MAKING THE INACCESSIBLE ACCESSIBLE

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SUMMARY

This paper considers the techniques that are available to mitigate the issues presented by submerged hulls, ensuring the necessary information is obtained to prepare cost effective conservation management plans as well as management and maintenance strategies.

With more historic ships being conserved afloat, underwater hull surveys can reduce the frequency of dry docking. The problems surrounding HMS Victory and Cutty Sark show the perils of conserving ashore. Afloat, it is relatively easy for a naval architect or historian to view the exposed internals and above water hull; the underwater hull however, is just if not more important to the survival of the vessel.

Wyn Davies (Wyn Davies 5201 Consultancy Ltd: Naval Architect) considers the areas of concern and types of problems that have arisen in a number of hulls, drawing on his extensive range of historic ship experience to illustrate some common problems and considering the more inaccessible parts that need survey.

David Tresidder (Beckett Rankine Ltd: Chartered Engineer and commercial diver) considers the challenges of the underwater environment, especially in various parts of the UK and looks at the options to provide meaningful results in the challenging environment.

1. INTRODUCTION

The long term preservation of the vessel's fabric should be the number one issue for nearly all historic vessels. When the vessel remains afloat and the majority of the hull is out of sight and beyond the reach of those best qualified to inspect it, preservation is that much more problematic, or is it?

No longer with a large crew to keep the brass polished and the revenue to help regularly dry dock and paint the hull, most museums rely on a small group of volunteers or an even smaller number of staff.

A review of these vessels worldwide reveals two main types of storage: preservation on land, usually in a dry dock, or remaining afloat in a suitable location including preservation by operation. Neither solution is without problems. Unless sufficiently supported, the land based solution runs the risk of deformation of the hull as a whole or in detail. Ships were designed to be supported by an envelope of water. Replacing this with a few discrete props is unlikely to provide adequate support.

Vessels kept afloat will be properly supported structurally, but remain subject to the often more hostile environment where corrosion, rot and marine borers can progress unchecked and largely unseen.

This paper will consider the problems associated with keeping a vessel afloat and specifically the inspection and management of a vessel's hull. The challenges of diving for afloat surveys are discussed and techniques to ensure achievement of suitable and meaningful results are presented.

The experience reflected by this paper includes recent surveys carried out on a number of vessels in the UK as well as reflections on similar experiences overseas.

2. LESSONS LEARNT

As noted in the Introduction, keeping a vessel on land can often lead to problems of structural distortion and damage. It is worth noting that some US Navy submarines have been embedded in gravel in an attempt to mitigate this problem. Good drainage is required to ensure facilitation of the driest and least corrosive or rot inducing environment possible. However, a gravel environment is less effective at hull preservation than a low humidity environment such as fresh air, or a high alkaline environment such as a solid concrete surround in the case of the Japanese battleship *Mikasa.*

Figure 1: Japanese Battleship *Mikasa*

This is not a solution that can be applied universally and, in many cases, may not be appropriate. The most important feature of the *Cutty Sark* for example, is her hull form. As the only surviving extreme clipper, her elegant lines had to be visible to the visitor. Severe local hull deformations caused by the original simple props have been addressed in her current support solution which includes support from a significant internal structure tied to the dockside. Current work on HMS *Victory* has led to a new design of a structure to provide better all-round support than the original for similar reasons.

Figure 2: *Cutty Sark's* original supports, note localised deformation of hull

Experience suggests that heritage and condition surveys are often far from simple and certainly present complex risks that are regularly difficult to manage. Many years of experience led to formalising some simple instructions for visiting such vessels, based in part on an MOD set of visit procedures. However, nothing can fully prepare the surveyor who finds that asbestos product deterioration has resulted in prolific and unconfined dispersal, or fuel tanks still containing 75 tonnes of furnace fuel oil some 15 years after the vessel was decommissioned. Modern Health, Safety and confined space entry regulations, amongst others, now govern the survey as much, if not more than the state of the fabric.

For ships that are retained afloat, the concept of underwater inspections has often been treated as too expensive and too difficult for the average historic ship trust or owner. Dive surveys are frequently too unreliable to offer any surety as to actual condition, a dry docking is sometimes perceived to be cheaper in the long run as well as being the only real option to ensure the fabric of the vessel is being properly preserved. In many cases however, the dearth of suitable dry docks makes their use close to impossible.

Whilst this is understandable in what is essentially a cash strapped aspect of our heritage industry, it is possibly a false economy. This can be demonstrated by a couple of recent examples, both from the west coast of the USA, but equally pertinent to Europe.

Firstly, a former Soviet Navy submarine was having a ballast tank pumped out when it was heard to crack very loudly and some movement was felt by the two volunteers in question. By their very nature, submarine hulls tend to be difficult to inspect internally as the pressure hull is usually surrounded by ballast or fuel tanks insulating the inner hull from the water and it was one of these tanks that had a problem.

An underwater inspection was carried out, although visibility was not good. This revealed that the recent crack was just the latest activity arising from a large deformation. It was subsequently discovered that this dent had been caused during unloading on delivery some 17 years previously. The event had gone unnoticed but it was recorded on at least one photograph taken at the time.

Figure 3: Unloading the submarine at its destination (photo courtesy of Steve Wilson's internet page: *http://blastitcleanitpaintit.com.au/photo-gallery/)*

Once finally afloat the dent was totally underwater and thus would have only been visible to a diver. Clearly no diver had inspected the craft (or at least had not noticed the damage) and a crack had continued to develop over the years until it was nearly two meters vertically and the bang was the result of the crack spreading horizontally for about a further meter, caused by differential water pressure following the attempt to pump the tank out.
The second example comes from a major survey of the RMS *Queen Mary* at Long Beach, Ca. During this survey

the underwater team found that the impressed current cathodic protection system consisted of a forest of dangling anodes, where replacement anodes had just been added over the years without removal of the existing. As a result of many anodes not working, the current had apparently also been turned up to the point where the otherwise excellent coating was being damaged.

Two examples within the UK illustrate the importance of checking the cathodic protection. HMS *Belfast* has anode rafts which over time have become buried in the mud of the Thames. This had significantly reduced their effectiveness and resulted in insufficient corrosion protection to the hull. In the case of the PS *Wingfield Castle* in Hartlepool, the anodes were very much incrusted by marine growth revealing they are not functioning at all due to faulty electrical hull connections.

3. PREPARATION FOR A DIVING SURVEY

It is important to understand the constraints that an underwater survey of a hull present and therefore why poor quality results can be so readily achieved. In this context, it is then possible to elaborate on the ways in which the value of an underwater survey can be improved to become the most appropriate method of afloat hull survey between dry dock repainting or repair activities.

Initially a desk study is recommended to establish the materials, form of construction, last known condition and the environment the hull has been subjected to since the last inspection. The quality and completeness of the last survey needs to be carefully considered and it may be necessary to refer back beyond this to when the vessel was last dry docked and repainted, for instance.

Records are often sparse and an initial survey to establish hull thickness from inside and to look at the hull condition along the water line will also help inform the scope of the diving work. As a general principle, a better quality and more cost effective survey is a dry survey. Therefore, any work that can be undertaken from inside the vessel should be - for example - taking ultrasonic thickness measurements of the hull. Areas that cannot be surveyed (full fuel tank locations for example) should be carefully mapped so the diver survey can be directed to these specific locations. Half-cell potentiometer testing can also be undertaken to help inform the likely ongoing corrosion activity and the effectiveness of any cathodic protection system in place. Noting the internal inspection of a hull will often be a confined space operation, this needs its own careful consideration and planning, taking into account the latest Health and Safety Executive (HSE) guidance.

It is preferable to complete the internal survey work prior to commencing the dive survey such that the extent of the diving can be minimised but, if this is not possible, a view will need to be taken as to the completeness of the internal survey that can be achieved. Once an understanding of the likely present external hull condition and the extent of the internal survey has been established, the scope of the diving survey can be developed.

A thorough, full coverage survey is often very time consuming and expensive for the reasons given below. A representative sample survey is usually more appropriate. Each vessel, location and hull condition is different and will dictate the most suitable solution to ensure a survey that is representative. Often the best solution is for the survey scope to remain reactive, although this prevents the possibility of a fixed price cost from the outset. Considerations for a representative survey should include:

- Area of hull;
- Predominant wave and current direction;
- Position of passing vessels;
- Likely hull condition and the potential for variability;
- Consistency of materials;
- Consistency of paint coat;
- Effectiveness of cathodic protection and location of anodes;
- Number of different plate thickness or forms of construction;
- Details that might be susceptible to corrosion;
- Vessel draught and therefore differences in conditions with depth;
- Time since last survey;
- Modifications such as blanking plates.

Hull degradation is a slow ongoing process which will generally be consistent for any given set of parameters. Once the number of different locations has been established, a view to the ongoing inspection strategy can be taken. Consideration should be given to the benefits of staggering a survey over a number of years, such that the degradation processes can be monitored as well as achieving the required coverage. Often a survey is seen as a single point in time action and this is rarely the most informative of cost effective in the long run.

The final stage is to develop a dive plan that will optimise the time in water. Diver safety needs to be considered throughout and in this respect a dive profile that regularly varies depth is not desirable. It is preferable for the dive to start at depth and gradually work shallower. This lends itself to longitudinal survey lines at constant depth. However, the easier way to provide a survey reference, as detailed below, is to run a rope traversing the beam of the vessel (a belly line). For shallow draughts (less than, say, 3 metres), the dive profile becomes less critical and transverse swim lines may well be preferable. Ultimately the diving contractor will have the final say on diver safety and it is worth involving them in the decision making process.

In developing the full scope of the survey, due consideration needs to be given to what can realistically be achieved, see Section 4. Alternatives to diving should also be considered. Whilst first hand feel and sight is the best method of interpretation, it may not always be needed. A remotely operated vehicle (ROV) camera survey could reduce the amount of diving time required by focusing the diving effort on areas of concern and verification of the ROV findings only. A high resolution multibeam survey that can produce a three-dimensional high density point cloud of the hull will pick up gross defects and acts as an excellent dimensional survey which, in most cases, diving could not achieve. For a very small vessel an underwater camera on a pole might avoid the need for a dive survey at all.

3.1 CASE STUDIES

In the case of HMS *Belfast*, a Town-class cruiser moored on the Thames in central London, the desk study revealed details of the paint system used and found that there had been some concerns with quality issues at the time of application that were reportedly resolved. Blanking plates had been installed but had been covered in a composite GRP material at last dry docking which highlighted a particular area for consideration. The bilge keels offered easy underwater references, but the vastness of the hull presented clear challenges. The content of many of the fuel tanks was also unclear.

Figure 4: HMS *Belfast* at her berth on the Thames

Initially, there was a clear need to establish the contents of the fuel tanks and the ability to enter them for internal inspection before the scope of the dive survey could be defined. A staged approach to the inspection was therefore taken. A one-day dive survey was also procured to establish the parameters that would enable the more detailed inspection to be planned out. Limited marine growth was found and initial indications of the likely paint condition were established from this.

Initial surveys were also able to verify the condition of the prop shaft glands and that the seals put in place remained in good condition.

Figure 5: Sealed prop gland of HMS *Belfast*

The ultrasonic thickness (UT) readings and tactile survey concentrated on the exterior of the hull where internal access was not possible and achieved a representative coverage of both sides of the hull from bow to stern and waterline to keel.

The desk study also revealed concerns with some localised thin hull plate from previous internal inspections with no records of the issues having been addressed at the last dry docking. Internal inspections were unable to repeat the concerning findings initially and this lead to a focused dive inspection in the same areas. The dive survey confirmed plate thicknesses and led to re-evaluation of original internal inspection. Through careful investigation it was possible to establish that the original internal thickness readings were erroneous and had been caused by laminations of rust product within the fuel tanks giving false thickness readings if they were not removed. The diver survey provided the evidence necessary to resolve the issue and enabled a serious longevity concern with the vessel to be entirely removed.

In the case of the middle water trawler *Ross Tiger* at her berth at the National Fisheries Centre, Grimsby, internal inspection of the hull was not possible for the insulated fish room and her fuel tanks. As such, external ultrasonic thickness measurements concentrated on these areas. Areas that could be accessed internally required a reduced sample to ensure appropriate representation, with measurements being undertaken mainly for the purpose of verification of technique and accuracy through consistency with the internal readings.

Figure 6: *Ross Tiger* at her moorings

4. THE CHALLENGES OF A DIVE SURVEY

Whilst there is no need to confine the contents of this section to the UK, the UK makes for an excellent example as its coastline, docks and rivers present the full range of the significant potential challenges that a diver is likely to face. Appreciating the constraints that a diver has to deal with can significantly help improve the quality of the survey results.

4.1 EXPERIENCE

Divers are rarely naval architects or engineers. Each has their own story but the route normally revolves around an interest in diving or the desire to have a unique skill that typically starts with aspirations for the offshore oil and gas industry. It is rare that an interest or knowledge base in naval architecture or similar leads to a person becoming a diver. As such, surveys undertaken by some commercial divers can suffer from a lack of suitable experience. However, most inshore divers will have some experience of surveying vessel hulls and underwater structures in varying states of repair. A high quality brief and close supervision of the divers can help significantly.

Placing the experience in the right place, i.e. using a suitably qualified engineer or naval architect to undertake all or parts of the survey, is the best way to achieving high quality results. Chartered Engineers and Naval Architects who are also divers do exist, although they are of course more expensive. But, with the cost of a dive team and vessel being in the order of £4,000 a day, the addition of an extra, say, £700 is a small proportion. Compared to undertaking an unnecessary dry docking, not identifying a defect or having to undertake emergency repairs, the cost of the additional relevant qualification is insignificant and a sound investment.

The other relevant experience is that of being in the underwater environment. It is without doubt a hostile environment. Someone who is worrying about where they are, not familiar or confident and may even be in fear of their own safety, is clearly not going to provide as good a service as someone who is regularly diving in the same conditions performing the same tasks day after day. Experience of diving is just as important as experience of the particular subject matter.

4.2 WEIGHTLESSNESS

Whilst gravity still exists, the ability of a diver to move around in three dimensions is one of the few benefits of the underwater environment. However, remaining on station, especially on the underside of a smooth hull is not simple. Anything other than neutrally buoyant and the diver is fighting to stay in position without assistance. In the first instance, survey diving experience will help significantly. Secondly, the easier it is for the diver to stay in position the better. Using magnets on steel hulls greatly reduces the work effort of the diver and the risk of moving off position. The use of a belly line (line placed under the hull and pulled tight) that the diver can hold onto and use as a reference is also of great assistance.

4.3 VISIBILITY

Locations away from the mouths of rivers and in areas of rocky coastlines such as Cornwall, and Scotland generally offer good visibility. Alas they are not the norm for a vessel hull survey and pitch black, zero visibility conditions are common in the UK. Even with good visibility, the act of removing marine growth or general silt disturbance can soon reduce the visibility to zero. However, underwater visibility is extremely valuable and will dramatically improve the quality, reduce the time and therefore cost of any survey. There are a few simple ways of ensuring the underwater visibility is as good as it can be. If possible, only dive:

- when there is good strong sunlight;
- after period of sustained dry weather;
- after periods of sustained calm conditions;
- on neap tides;
- during periods of slack water;
- at times of minimal marine growth (spring);
- when there are no algal blooms in the water;
- if high quality underwater lighting can be provided.

Most of the above pre-supposes that the survey is not urgent, but routine monitoring should by its very nature not be urgent.

Where there is need for a close visual inspection of the hull, for example where the paint condition of a riveted joint needs to be carefully inspected, limited or no visibility can be debilitating. One method to ensure a good view of the hull can be achieved is to use a clear water box. This technique was recently, very effectively, used on HMS *Belfast* to inspect the hull paint condition.

The principle of a clear water system is to replace the turbid water between the object being viewed and the point of view with clear water. The view may be achieved by the diver through their face mask, a camera, a remote video camera or a live feed video camera back to the surface. Each has its own merits and drawbacks and the decision on which to use is influenced by the competence of the diver to take the images / video and the ability of the surface team to effectively communicate with the diver from the surface.

4.3(a) Case Studies

In the case of HMS *Belfast*, high quality modern cameras were used which have a rear screen so that the diver could judge when a good image was being recorded and know when to move on. This was found to be the most effective method of minimising the survey time. A box was sealed to the hull using a soft neoprene seal and magnets around the edge to clamp it in place. Fresh water was pumped from the survey vessel and injected into the box from two sides with the excess water flushing out of holes on the remaining two sides. The camera was mounted at the rear of the box with the box being deep enough to achieve focus and optimum lens angle for the camera.

Figure 7: Diver preparing for the hull survey of HMS *Belfast*

The box would clear after two or three minutes with noticeable improvement in image quality after that time. Artificial light was added to illuminate the hull through the box and both still and video clips were taken. Marine growth was cleared by hand prior to attachment of the box.

The ability to adjust the magnets to form a close seal between the box and the hull, while the seal retained sufficient compressibility to accommodate the radii of the hull, was found to be critical to the success of the clarity of the water and image quality.

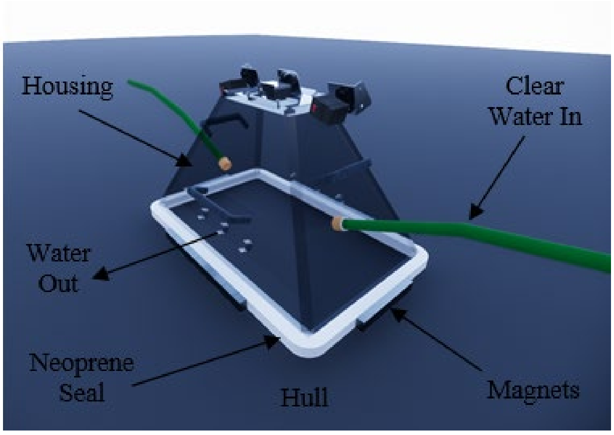

Figure 8: Diagram of a clear water box

Using the clear water box, cross cut adhesion tests in accordance with the Steel Structures Paint Council Standard D3359, were possible noting the adhesion tape limitations. This destructive test damaged the corrosion protection. Locations were, therefore, carefully chosen that were likely to be representative of the typical paint adhesion but where the hull thickness was such that future corrosion would not be critical (the advantages of surveying an armoured vessel).

In the case of the wooden sailing trawler *Esther*, sunk in Alexandra Dock, Grimsby, it was clear that significant volumes of fine silt had accumulated inside the vessel. At low water her deck was exposed. The decision was made not to send divers inside the vessel in the first instance as the water was relatively clear. Instead, a pole mounted camera was used to record the overall condition and details in good visibility. Subsequently a diver was directed inside to dimension members and to undertake knife penetration testing. However, this was primarily tactile due to poor visibility as the silt rose in plumes as soon as the diver entered the vessel. Where necessary, the measuring tape was locked and read in clear water or back on the surface.

Figure 9: *Esther* – Using a pole mounted camera prior to a dive into the interior

4.4 COMMUNICATIONS

Communications between the diver and the surface are vital for both recording the findings of the survey and directing the diver. Electronics and water never mix well and a very common source of avoidable poor quality surveys is the clarity of the communications. The system can be checked on the surface and spare communications boxes and even helmets can be provided, such that the system can be completely changed if necessary. The quality of the communications should be verified long before the diver gets in the water (preferable a day or two beforehand). If they are poor on the surface, they will be unrecognisable when the diver is in the water.

4.5 MARINE GROWTH

The more light that penetrates the water, the more marine growth you will typically find. Poor or zero underwater visibility often means only fine algal growth exists which can be wiped off by hand. However, in clearer water and particularly on the south facing sides of vessel, marine growth can be extensive. Hard and soft growth represent different challenges. Consideration of the potential damage to the paint coat that might occur when removing the growth versus the need to undertake a representative survey, needs to be taken. Trial removal areas should be undertaken first. Noting the worst marine growth is often very close to the water line, this can sometimes be done before the dive survey is commissioned. Avoid the use of sharp cornered scrapers and consider the use of equipment such as a Caviblaster or similar air cavitation process to remove larger areas of marine growth. High pressure water jetting can also be considered but the potential for paint damage increases significantly.

4.5(a) Case Study

The paddle steamer *Wingfield Castle,* at her berth in Hartlepool Harbour, presented a challenge in terms of the extensive soft marine growth that extended over the majority of her hull. It was necessary to adopt a representative sample approach to the survey despite the relatively good underwater visibility, as clearing the marine growth would have turned a one day survey into something closer to 10 days. Patches of marine growth were cleared and the sample survey was, in effect, the same as one that would be undertaken in low visibility conditions. The marine growth however, became less prominent along the keel line away from direct sunlight. A more comprehensive survey was therefore possible at the location where the vessel was more likely to have suffered damage from having run aground, for example.

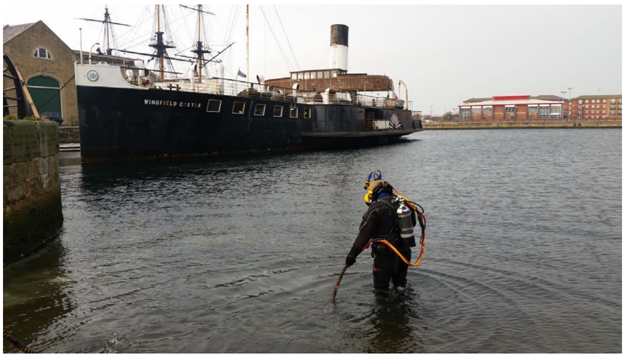

Figure 10: PS *Wingfield Castle* at her berth in Hartlepool Docks

4.6 ORIENTATION

Hulls are often vast and featureless, they sit above the divers head and noting the neutral buoyancy environment that the diver is in, the potential for disorientation can perhaps be appreciated.

It is often of little benefit to have found a defect without being able to accurately map where it is and a featureless hull can make this difficult. Reference to above water features is often sufficient and by using a belly line and measuring distance from the water surface, reasonably accurate locations can be achieved. If there are underwater features that reduce the measurement distance then this is likely to further improve accuracy. However, taking measurements underwater is often challenging, especially in low visibility. If the zero end of the tape(s) can be held in position below water and two triangulated measurements back to above water features can be made, then this should provide an accuracy of better than say 5% of the distance being measured. Measurements should be taken where possible in the absence of water movement as a current causing distortion in the tape will significantly degrade the accuracy.

Setting up a longitudinal chainage system along a vessel and then moving the transverse belly line along this chainage offers a highly repeatable survey. A diver can survey within a short distance either side of the belly line, for example, a 3 metre swath of hull can be surveyed in a single set up. Setting up belly lines at 6 metre centres in this instance would offer 100% coverage.

4.6(a) Case Study

HMS *Belfast* has a beam of over 19 metres; the potential for a diver to get disorientated was high. The need for a belly line from the outset was clear. However, the bilge keels and the current of the Thames presented additional problems that meant the lines needed frequent attention to ensure they remained in close contact with the hull. Finding small blanking plates welded to a flat hull was challenging and using the belly line as a reference from which to methodically search against, referenced back to above water features, proved the most successful.

4.7 TEMPERATURE

Water conducts heat away from the body 25 times more effectively than air. UK waters are rarely warm and a cold diver is not one that can concentrate. Ensuring the right thermally protective equipment is an important consideration. Changing the diver over to another member of the team does not take long and is invariably more cost effective than allowing a diver to continue to survey when cold.

4.8 COMFORT AND PHYSICAL EFFORT

The same rules apply to a diver who needs to relieve themselves as to one who is cold. Ensuring divers are as comfortable as possible is going to get the best quality results. Physical effort can be considerable and an exhausted and tired diver is again not going to perform a good quality survey. The following should be facilitated were possible:

- minimising the amount of time the diver spends on the surface fully kitted up;
- easy entry and exit from the water;
- shortest swim possible to the survey site.

Dive equipment is heavy and cumbersome out of the water and remains cumbersome in the water. It is often better to pass equipment to the diver when they need it than to overload them throughout the dive. Use of lighter weight helmets should be considered where a full hard helmet is not dictated by safety.

4.9 CURRENTS AND TIDES

As a general rule, diving is not safe in currents greater than 0.5 knots. Safety considerations include the diver being able to remain in the required location without excessive physical exhaustion, being able to safely get back to the exit point and exit the water safely. Divers holding onto belly lines or using magnets to extend the dive can be options, but the safety of the diver has to come first and such arrangements are not always the safest approach.

4.9.1 Case Study

When diving HMS *Belfast*, the tidal currents of the Thames severely restricted dive times. All diving was organised during periods of neap tides ensuring two slack period in each working day. Dive times were typically limited to 90 minutes at low water and 45 minutes at high water. The belly lines used helped the diver remain in position on the hull for as long as possible.

5. WHAT CAN A DIVER ACHIEVE?

Hull surveys in their simplest form may be visual only or tactile only, where the underwater visibility prohibits vision. Low light cameras can often identify objects that the naked eye may struggle to pick up but the camera cannot replace the three dimensions of two eyes or the benefit of being able to feel the condition. Below are a list of some of the tools that can be used underwater to improve the quality and value of a hull survey.

- Knife penetration tests to assess the deterioration of timber;
- Timber cores can be taken where they are not critical to heritage or integrity;
- Ultrasonic steel thickness measurements can be taken;
- Paint dry film thickness meter readings can be taken;
- Bathycorrometer readings can be taken to establish the effectiveness of a cathodic protection system or provide an indication of the corrosion activity.

6. ONGOING MANAGEMENT STRATEGIES

UK National Historic Ships (NHS-UK) has formulated various guidelines for preserving and, in this context, importantly, the recording of Heritage Vessels, including a formal risk assessment procedure. Further guidelines exist from the UK's Heritage Lottery Fund (HLF). The two relevant documents to this topic from HLF are the Conservation Management Plan and the Maintenance and Management Plans. The former will include the details of any survey, carried out using NHS-UK guidelines, and the latter will demonstrate the work needed to make good and then maintain the vessel in a safe and sustainable condition. Whilst both these documents are originally intended to support applications to HLF for grant support, they are equally useful in any long-term planning for a vessel. They encourage the authors to think in a logical fashion about their project and the implications of long-term ownership which will hopefully help to ensure the continued existence and understanding of much of our maritime history.

As noted above, on planning an underwater survey, consideration needs to be given to the extent of the survey. Whilst a visual survey of the whole of the accessible hull is always preferable, it is often most cost effective to use the in-water time to sample areas where possible defects are most likely to be found. The waterline is always a suitable candidate for detailed inspection and UT measurements, but elsewhere sample measurements can be taken as representative of the whole structure. The visual inspection, assuming any growth can feasibly be removed, should enable the diver to pick out areas where pitting is apparent and a search of the plating around the stern will also show any erosion damage from the propeller wakes and cavitation.

Regular high quality underwater inspections that provide representative sampling over time, offer a realistic and suitable management strategy that may result in the ability to delay dry docking activity.

7. CONCLUSIONS

We believe that we have established that underwater condition monitoring hull surveys are no longer too expensive to consider. Although the safety of divers needs consideration and the amount of dive survey minimised where possible, diving is not the high risk activity that it used to be.

High Quality surveys can be accurate and can meaningfully inform ongoing maintenance strategies and, in many circumstances, can delay the need to dry dock a vessel; an important feature given the few operating dry docks around the UK's coast. They can reveal potentially "fatal" defects in a timely fashion and are the only way of getting the complete picture without taking the vessel out of the water.

However, there are many challenges to an underwater hull survey, especially in UK waters, but with the right approach, all can be overcome and a high quality reliable and accurate survey can be achieved by following these simple steps:

- Survey in the best conditions possible;
- Use appropriately qualified and skilled surveyors;
- Minimise the diving required through thorough desk study and pre-survey work;
- Make the diver's task as easy as possible and set up referencing systems;
- Use tools and equipment that address the specific constraints that the dive site presents.

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Wyn Davies is a self-employed naval architect specialising in maritime heritage projects, European representative of the US Historic Naval Ships Association and member of the UK's National Historic Ships Council of Experts. To date he has worked on some 42 historic vessels as technical advisor or HLF Monitor/mentor, given around 17 papers at national and international conferences and has three books to his credit.

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