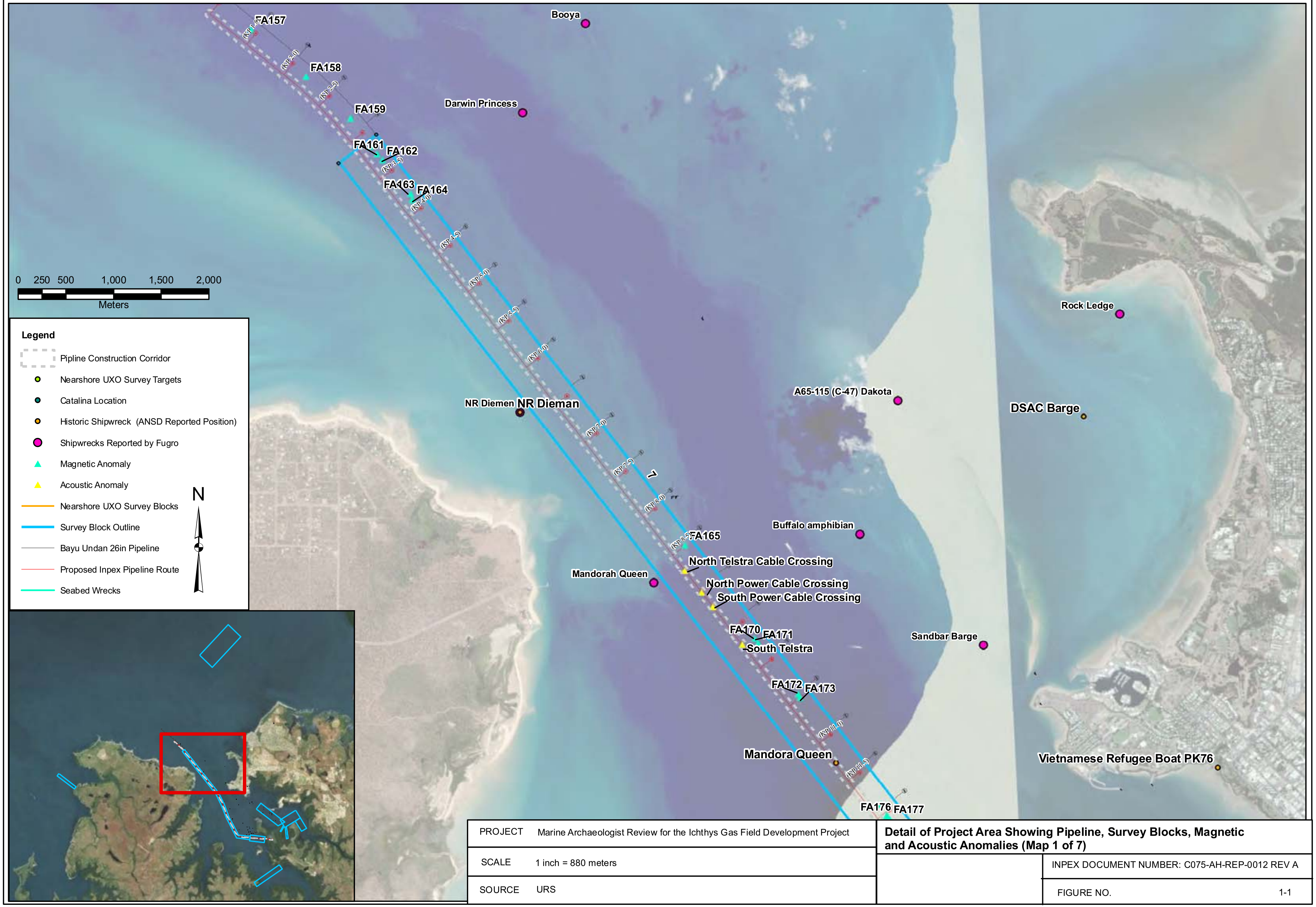
MA072	n/a	n/a	703951.1	8617942.5	n/a		1.6	108
MA073	n/a	n/a	703934.1	8617916.4	n/a		0.6	25
MA074	n/a	n/a	704053.9	8618060.6	n/a		1	23
MA075	n/a	n/a	703882.8	8617835.1	n/a		0.1	31
MA076	n/a	n/a	703962.6	8617929.3	n/a		2.2	123
MA077	n/a	n/a	703893.4	8617834.9	n/a		0.1	7
MA078	n/a	n/a	703988.7	8617946.5	n/a		0.8	26
MA079	n/a	n/a	703902.6	8617831.1	n/a		1.2	48
MA080	n/a	n/a	704000.3	8617918.8	n/a		0.1	5
MA081	n/a	n/a	704181.8	8617941.6	n/a		0.7	26
MA082	n/a	n/a	704173.1	8617921.8	n/a		0.4	17
MA083	n/a	n/a	704179.1	8617906.5	n/a		2	121
MA084	n/a	n/a	704104.0	8617809.5	n/a		0.6	28
MA085	n/a	n/a	704086.9	8617779.9	n/a		1.1	40
MA086	n/a	n/a	704183.8	8617900.0	n/a		0.1	12
MA087	n/a	n/a	704146.8	8617845.9	n/a	Disturbed seabed	0.4	13
MA088	n/a	n/a	704098.5	8617783.4	n/a		2.2	146
MA089	n/a	n/a	704023.0	8617674.9	n/a	In vicinity of the Kelat	0.1	62
MA090	n/a	n/a	704153.3	8617806.1	n/a		0.1	8
MA091	n/a	n/a	704194.0	8617839.3	n/a		1.4	33
MA092	n/a	n/a	704072.2	8617682.7	n/a	In vicinity of the Kelat	0.1	1
MA093	n/a	n/a	704151.3	8617775.5	n/a		0.3	7
MA094	n/a	n/a	704216.4	8617848.0	n/a		0.5	33
MA095	n/a	n/a	704155.8	8617769.5	n/a		0.6	95
MA096	n/a	n/a	704150.9	8617752.9	n/a		0.7	57
MA097	n/a	n/a	704145.4	8617742.2	n/a		0.6	76
MA098	n/a	n/a	704191.4	8617796.8	n/a		0.1	6
MA099	n/a	n/a	704203.5	8617811.0	n/a		1.2	76
MA100	n/a	n/a	704118.8	8617703.9	n/a	Located close to seabed scar	0.3	799
MA101	n/a	n/a	704134.6	8617721.9	n/a		0.5	26
MA102	n/a	n/a	704154.4	8617732.9	n/a		0.2	64
MA103	n/a	n/a	704085.6	8617642.9	n/a	In vicinity of the Kelat	0.1	3
MA104	n/a	n/a	704230.4	8617813.3	n/a		0	17
MA105	n/a	n/a	704098.3	8617642.3	n/a	In vicinity of the Kelat	0.1	36

MA106	n/a	n/a	704103.2	8617633.4	n/a	In vicinity of the Kelat	0.2	33
MA107	n/a	n/a	704143.5	8617664.3	n/a		0.1	23
MA108	n/a	n/a	704113.8	8617626.7	n/a	In vicinity of the Kelat	0.1	49
MA109	n/a	n/a	704098.9	8617602.4	n/a	In vicinity of the Kelat	0.1	843
MA110	n/a	n/a	704120.4	8617612.6	n/a	In vicinity of the Kelat	0	6
MA111	n/a	n/a	704226.7	8617741.1	n/a		0.1	7
MA112	n/a	n/a	704119.9	8617590.8	n/a	In vicinity of the Kelat	0.6	97
MA113	n/a	n/a	704135.6	8617598.0	n/a	In vicinity of the Kelat	0.1	163
MA114	n/a	n/a	704194.0	8617627.5	n/a		0.1	192
MA115	n/a	n/a	704289.9	8617726.2	n/a		0.6	15
MA116	n/a	n/a	704159.6	8617557.3	n/a	In vicinity of the Kelat	0.6	229
MA117	n/a	n/a	704234.2	8617618.6	n/a		0	5
MA118	n/a	n/a	704252.0	8617597.7	n/a		0.1	5
MA119	n/a	n/a	704211.1	8617541.0	n/a		0.1	17
MA120	n/a	n/a	704311.8	8617659.9	n/a		2.5	111
MA121	n/a	n/a	704270.6	8617600.8	n/a		0.3	265
MA122	n/a	n/a	704280.9	8617603.1	n/a		2.3	249
MA123	n/a	n/a	704240.0	8617546.4	n/a		0.2	18
MA124	n/a	n/a	704229.1	8617532.2	n/a		0.6	235
MA125	n/a	n/a	704278.6	8617592.4	n/a		0.8	219
MA126	n/a	n/a	704276.4	8617580.4	n/a		0.1	20
MA127	n/a	n/a	704235.3	8617522.5	n/a		0.1	11
MA128	n/a	n/a	704312.8	8617591.8	n/a		0.1	23
MA129	n/a	n/a	704317.3	8617587.2	n/a		0.1	16
MA130	n/a	n/a	704399.3	8617672.2	n/a		0.1	25
MA131	n/a	n/a	704393.6	8617664.8	n/a		0.1	37
MA132	n/a	n/a	704258.5	8617492.4	n/a		0.1	22
MA133	n/a	n/a	704305.6	8617533.9	n/a		0.1	18
MA134	n/a	n/a	704306.4	8617526.5	n/a		0.1	8
MA135	n/a	n/a	704287.2	8617480.0	n/a		0.1	20
MA136	n/a	n/a	704468.7	8617697.3	n/a		0.1	46
MA137	n/a	n/a	704303.1	8617465.5	n/a		0.1	59
MA138	n/a	n/a	704440.5	8617609.6	n/a		0.4	9
MA139	n/a	n/a	704446.3	8617607.8	n/a		0.7	2

MA140	n/a	n/a	704350.2	8617474.2	n/a		0.1	4
MA141	n/a	n/a	704349.9	8617454.1	n/a		0.1	36
MA142	n/a	n/a	704457.9	8617569.7	n/a		0.7	39
MA143	n/a	n/a	704508.4	8617600.1	n/a		0.3	22
MA144	n/a	n/a	704421.6	8617483.0	n/a		0.1	15
MA145	n/a	n/a	704427.4	8617485.0	n/a		0.1	16
MA146	n/a	n/a	704364.4	8617402.2	n/a		0.1	9
MA147	n/a	n/a	704461.2	8617462.7	n/a		1	70
MA148	n/a	n/a	704466.3	8617467.3	n/a		0.1	19
MA149	n/a	n/a	704447.2	8617437.7	n/a		0.8	160
MA150	n/a	n/a	704437.2	8617407.0	n/a		1.4	126
MA151	n/a	n/a	704457.6	8617432.0	n/a		1	65
MA152	n/a	n/a	704450.0	8617392.1	n/a		1.6	414
MA153	n/a	n/a	704436.4	8617371.5	n/a		0.1	161
MA154	n/a	n/a	704427.8	8617354.8	n/a		0.1	8
MA155	n/a	n/a	704597.2	8617563.6	n/a		0.1	20
MA156	n/a	n/a	704522.2	8617417.8	n/a		2	182
MA157	n/a	n/a	704500.1	8617369.6	n/a		1.9	34
MA158	n/a	n/a	704553.7	8617403.3	n/a		1.4	36
MA159	n/a	n/a	704670.6	8617547.0	n/a		0.5	48
MA160	n/a	n/a	704488.4	8617315.1	n/a		1.3	99
MA161	n/a	n/a	704666.3	8617490.2	n/a		0.1	115
MA162	n/a	n/a	704568.8	8617366.7	n/a		1.8	202
MA163	n/a	n/a	704523.8	8617305.9	n/a		0.1	4
MA164	n/a	n/a	704559.1	8617326.4	n/a		1.2	32
MA165	n/a	n/a	704560.0	8617306.9	n/a		1.3	59
MA166	n/a	n/a	704594.4	8617347.3	n/a		0.9	19
MA167	n/a	n/a	704549.3	8617290.3	n/a		0.5	55
MA168	n/a	n/a	704541.8	8617269.7	n/a		1	52
MA169	n/a	n/a	704732.2	8617503.0	n/a		0.7	41
MA170	n/a	n/a	704526.6	8617244.0	n/a		1	20
MA171	n/a	n/a	704613.1	8617337.9	n/a		0.1	7
MA172	n/a	n/a	704585.4	8617297.1	n/a		1.8	41
MA173	n/a	n/a	704706.1	8617440.9	n/a		1.2	25
MA174	n/a	n/a	704686.4	8617400.9	n/a		1.1	19
MA175	n/a	n/a	704641.0	8617336.0	n/a		0.4	12
MA176	n/a	n/a	704547.1	8617215.6	n/a		1.6	298
MA177	n/a	n/a	704722.8	8617432.9	n/a		1.7	703
MA178	n/a	n/a	704677.1	8617364.0	n/a		0.1	6

MA179	n/a	n/a	704694.9	8617370.7	n/a		0.3	8
MA180	n/a	n/a	704630.7	8617284.5	n/a		0.3	11
MA181	n/a	n/a	704720.6	8617392.2	n/a		0.1	9
MA182	n/a	n/a	704715.6	8617385.6	n/a		0.1	9
MA183	n/a	n/a	704681.8	8617339.2	n/a		0.1	9
MA184	n/a	n/a	704672.4	8617326.7	n/a		0.2	18
MA185	n/a	n/a	704661.5	8617305.8	n/a		1.2	14
MA186	n/a	n/a	704647.4	8617285.2	n/a		0.1	3
MA187	n/a	n/a	704654.1	8617293.2	n/a		0.6	107
MA188	n/a	n/a	704659.8	8617293.4	n/a		0.1	36
MA189	n/a	n/a	704699.3	8617338.3	n/a		1.2	81
MA190	n/a	n/a	704697.4	8617304.4	n/a		1.7	509
MA191	n/a	n/a	704720.7	8617330.6	n/a		0.9	83
MA192	n/a	n/a	704682.7	8617255.5	n/a		0.6	16
MA193	n/a	n/a	704603.1	8617151.2	n/a		0.1	143
MA194	n/a	n/a	704713.4	8617282.0	n/a		0.1	2
MA195	n/a	n/a	704737.3	8617240.0	n/a		0.1	8
MA196	n/a	n/a	704685.4	8617072.2	n/a		0.2	35
MA197	n/a	n/a	704850.8	8617186.5	n/a		1.8	60
MA198	n/a	n/a	704994.2	8617333.4	n/a	Located in area of masking	0.1	334
MA199	n/a	n/a	704762.1	8616984.7	n/a		0.1	47
MA200	n/a	n/a	704967.2	8617224.6	n/a		0.1	11
MA201	n/a	n/a	705064.6	8617283.9	n/a		1.5	44
MA202	n/a	n/a	705100.1	8617304.4	n/a		0.3	21
MA203	n/a	n/a	704909.5	8617056.8	n/a		0.1	5
MA204	n/a	n/a	705112.3	8617236.3	n/a		0.8	25
MA205	n/a	n/a	705139.0	8617248.5	n/a		1.1	36
MA206	n/a	n/a	704968.0	8617014.8	n/a		0.5	34
MA207	n/a	n/a	704893.4	8616876.2	n/a		2.1	109
MA208	n/a	n/a	705002.5	8617012.6	n/a	Located in area of masking	0.1	961
MA209	n/a	n/a	705138.3	8617176.0	n/a		1.1	72
MA210	n/a	n/a	705129.7	8617162.4	n/a		0.1	16
MA211	n/a	n/a	704892.1	8616859.2	n/a		0.2	14
MA212	n/a	n/a	705218.8	8617262.3	n/a		0.3	6
MA213	n/a	n/a	705145.5	8617152.2	n/a		0.4	11
MA214	n/a	n/a	705235.8	8617262.3	n/a		0.9	10

MA215	n/a	n/a	705227.6	8617172.2	n/a		2.1	69
MA216	n/a	n/a	704942.2	8616810.7	n/a	Disturbed seabed, mapped as pockmark	0.6	26
MA217	n/a	n/a	705177.5	8617087.7	n/a		1.8	94

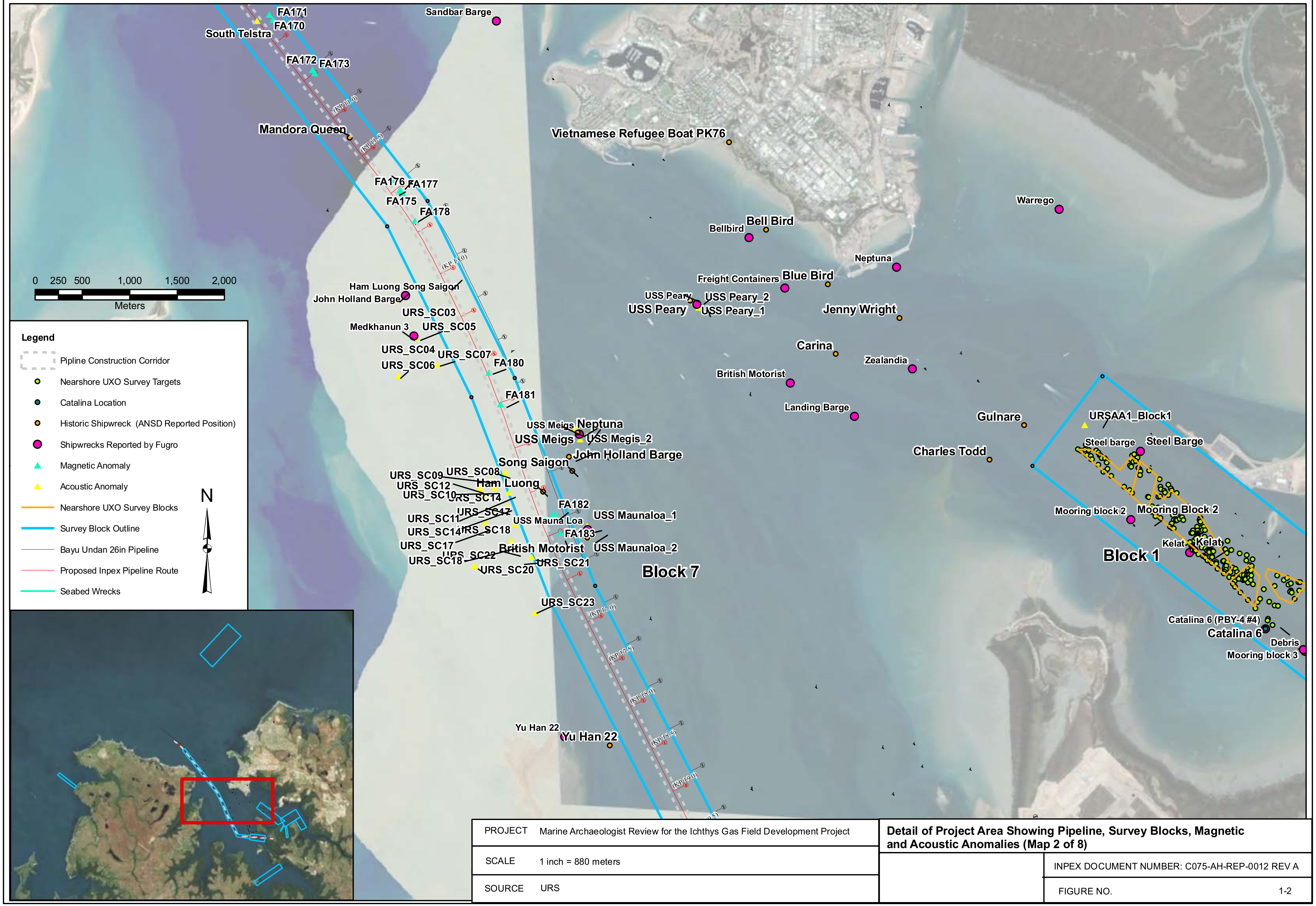


PROJECT	Marine Archaeologist Review for the Ichthys Gas Field Development Project
SCALE	1 inch = 880 meters
SOURCE	URS

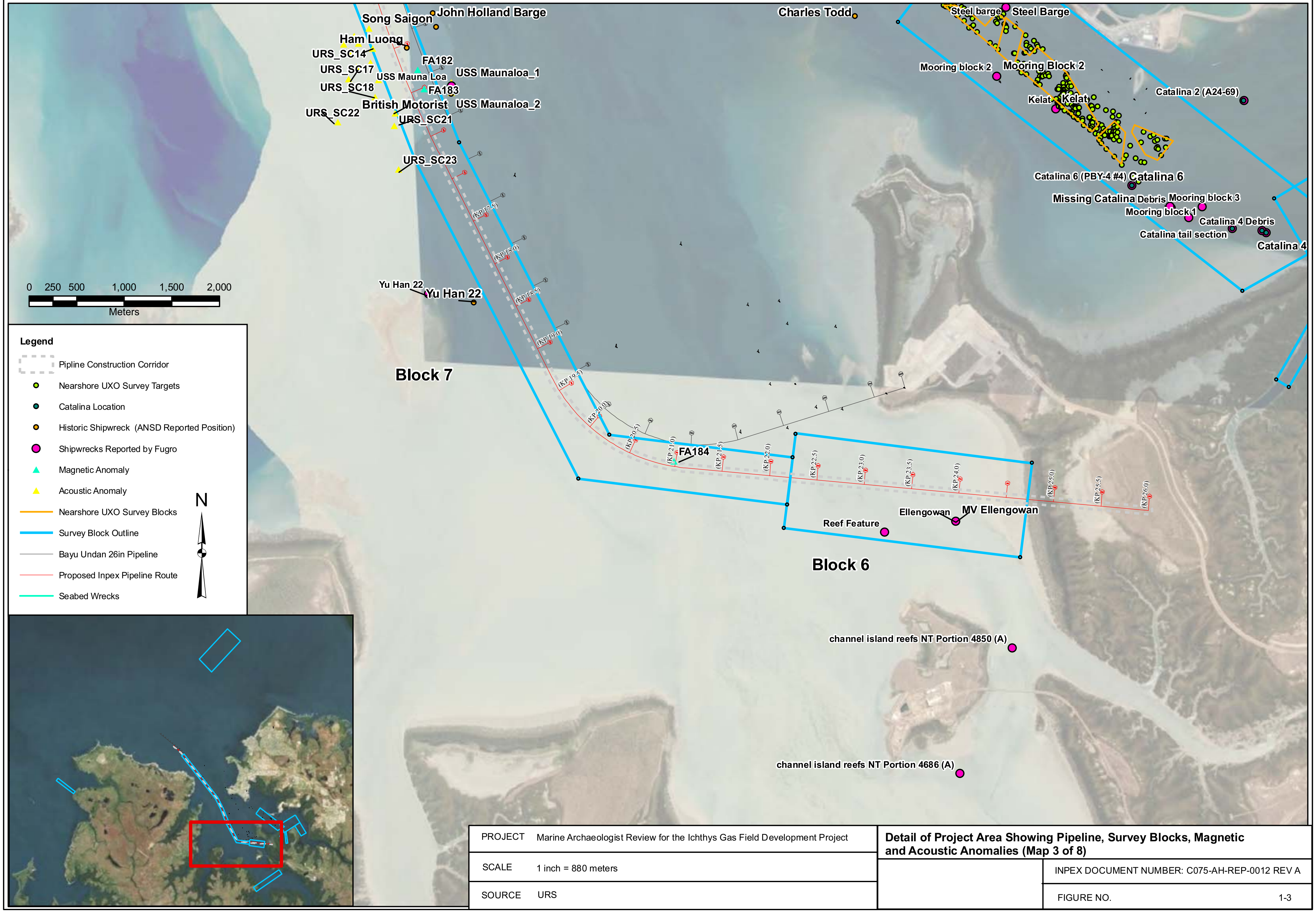
Detail of Project Area Showing Pipeline, Survey Blocks, Magnetic and Acoustic Anomalies (Map 1 of 7)

INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A

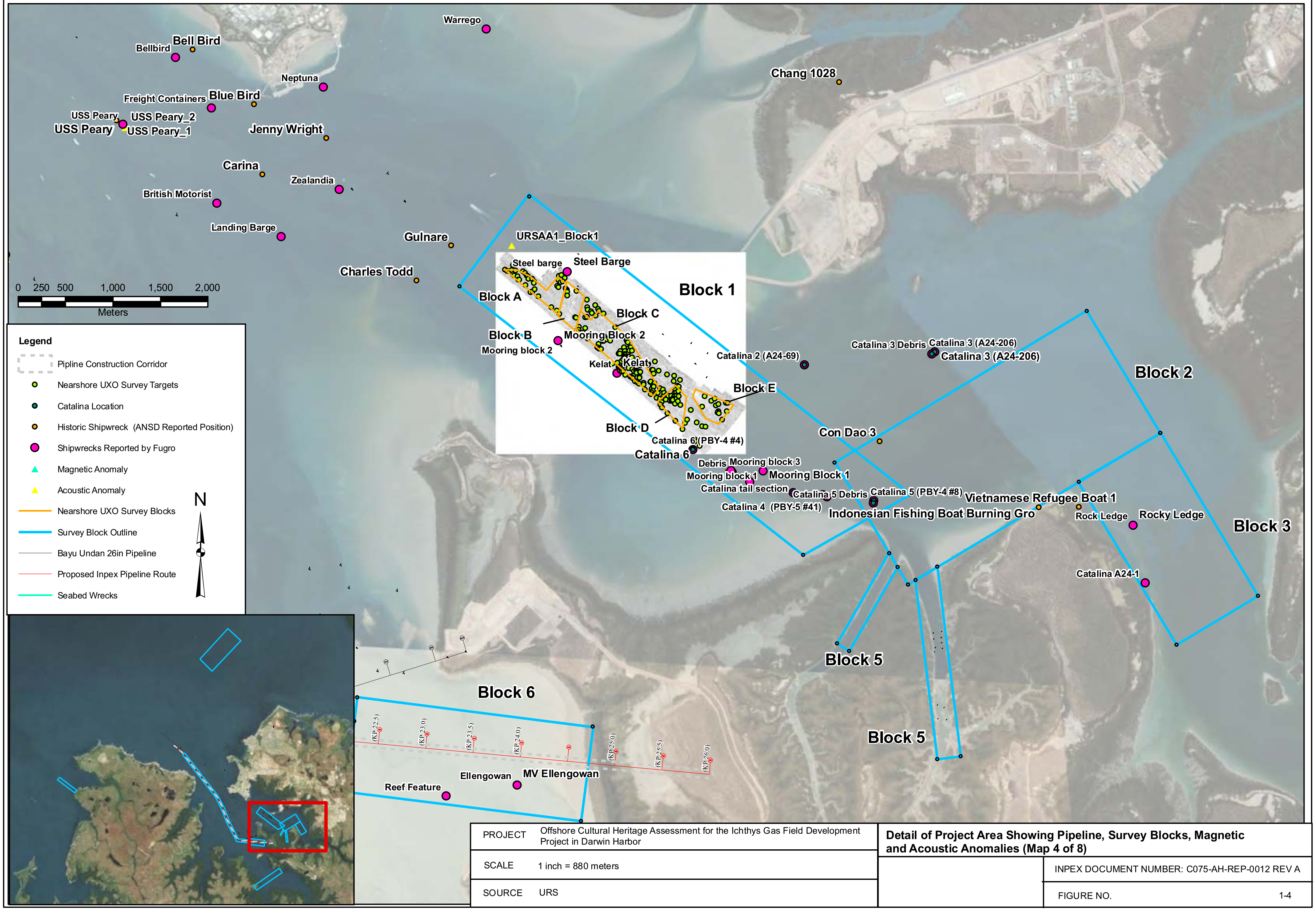
FIGURE NO. 1-1



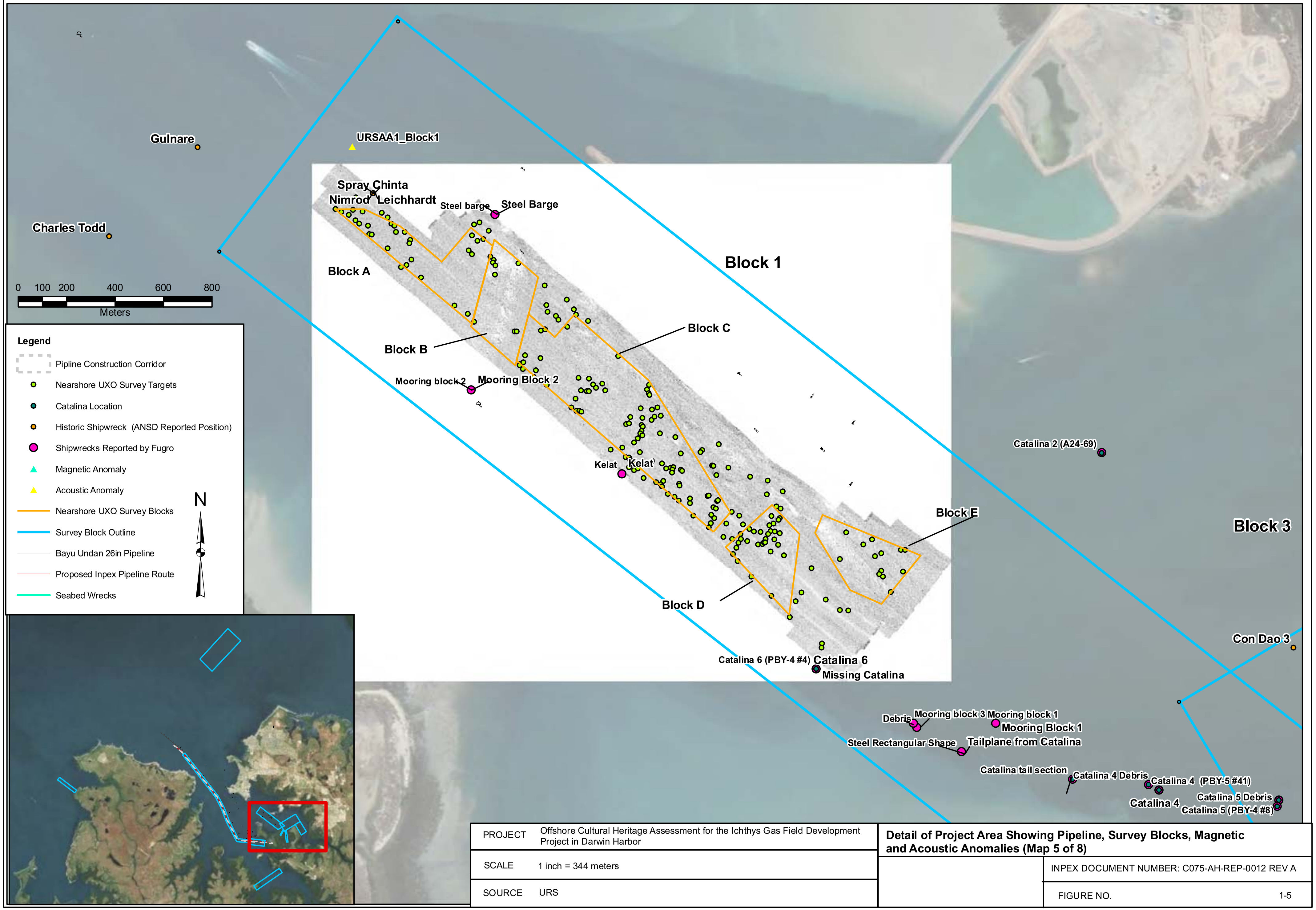
PROJECT	Marine Archaeologist Review for the Ichthys Gas Field Development Project	**Detail of Project Area Showing Pipeline, Survey Blocks, Magnetic and Acoustic Anomalies (Map 2 of 8)**	
SCALE	1 inch = 880 meters		INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A
SOURCE	URS		FIGURE NO. 1-2



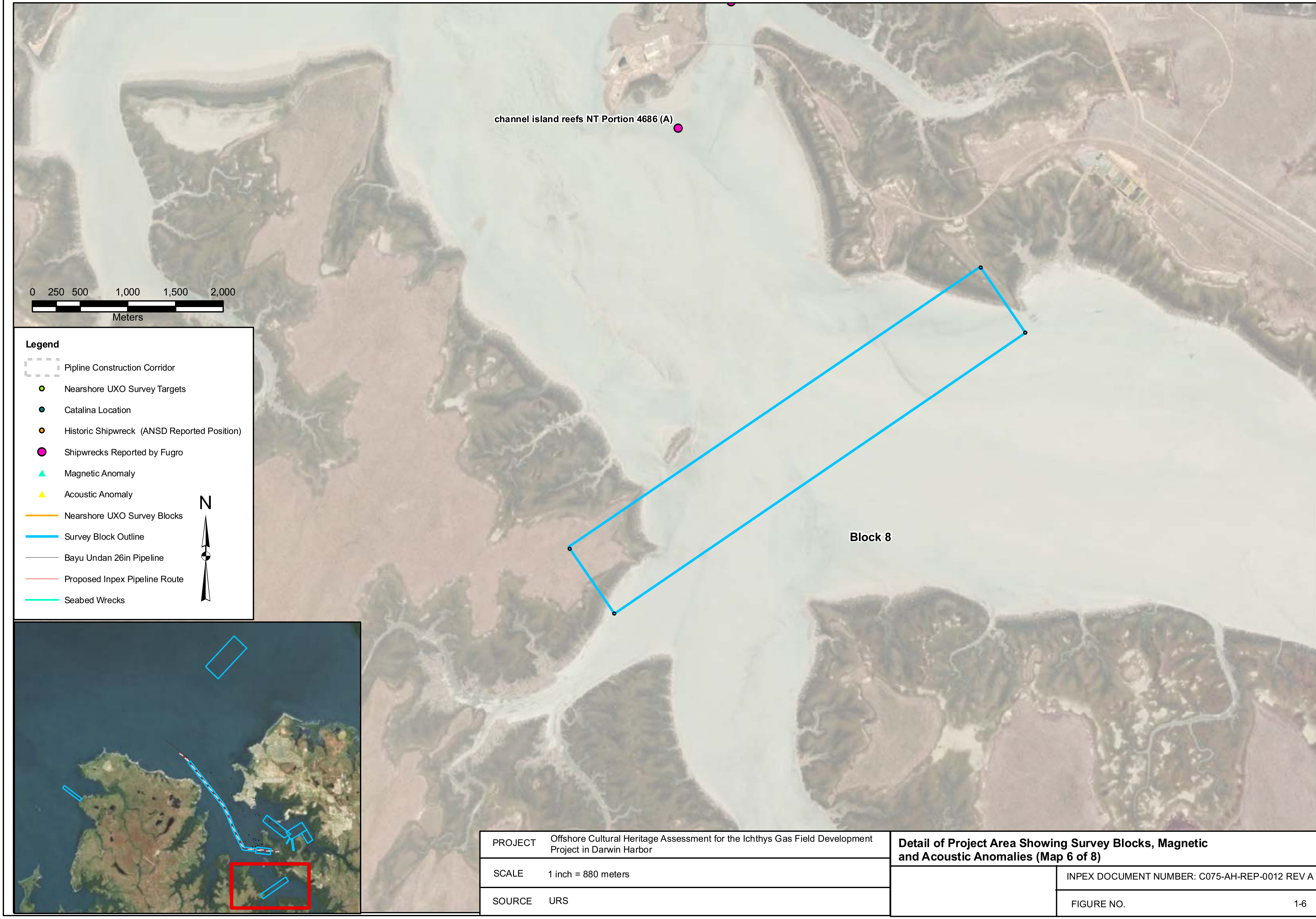
PROJECT	Marine Archaeologist Review for the Ichthys Gas Field Development Project	**Detail of Project Area Showing Pipeline, Survey Blocks, Magnetic and Acoustic Anomalies (Map 3 of 8)**
SCALE	1 inch = 880 meters	INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A
SOURCE	URS	FIGURE NO. 1-3



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Detail of Project Area Showing Pipeline, Survey Blocks, Magnetic and Acoustic Anomalies (Map 4 of 8)**	
SCALE	1 inch = 880 meters		INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A
SOURCE	URS		FIGURE NO. 1-4



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Detail of Project Area Showing Pipeline, Survey Blocks, Magnetic and Acoustic Anomalies (Map 5 of 8)**
SCALE	1 inch = 344 meters	INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A
SOURCE	URS	FIGURE NO. 1-5

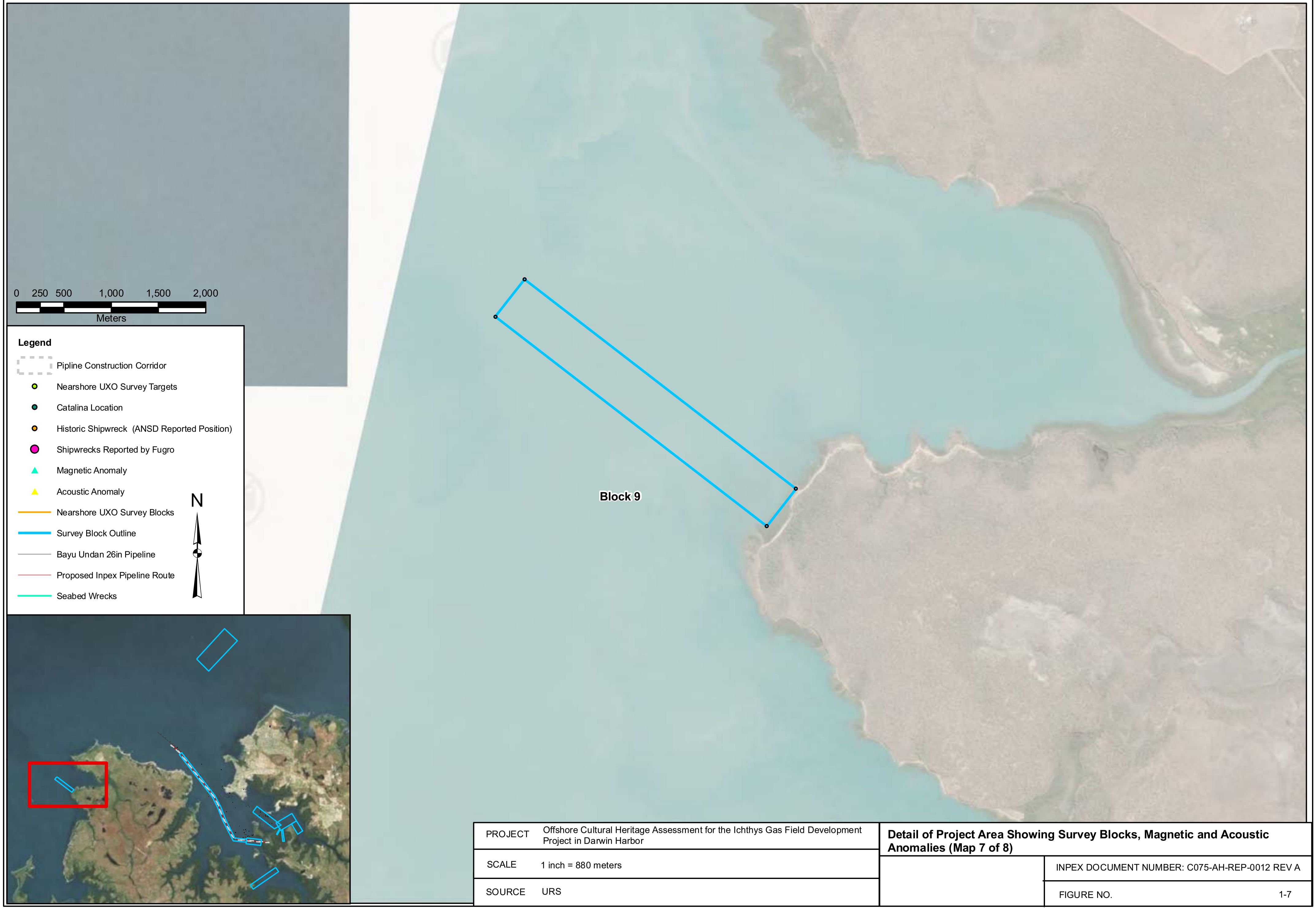


PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor
SCALE	1 inch = 880 meters
SOURCE	URS

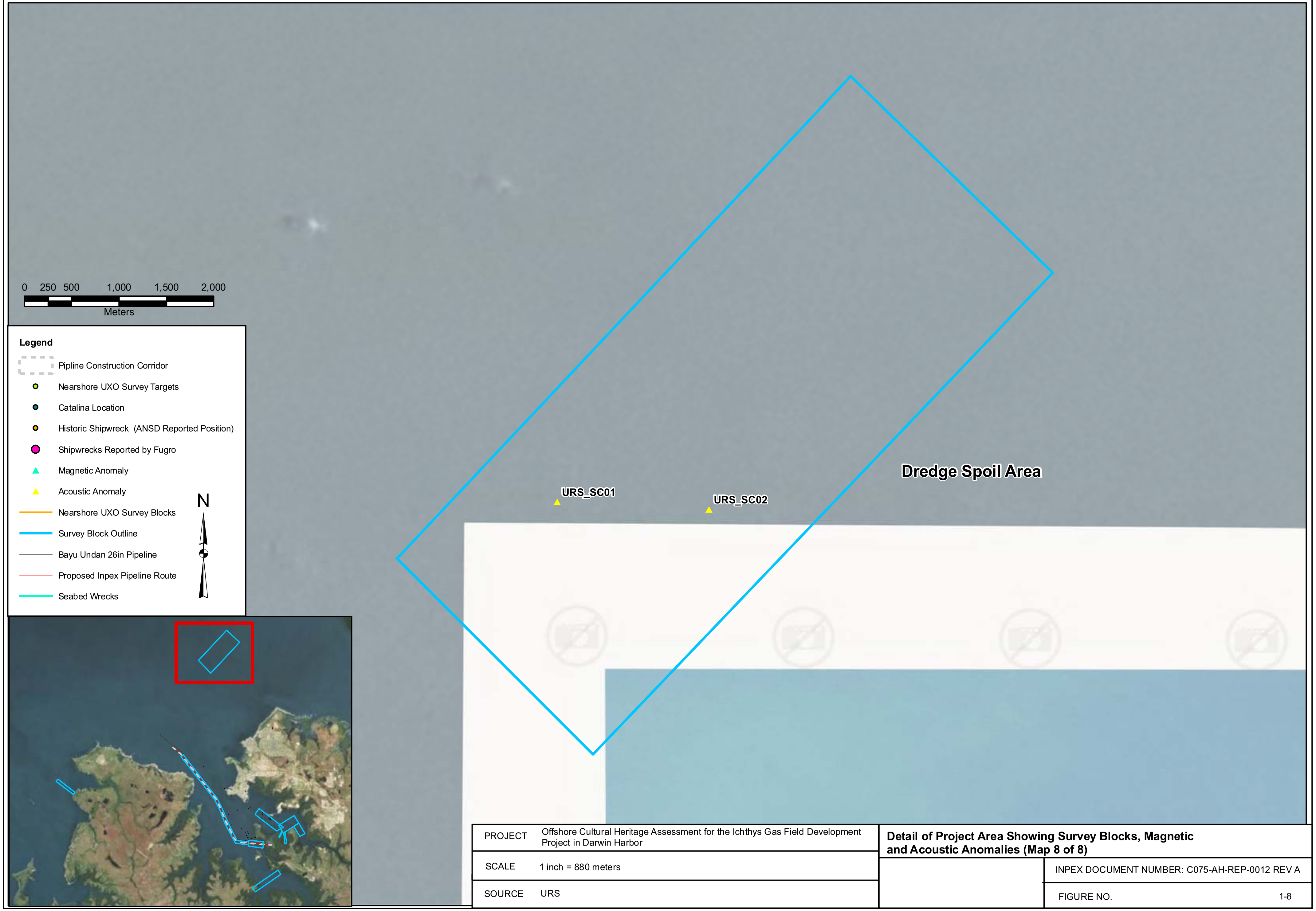
Detail of Project Area Showing Survey Blocks, Magnetic and Acoustic Anomalies (Map 6 of 8)

INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A

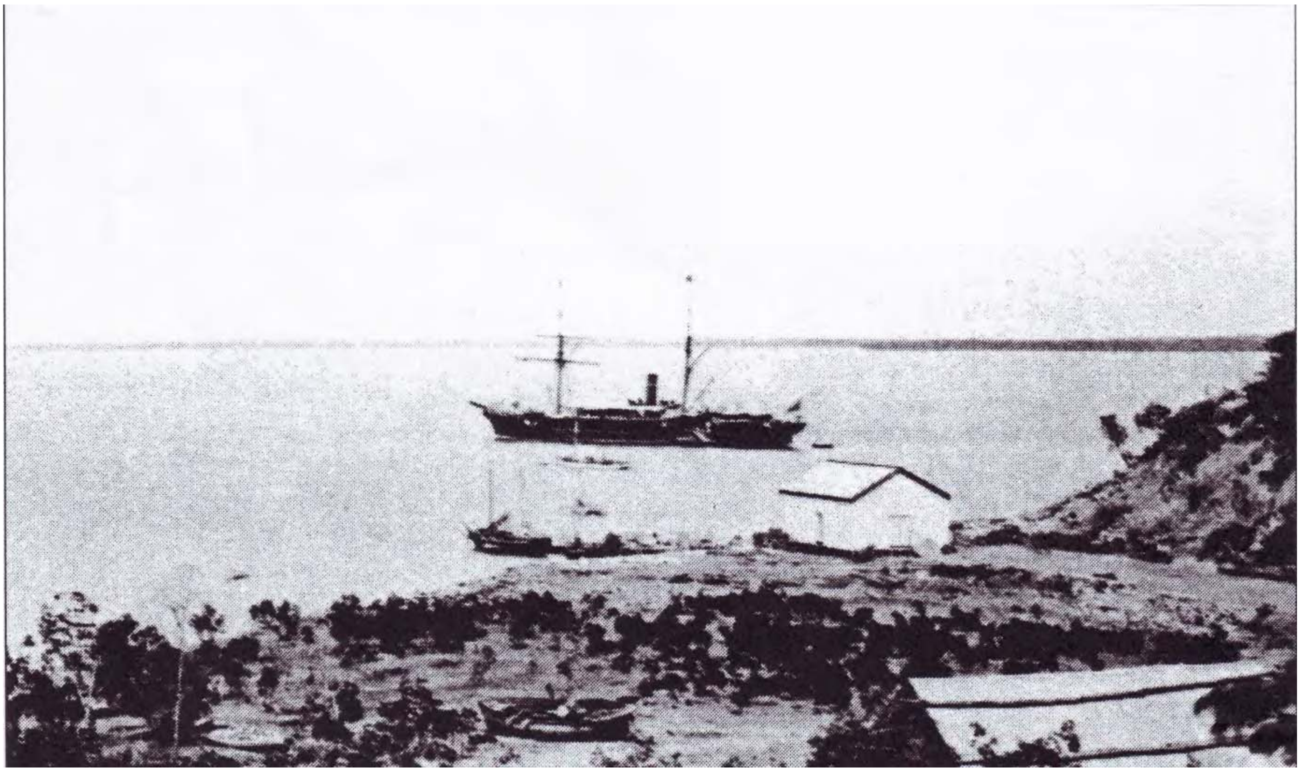
FIGURE NO. 1-6



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Detail of Project Area Showing Survey Blocks, Magnetic and Acoustic Anomalies (Map 7 of 8)**
SCALE	1 inch = 880 meters	INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A
SOURCE	URS	FIGURE NO. 1-7



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Detail of Project Area Showing Survey Blocks, Magnetic and Acoustic Anomalies (Map 8 of 8)**
SCALE	1 inch = 880 meters	INPEX DOCUMENT NUMBER: C075-AH-REP-0012 REV A
SOURCE	URS	FIGURE NO. 1-8



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**The *SS Brisbane* Moored at Fort Hill, Darwin Harbor 1879**
SCALE	n/a	
SOURCE	Steinberg 2005	URS — **PROJECT NO.** 15302605 — **FIGURE NO.** 3-1

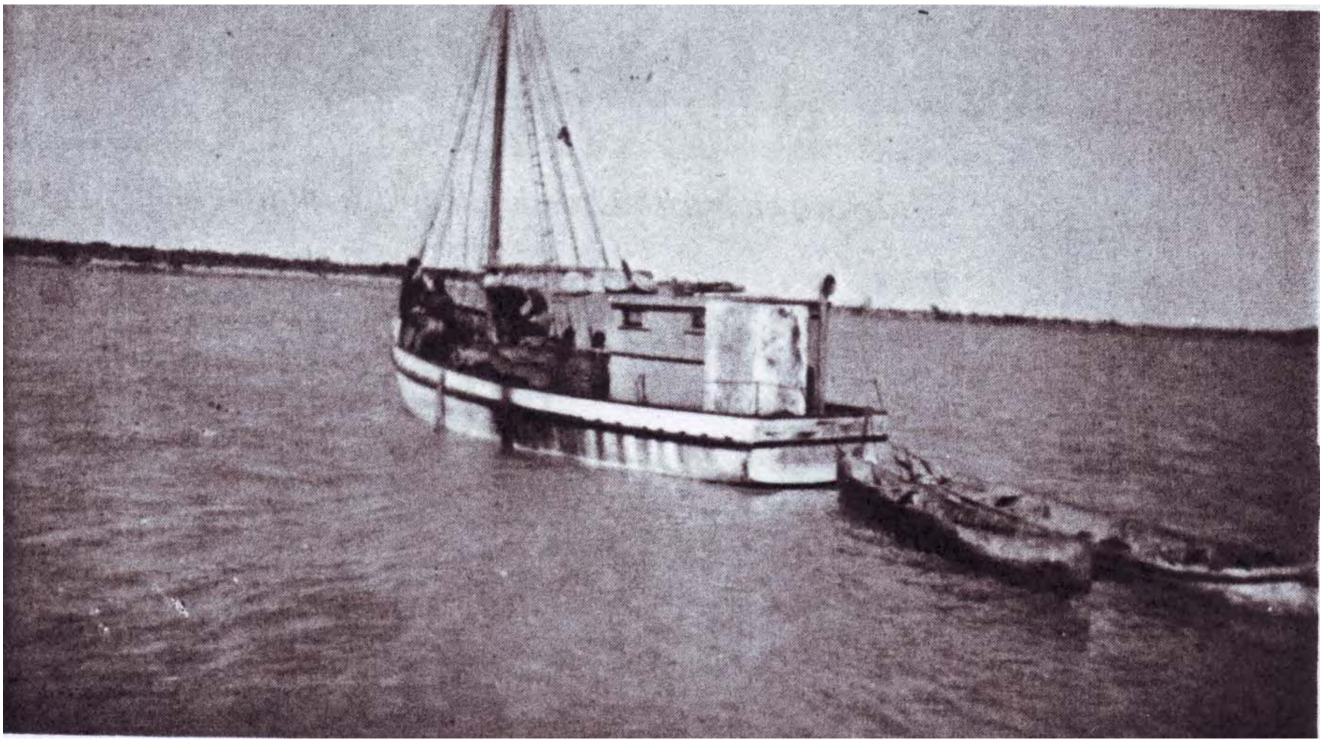
PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor
SCALE	n/a
SOURCE	Thursday Island Postcard Collection 1917

Darwin Pearl Lugger, ca. 1917-1920

URS

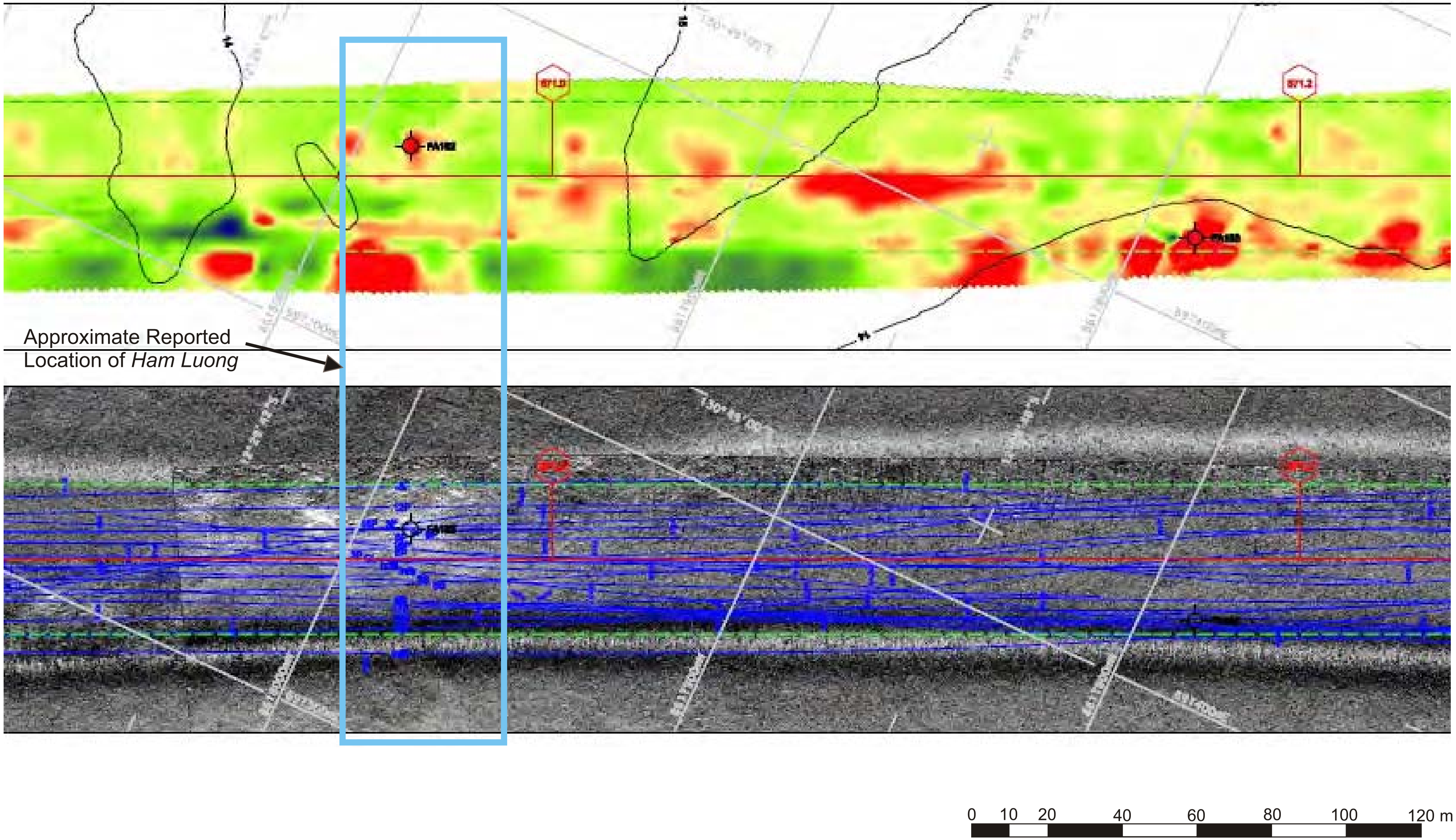
PROJECT NO.	15302605
FIGURE NO.	3-2

PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**A Typical Trading Lugger on the McArthur River at Borroloola, 1901**
SCALE	n/a	
SOURCE	Roberts 2005	URS — **PROJECT NO.** 15302605 — **FIGURE NO.** 3-3



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Small Cutter Equipped with Early Diesel Engine**	
SCALE	n/a	URS	**PROJECT NO.** 15302605
SOURCE	Cole 1975		**FIGURE NO.** 3-4

PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Small Vernacular Sailing Craft Indigenous to Darwin Harbor**	
SCALE	n/a	**PROJECT NO.**	15302605
SOURCE	Carmant 1996	**FIGURE NO.**	3-5

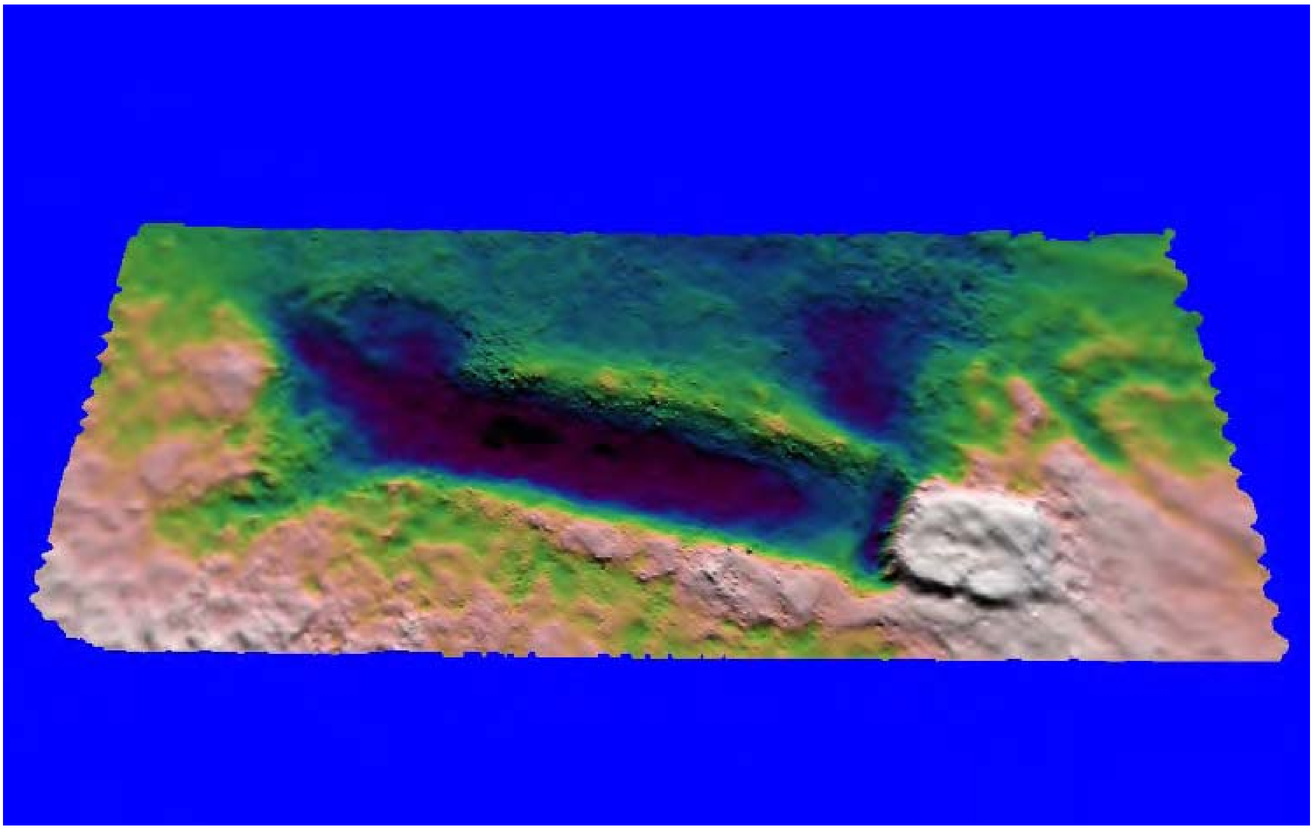


PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor
SCALE	1 inch = 20 meters (0.012 mile)
SOURCE	Fugro 2009b

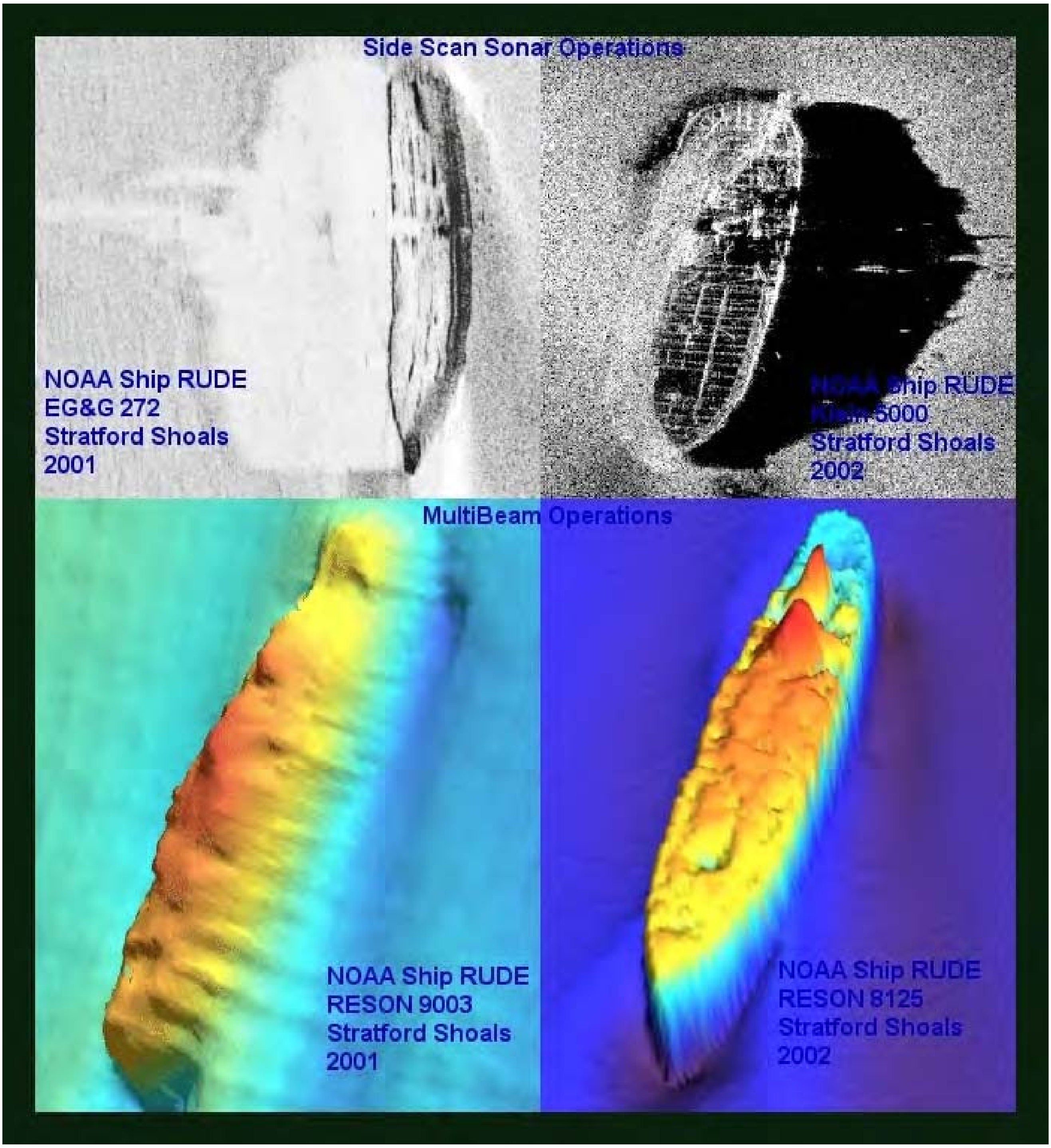
Magnetic and Side Scan Images in the Vicinity of Plotted *Ham Luong* Coordinates

URS

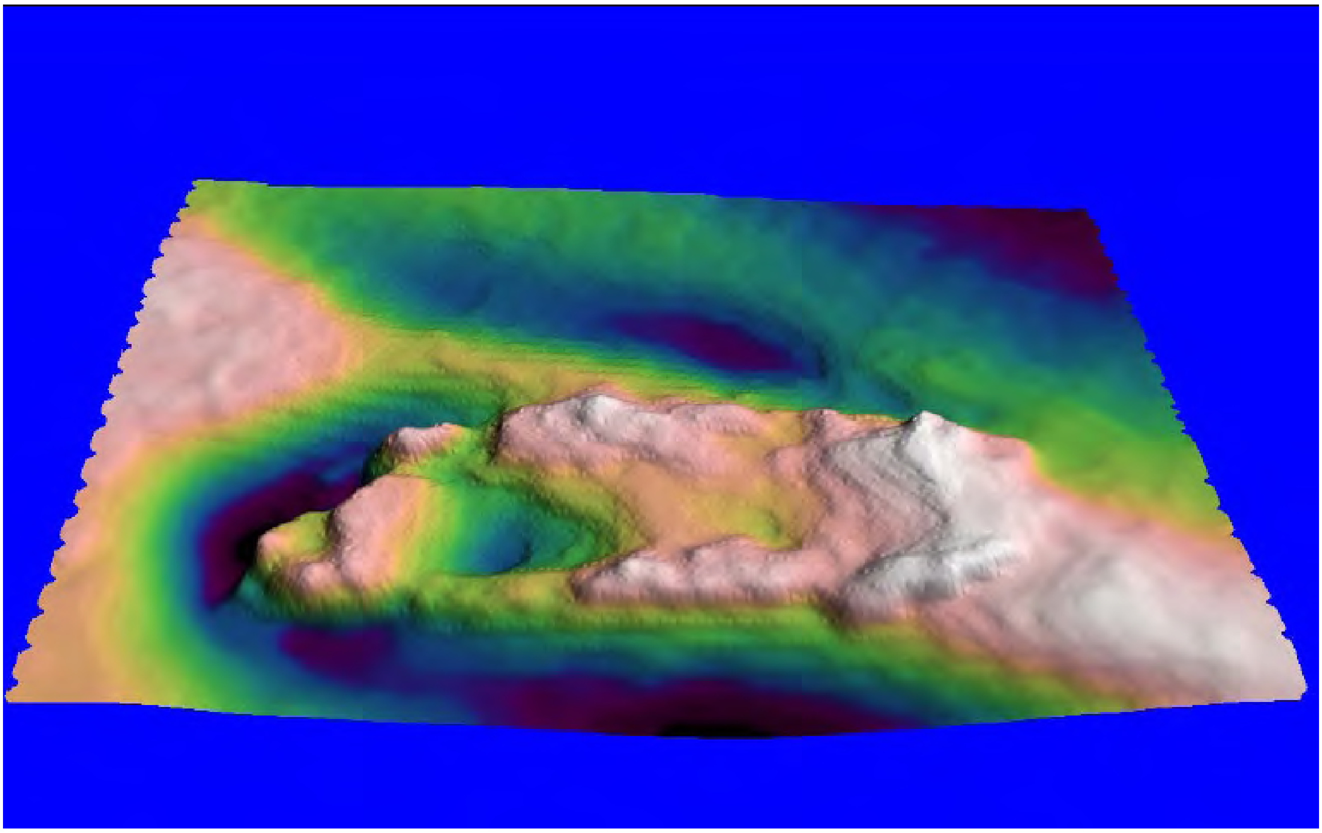
PROJECT NO.	15302605
FIGURE NO.	5-1



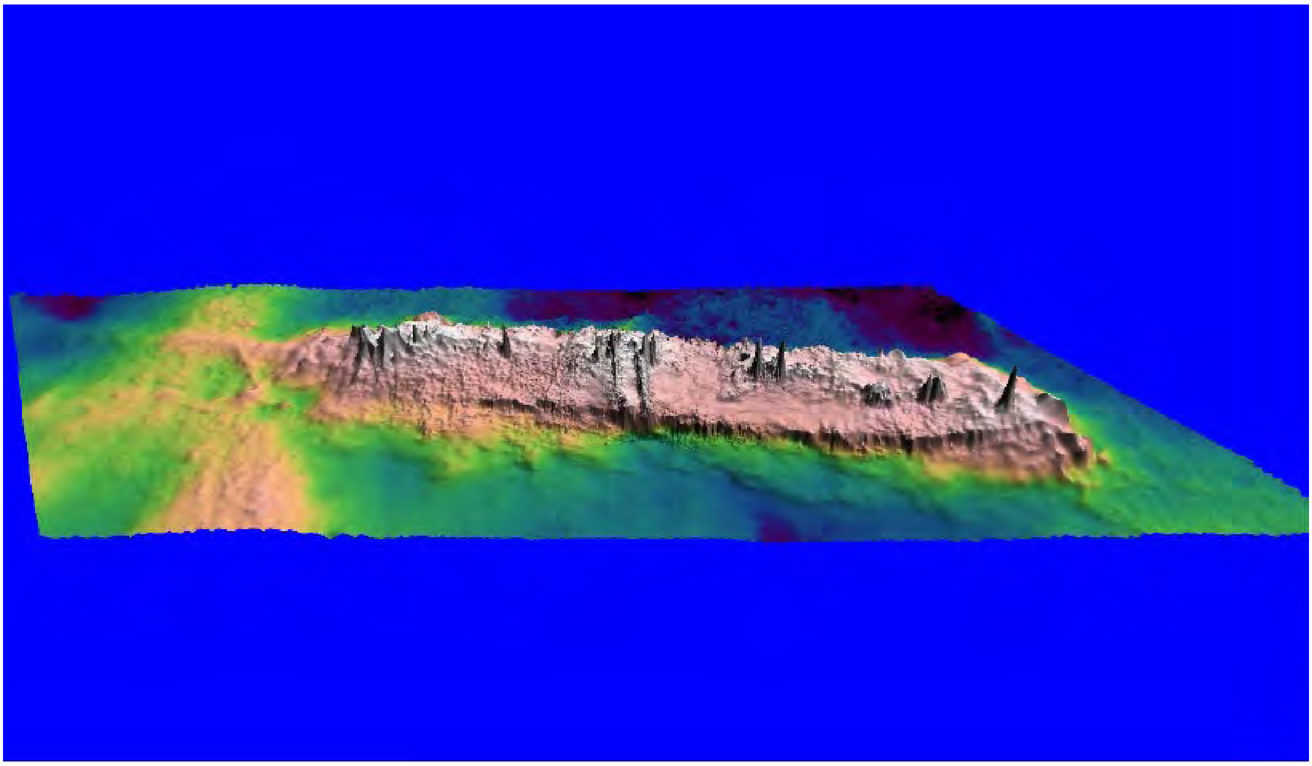
PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Mooring Block 1: Perspective View Looking at Approximately 0°**	
SCALE	n/a	**PROJECT NO.**	15302605
SOURCE	Fugro 2008a	**FIGURE NO.**	6-1



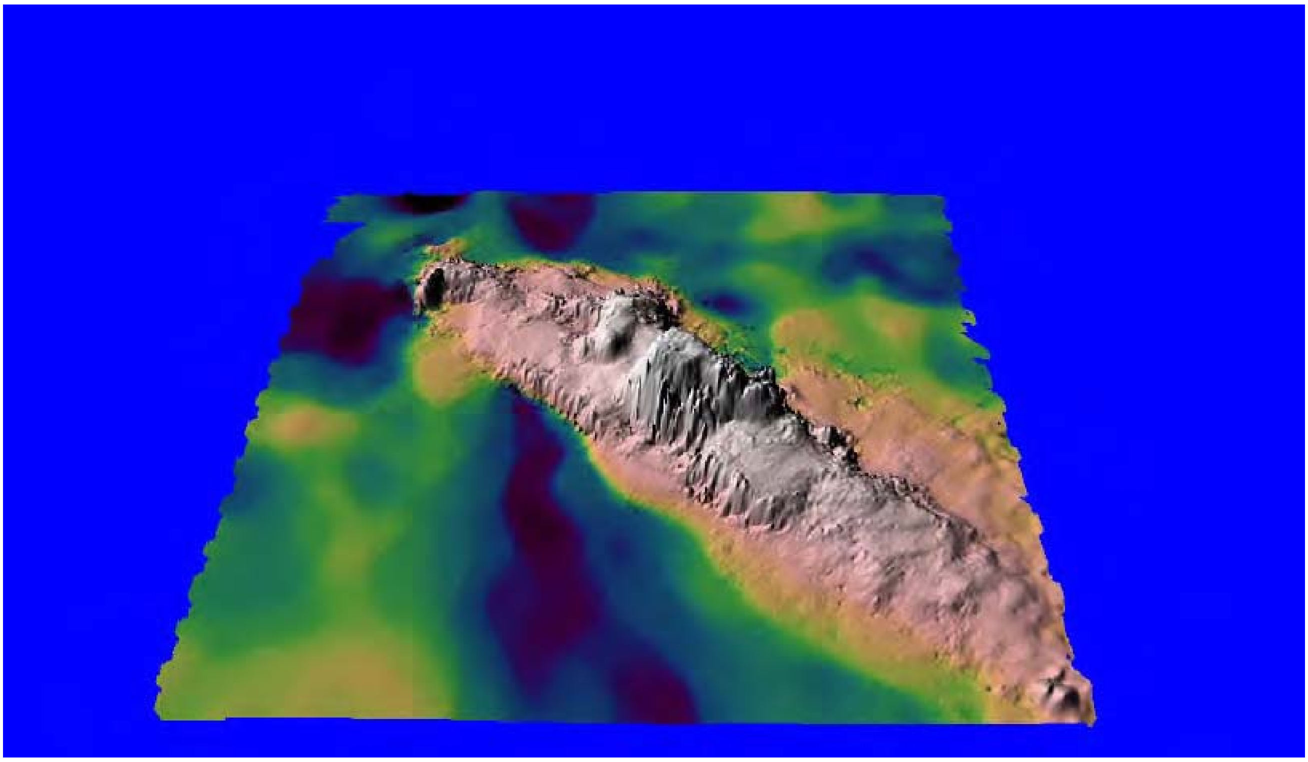
PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Side Scan Sonar and MultiBeam Comparison Image by NOAA Ship *Rude***		
SCALE	n/a	URS	**PROJECT NO.**	15302605
SOURCE	National Oceanic & Atmospheric Administration (NOAA) Photo Library 2010		**FIGURE NO.**	6-2



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Steel Barge: Perspective View Looking at Approximately 180°**	
SCALE	n/a	URS	**PROJECT NO.** 15302605
SOURCE	Fugro 2008a		**FIGURE NO.** 6-3



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	***Kelat*: Perspective View Looking at Approximately 20°**	
SCALE	n/a	**PROJECT NO.**	15302605
SOURCE	Fugro 2008a	**FIGURE NO.**	6-4

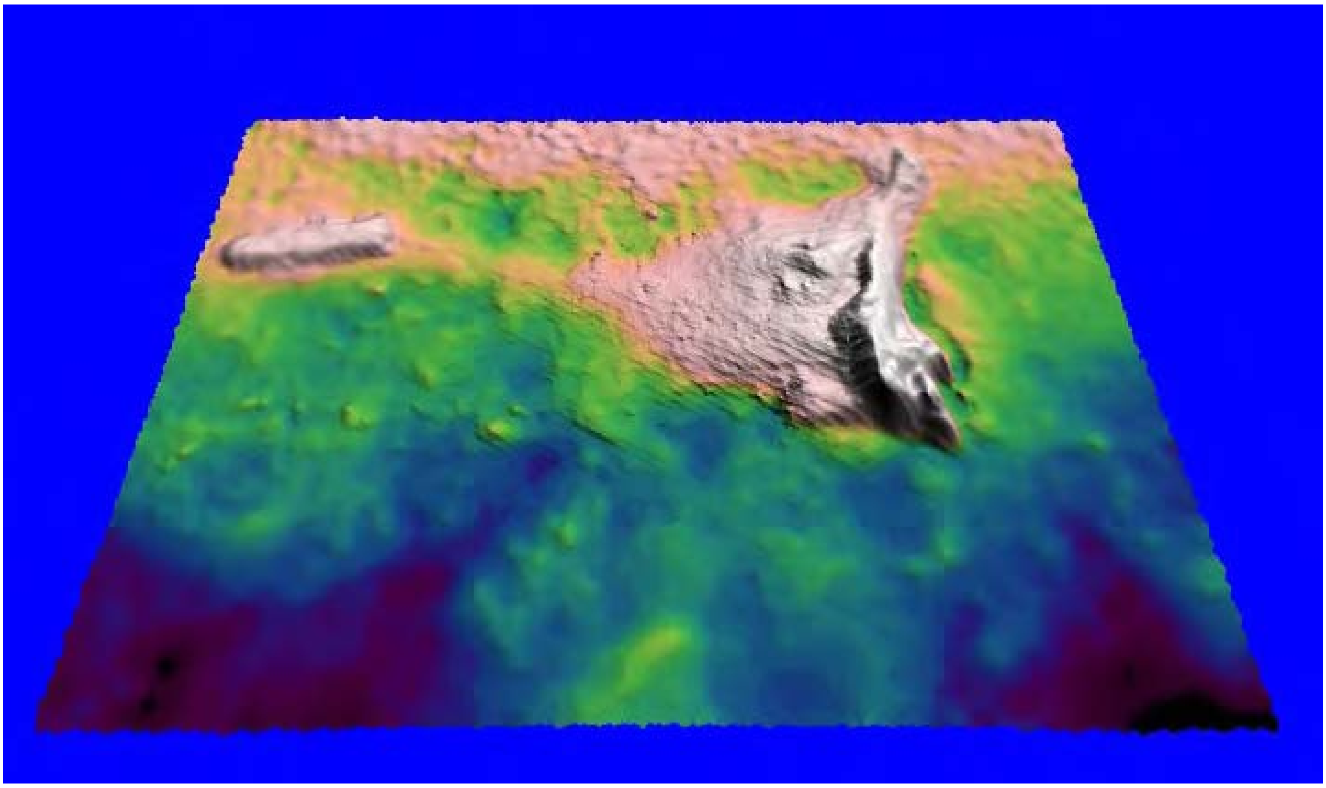


PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor
SCALE	n/a
SOURCE	Fugro 2008a

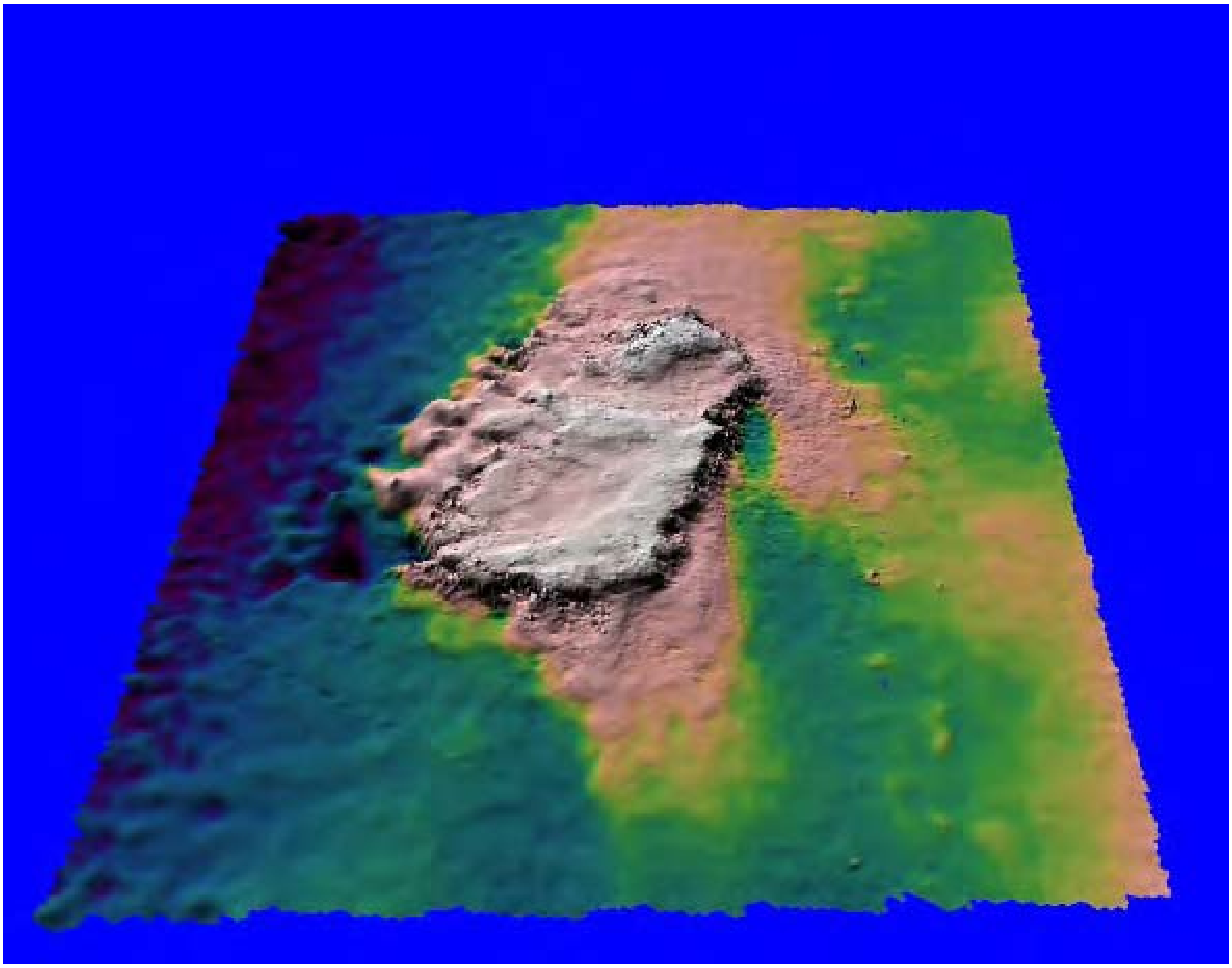
***Ellengowan*: Perspective View Looking at Approximately 180°**

URS

PROJECT NO.	15302605
FIGURE NO.	6-5



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Catalina 3 (A24-206): Perspective View Looking at Approximately 240°**	
SCALE	n/a	URS	**PROJECT NO.** 15302605
SOURCE	Fugro 2008a		**FIGURE NO.** 6-6



PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Rocky Ledge: Perspective View Looking at Approximately 150°**
SCALE	n/a	
SOURCE	Fugro 2008a	URS — **PROJECT NO.** 15302605 — **FIGURE NO.** 6-7

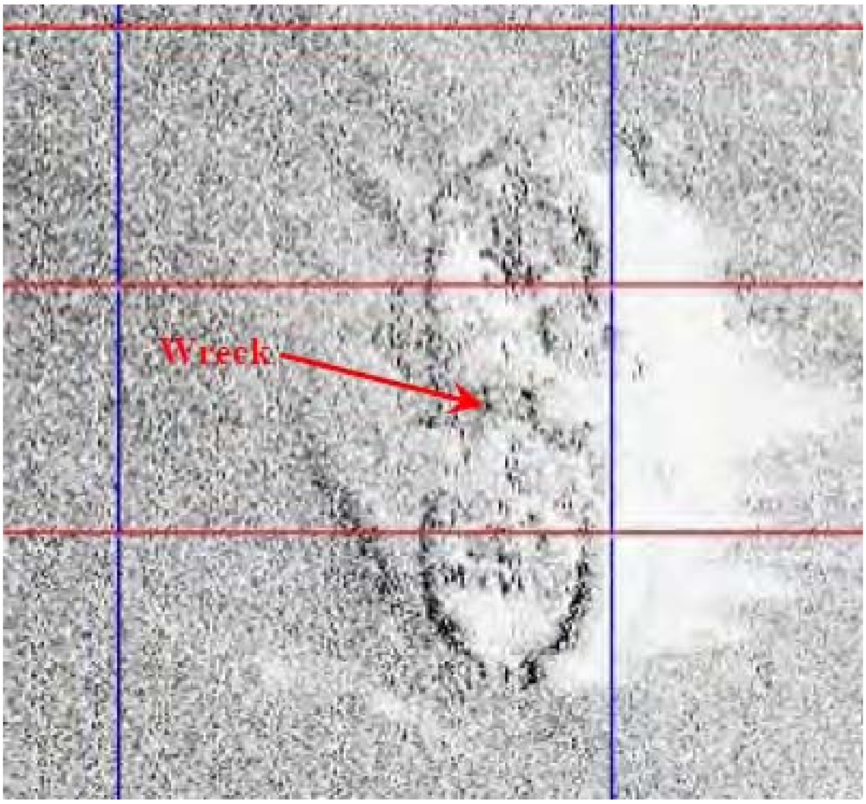


Figure 6-8. Side Scan Sonar Image of USS Maunaloa

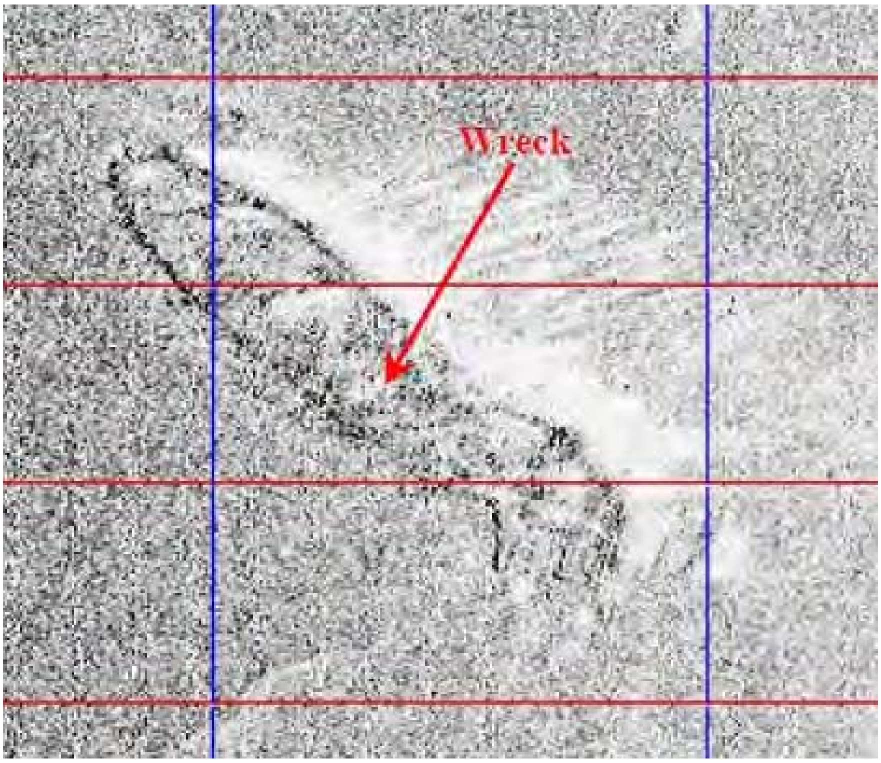


Figure 6-9. Side Scan Sonar Image of USS Meigs

PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Figure 6-8 and 6-9**	
SCALE	n/a	URS	**PROJECT NO.** 15302605
SOURCE	EGS 2009		**FIGURE NO.** 6-8 and 6-9

PROJECT	Offshore Cultural Heritage Assessment for the Ichthys Gas Field Development Project in Darwin Harbor	**Side Scan Sonar Image of Frances Bay Wreck**
SCALE	n/a	
SOURCE	McKinnon et. al 2010	URS
		PROJECT NO. 15302605
		FIGURE NO. 6-10