ex-HMAS Adelaide - Structural Condition Report

Prepared for Department of Planning, Housing, and Infrastructure

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Version C

OPPORTUNITIES THROUGH EXCELLENCE

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Contents

Document Control				
Revision	Date	Prepared	Reviewed	Approved
A	16/10/2024	Redacted	Redacted	Redacted
B	25/11/2024	Redacted	Redacted	Redacted
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REVISIONS

Revision ID	Commentary
B	• Added the Consequence Matrix from the DPHI Risk Management Guide • Added further commentary to the Risk Assessments in Section 6.2. • Added a disclaimed regarding professional diving commentary to Section 6.2. • Added Appendix A – Recommendations for Further Investigation and Monitoring.
C	• Further details on recommendations and ongoing monitoring provided.

1. Foreword

BG&E Pty Limited have been engaged by the Department of Planning, Housing, and Infrastructure to prepare a report on the ex-HMAS Adelaide dive site following a damaging storm event. This report is based on a desktop review of professional dive reports and inspections conducted from July 2024 to September 2024. However, to ensure thorough due diligence, reports have been reviewed from 2011 – 2023.

The purpose of this report is to provide structural, materials, and durability engineering perspectives on the damaged vessel, focussing specifically on the aluminium superstructure that has detached from the main hull. It should be noted that BG&E have not completed any dive inspections, material testing, or modelling as the data was not available to conduct these assessments.

2. History

The ex-HMAS Adelaide, an Oliver Perry-class frigate and former Royal Australian Navy warship was scuttled on the 13th of April 2011 to create an artificial reef for marine life and the enjoyment of divers. Located about 1.8 km off Avoca Beach, near Terrigal on the Central Coast of New South Wales, the ship lies approximately 32 meters deep and has become an attraction for divers.

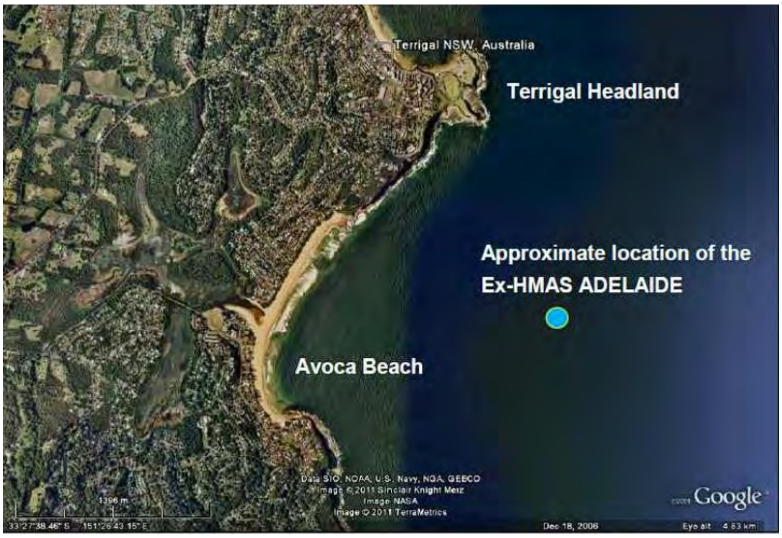


Figure 1 Approximate Location of the ex-HMAS Adelaide

During the clearance dive it was noted that all charges detonated correctly and that only minor cracks on 02 Deck were observed. The inclination of the ship measured 2.5-3 degrees to port.

Figure 2 Sequence of Scuttling Photos

We note the following inspection and engineering report history.

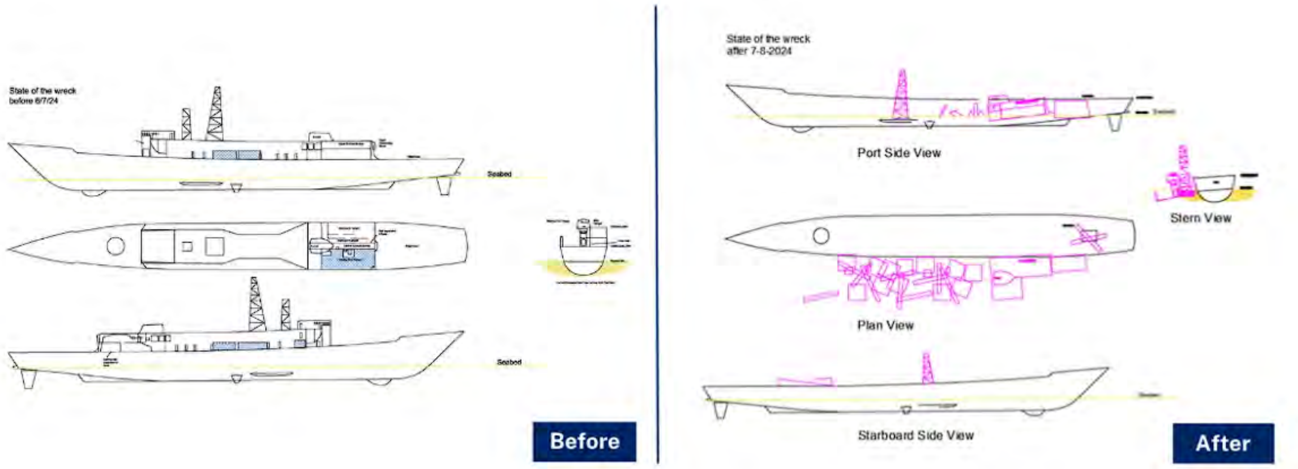
- Structural Monitoring – Diver’s Report – June 2015 (PDF, 1.7 MB)
- Structural Monitoring – Diver’s Report – April 2017 (PDF, 13.2 MB)
- Structural Monitoring – Diver’s Report – July 2018 (PDF, 3.7 MB)
- Structural Monitoring – Diver’s Report – June 2019 (PDF, 5.9 MB)
- Structural Monitoring – Diver's Report – March 2020 (PDF, 8.3 MB)
- Structural Monitoring – Diver's Report – April 2021 (PDF, 5.8 MB)
- Structural Monitoring – Diver's Report – July 2021 (PDF, 4.3 MB)
- Structural Monitoring – Diver's Report – June 2022 (PDF, 4 MB)
- Structural Monitoring – Diver's Report – August 2022 (PDF, 1,356 KB)
- Structural Monitoring – Diver's Report – June 2023 (PDF, 3.3 MB)
- Diver's Report – Ex HMAS Adelaide Panel Removal - October 2023 (PDF 1.1 MB)
- Structural Monitoring – Engineer’s Report – April 2015 (PDF, 165 KB)
- Structural Monitoring – Engineer’s Report – April 2017 (PDF, 132 KB)
- Structural Monitoring – Engineer’s Report – April 2018 (PDF, 121 KB)
- Structural Monitoring – Engineer’s Report – June 2019 (PDF, 118 KB)
- Structural Monitoring – Engineer's Report – March 2020 (PDF, 123 KB)
- Structural Monitoring – Engineer's Report – June 2021 (PDF, 123 KB)
- Structural Monitoring – Engineer's Report – June 2022 (PDF, 118 KB)
- Structural Monitoring – Engineer's Report – August 2022 (PDF, 119 KB)
- Structural Monitoring – Engineer's Report – July 2023 (PDF, 128 KB)

In January 2018 a Revised Long-Term Monitoring and Management Plan (LTMMP) was provided by Advisian.

On the 8th of July 2024 DPHI were alerted to damage sustained by the ex-HMAS Adelaide following a significant storm event. Following this, a diving inspection report was drafted on the 25th of July which described that…

“The vessel has suffered extensive damage since the previous inspection. The aluminium superstructure had separated from the steel hull aft of the main mast. The superstructure has broken away cleanly from the main deck and come to rest on the port side. The edge of the displaced superstructure is resting on the edge of the main deck.”

Ex-HMAS Adelaide Post Storm Report July 2024 – McLennan’s Diving Service.



Right: A drawing of how the wreck is now. The displaced superstructure is shown in magenta and lays off to the port side. Note: the mast is still upright but resting on the seabed.

Figure 3 Image taken from crownland.nsw.gov.au

3. Document Review

The following documents have been reviewed as part of this desktop assessment.

- Those documents listed above in Section 3 (20 of).
- Risk Management Guide – DPHI
- Ex-HMAS Adelaide Engineer Report Scope
- Ex-HMAS Adelaide Artificial Dive Reef – Revised Long-Term Monitoring and Management Plan – 2017-2026.
- Report – Ex-HMAS Adelaide LTMMP – March 2024
- Ex-HMAS Adelaide Post Storm Inspection Report – July 2024
- Ex-HMAS Adelaide Post Storm Inspection Report – August 2024
- Ex-HMAS Adelaide Post Storm Inspection Report – September 2024

We note the following findings pertaining to the structural integrity of the aluminium superstructure.

3.1 Long-Term Monitoring and Management Plan

The following key extracts from the LTMMP – Revised 2017-2026 have been provided for context.

- "The rationale for investigating the structural integrity of the Ex-HMAS ADELAIDE is to ensure that the vessel remains intact and is not showing signs of significant corrosion and weathering due to major storm events and that the vessel is suitable for on-going use as a recreational dive site."
- "A general assessment of structural integrity will be undertaken by annual visual inspections and visual inspections immediately following major storm events (before diving is permitted to recommence). Where the weather permits, inspections will be undertaken within 7 days. The assessment will be undertaken under the direction of a qualified maritime structural engineer or naval architect."
- "As the aluminium superstructure will provide anodic protection to the steel hull, divers will photograph and record areas where pitting is occurring and take measurements using an ultrasonic thickness tester. Where pitting becomes severe, or there is other damage due to storm waves, demolition works will be undertaken to mitigate the risk to divers."
- "AS 4997-2005 Guidelines for the design of marine structures specifies a corrosion allowance for untreated steel of 0.05mm/year for permanently submerged structures in sea water within the temperate zones (south of 30ºS). Note that the hull will still be protected by protective paint systems until they begin to breakdown."
- Regarding the monitoring of the structural integrity of the ex-HMAS Adelaide:
    - "Using an Ultrasonic Thickness Measurement Instrument, measure the thickness of the test site, and if there is significant deterioration (i.e. > 50% reduction compared to the pre-scuttling measurement) in the thickness of material (steel or aluminium) at the monitoring points, appoint a marine surveyor to determine the risk to divers of a structural failure. Advise divers not to enter internal spaces of the vessel until the area is certified safe and reopened."

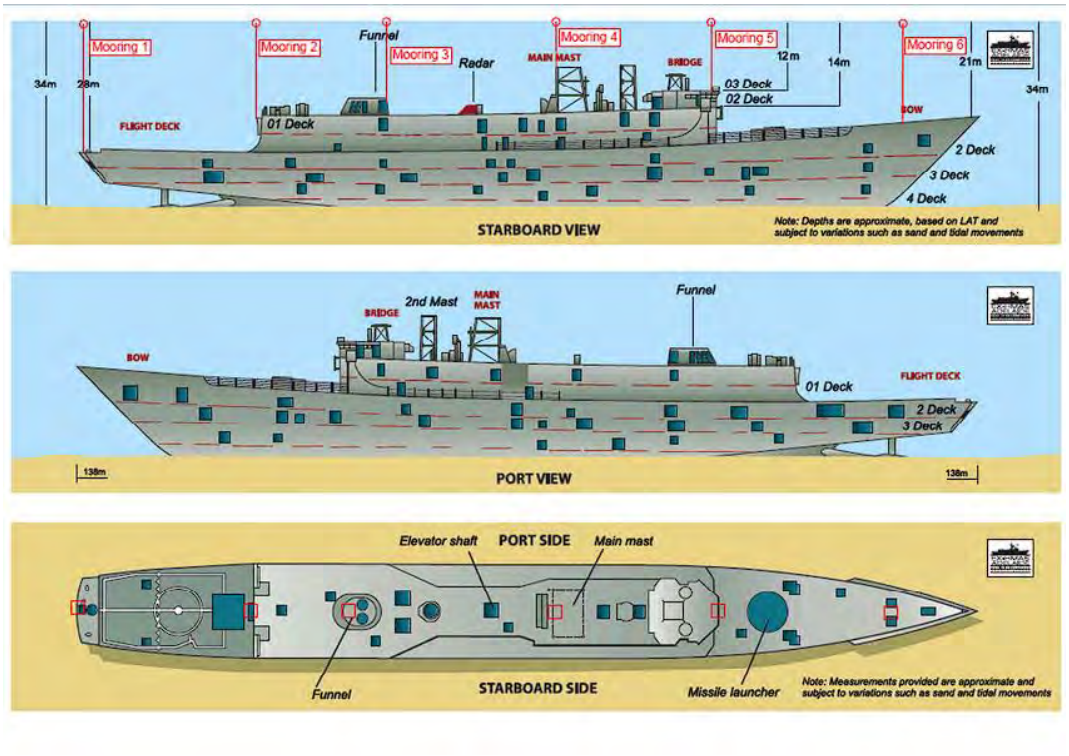


Figure 4 General Arrangement of the ex-HMAS Adelaide

3.2 Dive Inspection Reports

- Report from 13th April 2017
  - “The wreck can be divided into two halves. The upper section above the main deck is the aluminium superstructure which holds the mast and bridge areas. The lower section from the main deck to the keel resting on the seabed is the steel hull, which contains the machinery and living spaces.
  - “Corrosion levels appear to be very low.”
  - “We found no new cracking of the aluminium superstructure. In face the cracks that existed in the lift shaft area on Deck 02 have not propagated at all in the last year.”
  - “Location 2 – amidships at the base of the forward screen (where the superstructure and hull are bonded together) – There is no visible deterioration in this area. There is no sign of any separation between the forward screen and the hull.”
  - “Location 3 – at the vertical midpoint of the main masts – The entire main mast was examined. The mast is heavily encrusted with marine life restricting a detailed examination. However, no signs of crack or deformation were observed… The feet of the mast were also closely examined, and no signs of cracking or deformation were observed.
  - “There was no sign of corrosion observed. In previous surveys we have noticed red rusticles on the steel hull and white corrosion deposits on the aluminium superstructure. In this survey, we saw none of these telltale signs of corrosion. The marine growth coverage on all exterior surfaces is 100% indicating very stable metal underneath it.”
- Report from 12th July 2018
  - “The aluminium superstructure has suffered from major deterioration over the last twelve months and it appears that this will continue at ever-increasing rate in the future. During this inspection we observed wide spreading cracking, corrosion breakouts, missing and swinging panels, collapsed structures, and partially blocked passage ways.”
  - “Location 2 – amidships at the base of the forward screen (where the superstructure and hull are bonded together) – There is no visible deterioration in this area. There is no sign of any separation between the forward screen and the hull.”

- “There were no signs of corrosion observed in the steel hull. The aluminium superstructure has displayed numerous corrosion breakouts characterised by white deposits, especially on the external horizontal surfaces. This was not observed in this quantity in previous years.”

- Report from 28th June 2019
  - “The aluminium superstructure has suffered steady deterioration in the last twelve months and it appears that this will continue at an ever-increasing rate in the future.”
  - “The white chalky corrosion breakouts in the aluminium superstructure observed last year have become widespread. Also observed this year was a type of delaminating of the aluminium. It is peeling in sheets at many locations on the floor of the 02 Deck.
  - “I conclude that the aluminium superstructure has continued to deteriorate and that the rate of deterioration will increase as corrosion and water movement weaken the structure. I expect that many more sections of the aluminium superstructure will break away over the next year depending on the frequency and severity of heavy swells.”
  - “Location 2 – amidships at the base of the forward screen (where the superstructure and hull are bonded together) – There is no visible deterioration in this area. There is no sign of any separation between the forward screen and the hull.”
  - “The aluminium superstructure displays widespread signs of severe corrosion. The welded joints of the panels to the sub frame have corroded away in many areas leaving the panels poorly secured. The 02 Deck horizontal surfaces have numerous breakouts of an unusual delamination of the aluminium panels, and thick white deposits of corrosion products are visible over all exterior aluminium surfaces. Also, the aluminium frames have severe corrosion and have numerous holes through the frame members. The rate of deterioration of the aluminium superstructure appears to have greatly accelerated compared to previous years.”
- Report from 13th March 2020
  - “There were no signs of corrosion observed in the steel hull. The hull appears to be in the same condition as the last survey in 2019. The aluminium superstructure however displays widespread signs of severe corrosion. As seen in the last survey, the welded joints of the panels to the sub frame have corroded away in many areas leaving the panels likely to be dislodged. On the 02 deck there is widespread delamination of the aluminium panels. There are many deposits of the white corrosion products. There are a number of corrosion holes through the frame members. The weld seams of most of the exterior panels of the aluminium superstructure are highly corroded. As seen last year the corrosion is occurring in the heat affected zones of the welds. This is leaving gaps between the panel and the frame. We observed this last year also but there does not appear to be any panels missing on the deck from the delaminating or the weld corrosion.”
- Report from 29th April 2021
  - “The upper half of the vessel has continued its steady rate of deterioration. There is increased corrosion and cracking in most areas, but this is at the expected rate. We did not locate any new areas of cracking or panel breakouts since our last interim inspection in December 2020. The Divers swam through the centre of the superstructure and found that all the openings were clear. They found that several fittings that had been attached to a wall were loose and were near an entrance amidships, so they jettisoned these to the seabed.”
  - There were no signs of corrosion observed in the steel hull. The hull appears to be in the same condition as the last survey in 2020. In places the thick marine life was scraped off for thickness testing, the original grey paint coating was still intact. The aluminium superstructure however displays widespread signs of severe corrosion. As seen in the last survey, the welded joints of the panels to the sub frame have corroded away in many areas leaving the panels likely to be dislodged. On the 02 deck there is widespread delamination of the aluminium panels. There are many deposits of the white corrosion products. There are many corrosion holes through the frame members. The weld seams of most of the exterior panels of the aluminium superstructure are highly corroded. Despite the continuing corrosion of the superstructure, there has been no new cracks or loss panels since our last inspection.”
- Report from 12th June 2022
  - “The upper half of the vessel has continued its steady rate of deterioration. There is very widespread corrosion. The outer sheeting is heavily corroded along the welds to the stringers and frames and in the centre of the panels. The frames are heavily corroded at the frame connections. The corrosion is not uniform. Some panels are highly corroded, and some appear to be unaffected. The aluminium panels and frames are welded to the steel hull along a 100mm high vertical steel flat bar that extends at right angles

from the main deck. These aluminium panels and frames have commonly broken at this joint. The aluminium superstructure has reached a state of deterioration where additional panels would be expected to be broken out with every large swell event. There have been numerous new openings created into the aluminium superstructure along the 01-deck by the swell surge."

- Report from 12th June 2023
  - "The upper half of the vessel has continued its steady rate of deterioration. There is very widespread corrosion. The outer sheeting is heavily corroded along the welds to the stringers and frames and in the centre of the panels. The frames are heavily corroded at the frame connections. The corrosion is not uniform. Some panels are highly corroded, and some appear to be unaffected. The aluminium panels and frames are welded to the steel hull along a 100mm high vertical steel flat bar that extends at right angles from the main deck. These aluminium panels and frames have commonly broken at this joint. The aluminium superstructure has reached a state of deterioration where additional panels would be expected to be broken out with every large swell event. There have been numerous new openings created into the aluminium superstructure along the 01-Deck by the swell surge. These are shown in the attached drawing. In general, when these panels break out, it is a clean break, and no further attention is required."

3.3 2024 Post-Storm Reports

3.3.1 Report from 25th of July 2024

The aluminium superstructure separated from the main deck and came to rest off the port side of the ex-HMAS Adelaide. The superstructure was attached to the steel hull by 100mm steel plates, welded at right angles to the main deck. It was this weld that failed because of corrosion over 13 years. However, it was not just the failure of the welds that caused this separation, but a significant sea event which assisted in the detachment.

- "The displaced superstructure has settled in a stable position with on side resting in the sand and one side resting on the port gunwale of the main deck. It is now resting on the lee side of the wreck and is protected from the prevailing swell direction.
- "In this position we would expect that it will continue to corrode due to its contact with the steel hull. The structure is likely to be resting in this position for a long time, but a big swell may break it down rapidly.
- "The wreck has now been changed to a point where the requirements of the LTMMP for safe recreational diving no longer applies. The displaced superstructure is full of jagged, unstable aluminium panels and beams. The passageways that remain in the displaced superstructure can never be made safe.

Figure 5 Photo from 25th of July Dive Report

3.3.2 Report from 10th of August 2024

- "The entire aluminium superstructure has now been washed off the main deck and deposited onto the seabed off the port side of the wreck."
- "The main deck is in approx. 30 metres of water and is now quite flat and featureless… It is probable that the hull will remain in this condition for the foreseeable future.
- "The hull has not corroded during its years on the seabed. It remains in the same condition as when it was sunk with the original paint coatings still intact."

3.3.3 Report from 25th of September 2024

- "On this occasion, underwater visibility was much better and so we can now be confident of the layout of the displaced superstructure and the steel hull."
- "The steel stubs that the superstructure was welded to are very clearly visible on the main deck. The white remnants of the broken welds cause them to be very noticeable."
- "The superstructure broke into three distinct sections:
  - The Bridge Section
  - The Main Mast Section
  - The Funnel and Hanger Section

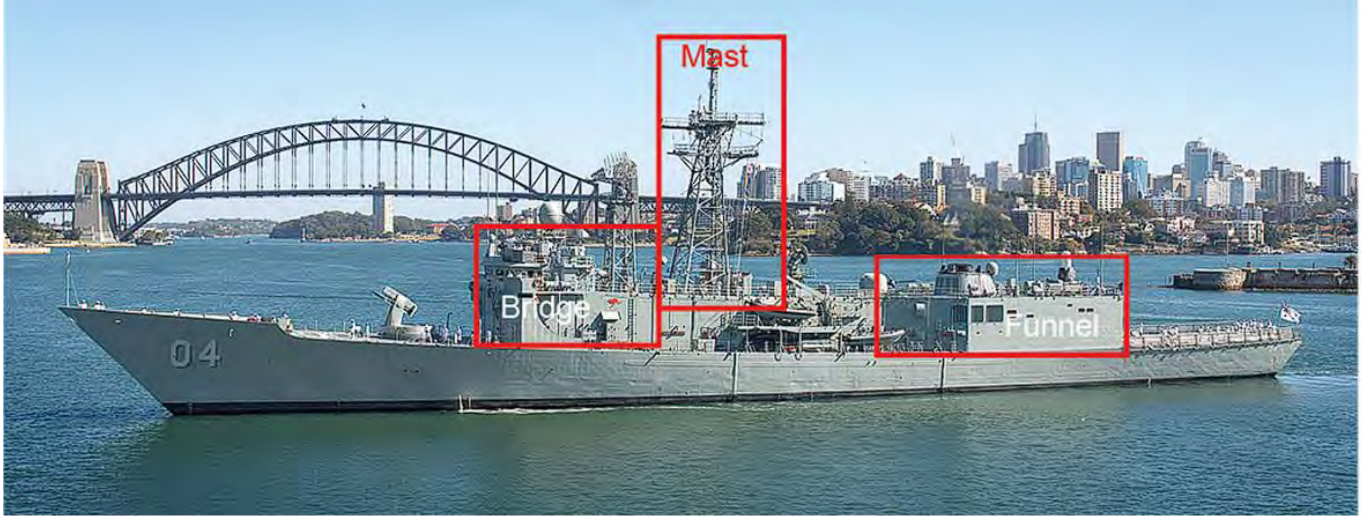


Figure 6 Photo from 25th of September Dive Report

3.3.3.1 The Bridge

"The Bridge section lifted off the main deck as one piece. All three upper decks (03, 02, and 01), and the weather shield broke away just forward of the main mast. The wreckages inverted as it separated and was deposited upside down on the port side of the wreck. The bridge area is now buried in the sand. The ceiling of 01 deck is now the uppermost. The outer walls of 01 deck have folded outwards like the flaps of a carboard box when it is opened. This wreckage has retained quite a bit of its shape so many open compartments are intact. However, they are full of torn and twisted aluminium panels and presents a very high risk to any divers who might attempt to enter those compartments. We would expect the structure to break down quickly in the next few swell events and it will then be consumed by the sand."

3.3.3.2 The Main Mast

"The Main Mast has come to rest upright on the sand on the port side in line with its original position on the main deck. It was rotated 90 degrees, so the mast now faces the port side. A section of 02 deck remains attached to the mast legs. The mast appears to be undamaged and all parts of it are intact. The top of the mast is in 19 metres of water. The sand is scoured away around the legs. It is remarkable that the mast has remained upright after washing off the wreck. Presumably, sufficient air is trapped inside the tubes that the mast is composed of to provide buoyancy to keep it upright."

3.3.3.3 The Funnel and Hanger

The Funnel section and parts of the starboard hanger separated in one piece from the main deck and came to rest partly on the seabed, and partly on the port side gunwale. Sometime since the previous inspection on 7th of August, this funnel/hanger section has collapsed leaving just one large section of the 02-deck roof resting against the port gunwale. We found no sign of the funnel or the starboard hanger. Presumable, they have fallen to the seabed. We expect that the remaining panel will also fall to the seabed soon as it is cantilevered over six metres between the seabed and the main deck and appears very prone to destruction by large swells.

4. Exposure Environment

AS 4997-2005 “Guidelines for the design of maritime structures” Section 6 – Durability, describes the effect of aggressive environments of the design of maritime structures. It is noted that the exposure classification of the ex-HMAS Adelaide is “Moderate” as per Table 6.7 which allows an annual corrosion rate of 0.05 mm. This is based on the position of the wreck. However, this does not consider microbiological effects or accelerated low water corrosion which may significantly increase the rate of corrosion for unprotected steel elements, namely, the aluminium superstructure.

4.1 Aluminium Superstructure

Ignoring the current position and state of the aluminium superstructure, the following context is provided to describe typical corrosion mechanisms of aluminium. Please note, at the time of writing this report, BG&E was not aware of the alloy composition.

4.1.1 Uniform Corrosion

Uniform corrosion is characterised by a regular, consistent decrease in thickness over the entire surface area of the metal. Typically, in immersion environments, uniform corrosion is miniscule, in the order of one micron per year, which is not measurable, thus, we say that during the service life of aluminium alloy, the element will not be limited by this type of corrosion.

4.1.2 Pitting Corrosion

A localised form of corrosion, pitting corrosion is common in most metals. This mechanism is characterised by the formation of small cavities in the material. This type of corrosion is heavily dependent on manufacturing processes, alloy composition, and the exposure environment. Aluminium is particularly sensitive to neutral pH environments such as surface water, sea water, and atmospheric moisture.

Pitting corrosion is particularly interesting in aluminium as it is characterised by very large, white blisters of hydrated alumina. The blister is always much larger than the underlying cavity. Alumina is insoluble in water, so once formed, adheres to the surface of the metal inside the pit cavities. The rate of pitting corrosion in aluminium decreases very rapidly in most environments. “Many decades of experience with the use of unprotected aluminium in shipbuilding corroborate the results obtained in the laboratory…the depth of pits hardly changes once they have formed during the initial months of exposure.” (Alcan Marine – Chapter 10 – Corrosion Behaviour of Aluminium in Marine Environments).

4.1.3 Transgranular and Intercrystalline Corrosion

This type of corrosion, inside the metal at grain level, can spread in two ways:

1. In all directions, indiscriminatory of metallurgical constituents, inside the grains.
2. Along preferential paths, along grain boundaries.

This type of corrosion is invisible to the naked eye and requires micrographic examination. Intercrystalline corrosion spreads from pits. There is no correlation between the depth to which this corrosion penetrates and the diameter or depth of the pit.

4.1.4 Exfoliation Corrosion

This form of corrosion spreads along planes parallel to the direction of rolling or extrusion. The build-up of corrosion products causes the corroded zone to swell, peeling away leaves of metal.

4.1.5 Waterline Corrosion

Waterline corrosion affects semi-submerged metal structures where the water/air boundary, particularly in stagnant water, must be painted to avoid the risk of this mechanism.

4.1.6 Crevice Corrosion

Crevice corrosion occurs when water penetrates cavities or recesses in the metal element but it no refreshed.

4.1.7 Bimetallic Corrosion

When two dissimilar metals or alloys are placed in direct contact in a wet and electrically conductive environment, one of those metals or alloys will dissolve while the other retains its integrity and appearance. When contacts are submerged, bimetallic corrosion of aluminium is unavoidable when in contact with most other metals.

5. Risk Framework

BG&E refer to the Department of Planning, Housing, and Infrastructure's Risk Management Guide. We provide the following key takeaways from this document and will use this as a basis for our risk assessment of the ex-HMAS Adelaide post-storm condition.

Rating	Control Design
Very Strong	Designed in such a way that will reduce risk substantially. High degree of automation or documented formalised processes.
Strong	Designed in such a way it will reduce risk substantially. Very automated or documented formalised processes. Rare exceptions. Places reliance on knowledge/ actions of key persons.
Adequate	Designed in such a way it will reduce risk. Expected to fail at times, however within acceptable appetite. Places reliance on knowledge/actions of key persons.
Limited	Designed in such a way it will reduce some aspects of risk. Likely to fail requiring remedial effort and actions. Places heavy reliance on knowledge/actions on persons to manually address exceptions/incidents.
Weak	Poor design even when used correctly. It provides little or no protection. Only addresses part of the risk requiring additional work arounds or manual processes to make up for deficiencies. Extreme reliance on knowledge/actions of key persons.

Figure 7 Control Design

Rating	Control Implementation
Very Strong	The control operates consistently as intended and is being correctly applied by the vast majority of users. Never known to fail in the past, highly unlikely to fail in a short to mid-term.
Strong	The control operates on a mostly consistent basis and is being applied correctly by most users. Control is mature and unlikely to fail significantly within 12-month period. Has significantly addressed the risk.
Adequate	The control operates as intended at least half of the time by sections of control users. The control has experienced a failure in the past 12 months but is not expected to experience more in the immediate future.
Limited	The controls are not operating consistently and/or effectively or have not been implemented in full. The control has experienced failures in the past 12 months and is expected to experience more, potentially more frequently. Rates of failure are deemed to be unacceptable.
Weak	Consistently not operating as intended, immature, operating inappropriately or inconsistently. Rates of failure are significant and deemed unacceptable.

Figure 8 Control Implementation Framework

		Control Implementation				
		Very Strong	**Strong**	**Adequate**	**Limited**	**Weak**
Control Design	**Weak**	Partially Effective	Partially Effective	Ineffective	Ineffective	Ineffective
	Limited	Partially Effective	Partially Effective	Partially Effective	Ineffective	Ineffective
	Adequate	Substantially Effective	Substantially Effective	Partially Effective	Partially Effective	Ineffective
	Strong	Effective	Substantially Effective	Substantially Effective	Partially Effective	Ineffective
	Very Strong	Effective	Effective	Substantially Effective	Partially Effective	Partially Effective

Figure 9 Control Effectiveness Matrix

Consequence Category	Description
Business Disruptions	Impacts threatening the function or viability of the business unit or wider Department.
Business Objectives	Any impact on the ability of the business unit to achieve its stated objective. This can include programs, projects and BAU operations.
Compliance	Any impact threatening the Department's ability to meet its legislative & compliance obligations.
Environment, Conservation & Heritage	Any impact to the natural environment or to conservation programs/activities.
Financial/Built Assets	Consequences involving a direct financial impact to the business unit or wider Department. This can include costs (repair or increased maintenance) associated with built assets.
Health, Safety & Wellbeing	Any consequence threatening the safety or wellbeing of staff, volunteers, contractors or the public at department worksites.
Reputation & Trust	Any impact resulting in a loss of trust or in the department's reputation being diminished.
Stakeholders & Community	Impacts felt by the public or other stakeholders (including businesses) and the reaction to those impacts.
Workforce	Impacts resulting in a loss of engagement or workplace morale among staff.

Figure 10 Consequence Categories

Category	Insignificant Minimal impact requiring marginal remediation activities/ management	Minor Small, local effects easily contained	Moderate Some impact or impact requiring remediation	Major Significant impacts/ costs with some objectives not met	Extreme Catastrophic event threatening viability of function and objectives
Business Disruption	Minimal impact on non-critical business activities able to be managed through standard operations within a day	Minor disruption of non-critical business activities for up to 1 week	Disruption of non-critical business activities for up to 1 month.	Disruption of non-critical business activities for over 1 month **OR** Disruption of identified critical business activities for up to 3 days.	Extended disruption of identified critical business activities exceeding 3 days.
Business Objectives	Isolated, internal or minimal impact on business objectives	Contained impact on business objectives with short term significance	Measurable impact to business objectives involving investigation & remediation	Significant impact to business objectives with long term significance. Potential failure to meet elements of business objectives	Extensive impact leading to total failure to meet business objectives. Intervention from Leadership
Compliance	Isolated, low-level non-compliance with standards and policy with negligible impact on local business activities	Minor non-compliance with legislation, regulation or policy with minimal impact on branch-wide activities	Repeated non-compliance with legislation, regulation or policy; reportable noncompliance requiring rapid remediation	Significant non-compliance with legislation, regulation or policy resulting in substantial regulatory responses issued against the agency.	Systemic and substantial non-compliance with legislation, regulation or policy. Prosecution with referral to external agencies such as Police or ICAC.
Environment, Conservation & Heritage	Negligible and temporary impact on the environment, including flora, fauna, ecosystems or heritage sites (including buildings). Will recover naturally with no remedial works required	Minor, localised, short-term environmental impacts such as damage to flora, fauna, ecosystems or heritage sites (including buildings). Will recover with minor/short-term site-based remedial action.	Moderate, short term environmental impacts. Damage to flora, fauna, ecosystems or heritage sites (including buildings). Will recover in a medium to long-term period with moderate & sustained remedial action	Significant environmental harm requiring comprehensive and sustained remedial action. Loss of local populations of particular flora, fauna or heritage sites (including buildings).	Severe and unrecoverable environmental harm. Extinction, loss of species diversity, ecosystem collapse or total loss of heritage sites (including buildings)
Financial/ Built Assets	Barely noticeable financial impact easily absorbed within project or program budget	One-off loss, under or overspend up to $10M or 5% of your budget **OR** Ongoing annual impact up to $5M or 5% of your budget	One-off loss, under or overspend up to $25M or 15% of your budget **OR** Ongoing annual impact up to of $10M or 15% of your budget	One-off loss, under or overspend up to $100M or 25% of your budget **OR** Ongoing annual impact up to $50M or 25% of your budget	One-off loss, under or overspend over $100M or 30% of your budget **OR** Ongoing annual impact over $50M or 30% of your budget
Health, Safety & Wellbeing	Physical or psychological injury/ illness requiring notification or treatment up to First Aid only	Physical or psychological injury/ illness requiring professional medical treatment	Physical or psychological Injury/ Illness resulting in moderate temporary impairment or disability (up to 6 months).	Physical or psychological injury/ Illness resulting in partial permanent disability or long-term temporary impairment (more than 6 months)	Single or multiple fatalities. Physical or psychological Injury/ Illness resulting in irreversible, total permanent impairment or disability
Reputation & Trust	Barely noticeable impact on goodwill or trust recoverable with little effort or cost	Some community and stakeholder complaints. Confidence and trust dented but satisfactorily resolved with consultation and negotiation. Modest cost within existing budget and resources.	Large volume of community or stakeholder complaints, short-term negative media coverage. Confidence and trust diminished but recoverable. Written advice to Deputy Secretary or Secretary.	Extensive negative media coverage. Confidence and trust damaged but recoverable at considerable cost, time and employee's effort. Written advice and follow up with Minister's Office.	Sustained media coverage. Potential removal of political/department leadership. Total breakdown of trust in the department, with full recovery questionable and costly.
Stakeholders & Community	Minimal impact. Primary acceptance and approval exist.	Some small distress to the community. Small disruption to a group of businesses in the community	Considerable disruption or distress to sectors of the community. Some businesses in the community put at risk.	Large public protests or widespread disengagement. Potential for significant harm to sectors of the community. Damage to relationships and loss of support.	Civil commotion & riot. One or more major industry within the state threatened.
Workforce	Minimal impact to employee engagement and productivity. Some complaints, but employees still proactively contribute to meeting objectives.	Short-term impact on employee engagement with temporary effect on productivity. Employees largely only 'doing what needs to be done'.	Mid-term impact on employee engagement affecting productivity. Employees not willing to proactively engage. Increase of people related issues, individual incidences of excessive absenteeism.	Major, long term employee engagement decrease. High employee turnover rates. Widespread absenteeism, increased misconduct, grievances and industrial disputes.	No confidence and trust from employees. High employee turnover. Stress and absenteeism levels extremely high. Ongoing industrial disputes/strike action

Figure 11 Consequence Matrix

Likelihood	General Description	Historical	Probability
Almost Certain	Expected to occur in most circumstances involving normal operations.	Large number of known incidents in the department. Occurs regularly in the industry.	Predicted to occur in almost every operation of this kind (>90%)
Likely	Considerable opportunity and means to occur. Could happen at any time.	Regular incidents known within the department. Has occurred many times in the industry	Likely to occur in more than 1-in-2 operations of this kind (50%-90%)
Possible	Some opportunity and means to occur.	Few infrequent, random occurrences recorded within the department. Has occurred several times in the industry.	Likely to occur between 1-in-2 and 1-in-4 operations of this kind (25-50%)
Unlikely	Little opportunity or means to occur. Might happen, but not expected to occur.	No known incidents recorded or experienced within the department. Has occurred once or twice in the industry	Likely to occur between 1-in-4 and 1-in-20 operations of this kind (5%-25%)
Rare	Almost no opportunity to occur. Might happen, but probably never will.	Not known or reported to have ever occurred in the industry.	Highly unlikely to occur (<5%)

Figure 12 Likelihood

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Extreme**
Likelihood	**Almost Certain**	Medium 11	High 17	High 20	Very High 23	Very High 25
	Likely	Low 7	Medium 12	High 18	High 21	Very High 24
	Possible	Low 4	Medium 9	Medium 13	High 19	High 22
	Unlikely	Low 2	Low 5	Medium 10	Medium 14	High 16
	Rare	Low 1	Low 3	Low 6	Medium 8	High 15

Figure 13 Risk Matrix

6. Discussion

6.1 Likely Cause of Failure

As described in the LTMMP the aluminium superstructure was intended to provide anodic protection to the steel hull. Professional divers were expected to photograph and record areas where pitting was occurring and take measurements using an ultrasonic thickness tester. The aluminium superstructure was expected to corrode and suffer from pitting corrosion. Pitting was evidenced in the dive inspection reports, first being recorded in 2017, characterised by white spots which concur with the expectations of the corrosion mechanism described in Section 5.1.2 of this report. However, it should be noted that this was not the corrosion mechanisms that caused the aluminium superstructure to detach from the main steel hull.

As noted in the July 2024 dive report, briefly after the storm even caused the detachment, the welds joining the 'right-angle' welded plates between the aluminium superstructure and the hull failed. The likely failure mechanism was bimetallic corrosion of the dissimilar metals over several years.

As described in the LTMMP, Location 2 (midships at the base of the forward screen) – where the superstructure and the hull are bonded together, was selected for ultrasonic thickness measurements. As per the updated LTMMP in March 2024 the following measurements were recorded.

Location – Main Deck except for Location 6	Frame Number	Recorded thickness (mm)					
		Nominal	2020	2021	2022	2023	2024
1 – Hangar Deck – 300mm aft of the centre pillar –	335	6.35	6.79	6.8	6.68	6.66	6.65
2 – 300mm off the change in shape at waist on the port side -	180	7.95	7.73	7.68	7.70	7.65	7.63

Figure 14 Ultrasonic Thickness Measurements

As can be seen in the table above, there was no clear thickness deviations to alert divers to a potential issue.

6.2 Risk Assessment

The following details focus primarily on the aluminium superstructure that has detached from the main hull and secondly on the main hull, which, from BG&E's document review, poses a low risk.

As described in the dive inspection reports from 2024, following the storm event, the risk to divers moving around and through the aluminium superstructure is high. Whilst the mast remains intact currently, the load transferred through the structure during the detachment event likely caused cracking of connections and further deterioration around corrosion pits. This applies to all three sections of the aluminium superstructure, the bridge, the mast, and the funnel/hanger.

BG&E provide the following risk assessment based on our document review and structural engineering experience. It should be noted, we are not professional divers, and commentary regarding safe diving practices has only been included as a reference and should be confirmed by professionals.

6.2.1 Blocked or Impeded Diver Entry and Access Points

This items mainly relates to the established diver entry and access points. As there are no established entry and access points on the detached superstructure, this item will focus on the main hull. BG&E believe the aluminium superstructure, including the Main Mast, the Bridge, and the Funnel and Hanger to have no safe access points.

Aluminium Superstructure
Whilst the aluminium superstructure remains in a state of continued settlement, deterioration, and unknown arrangement, the risk to divers moving around and through the features is Very High.

Risk	Undefined or structurally compromised entry and exit points.
Likelihood	Almost Certain
Consequence	Extreme
Risk Rating	Very High
Recommended Control	Isolate the detached superstructure and provide communication to divers to avoid the area. It is not recommended to dive within or near the aluminium superstructure.
Control Design	Very Strong
Control Implementation	Strong
Control Effectiveness	Effective

Main Hull
The main hull has predefined entry and exit points. These, according to dive reports, have not been compromised, nor do they show signs of deterioration.

Risk	Defined and structurally sound entry and exit points.
Likelihood	Unlikely
Consequence	Moderate
Risk Rating	Medium
Recommended Control	Continue to monitor the main hull entry and access points for deterioration.
Control Design	Adequate
Control Implementation	Adequate
Control Effectiveness	Partially Effective

6.2.2 Risk of Structural Damage or Failure

This item relates to three sections of the aluminium superstructure that have detached from the main hull.

Aluminium Superstructure
As the detached superstructure remains unstable, due to settling in the sand, corrosion of the aluminium elements, and unknown impacts by large sea swells, the risk of the structural continuing to fail is Very High. The risk of entrapment and elements falling on divers in and around the aluminium superstructure is Very High.

Risk	The aluminium elements further deteriorating, settling in the sand, becoming unstable, or failing due to ongoing corrosion and sea swell.

Likelihood	Almost Certain
Consequence	Extreme
Risk Rating	Very High
Recommended Control	Isolate the detached superstructure and provide communication to divers to avoid the area. It is not recommended to dive within or near the aluminium superstructure.
Control Design	Very Strong
Control Implementation	Strong
Control Effectiveness	Effective

6.2.3 Risk of Entrapment

This item relates to three sections of the aluminium superstructure that have detached from the main hull.

Aluminium Superstructure
As the detached superstructure remains unstable, due to settling in the sand, corrosion of the aluminium elements, and unknown impacts by large sea swells, the risk of the structural continuing to fail is Very High. The risk of entrapment and elements falling on divers in and around the aluminium superstructure is Very High.

Risk	Elements fall and block entry and exit points. Entry and exit points are narrow and unstable.
Likelihood	Almost Certain
Consequence	Extreme
Risk Rating	Very High
Recommended Control	Isolate the detached superstructure and provide communication to divers to avoid the area. It is not recommended to dive within or near the aluminium superstructure.
Control Design	Very Strong
Control Implementation	Strong
Control Effectiveness	Effective

6.2.4 Stability of the Wreckage

This item relates to three sections of the aluminium superstructure that have detached from the main hull. The main hull remains stable.

Aluminium Superstructure
As the detached superstructure remains unstable, due to settling in the sand, corrosion of the aluminium elements, and unknown impacts by large sea swells, the risk of the structural continuing to fail is Very High. The risk of entrapment and elements falling on divers in and around the aluminium superstructure is Very High.

Risk	The stability of the superstructure is unknown given the detachment from the main hull has recently occurred and it is currently sitting in sand that settles easily and can easily be altered by large swells.
Likelihood	Almost Certain
Consequence	Extreme

Risk Rating	Very High
Recommended Control	Isolate the detached superstructure and provide communication to divers to avoid the area. It is not recommended to dive within or near the aluminium superstructure.
Control Design	Very Strong
Control Implementation	Strong
Control Effectiveness	Effective

6.2.5 Risk to Divers posed by Loose or Jagged Metal Objects

This item relates to three sections of the aluminium superstructure that have detached from the main hull.

Aluminium Superstructure
As the detached superstructure continues to corrode, and elements detach there is a high risk that jagged and sharp edges will be exposed.

Risk	Further deterioration causing sharp, jagged edges with narrow access.
Likelihood	Likely
Consequence	Major
Risk Rating	High
Recommended Control	Isolate the detached superstructure and provide communication to divers to avoid the area. It is not recommended to dive within or near the aluminium superstructure.
Control Design	Very Strong
Control Implementation	Strong
Control Effectiveness	Effective

6.2.6 Depth of the Wreckage

This item relates to three sections of the aluminium superstructure that have detached from the main hull.

Main Hull
The main hull currently sits in approximately 30m of water. This territory is a high risk for divers for the following reasons:

- Nitrogen narcosis - A feeling of dizziness that can occur when divers absorb too much nitrogen. This can impair reasoning, decision making, and motor skills, which can lead to harmful mistakes.
- Increased pressure - The pressure on the body increases from 1 atmosphere at the surface to about 4 atmospheres at 30 meters. This is equivalent to around 40 T per sq.m.
- Decompression sickness (DCS) - Can occur if nitrogen doesn't return to the lungs before they expand, causing bubbles to form in the body. This can be caused by physiological factors like dehydration, fitness level, age, or cold, or by ascending too quickly.

Aluminium Superstructure
The top of the aluminium superstructure is in 19m of water.

Risk	The depth of the superstructure could change due to sea swells

	and settlement of the ground. The mast is likely very unstable.
Likelihood	Likely
Consequence	Minor
Risk Rating	High
Recommended Control	Isolate the detached superstructure and provide communication to divers to avoid the area. It is not recommended to dive within or near the aluminium superstructure. Monitor the depth of the detached superstructure.
Control Design	Very Strong
Control Implementation	Strong
Control Effectiveness	Effective

7. Recommendations

BG&E recommend gathering further information to make informed decisions regarding the risks posed by the ex-HMAS Adelaide detached aluminium superstructure. Further details for this recommendation include estimated costs can be seen in Appendix A.

In summary, the following scope is recommended to monitor settlement, movement, and deterioration of the detached aluminium superstructure over a series of months

- Conduct multibeam echosounder surveying and side scanning sonar to map out a general arrangement of the main hull and aluminium superstructure.
- Design a targeted inspection plan based on the general arrangement 3D model to inspect connections, elements of high risk of detachment or failure, and where significant corrosion is observed. This testing plan should include high-resolution imagery and thickness testing where possible.
- Remove or make-safe, high-risk items.
- Determine the depth of the main hull and detached aluminium superstructure via the general arrangement to monitor changes as it is likely the aluminium superstructure will continue to sink into the sand until it hits a harder substrate.

The total cost per mobilisation is estimated at **REDACTED** which included modelling, processing, and reporting. Further cost details are provided in Appendix A.

It is recommended that this monitoring be conducted every 2 months or following a significant weather event.

This approach addresses a few key unknowns and inefficiencies:

- Modelling the wreck allows for detailed risk assessment and engineering analysis. Currently, divers, whilst providing valuable information on the vessel, cannot assess or map the detached superstructure easily or quickly.
- Modelling the wreck over a series of mobilisations allows engineers to track the movement and settlement of the detached superstructure which informs safe access points, areas of high-risk, and target detailed inspections.
- Using survey methods allows inspections to retarget areas of concerns to monitor corrosion propagation or single elements within the superstructure that might be tricky to relocate using conventional diving techniques.
- Utilising underwater ROV's significantly reduces the safety risk to divers at those depths.

Appendix A –

A.1 Recommendations for Further Investigation and Monitoring

Scope of Works Proposed

- Map the wreck site and seafloor and detect objects that have broken off the main part of the ship and along the seafloor using multibeam echosounder technology.
- Obtain high-resolution imagery of the wreck and seafloor and detect the wreck and any small objects using side scan sonar technology.
- A 6m survey vessel will be launched and equipped with the Norbit i77h multibeam echosounder and Edgetech 4125 side scan sonar.
- The survey area will be systematically covered to ensure complete data acquisition.
- Data will be processed and analysed to create detailed maps and imagery of the shipwreck site.
- Data collected during the survey will be processed using specialised software (Hypack and sonarwiz) to generate bathymetric maps and high-resolution imagery.
- A comprehensive report will be prepared, detailing the findings and providing recommendations based on the survey results.

Proposed Equipment

<u>Norbit i77h Multibeam Echosounder</u>

The Norbit i77h is a state-of-the-art multibeam sonar system designed for bathymetric surveys, construction surveys, and uncrewed surface vehicle (USV) type surveys. It features:

- Ultra-high resolution with a 0.5×0.9-degree beam width.
- True 1024 beams beamformer for precise data.
- Integrated GNSS/INS (Applanix OceanMaster) for high-end positioning.
- Real-time sound velocity integration for accurate depth measurements.
- Portable and lightweight design for easy deployment.

<u>Edgetech 4125 Side Scan Sonar</u>

The Edgetech 4125 is a high-resolution side scan sonar system designed for search and recovery (SAR) and shallow water survey applications. It offers:

- Ultra-high-resolution imagery for easier identification of targets.
- Lightweight design for one-person deployment.
- Dual simultaneous frequencies (400/900 kHz) for versatile applications.
- Standard heading, pitch, roll, and depth sensors.
- Portable topside processor and laptop for open boat operations.

Fee Breakdown per Inspection

Task	Description	Fee $ (ex GST)
1.0	Project Management	REDACTED
2.0	Mobilisation (including disbursement)	REDACTED
2.1	Multibeam Survey	REDACTED
2.2	Side Scan Sonar	REDACTED
2.3	Demobilisation	REDACTED
3.0	Processing and Modelling	REDACTED
4.0	Survey Report	REDACTED
5.0	Engineering Review and Report	REDACTED
TOTAL		REDACTED

Timeframe

From mobilisation to survey report it would take approximately 2 weeks. An extra week is likely required to conduct the engineering review and report.

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At BG&E, we are united by a common purpose – we believe that truly great engineering takes curiosity, bravery and trust, and is the key to creating extraordinary built environments.

Our teams in Australia, New Zealand, South East Asia, the United Kingdom and the Middle East, design and deliver engineering solutions for clients in the Property, Transport, Ports and Marine, Water, Defence, Renewables and Resources sectors.

We collaborate with leading contractors, developers, architects, planners, financiers and government agencies, to create projects for today and future generations.

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