‘The Oil Spill Response to the SEA DIAMOND Incident’

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ABSTRACT

While approaching a mooring off the cliffside tourist town of Thira on Santorini Island (Greece) on April 5, 2007, the cruise ship SEA DIAMOND (1986 built, 144m LOA, 1537-pasenger capacity) came into contact with an uncharted extension of rocky reef and suffered hull damage. She immediately began taking on water and slowly sinking. An emergency evacuation of the 1156 passengers and 391 crew members was carried out. Tragically, two French passengers did not survive the incident which saw the vessel capsize and sink the next morning.

When the vessel went down she took with her some 572m^3 of oil, including heavy fuel oil, diesel, and lube oil. The rapid decompression of the tanks as she sank would have forced these to implode, releasing their oil contents first to other areas inside the vessel’s hull, then outside. On the sea surface a significant ‘instantaneous’ oil spill occurred in the hours immediately after the sinking which transformed over the following, days, weeks, and months into a small and declining, but continual release. This continued for over a year but died out by early 2009.

Immediately after the grounding and even before the sinking, the vessel owners and insurers teamed up with Environmental Protection Engineering (EPE) of Piraeus to respond to the oil spill. Working together with the International Tanker Owners Pollution Federation Ltd. (ITOPF) of London, EPE carried out a multi-facetted response operation. The response successfully dealt with the immediate issues of floating bulk oil and the contaminated shoreline on the one hand, and the longer term issues of the continuing release on the other. In addition to the challenge of delicately addressing an oil spill on the doorstep of a world-famous tourist destination, responders had to deal with the logistics of working on isolated shores under crumbling cliffs hundreds of meters high. The wreck itself posed numerous challenges as well, including its precarious position on the steep (submerged) crater walls of the old volcano, depths too great for conventional diving, the significant damage to the vessel as it sank, and a sea bottom too deep and steep for conventional boom anchoring. Nonetheless, the results were impressive: It is estimated that 300m^3, more than half of the oil that was in the vessel at the time she sank, was successfully recovered; the shores of Santorini were cleaned of all visible oil within 3 months of the accident; the continuing release was well-contained by a unique booming arrangement; the tourist trade suffered no measurable impact; and no negative environmental effects were measured by the government’s marine research institute.

This paper highlights the response methods and results, especially the ‘at-sea’ operations. The unique characteristics of the location and the spill, as well as the response equipment and techniques used are presented in ‘lessons learned’ case study fashion. The result is an interesting review of what can be achieved, for example in terms of maximum percent oil recovered, by well-equipped professionals taking advantage of favourable local circumstances.

INTRODUCTION

In April 2007 the 1500 passenger cruise ship SEA DIAMOND was involved in a tragic incident which resulted in the loss of two lives and the sinking of the vessel near the Greek island of Santorini. In addition to this, the vessel's fuel oil, diesel, lube, and slops tanks were damaged in the sinking, resulting in a serious oil spill which threatened both the environment of this geologically significant place as well as the flourishing tourism trade of the island.

Under the supervision of the Greek authorities, the owners and insurers of the vessel teamed up with international experts and national clean-up responders to mount an emergency operation to counter this threat. Among its successes, this timely and professional operation managed to remove, directly from the sea surface, a large part of the released oil, thus limiting the contamination of the shores of the island. The following paper offers a brief summary of the incident and the emergency on-water oil spill response operation, setting the achievements in relation to the obstacles faced and advantageous circumstances experienced. Above all, the choices of equipment used, strategies developed and practices employed are described so that lessons can be learned for other spills, elsewhere.

THE INCIDENT, RELEASE, AND LOCATION

As widely reported in the press, the 21,848 GT SEA DIAMOND (143m LOA, 1985 launched) touched bottom on an incorrectly charted rock outcropping while approaching the tourist port of Fira, Santorini, on April 5, 2007. The vessel began taking on water and listing within a very short time but did not begin leaking oil until some time after she sank in the morning hours of the next day. During the evacuation of the more than 1500 passengers and crew, the vessel drifted in the deep near-shore waters directly under the cliff-side tourist town. By the time of the sinking, 15 hours later, the incapacitated vessel had been moved some 2.5 km away and positioned off a narrow beach in a quiet bay near the small commercial port and ferry terminal at Athinios. At about 7am, April 6, 2007, the SEA DIAMOND, having slowly capsized over night, slipped below the calm surface of the water and disappeared from sight.

Later ROV surveys found the heavily-damaged wreck in even deeper waters, somewhat further towards the center of the 'Caldera', as the large bay formed by the volcanic crater is known. A careful reconstruction of events by naval architects and other relevant experts determined that as the vessel hit the bottom it rolled down the steep sea bed before coming to rest in a nearly upright position. According to the experts, the bow of the wreck now rests in 125 m of water, the stern in 147 m. The rolling contact with the sea bed resulted in significant damage, both to exterior of the vessel and the interior, where all the loose contents were tumbled about. In addition, it is expected that the immersion in sea water caused the many softer materials inside the ship (such as cabin furnishings and compartment walls) to quickly deteriorate.

One of the most important forces that would have played upon the vessel as it sunk was the rapid increase in water pressure as it quickly dropped into the deep waters of the 'Caldera'. Because the compression forces of the water column have their strongest effect on gases, rather than solids or liquids, as the vessel sank, its partially-filled oil tanks would have come under great pressure to implode.[1] Nearly full tanks, for example, as one might expect to find in a laden crude oil tanker, would be subject to very little effect from the pressure differential in a situation like this. However, for the cruise ship SEA DIAMOND (which was well into a week-long outing that didn't require full tanks even at the start) all of the tanks were partially-filled at the time of the incident and would have all lost their structural integrity as they imploded. Water would have rushed into the tanks until the pressure became balanced. Oil would have entered the rooms and interior ship spaces around the internal tanks.

The wreck quickly settled into its final, nearly upright resting position. The fuel oil, diesel, and lube oils were all lighter than the sea water and immediately began to migrate upwards, inside the ship, once free from the damaged tanks. Where openings or structural damage would have allowed it, the oil passed upwards from one deck to another. Where no such openings were immediately available, the floating oil would have first formed pools in the ceiling spaces. For the more viscous heavy fuel oil it would have been a relatively slow migration, from one deck up to the next. For the lighter, more fluid oils the progression would have been quicker. Along the way, the many furnishings and broken interiors of the ship would have formed countless obstacles and 'sinks' for small pools.

Based on statements by the crew, it is estimated that approximately 516 m^3 of *persistent* oils[2] went down with the ship. The imploding-tank scenario suggested by naval architects and salvage experts is consistent with the observation that a significant quantity of oil was released from the vessel in the first few days after sinking, followed by a long 'tail' of declining continual release over weeks and months. It is known from the response operation that more than half (275m^3, figure adjusted for water content) of the oil that went down with the vessel was recovered in liquid form from the water surface. A further 25 m^3 of pure oil mixed in a larger amount of solid waste were estimated to have been recovered from nearby island shores.[3]

The SEA DIAMOND also sank with some 56m^3 of *diesel oil*. For more than a month after the sinking there was a continual sheen of diesel blown away from the site into the open waters of the 'Caldera' where it could be observed dissipating. It is expected that as much as 70% of this would have evaporated soon after it reached the sea surface. A smaller quantity, perhaps 20-30% of the diesel might, in theory, have dispersed naturally into the water column.

Surveyors on site reported that oil was first seen on the sea surface some hours after the actual sinking. In contrast to an instantaneous oil release (as experienced after some ship collisions, groundings, or other events leading to serious structural damage), the oil spill that resulted after the SEA DIAMOND sank was a long, continuous release, rising from below in a steady stream of 'bubbles' of oil. The actual release was observed in the early ROV surveys which found a slow stream of individual oil bubbles leaving the wreck near the upper decks. On the

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[1] Atmospheric pressure at sea level is 1kg per cm^2, the standard unit of measure. With an extra unit of pressure for each 10m of depth, the pressure exerted on the wreck at 120m is 12 times greater, namely 12kg per cm^2.

[2] ITOPF understands that some 516m^3 were on board the SEA DIAMOND and that these fall in three categories – IFO 380 fuel oil: 460m^3, lube oils: 36m^3 and sludges 20m^3

[3] The remaining 216 m^3 are thought to be have been either lost to evaporation and natural dissipation or remain in the wreck, scattered throughout the decks in a great number of tiny pools and streams.

sea surface above the wreck the water was covered in thick black slicks and considerable sheen in the early days which obscured the view of the rising oil.

SUMMARY OF THE OIL SPILL RESPONSE

One of the first anti-pollution measures undertaken was the deployment of 500 meters of locally-stationed Coast Guard boom. This was new, foam-filled fence boom. It was tied to the vessel, as she lay heavily listing in the water, just in case any oil might begin leaking from her. Unfortunately, when she sank the next day, the vessel pulled the entire chain of boom segments with her to the depths. On later ROV observations the boom could be seen lying without any buoyancy on the sea bed, having lost all floatation because of the compression from the massive water pressure.

Even before the vessel sank, various specialized spill response resources from private and government sources were sent to site. The backbone of the emergency response and also the project-phase clean-up work was provided by the Greek clean-up specialists, Environmental Protection Engineering S.A. (EPE), a firm contracted by the SEA DIAMOND owners in the early hours of the emergency. EPE quickly began mobilizing its resources from its various bases around the country and arrived on site on April 6 with boom, skimmers, and the first two of the four self-propelled ('AKTAIA') skimming vessels it would use in the response. Vacuum trucks, more boom, support vessels, and further 'AKTAIA' skimming vessels arrived soon afterwards.

The emergency response during the first few days and weeks focused on capturing and recovering free-floating heavy fuel oil (HFO) with the self-propelled skimmers; encircling and containing, for later recovery, thick slicks of oil in short lengths of fence boom; deployment of long lengths of fence boom in circular formations above the wreck site; deploying spurs of boom from the shore to catch drifting slicks; recovering contained oil with weir and other skimmers; vacuum-sucking heavy oil accumulations from the quay-side waters of the port; and surveying near-shore waters, beaches and cliffs for impact.

After a few days of continuous oil recovery, it became apparent that whilst the initial outflow of oil after the sinking had been at the greatest rate, and although the on-going release was declining, there was no knowing just how long the release would continue. The decisions were made to continue at-sea recovery with all the available resources that were performing well, to demobilize resources that were not performing well (e.g. oleophilic skimmers), and to postpone large-scale shoreline cleaning until the risk of re-oiling was under control. Although limited shoreline activities were undertaken from the start, the continual release and its inherent risk of re-oiling any of the shoreline areas at any time meant that the shoreline cleaning outside of the port had to be limited to the removal of debris and some removal of 'pure-oil' pools on the shore. This unfortunate situation, where final shoreline cleaning could not be undertaken, continued into May, 2007 when the release quantities reduced further, when numerous challenges with the booming had been overcome, and when the original slicks of floating oil had been addressed (i.e. allowing the daily skimming operations to concentrate on the freshly released oil). It wasn't until the end of June, 2007 that the booming challenges over the wreck were ovrtcome and the risk of uncontrolled losses from the immediate wreck area minimized.

Although the shoreline response was officially ended on July 19, more than 100 days after the sinking, the release from the wreck continued on, albeit at a slow and diminishing rate. For some time it was observed that multiple types of oil were rising from different locations, mostly a lighter oil that appeared to be diesel/ gas oil and a heavier, HFO. On calm days in the summer it could be observed inside the boom enclosure that the rising drops of diesel quickly spread out into thin sheens. These could be seen to evaporate and disperse without the need for further action. The rising HFO surfaced in the form of 5 – 10ml 'pearls' or 'bubbles' which flattened out on the sea surface into large, thick 'coins' before 'melting' in the sun and spreading to black and brown sheens. These, when blown against the boom walls of the enclosure, would form thick, slicks of emulsified heavy fuel oil. On the basis of the area and thickness of the slicks that formed between once-daily removal operations, it was estimated in early summer that approximately 100-150 litres of oil were being released each 24 hours.

As of February, 2008, the release of oil from the wreck continued in the form of a very slight release of diesel/ gas oil (<1 litre/ day) and the continued troublesome release of heavy fuel oil, albeit at a greatly reduced rate of 10-20 litres/ day. There was no longer a visible release of lube oil at that time. By the same time the next year in 2009, the release came to an end.

BOOMING

Especially because of the continual, on-going release of oil from the wreck, there was a long-term need for operations to somehow capture the oil which surfaced each night, or at least slow down its escape from the immediate area, so that the self-propelled skimmers could address it during the day.[4] There was also some limited booming of distant water intakes and a water passage between a pair of geologically interesting volcanic islands.

The central feature of the booming program throughout the response was maintaining a roughly circular boom pattern over the wreck site in an attempt to catch the rising oil as it surfaced. In the early days there were also several long spurs of boom deployed from the shore to the north and south of the wreck in an attempt to keep oil in the small bay where the wreck lay. In the first 3 months of the operation (until the start of July), all of the boom used for these installations was foam-filled, plastic-coated, fence boom. This is a standard type of boom held in private and government stockpiles in Greece. It comes in various skirt sizes, typically in the 90-110cm range, and is generally weighted with a heavy chain in a lower sleeve. It is easy to deploy, tow, recover, clean, and store. It can be anchored to the shore or held in place by anchors fitted with small buoys. It is ideally used in port areas or areas of calm waters. It is, however, not well suited for waves, swell, or currents, all of which allow sheens and slicks to easily pass below or above.

In the case of the SEA DIAMOND response, large quantities of fence boom were available from private and government stockpiles, but a number of challenges were faced in practical deployment, the most serious of which was securing the boom in place and keeping it there. On numerous occasions, sections of boom either broke apart or were torn away from their

[4] There were some night-time skimming operations in the early days of the response, but such operations are generally not well advised due to the difficulty of seeing the black oil, the need for vessel crews to rest, as well as for safety reasons.

anchoring lines. Typically, in the morning after a storm, the intended boom configuration was lost and boom was drifting where it wasn't supposed to be. While the relatively enclosed waters of the 'Caldera' are quite calm on most days, when storms arrive and the wind shifts, the forces of wind and waves at the wreck site can be considerable.

A much more serious and unique challenge faced by responders on this case was the complete loss of long lengths of boom on at least three occasions. In the first such episode, a storm on April 12 pulled nearly 600m of 90cm fence boom from its anchored position just off the cape to the north of the wreck site. It disappeared completely and left all those on site wondering what had happened to it. The answer came the next day, when a new length of boom (more than 400m) was deployed and also lost without a trace. In this case, the new boom, although marked with battery-operated safety/ navigation lights, had become entangled with an official survey vessel which pulled the installation from its mooring place. Because of the deep water, the heavy anchors and long chain used, the entire length and all the mooring tackle were lost into the depths. Several days later, and in an attempt to meet a demand by the authorities to completely boom off the side bay where the wreck is located, a new batch of 500m fence boom was deployed. Shortly after deployment, however, this boom also sank and took down with it approximately 400m of already-deployed boom. Interestingly, one end of this 900m of boom remained anchored to the shore. However, because of the weight of the mooring tackle still attached and the loss of buoyancy due to the water pressure at depth, no amount of mechanically-assisted lifting and pulling was able to recover any of this boom. In all, some 1,900m of fence boom were permanently lost in this way.

Resolution to the problem of sinking boom was found by bringing in an anchoring specialist for open-water aquaculture facilities who designed and oversaw the installation of a permanent anchoring system at the site in early May, 2007. The main elements of this system included: two large cement blocks (approx. $1m^3$ each) sunk in deep water beyond wreck and each connected vertically via 18mm steel cable to large (1600 litre) buoys on the sea surface; two long (950m) and large diameter (28mm) ropes each connected (subsurface and under tension) on one end to the riser cables via special connecting 'wheels' and the shore on the other end; and two shorter lengths of 28mm rope, one between the two connecting wheels on the riser cables and one on the shore side of the wreck between the two long lengths of rope. In this way, a square 'box' of large diameter rope was created around the wreck which was held horizontally 6m below the sea surface by a series of smaller buoys to which the boom itself could be tied. The result was a dynamic mooring system that ended the problem of sinking boom as soon as it was installed on May 11 and the fence boom attached in a new encircling configuration.

The new anchoring system, could not, of course, improve the actual oil-retaining performance of the fence boom itself. Although the location is not subject to tides, currents or swell, it is exposed to strong winds which can produce waves and temporary surface currents. The experience on site with the fence boom was that it regularly failed to hold oil whenever the wind picked up. For this reason, the decision was made to install heavy-duty inflatable boom. Unfortunately, this had to be made to order abroad and was not delivered to site until late June. However, once it was installed, its wave-following characteristics, low skirt and high freeboard eliminated all further release of oil, even in windy conditions. This boom and the anchoring system have been in place ever since (as of the time of writing, April, 2009), as a permanent and well-functioning system.

A key part of any successful boom operation is the ability to regularly empty oil that has accumulated in/ against it. While it may seem obvious, this is a point that is often overlooked around the world. In the case of the SEA DIAMOND response, this was not an issue. Regular boom maintenance and recovery of oil was undertaken on a daily basis. The approach employed was to send a small (1-2 man) workboat with a water pump inside the boom enclosure to flush the accumulated oil into one area. Then, one of the self-propelled skimming vessels outside the enclosure would approach a special part of the enclosure outfitted with light-weight fence boom. The boom would be manually lifted just enough to allow the oil to be flushed straight into the bow opening of the skimming vessel.

In terms of protective booming, two operations were undertaken, one successful, one not. The protective booming that did work was the installation of small fence boom enclosures around the intakes of two water desalination plants. While neither intake was actually exposed to oil, the smaller of the two was in the general area of the spill and could very easily have been threatened by slicks. The larger facility was some distance away and was never seriously threatened. In both cases the fence boom installations remained intact and required no real maintenance.

In contrast, the protective booming operation that failed was an attempt to string some 400m boom across a small strait between the two central islands in the 'Caldera'. The installation was controversial, but undertaken to satisfy 'political' needs of the authorities. In any case, the boom could not withstand the forces of wind, waves, and minor surface currents to which it was exposed and broke within hours of being installed. It was not replaced.

SKIMMING OPERATIONS

As described above, one of the key features of the SEA DIAMOND response was the above-average recovery rate of liquid oil from the sea surface. Three approaches were taken which were particularly successful: vessel-based skimming in the early days of the response, self-propelled skimmer operation throughout the entire response, and vacuum truck skimming from the quay-side of the port.

The support-vessel-based skimming worked well in the first few days of the response when significant quantities of oil could be easily contained and brought alongside the support vessel (a converted tugboat). Short lengths of boom and small outboard workboats were useful for this task. The skimmer was dropped by a small crane directly into the small boom enclosure which was continually made smaller to keep the oil concentrated. The recovered oil was pumped into the internal holding tanks of the tug. A weir skimmer and a disc skimmer were both tried, with the former being the obvious choice: Its capacity was much larger and it was able to deal with the emulsified oil much more efficiently than the disc skimmer. The weir skimmer was used for 4 days in the first week; the disc skimmer on just one day. In this period, 26m^3 oily liquids were recovered and stored in the hold of the support vessel. It is not known to what extent any entrained water was removed from the stored liquids.

By far the greatest share of the recovered liquid oil was brought in by the four self-propelled 'AKTAIA' skimming vessels. These arrived on site on days 1, 2, 4, and 8, in tow from various stand-by bases around Greece. Over the period of the first month the average daily response included 3-4 of these vessels. In detail, the 19m-long 'AKTAIA' vessels are powered by 135hp engines, and have bow doors at the water level that open into an internal water channel through which water and floating oil are driven by a stream of water created by the turning of the vessel's propeller. An internal grate is fitted in such a way as to scoop any debris from the central water and oil channel and lift these up into a temporary storage bin. Collected oil can be held in the central channel for immediate removal via, for example, a vacuum truck stationed on a quay. Alternatively, the oil can be passed over an internal weir and pumped into two internal storage tanks, thus maximizing overall storage capacity. When the collected material is held only in the central channel the pumping time for internal transfer is eliminated. This is often the case when heavily emulsified or debris-laden oil is encountered which is best removed overhead via vacuum truck pumping. Further, if a vacuum truck can be positioned on land relatively close to the area of operations, the reduced capacity from using only the central channel for temporary storage is less an issue.

The 'AKTAIA' vessels are additionally equipped with discharge pumps, water pumps for oil flushing, and hot water/ steam spraying capability for cleaning. They are typically manned by a crew of 2-3 with a small accommodation for use when required. The 'AKTAIA' skimmers have proven themselves, over the years, to be highly maneuverable and widely deployable with their low draft. They can operate both by steaming through free-floating oil or recovering oil when tied up to fixed structures, using both the built-in, propeller-driven water stream or external assistance with water-pump flushing. With their bow-door construction, rather than sweep-arm configuration, they are well suited for working in tight spaces or rough waters. In the case of the SEA DIAMOND response, these skimmers were able to operate on far more windy days than would have been possible for side-sweep or V-configuration collection systems. They were also far easier to control and keep out of the way of the frequent transit of fast-ferry services.

An important feature of the 'AKTAIA' response was the ease with which these skimmers were able to recover both emulsified oil and debris-oil mixes. Whereas many oleophilic-based systems (e.g. drums, discs, rope mops, and to some degree brushes) have basic trouble dealing with non-sticky emulsions, and many weir and other skimmers are challenged by thick, viscous oils and oils mixed with debris, the central collecting channel of the 'AKTAIA' skimmers does not require any active mechanical principles to capture the oil.

It is interesting to note that in the case of the SEA DIAMOND response, a novel sort of debris was encountered, namely floating pumice stones. Santorini was once a key source of these stones which were mined from the cliffs above the 'Caldera'. Especially in stormy weather, great quantities of these lightweight stones are routinely washed and blown into the sea where they form their own floating slicks. In some instances, these slicks crossed with the oil slicks and were removed without difficulty using the 'AKTAIA' skimmers. Other, pump-based skimmers would have had great difficulty dealing with the floating stones. On some occasions the pumice stone slicks were picked up by the 'AKTAIA's and delivered to shore before becoming oiled.

The third key aspect of skimming operations in the response was the vacuum truck work undertaken in the port. Given the breathtaking cliffs of the 'Caldera', which generally fall straight into the water, the only place the vacuum trucks could be used was in the small local port itself. In total the length of working area for these two trucks (no more than 300 m), represented less than 5% of the total length of shoreline affected by the incident. As luck would have it, however, there were many days when the prevailing winds pushed the freshly-released slicks directly into the small port. This was a nuisance for the frequent ferry boat operations there, but it was a great opportunity for the vacuum truck teams to directly recover the oil from the water without any real impact to the shoreline. In most cases the vacuum truck teams were also able to decant and discharge excess water directly back into the oily seawaters of the port. Equally importantly, the vacuum trucks were able to quickly empty the 'AKTAIA' skimmers which would have required much more time to discharge via their own pumps. This improved turn-around times for the at-sea response.

Overall, the main reasons for the great success of the skimming operations were the following:

- The skimmers were well-suited for the oil characteristics and typical sea states and those which were not so well-suited were quickly demobilized
- The teams were very experienced and competent with their equipment and vessels
- The skimmers were able to deal with the debris and deliver a relatively pure liquid
- The prevailing winds generally pushed the oil in the same direction and never out to sea or otherwise beyond the easy reach of the response operation
- There were minimal surface currents or tides, only wind
- The emulsified oil typically did not stick to the cliffs or other surfaces in the early days of the response (when the weather was cooler)
- The location and direction of oil drift was always easily observed from the cliffs above
- The wind often blew the oil into the port where the vacuum trucks were able to reach it.

SHORELINE CLEANUP OPERATIONS

As described above, the shoreline cleanup phase did not start before the end of May when the diminishing oil release from the wreck could be more or less efficiently controlled in the area between the wreck and Athinios port. Re-oiling of the shoreline was by then limited to sporadic tar balls washed on the shore and the re-appearance of minor amounts of buried oil on the beaches. After an initial phase of collecting pure oil trapped in cavities of the shoreline with vacuum pumps and by hand, the cleanup focused mostly on manual techniques, mainly because of the difficulty of access to the shore.

The total area cleaned was about 6 km of which 40% was pebble (4-64 mm in dia.) or cobble (64-256 mm dia.) beaches with small intervals (or layers) of coarse sand. Considerable efforts were put in the cleanup of these beaches as some were used for recreation in the summer. Here the cleanup consisted of repeated phases of manual, selective collection of emulsified oil (mousse patties and tar balls), heavily oiled pebble/ sand, and oiled debris (vegetation, garbage and the above described pumice stones). Later on, and in order to reduce the quantities of beach material to be removed from the area, especially in the cobble parts, low pressure washing was carried out supported with absorbent booms.

About 55% of the shore was volcanic high cliffs, large rocks, boulders (>256mm dia.) and a further 5% were man-made structures including concrete walls, rip rap and breakwater. Both were cleaned in large part with high pressure washers and collection of the washed oil with sorbents. A large part of the shoreline cleaning had to be carried out with use of landing craft and other work boats because of access and safety issues, especially under the crumbling cliffs. Ladders and wooden bridges were necessary at times to allow access. High safety standards allowed the completion of the work without any accidents. High-pressure washing was highly successful, partly because of the nature of oil (emulsified in various degrees) and the type of rocks. In most places all traces of oil disappeared entirely.

TEMPORARY STORAGE FOR COLLECTED SOLID WASTES

Following an agreement with the local municipality, an area of the city's landfill was assigned for the temporary storage of the collected solid waste. The area was lined with nylon sheets and sorbent rolls. Waste was placed in heavy duty plastic bags inside heavy-lift 'big bags'. The different types of waste were stored separately: Oiled garbage (destroyed oil booms, wreck remains, wood, plastic), oiled vegetation, oiled beach material (pebbles, sand) and large quantities of oiled pumice stone. By the end of July, 2007 all wastes were placed in skips and containers and transported to Piraeus on the mainland for final disposal.

SUMMARY

The oil spill that resulted from the loss of the SEA DIAMOND was serious, but the emergency response, both in terms of the at-sea skimming and shoreline cleaning, was successful. The greatest part of the oil that was released from the wreck was picked up directly from the surface of the water, thereby greatly reducing the shoreline impacts. A specialised anchoring system was installed around the wreck that successfully held in check the bulk oil so that it could be recovered by skimming vessels. This allowed the operations to shift emphasis to the shorelines for fine cleaning. This was a time-intensive operation due to the fact that hotwater/ high-pressure washing was needed to clean to a standard in keeping with the high tourism value of the area. Given the difficulty of this work, it was especially important that the boom arrangement over the wreck worked, in order to minimise the risk of re-oiling from the wreck.

The deep waters and formidable cliffs posed great challenges for booming and access, but these were overcome through a variety of tailored strategies. As a result of the continued efforts of the clean-up teams over many months, a relatively large amount of the spilled oil was collected from the surface waters above the wreck, much of which was in the end safely stored in a small tanker and delivered for recycling in another port within Greece.