An update to the Summary of the Risk to future operations Associated with the Torpedo remaining aboard HMAS AE2

By Capt Roger Turner BSc CEng FIMarEST RN

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Preamble

A paper summarising the risks to a dived survey associated with the torpedo believed to be remaining aboard HMAS AE2 was produced in advance of conducting a Marine Archaeological Assessment on the wreck in September 2007[1]. The aim of that paper was to bring together the knowledge associated with the remaining torpedo in order that the risks to the MAA could be minimised.

That paper concluded that:

- there is a torpedo on board (99%)
- it is in the stern tube (95%), bow tube (2%), stern rack (2%) bow rack (1%), midships tubes (less than 1%)
- The possibility that a low energy event in the vicinity of the warhead could stimulate a detonation is too great to be ignored.
- such detonation would be catastrophic.

Further, the paper recommended that the MAA plans be subjected to scrutiny to ensure that:

- No planned event includes
  - any high energy event anywhere on the hull and
  - no low energy event within 5m of any of the torpedo tubes.
- No single unplanned occurrence could lead to the low energy disturbing event needed to detonate the warhead or one of its components.
- These conclusions be offered for scrutiny to all participants of the MAA and to such external authorities as the project considers appropriate.

The MAA has concluded with much knowledge gained from the experience. This has been reported in full in associated papers. It is now the intention to combine that knowledge in order to scope in full the options for the future of the wreck. These options will range from “do nothing’, through “preserve and protect in situ” to “raise and land to form part of a shoreside museum”.

In any such event, the continued existence of the torpedo will affect how those options could be pursued. It is the purpose of this paper to use the experience of the MAA to update the risk which the torpedo may pose to the options being scoped for the wreck of the AE2.

[1] A Summary of the Risk to a Dived Survey Associated with the Torpedo remaining aboard HMAS AE2 by Capt Roger Turner BSc CEng FIMarEST RN dated 21 June 2007

Aim

It is the aim of this paper to update the knowledge associated with the remaining AE2 torpedo in order that appropriate action can be taken to mitigate the risk and minimise the possibility of an unplanned event occurring as a consequence of any of the options being scoped for the future of the wreck.

The MAA

The MAA was conducted with knowledge of the torpedo and all activity was planned and undertaken following the recommendations noted above. The exception to this was the 'Descent Line Mooring Clump' incident described below. The evidence gathered during the MAA allows a number of conclusions to be drawn as follows.

State of preservation

The MAA made extensive video recordings of the hull (including some from within the conning tower). It gathered concretion samples and took ultra-sonic thickness readings of the hull. The findings are examined in great detail in Dr Macleod's paper[2] which describes the environment and draws conclusions with regards the effect this has had on corrosion rates. It concludes that the environment is surprisingly benign and hence the wreck is in remarkably good condition. The visual evidence supports this and it can be seen that, for example, bronze worm and gear wheels in the bow-tube operating gear retain their original shape with very little marine growth or encrustation. Similarly, the bronze fittings seen immediately inside the conning tower are well preserved with little corrosion or loss of shape. Dr Macleod concludes that the non-ferrous fittings have developed a "thin, adherent white calcareous concretion" which assists in their preservation.

Following our earlier assumption that the torpedo is most probably (95%) in the stern tube we can assume that it is enjoying an environment which is still more benign than that of the open submarine. If the tube were dry at the time the AE2 was scuttled, it is quite possible that it is still dry. If the tube were wet, there being no flow, the oxygen would have long been depleted and the corrosion rates slowed or even halted. While it is difficult to quantify this we can conclude that if the non-ferrous fittings in the hull are well preserved, those in the tube will be still better preserved.

The warhead is of phosphor-bronze. The firing pistol is of gunmetal. Whilst it is difficult to assess all the options for corrosion paths within these components we can conclude that the probability of the metal having deteriorated sufficiently to allow the free passage of sea water into the warhead such as to cause the gun cotton to have become an innocuous slurry is low.

On this basis we must re-examine the affect of time on gun-cotton which has been left undisturbed for over 90 years.

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[2] Conservation assessment of the microenvironment of AE2 Oceanography and site assessment of the wreck in the Sea of Marmara, November 2007, Dr Ian D. MacLeod Executive Director Collections Management and Conservation,Western Australian Museum

Time and Gun Cotton

The affect of time on the explosive material has been summed thus - 'Guncotton of this type and vintage was probably Lyddite based. This was a 'dirty' explosive and the cotton was a carrying medium for a picrate based chemical. This is fairly unpleasant stuff in that it becomes unstable with time especially in proximity to metals. If some moisture has penetrated the head it will tend to dissolve the picrates and the inherent acidity of the medium will lead to corrosion of the surrounding metal'[3].

As the gun cotton was kept wetted (25lbs of water to the 200lbs of guncotton) there would be sufficient medium for the migration to have occurred and picrates to have formed. While there is a possibility that the warhead is unarmed and stable, the evidence drawn from the MAA indicates that the probability that it has become unstable and that detonation could be caused by a low energy event is greater than we assumed prior to the MAA.

That argument can be quantified using the risk tree developed prior to the MAA. The probabilities assigned in this exercise are somewhat arbitrary and very much open to discussion. However, amending the wet/dry probabilities by an order of magnitude leads to a risk conclusion as shown in Attachment A. This demonstrates that the probability of an unplanned detonation has risen from 2% to 16%. Admittedly there is considerable supposition involved in reaching this conclusion but it serves to reinforce the previous position that:

The possibility of occurrence of a low probability, high consequence event cannot be ignored.

Unplanned blows to the hull

While this same risk was very much in mind in the planning and conduct of the MAA, regrettably there was one unplanned occurrence which fell outside of the planned operating limits. On that occasion, the Diver Support Vessel dragged its moorings in unexpectedly heavy weather. This would not have been of concern to the wreck except that the divers' descent line anchor (comprised a concrete mooring clump weighing some 3 tonnes and secured to the DSV by a 2" warp) was dragged across the wreck. The divers subsequently observed that the block had passed up the port side of the wreck just aft of the fin and then fallen clear of the starboard side. It had caused some damage to the wreck in the form of a number of 2-3cm dents in the casing which had caused up to five rivets to spring and scraped the metal clean of marine growth.

This description is included principally to allow an assessment of the effect the blows may have had on the torpedo.

[3] Conservation and Corrosion Issues on AE2: Assessment of water penetration into the unspent torpedo and risks associated with underwater activity during the Maritime Archaeological Assessment Phase, Ian D. MacLeod, Western Australian Museum (22 March 07)

It is hard to quantify the strength of the blows. The pitching motion of the DSV would have caused the clump to move mostly in the vertical plane thus the blows to the wreck would have been largely oblique. It is probable, however that blows of significant energy would have occurred on at least one occasion sufficient to cause the dent.

How much of that energy would have been transmitted to a torpedo resting in the stern or bow tubes is again difficult to estimate. The distance from the damaged area to the stern tube is approximately 18m; to the forward tube 26m and the midships tubes, 4m. These distances are not great but the critical issue is how much energy would have been transmitted. The transmission path is likely to be broken up by the reduced integrity of the riveted hull structure. The damping effect of the hull in the silt would also reduce the energy transmitted. Certainly the energy of the impulse would have been significantly less at the bow and stern than amidships. We can also conclude that such a blow if applied in close proximity to an unstable explosive could have caused detonation. That it did not might lead us to conclude that either the torpedo is not in either of the midships tubes or that it is stable. While of academic interest this conclusion does not assist in mitigating the risk to any future operations.

It is more prudent to conclude that although the impulse did not cause a detonation on that occasion it cannot be assumed that a similar impulse will not cause a detonation in the future.

Suffice to say that it should not be repeated.

Other hull damage

The video footage shows that extensive damage has occurred to the forward casing. The damage is consistent with the possibility that the port towing bridle has been snagged and considerable force applied sufficient to tear the bridle from its hawse-hole and to remove a 2-3m section of casing. The extent of the marine growth in the damaged area would suggest that the damage occurred some years ago. There was no evidence of the damage at the time of the initial 1998 survey. Hence we might conclude that this event took place between 2 and 9 years old.

The force which would have been required to do this would have to be excessive and the resultant impulse to the hull (and the torpedo) would be some orders of magnitude greater than that inflicted by the descent line clump incident. Again that it did not cause a detonation of the torpedo is fortunate but does not allow us to rule out the possibility that a similar impulse would now cause a detonation.

Future Options

A range of six options has been identified for the future of the AE2 [4]. Of these Options 1 and 2 involve limited interference with the wreck. The detailed planning will need to be mindful of the basic requirement to avoid impulse to the wreck with no operations to take place within 5 metres of the tubes.

[4] AE2 Future Options Matrix V3 dated 17 Dec, AE2 Foundation, Capt Ken Greig RAN

Options 3 to 6 all involve interfering with the hull with in each case an intention to conduct an internal survey, prepare the hull for lifting and then lifting the hull for the purpose of relocation to a permanent either wet or dry berth. Clearly even the preparation for any of these options will involve contact with the hull with the inevitability of certainly low and probably high energy impulses being administered. The outcome of not neutralising the torpedo risk would at best case be, nothing with the option of recovering the torpedo itself from the wreck once it has been lifted. However, we have above established that there is a 16% chance that a low energy event will cause a detonation of the warhead and with that a certain loss of the wreck and a probable loss of life. This outcome is not acceptable hence we are obliged to eliminate fully the risk from the torpedo prior to embarking on any of Options 3 to 6.

Eliminating the risk from the torpedo

The options for eliminating the risk of an unplanned detonation can be summed as follows.

Remove the torpedo

This is not a practical option. The torpedo is probably in a tube behind an outer door and a sluice valve with a top-stop latching device to prevent its movement. It is unrealistic to think that these could be operated sufficient to remove the torpedo. The doors could probably be cut but it is hard to visualise removing the top-stop without major surgery which is likely to introduce the trauma which this operation is intended to avoid. However, having said that, the option should not be ruled out until the torpedo has been positively located and its condition verified.

Flood the warhead

The principal risk is from the warhead itself detonating. This risk can be eliminated by flooding the warhead and hence rendering the gun cotton charge inert.

Assuming that the torpedo is in the stern tube, this could be achieved by trepanning through the starboard pressure hull at a point some 3.8 m forward of the stern tube outer door apex and some 0.31m above the (horizontal) after planes. This would give access between frames 5 and 6 to the side of the stern tube. Trepanning through the stern tube itself would then give access to the warhead. Drilling through the warhead shell would expose the gun cotton to sea water. Drilling a second hole would allow water to be sucked through the warhead and thus flush out the gun cotton charge or render it inert.

Clearly this is an extremely hazardous operation which will require extensive planning and exposure for critical scrutiny to all the expertise that can be identified. For execution it will require expertise and technology which is well outside the immediate grasp of the AE2 Foundation. To pursue this option, will require identification of advice first to scope fully the practicalities of the proposed operation together with the associated hazards and then form a plan which also mitigates the risks at each stage.

While the plan should focus firstly on the stern tube there exists the possibility that the torpedo is in the bow tube or one of the reload racks. Prior to commencing the operation, arrangements should be made to conduct an internal survey to eliminate the possibility of the torpedo being in the reload racks. A contingency plan should also be in place to conduct a similar operation to enter the bow tube between frames 93 and 94 on the starboard side.

Should the torpedo not be found in either of these tubes or the reload racks it must then be in the midships tubes or no longer on board. The probability of these options is low but to be certain a contingency for drilling into the midships tubes should be developed. The most practical way to attempt this will be to drill through the outer doors and then through the sluice valves. This can expect to meet complications and will require careful planning.

Whilst at this stage the routes into each tube has been identified as being the most likely lines of approach, it should not be assumed that they are without other impediment (eg internal stowage racks, hull stiffeners, etc) and should be subjected to full scrutiny prior to firming the plan.

Primer
The torpedo primer comprises 7oz (200gm) gun cotton which could still detonate if impacted/shocked. Configured as it is, the possibility of an unstable detonation is low. This probability is reduced further if the primer has become wet. From this it is concluded that the primer does not present a hazard once the main charge has been neutralised. This assumption should be scrutinised by an appropriate explosives expert before it is accepted.

Detonator
The detonator comprises 77 grains (5gm) of fulminate of mercury located in a closed copper tube. It is possible that this could still detonate if impacted. The consequence of this event is reduced significantly if the main charge has been neutralised. However, the possibility of the detonator causing detonation of the primer should not be overlooked. The outcome of this event should be considered in greater detail in conjunction with planning for neutralising the main charge.

Conclusions

It is concluded that

- The torpedo presents a risk to any of the Options currently being planned for the AE2.
- The extent of that risk should as a consequence of the MAA findings be considered as being in the order of 16% chance that an energy event to the AE2 will lead to a > 95% chance of catastrophic detonation of the torpedo main charge.
- The impact caused by the descent line mooring clump does not allow that risk to be lowered.
- The risk to Options 1 and 2 can be managed by taking due precautions to avoid energy events on the wreck.

- The risk to Options 3 to 6 can only be mitigated by neutralising any risk that the torpedo main charge will detonate.
- The only practical option identified for neutralising the main charge is to drill into the warhead and flush the gun cotton.
- That operation is extremely hazardous and should not be attempted without having explored all other options and completing due planning.
- The plan for drilling into the warhead should also include a plan to survey the submarine internally to eliminate the possibility of the torpedo being in the reload racks.
- The plan for drilling into the warhead should include a contingency for drilling the bow tube for the event that the torpedo is found not to be in the stern tube.
- A further contingency should be considered for the event that the torpedo is found not to be in either the stern or bow tubes.
- All of these plans should be subjected to scrutiny by as many experts as can be identified. These should at a minimum include:
    - Representatives of the ADF
    - Representatives of the Turkish Naval Staff
    - Representatives of other allied nations if possible.

Recommendations

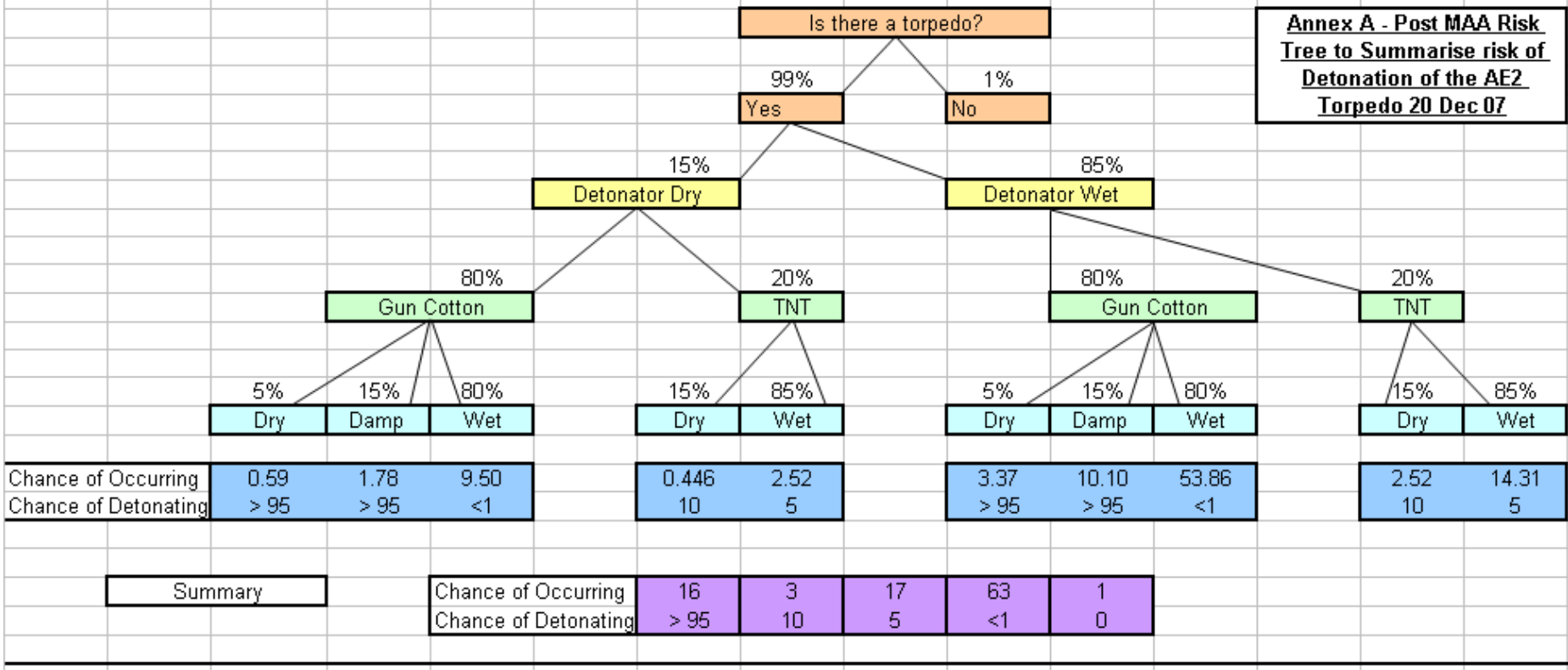
It is recommended that the conclusions of this paper be considered in depth to develop a step by step plan for eliminating the risk from the torpedo commensurate with the Options to be pursued for the AE2's future.

RBT
20 December 2007

Attachment

Annex A
Post MAA Risk Tree to summarise risk of detonation of the AE2 torpedo
20 Dec 07

Annex A - Post MAA Risk Tree to Summarise risk of Detonation of the AE2 Torpedo 20 Dec 07



Chance of Occurring	0.59	1.78	9.50	0.446	2.52	3.37	10.10	53.86	2.52	14.31
Chance of Detonating	> 95	> 95	<1	10	5	> 95	> 95	<1	10	5

Summary						
Chance of Occurring	16	3	17	63	1
Chance of Detonating	> 95	10	5	<1	0