

## “SEA DIAMOND 3 Years on... Dealing with continual leakage from sunken wrecks”

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### 1. Introduction

As a matter of convenience, specialists dealing with oil spills from shipping incidents tend to classify spills and the casualties from which they originate into one of two categories, either they are “instantaneous” or “continual” releases. A true instantaneous release may be what happens, for example, when hundreds or even thousands of tonnes of oil rapidly spill into the sea in the minutes and hours after a catastrophic collision directly into the fuel oil tank of a blue water cargo vessel or the cargo tank of a loaded tanker. A continual release, on the other hand, might be the slow bubbling out of oil from a sunken war wreck or commercial vessel. There are, of course, many spill cases that start out as an instantaneous release after a key triggering event before developing into a slower, yet on-going, release. Fortunately, in many cases, the casualty remains near the water surface and the damage to the tank(s) can be patched, the vessel can be refloated, or at least the oil transferred/removed from the leaking tank(s). Often the release subsides within a short time, even if no active response is possible.

In some cases, especially when the vessel has sunk, the casualty and the oil reserves within it may be out of practical reach from responders. For example, the waters may be too deep for safe diving; specialist divers/ equipment may not be available; the vessel may have suffered too great damage to allow access for bunker removal systems; the tidal currents may be too strong (or weather too bad) for remotely operated work; the affected tanks may have been internal and inaccessible from the outside of the hull; the tanks may contain too little oil to remove; the oil may have migrated to other internal areas in the sunken vessel, and/ or the oil is leaking from areas too numerous/large or damaged to be plugged or patched. The result is the unfortunate situation where not only is it impractical to bring the release under control, but it is also unrealistic to try and make any reasonable forecasts of the future evolution and duration of the release. In the real world of response to sunken wrecks there are times when the technically most reasonable approach can be no more than just ‘wait-and-see’.



Photo 1: View of boom enclosure from the cliffs above (enclosure diameter: 150m, circumference: 450m), March, 2010

In April, 2007, after the cruise ship SEA DIAMOND ran aground and sank off the Greek island of Santorini it became an unfortunate example of many of these challenges. Once it disappeared from the sea surface, the vessel sank very quickly to the deep sea bed. The result was a substantial, instantaneous spill of fuel oil as the vessel's partially-loaded fuel tanks imploded under the quick pressure change. The cruise ship capsized as it sank and then hit the sea bed relatively hard, rolling back onto its hull in a nearly upright position. This resulted in significant internal and some structural damage to the vessel. Oil spread through the ruined decks, cabins, and internal debris. Early ROV surveys observed oil leaking from broken windows high up on the vessel, many decks above the tanks. More than half of the fuel reserves (approximately 300 MT) were observed to have risen from the wreck within the first days and weeks. These were collected at sea and on the shore within the first 2-3 months. Throughout this clean-up operation the release slowed and changed form: the lube oil content in the release diminished, followed by the diesel oil. As the 3 months of active clean-up operations drew to completion in mid-summer 2007, the release of heavy fuel oil did not, however, cease. The 'tail-end' of the instantaneous release turned out to be a small and unfortunate continual release. Neither at that time, nor now, nearly 3 years on, has it been possible to predict just when this release will stop.

In light of this situation, a sophisticated anchoring system was put in place and an enclosure of high-seas quality boom was installed above the deep, yet near-shore wreck. Then, in the summer of 2009 an ROV-based bunker removal operation was undertaken which succeeded in draining another 150+ MT of fuel oil from several natural collection points in the wreck. As of the spring of 2010, the release continues, albeit slowly, and the boom enclosure with its daily maintenance regime remains in place.

The following paper picks up the story, 3 years on, looks at the current situation, compares it in a qualitative way to other cases around the world, and reviews some of the options that have been suggested in different quarters. The scene is set through is a short recap of the response operations and the successes achieved in terms of oil recovered.

## 2. Emergency Response, Shoreline cleaning and Bunkers Recovery

Following the grounding of the SEA DIAMOND and its subsequent loss in early April 2007, an intensive clean-up operation was initiated under commercial contract to the shipowner. An at-sea response was rapidly mobilised to deal with the large quantities of oil released in the initial hours after the sinking, using specialised booms, skimmers, and various vessels, all operated by experienced professionals. Given the optimal conditions of relatively calm seas with little current and tidal action, the on-water recovery operation succeeded in collecting the equivalent of 275 tonnes of 'pure' oil<sup>1</sup> before the oil had the opportunity to cause any measurable environmental or commercial damage.

Once this threat was brought under control, an intensive shoreline cleaning effort was carried out for several months until all stained surfaces along the affected shoreline from the old port of Thira until the lighthouse at Akroteri were cleaned to the highest standards. Although many of the areas affected are virtually inaccessible by land (i.e. well beyond the sight of locals and tourists alike), and it would not have been strictly necessary to carry out such intensive cleaning from an ecological perspective, the fact that the island

receives daily visits from as many as a dozen cruise vessels within the "Caldera" meant that it was found appropriate to remove as much of the visible contamination as practicable. Given the porosity of the



**Photo 2: Map of Santorini, upper end of green circle is approx. Wreck location, red line is originally impacted shoreline**

<sup>1</sup> The 275MT estimate takes into consideration (and deducts) water that was collected together with the oil.

rock involved and the low-energy wave exposure of many of the shores, high-pressure, hot-water steam cleaning machines were required to even begin much of the work. This meant that it was possible to clean the area to a high standard from the start. In the end the shores, beaches and rocky cliffs alike, were left with practically no visible signs of the incident. This was also true for areas where the shoreline responders were able to collect bulk oil and contaminated substrates. In all, the equivalent of around 25 MT of pure oil was collected from the shores.

The 2009 bunkers recovery operation was focused on reducing the threat of a large oil spill in the low-probability case the wreck should undergo some further structural deterioration. In this intensive operation a team of specialists used ROV technology to access and pump out oil that had accumulated in a number of key locations accessible from the outside of the vessel.<sup>2</sup> It is reported that in excess of 150 MT of pure oil were recovered from the wreck during this operation (i.e. after oil-water separation). Given the wide distribution of the oil within the wreck, the operation must be seen as a tremendous success in that it was able to locate and recover such a large quantity of oil trapped within various enclosed spaces, far from the tanks themselves. While this success has not yet manifested itself in terms of slowing the on-going, 'nuisance' release (described below), it must be stated categorically that it has drastically reduced the potential for a large, instantaneous release in the future.

Together, the at-sea containment and recovery operations, the shoreline clean-up, and the subsequent bunkers removal operation accounted for an estimated total of 450 MT of oil, a figure that represents 87% of the total quantity of persistent oil (516 MT)<sup>3</sup> that went down with the ship and which includes the greatest part of that which resurfaced.

In order to deal with the nuisance posed by the small-yet-continual release, the shipowner agreed early on to take advantage of the enclosed and relatively protected waters of the location and have a special boom enclosure designed, installed, and maintained by its appointed clean-up contractor. This unique boom system was installed in June 2007 and is still in place (albeit with much maintenance and upgrades), nearly 3 years on.

### 3. The Current Situation – March 2010

Currently, the casualty location is marked by the boom enclosure, albeit with a somewhat smaller diameter, one that does well to catch any and all the oil that rises to the surface. The relatively enclosed nature of the body of water and lack of measureable tides make this possible. It is highly unlikely that such a boom enclosure would be able to 'target' the rising oil or hold it in place in time for recovery in tidally-influenced or open waters.

The release of diesel/ gas oil or lube oils, as observed in early months appears to have stopped entirely. The heavy fuel oil, on the other hand, continues to rise from the wreck. To be sure, the release is as minor in quantity as it is regular and continual. Based on observations in March 2010, the current, daily release rate for the heavy fuel oil (HFO) is thought to be about 20-30 kg (or approx. litres). This is in line with the results of the current boom maintenance and clean-up operations which recover between 25 and 35 kg of oil waste each day from the boom arrangement. This waste includes debris, sorbents used to capture the oil, and water that is absorbed into the oil through the beginning stages of emulsification. On average, this would indicate a release rate of about 1kg per hour. The release appears to be consistent from hour-to-hour and over the months since late summer 2007 (i.e. over the past 2 ½ years).

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<sup>2</sup> It is standard practice in deepwater operations such as these, whether divers and/ or ROVs are used, that all work is undertaken outside the vessel. Internal tanks and spaces (including doubled hulls) are exceptionally difficult to access and can only be worked on from outside the outer hull.

<sup>3</sup> In terms of persistent oil, ITOPF understands the SEA DIAMOND was reported to have had on board 460MT HFO380, 36MT lube oil, and 20MT sludge.

The oil that rises to the surface can be seen to be a mix of small spheres, like large grapes.<sup>4</sup> These range in volume, generally from that of a teaspoon to a tablespoon (i.e. 5 to 15ml or grams)<sup>5</sup>. It is extremely difficult to quantitatively observe the phenomenon because the oil rises in more than one place and is very hard to see. The current best estimate is that the oil spheres rise at the rate of about 2 or 3 per minute. Based on the observed size of 5-15ml each, this is also consistent with the estimate of 20-30kg rising per day.

In addition to the spheres of very heavy, black and sticky fuel oil there can also be observed some very light, thin, sheens which appear to dissipate/ evaporate naturally. The latter could still be traces of diesel oil (DO) or a lighter fraction of the HFO that quickly separates from it as the black oil reaches the surface. In either case, these sheens are inconsequential in terms of quantity and effect; they cannot be observed to cause any shoreline contamination or other impact. Given a standard thickness of 0.0001mm for thin grey sheens, the quantity involved can be estimated as 1 tablespoon (i.e. 15ml) per sheen of dimensions 5m x 30m.

#### 4. Risk Analysis / Comparison with other incidents

An international standard for contingency planning in all locations and for all eventualities is the matching of contingency arrangements with risk. In the case of oil spills, planners consider both the expected frequency/ probability and the likely impact of a spill. The *probability* of a large spill from the SEA DIAMOND, for instance, is a function of the stability of the wreck, the quantity of oil on board, and the disposition of this oil. The potential *impact* will also depend on the quantity spilled, the nature of the incident (i.e. instantaneous or continual), and the environmental/ commercial sensitivity of the location. The decisions that are made will be based on such a technical weighing up of risk factors, availability of options, and overall sense of proportionality.

While the discussion of the stability of the wreck is beyond the scope of this paper, it can be clearly and definitely stated that the probability of a large spill is exceptionally low. As discussed above, the original spill was on the order of 300 MT of oil. This was recovered early on and sent for recycling. A further 150 MT were recovered and sent for recycling 2 years later. The ship originally carried some 516 MT of persistent oil. Mathematically, the largest conceivable spill would be 66 MT. This is only one fifth of the quantity that was spilled originally. Further, this oil is known to be distributed throughout the wreck and would not all spill at once. Also, it is likely that no matter what happens to the wreck over the years, a considerable amount of clingage and internal contamination will remain inside. Salvors regularly assume *in-tank* clingage figures for oil or other cargoes that are not all that much lower than the residual figures known to be inside the *vast and complex spaces* of this wrecked cruise ship now.

In terms of potential impact, in general one can differentiate between 'environmental' and 'economic' sensitivity. In the case of the SEA DIAMOND incident in Santorini, the following points should be considered:-

- The island and its waters are a significant economic resource that could, in theory, be seriously affected by an oil spill, but because of its timing, location, and the efficiency of the response, the SEA DIAMOND incident is not thought to have adversely affected the tourism economy of the island in any measureable way, and

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<sup>4</sup> Note that with a specific gravity/ density of 0.991, the SEA DIAMOND heavy fuel oil is lighter than the sea water and will always float when fresh. However, for the purposes of visualizing the quantities/ volumes described here, the reader may think of 1 kg as being approximately equivalent to 1 litre. In terms of waste, 20 kg of oil waste would easily fit into one common black bin liner and would generally require a person to use two hands to lift without too much strain; 30 kg would be a strenuous lift for most people and would require two bin liners.

<sup>5</sup> Based on the standard formula for the volume of a sphere, a 5ml oil sphere would have a diameter of just over 2cm; a 15ml sphere would have a diameter of just over 3cm.

- Although the natural beauty of the caldera of Santorini is a major tourist attraction, the coastal environment is robust and has not been appreciably impacted by the spill. There have been no known complaints of injury to the geological aspects that make this site such a unique place. Likewise, intensive study by the national marine research institution of Greece (HCMR) has not identified any adverse environmental effects.

HCMR (the Hellenic Centre for Marine Research) have carried out regular monitoring, both immediately after the sinking and over the years, of all appropriate ecological measures, studying the water column, sediments, and marine organisms. They have tested for hydrocarbons, heavy metals, and possible biological change over an array of sampling stations, both at the immediate casualty site, in nearby/distant waters and at control sites. Their findings have been extremely encouraging:

- Petroleum hydrocarbons: extremely low/ similar to control sites
- Hydrocarbons in sediments: particularly low in all samples
- PAHs: extremely low at all but 2 stations (and those are pyrogenic, not from spilled oil)
- Synthetic compounds: no sign of increase above background (e.g. polymers such as plastics)
- Heavy metals: particularly low concentrations at all stations/ depths, similar to those found in open sea

Based on the information gathered during extensive surveys of the area by ITOFF and local surveyors, and on the reports of HCMR, it can be logically concluded that the particular location where the incident occurred, while valuable to the heritage of Greece and an important tourist site, is not sensitive to the type and degree of pressures presented to it by a vessel sinking and oil spill of the magnitude of the SEA DIAMOND. The incident has so far not caused any known physical, environmental or reputational loss to the island of Santorini or its people and there is no indication that it will do so in the future.

To help put the risk situation in perspective, a brief, qualitative, look at a number of similar cases is made. Table 1 summarises the key, relevant data for 6 cases, all involving leaking, sea bed casualties. Some of the key aspects of this review:

- In 3 of the 6 cases, some underwater bunker recovery work was undertaken (column 1, Cases B, C, and E). In two 'shallower' cases (60m depth), it was possible to use specialist divers; in the SEA DIAMOND case (E), the work was undertaken with the aid of ROV, a much more complicated venture.
- In only 1 of the cases, the bunker barge that sank in Spain (Case B), was the wreck lifted from the sea bed (column 2). In that case a very large quantity of oil was involved (i.e. In excess of 1,300 MT in all), the vessel was entirely intact, specialist divers were available to reach it, and it was determined that because of the vessel strength inherent in the small size of the vessel the easiest and safest way to remove the oil was to lift the vessel in entirety, with the oil still in the tanks. Further, the operation was in protected waters and 200m from an oil terminal loading buoy.
- In only one other case was the option of raising the wreck seriously considered, namely the small general cargo vessel that sank in 75m in Japan (Case D). In that case the wreck was directly under (although it did not impede) an exceptionally busy traffic lane. More importantly, however, the continual, yet small loss of HFO had direct and dire consequences for neighbouring mariculture facilities and local fisheries. However, even with estimated losses reaching up towards USD 100 million, no underwater operations at all were found to be technically feasible and none were carried out.
- In the three offshore cases considered only one (Case C) saw any bunker removal work. In that case, the depths, while considerable at 60m, did not prohibit the operation. The large quantity of HFO in relatively few locations (in intact tanks) and cargo-related issues led to a decision to undertake the bunker removal operation which proved successful (some 800 MT were removed). In the two other cases, divers made attempts to plug holes in the shallower one (Case A at 57m) while no underwater work was attempted at the other (Case F at

170m). In both cases, the coast guards monitored the slick movements and either sprayed dispersant or cleaned up what oil eventually came ashore.

	1	2	3	4	5	6	7	8	9	10
	Bunker removal work?	Salvage work?	depth	Country	Vessel type	GT	Location	distance offshore	DO (MT)	HFO (MT)
A	no	no	57m	China	gen cargo	>20,000	offshore	50-100km	40	>600
B	yes	yes	60m	Spain	bunker barge	<1,000	well-used bay	<3km	>300	>1000
C	yes	no	60m	Denmark /Sweden	bulker	>30,000	Offshore/ shipping channel	25-50km	100	>1600
D	no	no	75m	Japan	gen cargo	<2,000	well-used strait	<3km	15	60
E	yes	no	130m	Greece	cruise ship (SEA DIAMOND)	>20,000	well-used bay	<3km	80	516
F	no	no	170m	Japan	gen cargo	<3,000	offshore	25-50km	0	100

**Table 1: Brief overview of 6 recent cases of sunken wrecks with continual leakage involving non-tankers and one bunker barge.**

In summary, it is clear from this group of cases that water depth, oil quantity, and disposition of the oil in tanks are the driving factors in the decision to attempt bunker removal operations.

It is worth noting that whilst public pressure on government and ship owners has resulted in a small number of intensive/ expensive oil recovery operations from sunken *tankers*, most notably the PRESTIGE off Spain and the ERIKA off France, those cases *are very different* than those described here in so far as they involve very large quantities of oil trapped in large, externally-accessible, tanker holds.

- In the case of the ERIKA (1999) the single hull tanker was carrying 30,000 MT of heavy fuel oil of which between 14,000 and 20,000 MT were estimated to have spilled. According to IOPC Fund reports at the time, this left as much as 6,000 MT in the bow section (which sank to the seabed at 100m depth) and 10,000 MT in the stern section which came to rest 18 km away in 130m depth.<sup>6</sup> Operations to pump out oil remaining in the sunken sections of ERIKA were undertaken in the following summer once the weather improved. Over the course of 3 months some 11,200 tonnes of oil were recovered. The costs for the pumping operation alone, as reported in the still-on-going court case, exceeded €200 million.<sup>7</sup>
- In the case of the PRESTIGE (2002) the single hull tanker had been carrying 76,972 MT of heavy fuel oil of which an estimated 63,000 MT of cargo were estimated to have spilled. The Spanish government estimated that the wreck, at 3,650m depth, contained approximately 13,800 MT of cargo. Over the course of 5 months in mid-2004, ROV-based operations succeeded in removing 13,100 MT of cargo at a cost in excess of €100 million. At least 700MT of cargo oil were left in the wreck.

While such operations have, at times, been successful, especially in light of the challenges faced, others have resulted in recovery of relatively little oil. The following three cases involved small tankers that where relatively small recovery quantities and high costs were realised.

<sup>6</sup> See, for example, the IOPC Fund summary at: [http://www.iopcfund-docs.org/ds/pdf/92exc6-2\\_e.pdf](http://www.iopcfund-docs.org/ds/pdf/92exc6-2_e.pdf)

<sup>7</sup> See, for example: <http://www.upstreamonline.com/live/article210685.ece> .

- In the SOLAR 1 in the Philippines, the small tanker was carrying some 2,081 MT of fuel oil cargo and sank (2006) in some 630m depths. A large instantaneous spill occurred, followed for several weeks by a decreasing continual release. Some 8 months later a \$6 million pumping operation was undertaken which recovered only 9 MT of oil.
- The small, single-hull tanker YUIL No. 1 (1,591 GT) was carrying 2,875 MT of fuel oil cargo when she sank (1995) in 70m off a South Korean island.<sup>8</sup> The emergency spill response was estimated to have collected between 1,000 and 2,000 MT. A 66-day, ROV-based, underwater recovery operation 3 years later (1998) collected some 634 MT at an approximate cost of \$5.6 million. It was reported that there was a small oil spill incident during that operation.
- The OSUNG No. 3 (1,115 GT) with double-bottom tanks was carrying 1,614 MT of heavy fuel oil when she sank (1997) in 70m off a South Korea.<sup>9</sup> A spill occurred at the time of sinking, but no reliable quantity estimate was made. The same ROV-based operation as was used for the YUIL No. 1 worked on this case for 69 days (1998) to recover approximately 20 MT. The cost was approximately \$5.8million.

In summary, it is important to differentiate between situations: (1) where large quantities of oil are directly accessible from outside the hull (e.g. laden single-hull tankers and large non-tankers with laden, hull-integral, bunker tanks) from those (2) where the oil is in smaller quantities, drifting freely within the vessel, or in ship-internal tanks. Double hull tanks in newer tankers present challenges, yet these can be overcome if the two skins are relatively intact and *parallel* to each other. Finally, it is important to note that even the successful underwater removal operations for tanker cargoes typically do not address the bunkers carried by those vessels AND often leave more residual cargo oil in those wrecks after they are finished than is in these smaller cases from the very beginning.<sup>10</sup>

## 5. Review of Proposed Actions

The fore-going discussion of risk is not an attempt to discount entirely the current situation at the wreck site of the SEA DIAMOND. There can be no doubt that the continued daily release of droplets of heavy fuel oil, as currently observed, poses a nuisance to the island. In particular, the port at Athinios, which is often directly downwind from the wreck site, would be subject to low-but-continual staining from the released oil, if the oil boom enclosure were not kept in place and maintained.

When identifying possible solutions, the international standard would be to ensure that they are both: (1) in line with the risk, as described above, and (2) compatible in terms of cost and effort to the costs of, say, a 'worst-case' clean-up scenario. The following paragraphs offer some thoughts on several of the response proposals that have been brought forward by different quarters:

### 5.1 Monitoring

It is understood that there have been calls for "more systematic" and continued scientific monitoring of the SEA DIAMOND impacts with an additional focus on accumulation of oil within marine organisms. With regard to these proposals it is important to consider that the SEA DIAMOND case has seen repeated and thorough scientific monitoring efforts by the government's own national marine monitoring centre, the Hellenic Centre for Marine Research (HCMR) since 2007. Based on observations of HCMR personnel at work on site and reviews of their preliminary work, it appears that their work has been both thorough/ systematic and has been carried out according to international scientific standards and protocols. In addition, the results of their investigations should

<sup>8</sup> See <http://www.iosc.org/papers/01431.pdf>.

<sup>9</sup> See <http://www.iosc.org/papers/01431.pdf>.

<sup>10</sup> (See, for example, a number of ITOPF papers on removing sunken oil from wrecks at: <http://www.itopf.com/information-services/publications/papers/#sunken>)

allay any concerns regarding long-term impacts, including the accumulation of pollutants in the tissues of marine organisms.

Experts around the world have understood and agreed for many years that the environmental impacts from oil spills arise from two possible pathways: (a) smothering by thick oil or (b) toxic effects that kill or change behaviour. Possible effects from a given incident are investigated in monitoring studies such as carried out by HCMR in teams of experts, each with a deep knowledge of a certain group of potentially affected organisms. They know which organisms to look for, which are sensitive, and how to test for potential adverse effects. If any exist, they can find these immediately. In fact, the sooner after the incident that they make their tests, the better chance they have of finding any effects. As time passes, the effects of the incident, if any, will be harder and harder to find. Medium term impacts, if any, will have been observed in the short term. Long-term impacts, if any, will have been observed in the medium and short term as well. It is not a characteristic of monitored oil spill impacts that long-term impacts 'pop up' without being measureable in the short and medium term. Conversely, where there are no short-term impacts measureable by scientific studies, there will be no medium or long term effects measured or realised. It is for this reason that the international standard is to carry out post-spill monitoring until no more impacts can be measured. Once the monitoring results fall below impact thresholds, the studies are concluded.

## 5.2 Detection Systems

The idea has been proposed that an automatic, remote oil spill detection system is installed to alert the local maritime authorities should there be another oil spill. While this type of equipment may seem appealing as a means of 'passively' monitoring the situation, arguments could be made that it has questionable technical merit in this case:

- Open-water remote sensing of any type is not tried-and-tested technology. It is used in industrial applications, especially in controlled environments (e.g. holding tanks) and where it is tied directly to industrial systems (e.g. to turn off valves when holding tanks contain oil). We are not aware of any form of remote sensing that is currently capable of reliably and accurately detecting and quantifying spilled oil in open-water applications without, for example ground truthing.
- The proposed UV-fluorescence detection system is unlikely to work well with the oil in the form that it is currently surfacing, i.e. small spheres or 'tar balls'. Instead, fluorescence systems like this are designed for slicks and sheens with considerable oil.
- The time between when the oil rises and is trapped by the boom is only slight (often less than 5 minutes, depending on the wind).
- The introduction of such a system three years after the incident does not conform to the current risk profile. There is no new and compelling reason for it based on a risk assessment.
- It is very likely that installing oil sensors would only serve to heighten public sensitivity about oil in any quantity, no matter how inconsequential.
- The sensor may also detect other types of oil from different sources unrelated to the releases from SEA DIAMOND resulting in 'false alarms'.
- It would be expected that any large-scale releases would be reported to authorities by vessel or aircraft operators in the area. Over the past 3 years there have been workers maintaining the boom every day; as long as the boom stays in place, it is realistic to expect that specialists would have to be on site more or less regularly. These would be the best qualified people to assess any changes in the release.
- Periodic observations of the site from the cliffs above would also be an effective means of monitoring the situation. Alternatively, a webcam could be installed for remote monitoring.



### 5.3 Booms

Booms are among the most standard of oil spill response equipment. They are commonly used both to collect oil and keep oil from moving in particular directions, although the success at either task depends very much on the environmental conditions, the oil, and the skill of the user. Generally speaking, it is rare to be able to successfully use a boom in the fashion used in the SEA DIAMOND. In most cases, surface and underway currents are too strong and/or variable to capture and hold the oil. However, as discussed above, the purpose-built boom installation in this case has proven to be a viable, albeit expensive, means for preventing the spread of oil rising from the wreck. Several points are worth considering:

- The boom used in the SEA DIAMOND case is of the highest specification on the market; it is ocean-going boom used in an enclosed water situation (See photo below).
- The anchoring system is complex and also of very high specification. It is similar to that used to hold open-water fish farm facilities in place.
- The boom system requires daily attention. The mooring lines/ buoys must be checked daily and replaced frequently; the boom inflation must be topped up regularly; and most importantly, the oil that collects each day must be removed manually.



**Photo 3: Inflatable boom used in SEA DIAMOND enclosure (July, 2007)**

### 5.4 Skimming Capability

It has been proposed that a 'low-tech' mechanical skimming system be supplied which can be operated by local workers. Among other comments, the following appear appropriate:

- Oil skimmers are best operated by experienced oil spill response contractors. They are difficult to operate and particularly dangerous.
- The logistics of setting up a long-term skimming capability in the location are complicated in relation to the expected benefits. The location is subject to severe, acute weather conditions which would require the complete demobilisation of the system between uses. There are no nearby safe moorings, no power supplies, no boat ramps, no boats cranes, etc.
- The most appropriate solution would be to contract out the oil-collection task to a local organisation which could be trained and supplied with sufficient materials for manual recovery with limited daily sorbent deployment and recovery (as is currently done). Individual pieces of sorbent 'snare' and sorbent pads, as described above, are entirely sufficient. The local team (perhaps 2 persons) could use a local boat to replace sorbent

material, as necessary. This type of material is ideally suited to this task since it can stay in the water indefinitely, selectively trapping fuel oil.

- A large-scale release warranting the use of a skimmer is highly unlikely and unexpected, but such equipment could be mobilised to site in emergency mode, along with the appropriate operating personnel within a few hours should the need arise.

## 5.5 Bioremediation

It has been proposed that a pump and distribution system be installed that would administer nutrients and micro-organisms. The following comments could be made:

- Bioremediation through the addition of microorganisms or nutrients is an unproven means of removing oil from the marine environment. There have been no replicated studies which show that human efforts to amplify natural biodegradation are successful.
- It is widely agreed that the action of adding nutrients to the sea is not only ineffective, but potentially damaging. It is well-known that eutrophication caused by excessive nutrients in the marine environment is a problem, and this is now addressed through several EU policies and directives, including the EU Water Framework Directive, which Greece is committed to implementing. In nearshore waters the concentrations of nitrogen and phosphate are usually more than sufficient to enable indigenous oil-degrading bacterial to break down hydrocarbons.
- Furthermore, and practically of more importance, biodegradation occurs over a longer period than the movement of this oil across the water body. Consequently, the nutrients will merely just be poured into the sea and diluted without having the desired effect as a catalyst.
- Indigenous micro-organisms are acclimatised and better equipped to deal with their local environment than introduced species.<sup>11</sup>

## 6 Conclusions

Overall, the conclusion we would draw is that the wreck of the SEA DIAMOND continues to pose no more than a low-risk threat. The original oil spill was cleaned up to the highest standards; the duration of the on-going release cannot be reasonably predicted but remains entirely under control; there is not enough oil remaining in the wreck to ever cause a large spill; the oil that remains in the wreck is too diffuse to collect, yet also too diffuse to pose a risk of being released all at once; if a spill were to ever happen in the future there are sufficient professional responders in the country to deal with it effectively and timely; there have been no measurable economic, social, or health impacts; and very significantly, the national marine research institution has carried out regular and detailed studies that have found no evidence of ecological impact.

The only continuing actions for which there are strong technical arguments are: (1) the continued maintenance of the boom enclosure to collect the rising oil (not to protect against a possible future spill!) and (2) the continued, albeit scaled-back environmental monitoring of the local environment (for example, by HCMR).

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<sup>11</sup> See, for example, the IMO - Bioremediation in Marine Oil Spills, 2005 Edition