Report on the investigation into the grounding,

and subsequent loss, of the ro-ro cargo vessel

Riverdance

Shell Flats – Cleveleys Beach, Lancashire

31 January 2008

Marine Accident Investigation Branch
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United Kingdom
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Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able Bodied seaman
BMA	-	Bahamas Maritime Authority
CM	-	Crisis Manager
CMS	-	Crescent Marine Services
CMT	-	Crisis Management Team
COG	-	Course over Ground
con	-	Control of navigation
CPP	-	Controllable pitch propeller
DfT	-	Department for Transport
DOC	-	Document of compliance
DNV	-	Det Norske Veritas
ECR	-	Engine control room
ERS	-	Emergency response service
ETA	-	Estimated time of arrival
GM	-	Distance between a ship's metacentre and the centre of gravity, one of the measures of a ship's stability
ICS	-	International Chamber of Shipping
IMO	-	International Maritime Organization
ISM Code	-	International Management Code for the Safe Operation of Ships and for Pollution Prevention
JONSWAP	-	Joint North Sea Wave Project
KG	-	Distance from the keel to the centre of gravity
kt	-	knot
kW	-	Kilowatt
LCG	-	Longitudinal centre of gravity
MARPOL	-	International Convention for the Prevention of Pollution from Ships
"Mayday"	-	The international distress signal (spoken)

MCA	-	Maritime and Coastguard Agency
MCR	-	Maximum Continuous Rating
MGN	-	Marine Guidance Note
MSC	-	Maritime Safety Committee (of IMO)
MSN	-	Merchant Shipping Notice
mt	-	metric tonnes
OOW	-	Officer of the Watch
OS	-	Ordinary Seaman
RAF	-	Royal Air Force
Ro-Ro	-	Roll on – roll off, used to describe a design of ferry where wheeled cargo is driven on and off
SMS	-	Safety Management System
SOG	-	Speed over Ground
SOLAS	-	International Convention for the Safety of Life at Sea
SOSREP	-	Secretary of State's Representative
STCW	-	Standards of Training, Certification and Watchkeeping for Seafarers
UK	-	United Kingdom
UTC	-	Universal Co-ordinated Time
VCG	-	Vertical centre of gravity
VDR	-	Voyage Data Recorder
WCS	-	Worst case scenario

Times: All times used in this report are UTC unless otherwise stated

Riverdance aground

SYNOPSIS

On 31 January 2008, the Bahamas registered ro-ro cargo vessel, *Riverdance*, grounded and became stranded on the Shell Flats, off Cleveleys Beach, Lancashire. The prevailing severe weather conditions prevented the vessel from being refloated, and subsequent attempts to salvage her failed. *Riverdance* was finally cut up in-situ. Fortunately, the crew were all safely recovered and there was no pollution.

The following is a summary of the main causal factors and key events that were identified during the investigation:

- The true weights and the disposition of the vessel's cargo were not known.
- The stability of *Riverdance* was not calculated before sailing from Warrenpoint.
- Ballast was never adjusted regardless of cargo or expected weather.
- The vessel was known to be tender[1].
- Some openings on the weather deck were not closed off in anticipation of the expected poor weather.
- The vessel was proceeding in following seas at a speed slightly slower than that of the following wave train. Under these circumstances, a reduction in the vessel's stability can occur and more pronounced rolling can be experienced.
- As the vessel approached more shallow waters, the seas became steeper and rolling increased further. This resulted in a small shift of cargo to port.
- The vessel sustained a series of large rolls to port which caused additional trailers and their contents to shift.
- In an attempt to bring the vessel's head into the wind, the master decided to make a broad alteration to starboard. This exacerbated the port heel causing the deck edge to immerse, possibly allowing water to enter the vessel through openings on her weather deck. Ingress of water would have further reduced the vessel's residual stability.
- The port main engine tripped due to the excessive list and, with only one engine, there was not enough power to bring the ships head into the wind. The vessel lay beam on to the wind and seas, rolling heavily with a large list to port as she drifted towards shallow water. The weather deck on the port side continued to be intermittently immersed.
- The vessel took the ground and returned to an almost upright position. An attempt was made to redistribute the ballast to compensate for the expected port list once she refloated on the rising tide.
- Because the disposition of the weights on board the vessel was unknown, the amount of ballast transferred was based on the master's estimate. The owner's shore based crisis management team did not have access to accurate stability information. Had this been available, they would have been able to provide better support to the master.
- Attempts to use the engines to refloat the vessel were unsuccessful and resulted in *Riverdance* drifting closer to the shore.
- *Riverdance* grounded again and began to roll progressively more heavily to starboard until she came to rest on her starboard bilge. During this period the vessel lost all power and the crew were evacuated.

A number of safety issues have been identified and recommendations have been made during the course of this investigation.

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[1] Term used to describe a vessel with a relatively small GM. This produces a slower/easier rolling motion.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *RIVERDANCE* AND ACCIDENT

Vessel details

Registered owner	:	Seatruck Navigation Ltd
Manager(s)	:	Seatruck Ferries Shipholding Limited
Port of registry	:	Nassau
Flag	:	Bahamas
Type	:	Ro-ro cargo ship
Built	:	1977 – Bremerhaven
Classification society	:	Det Norske Veritas
Construction	:	Steel
Length overall	:	116.3 m
Gross tonnage	:	6,041
Engine power and/or type	:	2 x 8M453AK, total MCR 4,536 kW
Service speed	:	15.00 kts
Other relevant info	:	Twin Controllable Pitch Propellers (CPP), each with a spade rudder One bow thruster, 441 kW

Accident details

Time and date	:	c. 1922 on Thursday 31 January 2008
Location of incident	:	Sustained severe list to port in heavy seas off Lune Deep. Drifted and subsequently grounded with severe starboard list off Cleveleys Beach, Blackpool North shore.
Persons on board	:	4 passengers and 19 crew
Injuries/fatalities	:	None
Damage	:	After the failure of salvage attempts, *Riverdance* was declared a total constructive loss and broken up for removal.

1.2 BACKGROUND TO INVESTIGATION

In the days following the grounding of *Riverdance,* poor weather prevented access to the vessel for all except those directly involved in the salvage effort, under the oversight of the Secretary of State's Representative for Maritime Salvage and Intervention (SOSREP)[2]. Since MAIB inspectors were prevented from boarding the vessel, and salvors' personnel did not prioritise the recovery of perishable evidence, valuable information was lost regarding the vessel's physical condition upon grounding, together with much of the ship's documentation and her operational records.

Notwithstanding the information gleaned from witness interviews, the absence of contemporaneous evidence made the investigation a difficult one. This had an undesirable consequence of protracting the time taken to produce this MAIB report. Extensive computer modelling was undertaken by QinetiQ[3] to, in so far as was possible, replicate the vessel's loading condition and the effect of the weather conditions she experienced off Lune Deep **(Annex 1 - QinetiQ report)**.

1.3 ENVIRONMENTAL CONDITIONS

Weather conditions at the time of the accident were taken from nearby weather recording stations located at:

1. Morecambe Bay gas field
2. Shell flats wind recorder buoy
3. Barrow wind farm

The data from these locations was generally in agreement and can be summarised as:

Wind	West-south-west, Beaufort force 9 to 10
Significant Wave Height	greater than 7.0m
Visibility	Fair to good, with sea spray
Tidal Stream	1.5 – 2.0 kts from the north-east Ebb tide from Morecambe Bay

In addition, reports from vessels in the area, or involved in the search and rescue, were generally in accordance with this data.

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[2] SOSREP - The SOSREP role was created in 1999 as part of the Government's response to Lord Donaldson's review of salvage and intervention and their command and control.
On behalf of the Secretary of State for the Department for Transport (DfT), SOSREP is tasked to oversee, control and if necessary to intervene and exercise "ultimate command and control", acting in the overriding interest of the United Kingdom in salvage operations within UK waters involving vessels or fixed platforms where there is significant risk of pollution.

[3] QinetiQ is the principal source for UK Ministry of Defence research, experimentation and technical assurance and has been at the forefront of scientific and technological development for over 50 years. Staff are naval architects, marine engineers, hydrodynamicists and specialists in structures, survivability, noise, vibration, hyperbarics and diving. They have direct access to world-class hydrodynamics facilities and ship design tools.

1.4 BACKGROUND

1.4.1 General

The Bahamas registered ro-ro cargo ship, *Riverdance,* had been owned by Seatruck Navigation Limited since 1996. The vessel was one of four managed by Seatruck Ferries Shipholding Limited (referred to throughout this report as Seatruck) based at Heysham in Lancashire.

1.4.2 Operation

Riverdance operated on the Heysham to Warrenpoint route and was certified to carry up to 12 passengers. Trade was predominantly centred on transporting self-drive trucks and freight trailers. The cargo was loaded via a stern ramp and stowed on the upper deck and the main deck. Although there was a lower hold deck, which was designed for carrying cars, this was no longer used for the carriage of cargo. The general arrangement of *Riverdance* is shown in **Figure 1**.

The trading pattern typically involved daily sailings from Heysham at 0800 and arriving at Warrenpoint between 1600 and 1700. Following off-loading and re-loading cargo, the vessel sailed at about 2000, returning to Heysham at 0500 to continue the pattern. The company operated a three-ship schedule on the route, which allowed all vessels periods of "lay-over", either in Heysham or in Warrenpoint on Sundays **(Annex 2)**.

Ballast and bunker soundings were usually taken during these weekly layover periods, as the sounding pipes were located on the cargo decks, making the taking of soundings difficult with the vessel in operation.

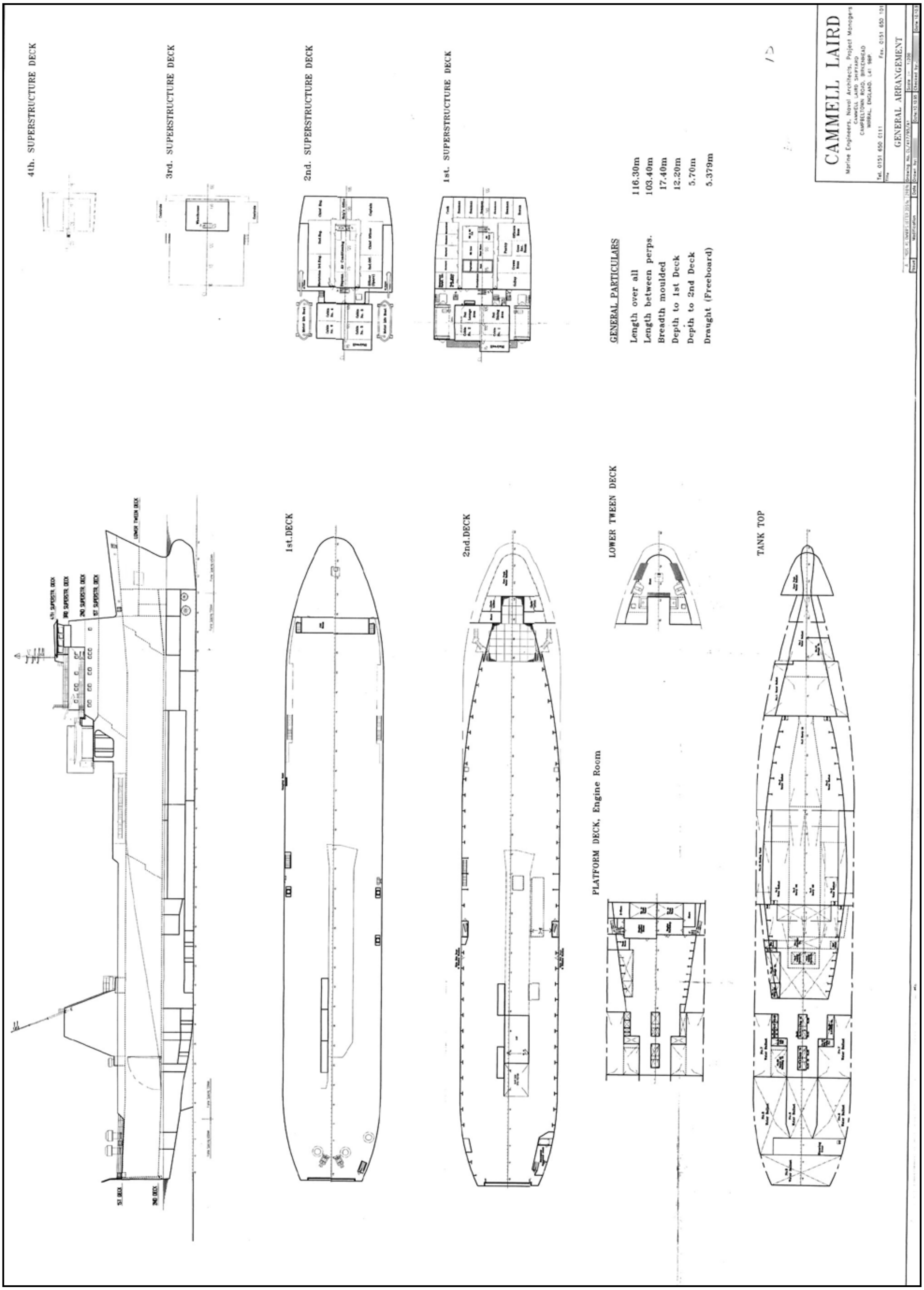
Four of the nineteen crew on board *Riverdance* at the time of the accident were British: the master, chief officer, chief engineer and one supernumerary chief engineer; the remainder were Polish nationals. The working language on board was English.

Riverdance was fitted with a voyage data recorder (VDR), but this unit had not been commissioned at the time of the accident. There was no machinery data logging system fitted.

1.4.3 Seatruck Ferries

Seatruck Ferries had been operating a freight ferry service between Heysham and Warrenpoint since April 1996; its first vessel, *Bolero*, was joined by *Riverdance* in August that year. *Riverdance* proved to be well suited to both of the ports on this trade and so, in 1997, her sister vessel, *Moondance*, was acquired to replace *Bolero*. At the time of this accident both vessels had been operating on this route for over 11 years.

Figure 1



Vessel General Arrangement

Initially Seatruck was part of Crescent Ship Management Ltd, which managed the vessels. In 1999 Crescent Ship Management Ltd merged with Crescent Shipping Ltd to form Crescent Marine Services Ltd (CMS).

As a result of the diversification of operations and control, in 2005 Seatruck Ferries was issued with a Document of Compliance (DOC) to operate ro-ro cargo vessels. Seatruck became, operationally, totally independent of CMS in 2006 when CMS changed ownership and became part of Clipper Marine Services.

1.5 NARRATIVE

1.5.1 The voyage from Heysham to Warrenpoint

After completing a quick turn around at Heysham on 30 January, *Riverdance* departed around 1830. However, the crossing was slow due to strong westerly winds, and the vessel was late arriving at Warrenpoint. She was made "all fast" at 0838 the following day. The courses from Heysham to Warrenpoint had been adjusted to follow a dogleg to the south to avoid punching directly into the weather, and the speed achieved on this crossing was around 6 to 7 kts.

1.5.2 Decision to sail from Warrenpoint

After completing loading operations at Warrenpoint, *Riverdance* was prepared for departure to Heysham. Her master was aware of the conditions in the Irish Sea from the difficulties experienced during the previous passage. He consulted the latest weather forecast prior to departure, issued by the meteorological office at 0620, which stated:

> *"SW veer NW gale 8 to storm 10 veer NW 6 to gale 8. Rough or very rough. Rain then showers. Mod or poor."*

The outlook for the following 24 hours was:

> *"Storms exp in Irish Sea….."*

The master had operated *Riverdance* in these, or worse, conditions many times before and, considering the forecast was little worse than the weather encountered during the previous crossing, he had no hesitation in deciding to proceed with the voyage and to leave Warrenpoint.

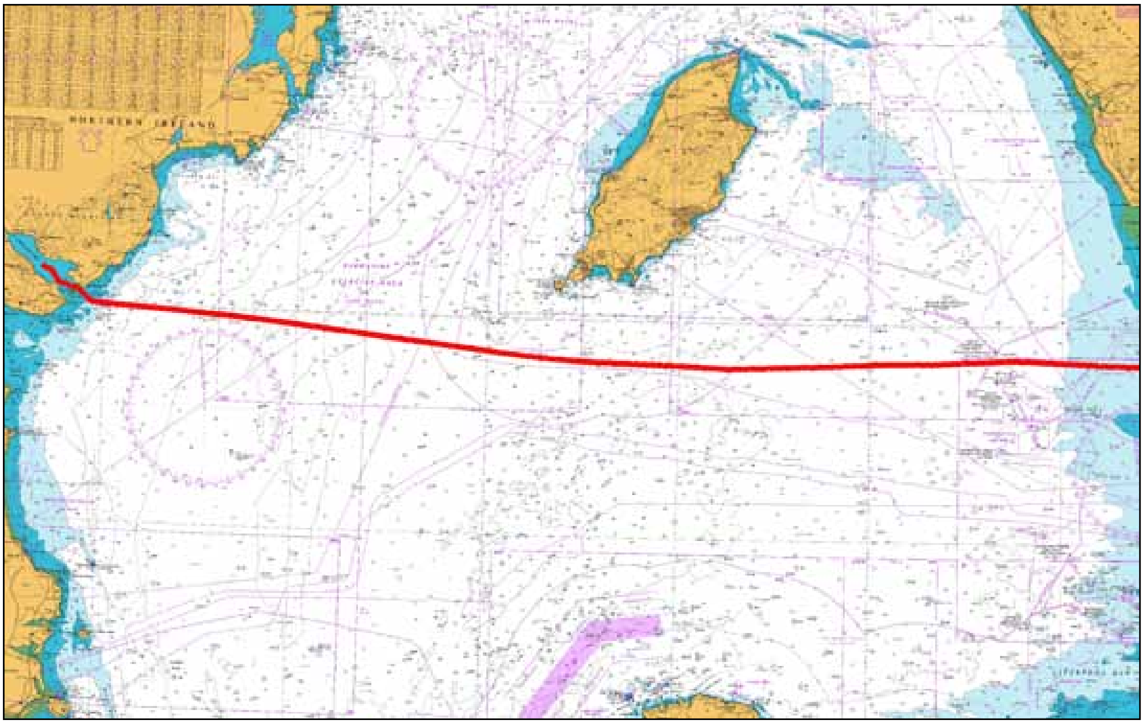
The master was also confident that the lashings on the trailers, attached and secured before *Riverdance* left the berth, would be adequate in the expected weather conditions.

1.5.3 Voyage from Warrenpoint to Heysham

Upon completion of loading, the departure draughts were read and noted as forward 4.60m; aft 4.80m. However, no stability calculations were made prior to leaving the berth. *Riverdance* left upright with the levels in the heeling tanks about equal, based on the tank level indicator lights. The system cross-over valves in the engine room workshop were closed, securing the system for the sea passage. *Riverdance* departed Warrenpoint, with 19 crew and 4 passengers on board.

Once safely clear of the berth, *Riverdance* proceeded seaward out of Carlingford Lough. On clearing the Hellyhunter buoy the autopilot was engaged, and a course of 096º was set, directly to the entrance of the Lune Deep **(Figure 2)**. By the time *Riverdance* departed Warrenpoint at 1136 she was more than 5 hours behind schedule, mainly due to the late arrival from Heysham. The wind was from the west-south-west between force 7 and 8.

Figure 2



AIS track of the voyage from Warrenpoint to Heysham

After setting course, the master handed over the con to the OOW and retired to his cabin to take a rest. The crossing was undertaken at full speed which, with the following wind, sea and swell, made the crossing speed around 14.5 kts, giving an estimated time of arrival (ETA) at Lune Deep Buoy of 1930. Several crew members also took rest during the afternoon, and the passage was described as “comfortable”. *Riverdance* was renowned for her good seakeeping, and her motion was variously described as “nice and easy”, or “lazy rolling”.

While at sea it was standard procedure to check the trailer lashings frequently. In good weather the duty bridge AB carried out hourly deck patrols; during poor weather they were made every 30 minutes.

During the afternoon, winds were recorded in the deck log as increasing to force 9 and occasionally 10, veering to westerly. *Riverdance* was still reported to be rolling gently, no more than a few degrees either side. Soon after returning to the bridge at 1700 the master took over the watch and noticed that the main engines were slightly overloaded, so propeller pitch and speed were reduced a little.

1.5.4 Approaching Lune Deep

At 1830, as *Riverdance* approached the coast, the engine room was given 1 hour's notice for the arrival stand-by. The duty engineer then began his pre-arrival preparations **(Annex 3)**.

Shortly after *Riverdance* crossed the 20m depth contour the sea state deteriorated noticeably and rolling began to increase. However, the rolls were still described as "slow" and not uncomfortable. Soon after these initial rolls, the heeling tank system was made ready for use. This was earlier than normally required by the ship's established routine.

Shortly after 1830 Heysham Port Control was contacted and the prospects for berthing were discussed. The strength of the wind in Heysham harbour was reported to be 30-35 knots, so the master decided to proceed to Heysham and anchor *Riverdance* until the weather conditions improved.

It was around this time that *Riverdance* experienced the first of a series of noticeably larger rolls which, reportedly, increased rapidly from about 10º either side to about 25º, before dying away again. During this time there were several breakages within the accommodation, galley and mess rooms. Crockery and personal effects were thrown about, and two trailers slipped from their trestles, which loosened the lashings.

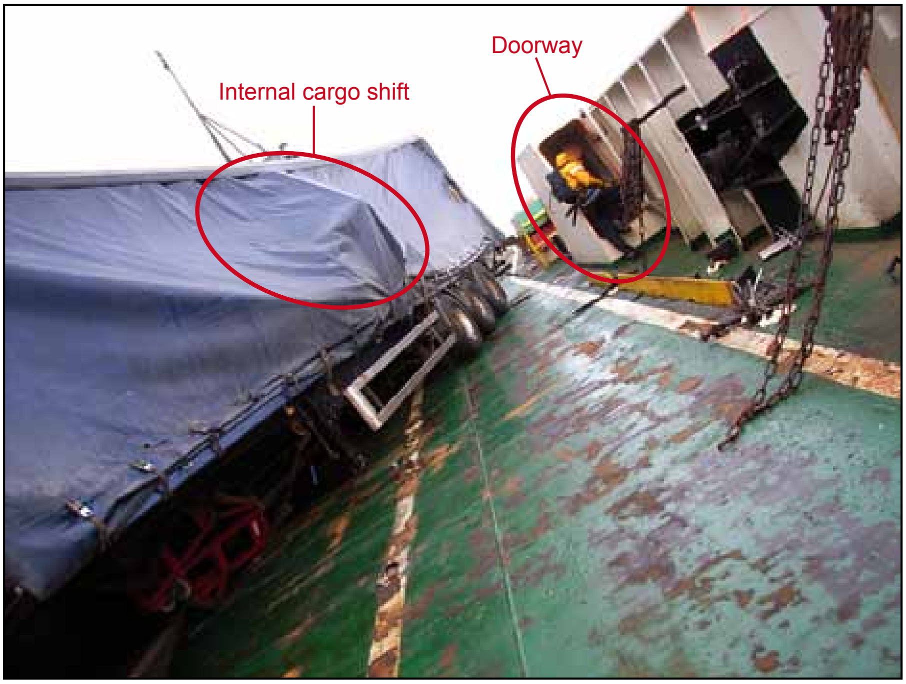
After this period of rolling, the chief officer donned his working clothes and proceeded to the bridge, where he found the master in discussion with the chief engineer. It was noticed that, at this stage, *Riverdance* had a slight list, and the chief engineer expressed his intention to ask the duty engineer to correct this.

When the duty AB returned to the bridge, following his deck patrol, he reported that the two trailers had shifted slightly. The master accordingly instructed the chief officer to go onto the vehicle decks with the AB and to re-check the trailer lashings.

The chief officer and AB proceeded to the upper deck, and had reached, and opened, the port side weather deck entrance door to the main deck stairs, when *Riverdance* began to roll again. This period of rolling was more extreme, with a succession of rolls quickly reaching large angles. *Riverdance* then suffered a particularly large roll to port, and seemed to hang over, struggling to return, before she was thrown further over to port.

Cargo began to shift from within some trailers, and trailer units near the port side entrance to the main deck stairs shifted to rest against the bulwarks, blocking the chief officer's and AB's return path to the accommodation. Cargo inside one of these trailers shifted further **(Figure 3)**, until it was resting against the weather door casing. Although very few trailers broke free of their lashings, cargo within several units broke loose, and the sound of moving cargo could be heard throughout the accommodation and in the engine room.

Figure 3



View of main access to main deck and trailer with indication of internal cargo shift. The cargo shift is in line with the access door and when listing to port may have hampered attempts to close the door

The chief officer and AB had taken shelter in the stair well doorway when this period of rolling commenced. After the rolling had reduced, they found it impossible to return to the accommodation past the shifted trailers. The alternative route down through the main deck was thought to be impassable, until the duty engineer appeared, coming up the stairs from the engine control room (ECR). The chief officer told the engineer and the AB to go back through the engine room and to use the starboard aft stairs out onto the upper deck. He then remained at the stair well for a short period, during which he managed to close the weather door before following the others into the engine control room.

Meanwhile, on the bridge, the master had disengaged the automatic pilot and, in manual steering, placed the wheel hard over to starboard. It was his intention to bring *Riverdance*'s head round into the wind to reduce the rolling. *Riverdance* then experienced a change of ship's head from 103º to 170º within 39 seconds, a rate of turn of over 100º per minute **(Figures 4a and b)**. During the turn, the vessel's list to port increased substantially, reportedly up to 50º.

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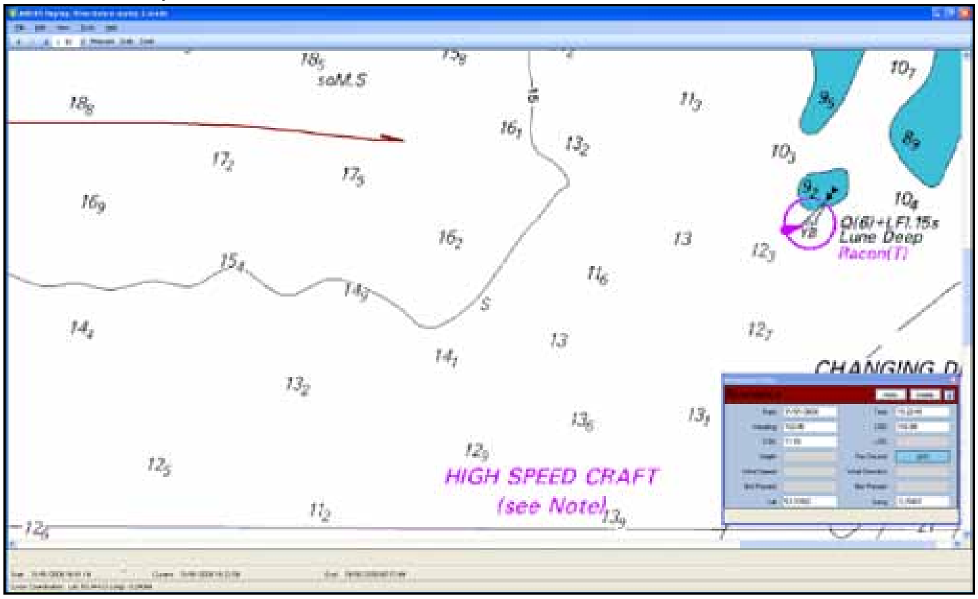
AIS data courtesy of MCA

Figure 4a



Riverdance AIS track prior to the turn (Time: 19:22:49)

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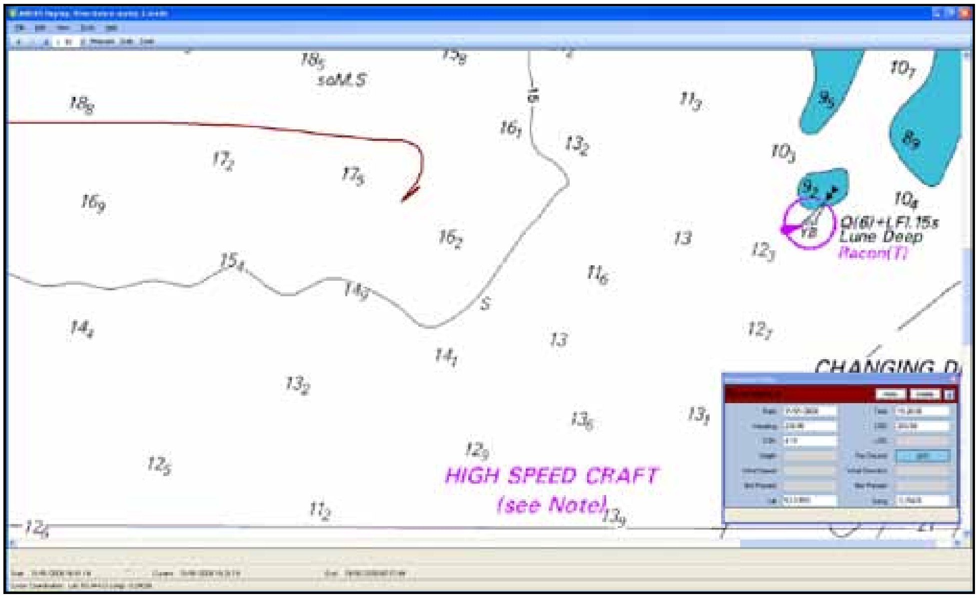
AIS data courtesy of MCA

Figure 4b



Riverdance AIS track after the turn to starboard (Time: 19:26:09)

Thereafter, the turn to starboard continued at a reduced rate until the ship's head reached 250º, almost into the wind, when the list reduced to between 30º and 40º. The port main engine stopped around this time.

With the starboard engine operating alone, at reduced power, it was not possible to hold the vessel's head into the wind. *Riverdance* began to fall off the wind to port, finally settling on a heading of 175º, where she lay beam on to the wind, sea and swell.

1.5.5 Actions taken once vessel listed to port

The fire alarm activated as *Riverdance* adopted her initial large list to port, and her passengers and crew went to their muster station. Although the list reduced as *Riverdance* settled beam on to the wind, the conditions on board were a source of great concern for everyone on board.

The master's first priority was to gather everyone together and verify the safety of his passengers and crew. With the exception of the chief officer and AB, who were still on deck with the duty engineer, personnel assembled in the lower alleyway, where they donned lifejackets and awaited instructions.

While in the engine control room the chief officer had contacted the bridge to confirm that the ballast system was not in use and that the electrical breakers for the ballast and heeling pumps were out. He did not check the position of the individual ballast tank or heeling cross-over valves. He then left the ECR, making his way through the engine room workshop onto the starboard side of the main deck to the stairs, and up to the poop deck. There, he found the AB waiting with the duty engineer at the weather door. The chief officer saw water on the port upper deck edge, reaching up about 60 to 90 cm inboard of the edge at the transom.

Once the party had returned to the accommodation, they went to the bridge and told the master about the water over the deck. The master contacted the vessel's superintendent to advise him of the emergency. Seatruck's preplanned "Crisis Management" plan was implemented, and the members of the Crisis Management Team (CMT) were assembled in the company offices in Heysham **(Annex 4)**. At 1941, the master called Liverpool coastguard to report that the vessel was in serious trouble, with a list of 40º. He did not immediately declare a "Mayday", but he did request tug assistance. As a precaution, Liverpool coastguard informed RAF Kinloss of the developing situation and the possibility that helicopter assistance may be needed.

At 1956 the master declared a formal "Mayday" and informed Liverpool coastguard that he would need to evacuate the vessel. The coastguard then contacted RAF Kinloss to confirm that helicopter assistance was required. Initially, two rescue helicopters were dispatched to the incident, R122 and R177; later R116 from Dublin was asked to attend and stand-by at the scene as required.

Further reports to Liverpool coastguard followed; at one stage, the list was reported to be as much as 60º to 70º. However, subsequent analysis of the video taken from RAF rescue helicopter, R122, showed *Riverdance* to have a median list of about 35º (although during extreme rolling, angles of 50º were observed) **(Figures 5a and b)**.

Figure 5a

Video still from R122: Initial encounter with *Riverdance*

Figure 5b

Video still from R122: Initial encounter with *Riverdance*
Note: seas breaking on the upper deck

At 2032, a party of three volunteers made its way back into the ECR, from the starboard weather deck. Their task was to transfer ballast to reduce the list, and then try to restart the port main engine.

On entering the engine room, they found that the port main engine had stopped automatically because of low lube oil pressure. This was probably due to the pump losing suction because of the large list angle. Also, there was only one generator running and the load, at over 200kW, was well above normal, so a second generator was started as a priority.

They then attempted to redistribute ballast, but the ballast pump could not be primed. Consideration was given to attempting to transfer water between the heeling tanks which operated on an independent closed system with a dedicated transfer pump. However, before this was attempted, preparations were made to re-start the port main engine.

Conditions were extremely hazardous in the engine room, not only because of the list, but also because many surfaces were very slippery after lubrication oil had been lost from one of the lube oil purifiers following a seal failure which had occurred during the accident.

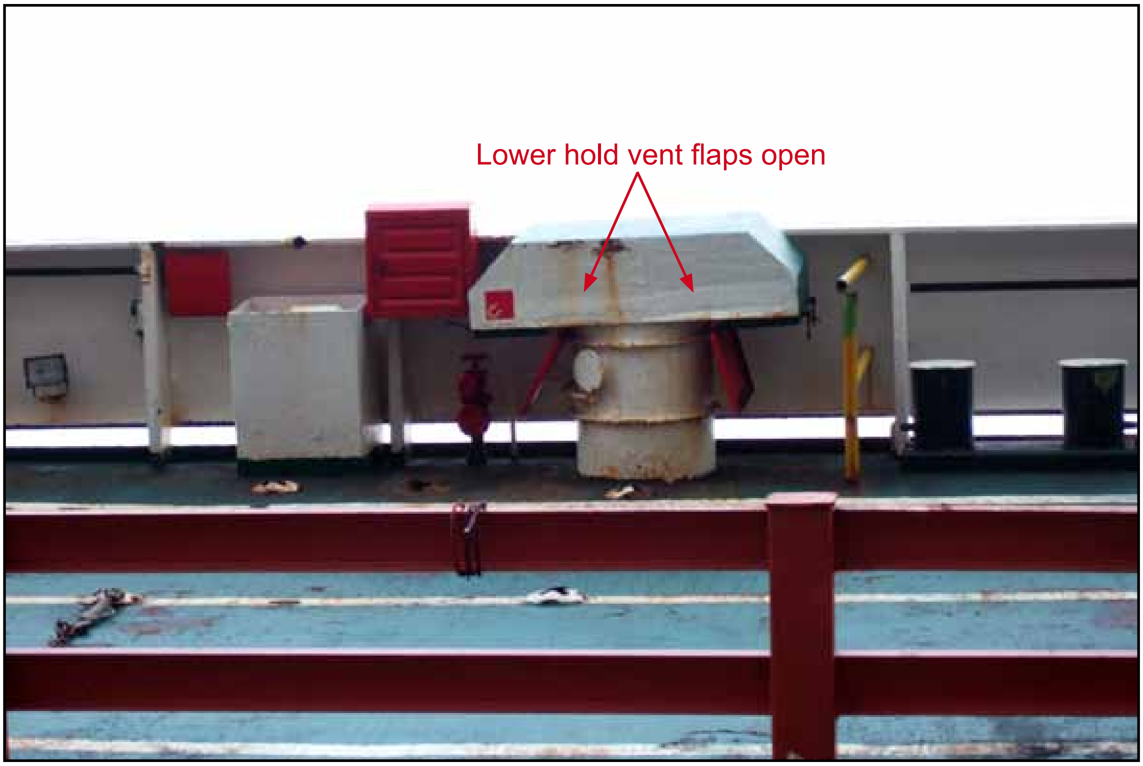
At 2042 *Riverdance* passed close by a wind data tower when the first rescue helicopter, R122, arrived on scene and commenced a cautious approach to the vessel. Considerable difficulty was experienced in finding a safe position for the helicopter to hover relative to the vessel. As R122 was being positioned over *Riverdance,* the vessel was seen to be rolling between 30º and 40º in large seas. Seas were also seen breaking over the port side upper deck **(Figure 5b)**.

Video recording taken from the rescue helicopter confirmed that during this period, the port side weather deck door and lower hold vents, positioned near the ship's side, were repeatedly submerged by breaking waves as *Riverdance* rolled to port. Although it is understood that the chief officer did manage to close the weather deck door prior to descending to the engine control room, the lower hold vent flaps were found in the open position when *Riverdance* was examined after the foundering **(Figure 6)**.

The pilot of R122 became increasingly concerned about the situation, and asked the master to confirm that all crew were mustered together on the bridge in readiness for being airlifted from the vessel. At 2100, the master ordered the engine room to be evacuated, in anticipation of the first winching operation.

Just before the engine room was abandoned, one of the volunteers had started the heeling pump, and left it running in an attempt to reduce the port list. Further video taken from rescue helicopter R122 shows the list reduced to about 20º during the next 30 minutes **(Figures 7a and b)**.

Figure 6



Port side lower hold vent (after grounding)

Figure 7a

At 2100 - list approximately 35°

Figure 7b

At 2130 - list approximately 20°

By 2110 all crew were mustered on the bridge and the master passed an updated report to Liverpool coastguard. In this report he advised that *Riverdance* still had electrical power, but that both main engines were stopped. The list was reducing, and now estimated to be about 20º. The coastguard asked if the master could deploy the vessel's anchors, but he responded that he considered it too dangerous to place men on the forecastle to do this.

The winching operation then began with the four passengers being evacuated first, followed by four non essential crew. R122 departed *Riverdance* at 2226.

1.6 ACTIONS DURING THE GROUNDING

1.6.1 Crew actions

By 2230 the situation had greatly improved, so a second team of volunteers went back into the engine room. During this entry it was much easier to move about the engine room and on the stairs. By that time, *Riverdance* had drifted into shallow water and could be felt bumping along the seabed until, at 2248, during the second winching operation, she grounded at right angles to the beach off the promenade at Cleveleys, with a list of between 5º to 10º to port.

Although *Riverdance* was now aground, she was still rolling to the waves as the second rescue helicopter, R117, began her winching operation. R117 left at 2309, evacuating a further six crew and leaving a skeleton crew of nine volunteers on board. By this time, the Irish coastguard helicopter, R116, had arrived on scene and was standing by for instructions.

As the tide fell, the list further reduced until the vessel settled on the sandy bottom of Cleveleys Beach. Eventually, when *Riverdance* was hard aground, the list had reduced to about 5º to port, and the situation was thought to be stable, with the worst over. It was felt there would now be sufficient time for the remaining crew to prepare *Riverdance* for refloating on the next rising tide.

The team in the engine room had bled the ballast pump so that the transfer of ballast could begin. The initial plan was to transfer the heeling tank fully over to starboard, then to pump out number 3 port ballast tank and fill ballast tanks numbers 2 and 8 starboard. No calculations were made on board to support this plan. No calculations were possible ashore as the CMT had no means to do so. In the event, it was not possible to open the tank valves for number 2 starboard due to a suspected fault in the hydraulic line to the tank valves, so it was decided that pumping out the ballast from number 3 port, and filling number 8 starboard, would be sufficient to bring *Riverdance* upright on refloating. Again, no calculations were made to support this decision.

During the subsequent ballasting operation, it was not possible to check the ballast tank levels because the sounding points were on the main deck, which was inaccessible due to the unsafe state of the cargo there. The ballasting operation was therefore conducted by pumping out number 3 port until the load fell on the ballast pump, and then ballast was pumped into number 8 starboard for 30 minutes.

At the time of the first engine room entry, the heeling tanks were thought to have been transferred from port to starboard. However, as access to the main deck was dangerous, it was not possible to take soundings or check the status of the system's level indicator lights to verify if the contents of the heeling tanks had actually been transferred. Also, it had been reported that the pump had tripped during the operation, so the amount of ballast actually transferred was unknown. During the second entry, the heeling pump was again operated, with the intention of transferring the contents of the port heeling tank to the starboard tank. Still no checks were made on the heeling tank levels, so there was no confirmation of how much ballast was transferred from port to starboard on either occasion.

Once the redistribution of ballast was completed, engineers continued preparing both main engines for restarting as it was planned to attempt to refloat *Riverdance* using her main engines, and the bow thruster, on the next rising tide. This plan was discussed with the CMT, and it was agreed to proceed, despite the prevailing conditions and non-availability of suitable tugs to assist the vessel.

At about this time, it was noticed that the bilge high level alarm for the lower hold or bow thruster room was in alarm, indicating there was water in one, or both, of these spaces. One of the engine room party investigated both areas. The bow thruster space contained only a couple of centimetres of water, which was insufficient to activate the bilge alarm. When the lower hold was entered, water was seen in the port aft corner; this was estimated to be 60 to 90 cm deep (2-3 feet). This was not thought to be significant and, as the engine room party were still working to restart the machinery, no attempt was made to pump out the water, so the bilge alarm could not be reset. Also, during this period, the sounds of sloshing water were reported by one of the crew in the vicinity of the main deck. However, the amount of water involved was indeterminate.

The deck crew checked the trailer lashings on the upper deck and found most were still tight. The few trailers that had shifted were then resecured. However, the main deck space was considered too dangerous to be entered, and only a visual inspection of it was made from the top of the upper deck ladder. From that position, it appeared that not many trailers had shifted, but several units had lost their loads. Those trailers that had shifted appeared to have come to rest against other trailers that had retained their lashings or were being restrained by the ship's structure.

The remaining crew were employed in cleaning up the broken crockery in the accommodation, and cleaning and washing down the galley. Cabins were cleared and tidied. In the engine room, the main engine sumps were re-filled with lubricating oil, and the lube oil pumps primed and made ready for starting of the main engines. Both generators were connected to the main switchboard and the chief engineer remained in the engine control room attending to routine end of the month paperwork.

When these tasks were completed, several of the crew took the opportunity to get some rest before the refloating operation began.

1.6.2 Assistance provided by the Crisis Management Team

Seatruck's SMS contained emergency checklists covering both cargo shift and grounding situations **(Annexes 5 and 6)**. Although the CMT referred to these checklists during the crisis, the team was hindered in the support it could provide to the master due to the lack of detailed information available to it regarding the vessel's loaded condition and stability situation during the various stages of the incident.

1.7 EVENTS LEADING TO THE FINAL GROUNDING

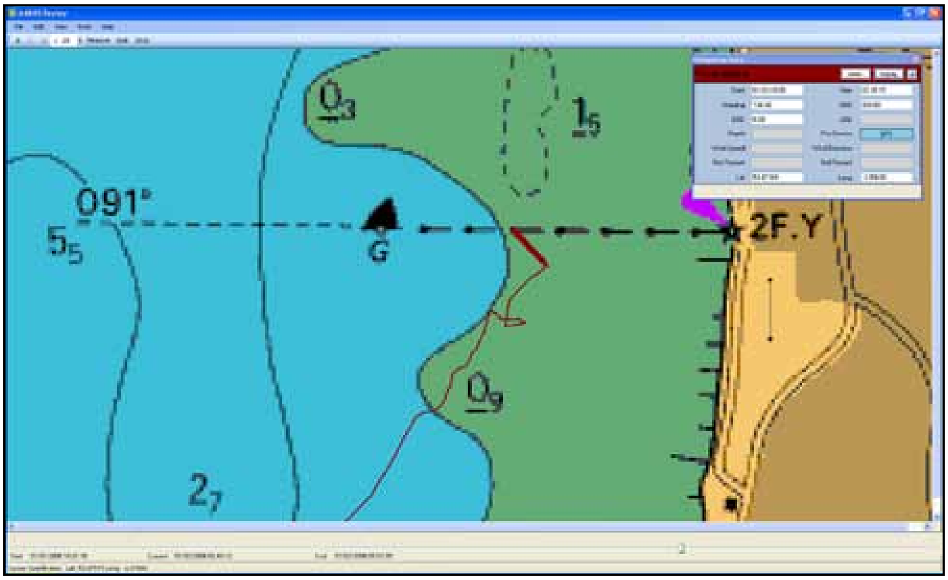
1.7.1 The decision to refloat

During the period *Riverdance* was aground, several discussions took place between the master and the CMT, and while the decision to refloat was left to the master, it was generally assumed that an attempt would be made on the next rising tide. Low water at Heysham was predicted to be at 0007, but it was slightly late and 0.7m above prediction. At 0112, *Riverdance* started to bump on the bottom again. Weather at the time was poor with storm force 10 winds forecast.

Initial attempts were made to manoeuvre *Riverdance* off the beach just after 0135 when the port main engine was started, and a combination of ahead and astern engine movements, in conjunction with substantial use of the bow thruster was used. The starboard main engine was started at 0203 and the master informed Liverpool coastguard that both engines were running astern. At 0217 *Riverdance* started to move slowly to the north-east, but then stopped with her stern close to a sewer outfall pipe. Soon after this, she swung parallel to the shore line **(Figure 8)**.

Reproduced by permission of the Controller of HMSO and the UK Hydrographic Office
AIS data courtesy of MCA

Figure 8



Position of *Riverdance* at 0239

At 0340 the master informed Liverpool coastguard that *Riverdance* was lying beam on to the beach, head south and rolling. As the weather forecast was still poor, he decided to suspend further attempts to refloat the vessel until high water at 0600, and both the main engines were stopped.

1.7.2 The final grounding

Once the attempts to refloat *Riverdance* were suspended, she began to roll as the waves crashed into her side. Several rolls were felt to starboard, against the wind and sea. These were followed by a lurch and a quick roll, before *Riverdance* settled over on her starboard side at an angle of about 30º **(Figure 9)**. Her final grounding position was close to the sewer outfall pipe, which was subsequently found to have suffered slight damage.

Images courtesy of MCA

Figure 9

Riverdance aground on the morning of 1 February 2008

During the final roll to starboard the sea suction, located on the port side, came clear of the water and the generators tripped as cooling water was lost. An attempt was made to counter the roll by operating the heeling pump to transfer water back from the starboard heeling tank to the port tank. However, this was too late to arrest the final roll to starboard and, as *Riverdance* listed over, the engine room was evacuated and there was a short blackout until emergency power took over.

A further "Mayday" was then broadcast and the remaining crew were mustered back on the bridge, awaiting the return of R122 from Blackpool airport, where it had been standing-by.

By 0445, R122 was back on scene and, at 0516, *Riverdance* had been successfully abandoned.

1.8 MANNING

Senior officers employed by Seatruck worked a flexible roster around a 2 week 'on', 2 week 'off' duty pattern. As officers were assigned to individual vessels, much of the relieving scheduling was decided by mutual agreement and co-operation between the officers concerned.

At the time of the accident both the master and chief engineer of *Riverdance* had been with the company, and the vessel, since the service began. Both had considerable experience of the Irish Sea in winter, and of operating ro-ro vessels of this size.

Seatruck was due to take delivery of several new vessels which were to be employed on its Irish Sea services. Personnel destined for the new vessels were being trained and one of these, a chief engineer, was being carried on board *Riverdance* at the time of the accident.

1.9 CARGO OPERATIONS

1.9.1 Information provided to the master

The cargo operations in Warrenpoint and Heysham were conducted in broadly similar ways. Seatrucks' operation was designed to offer a flexible service with a "turn up and go" option forming an important part its operating philosophy. Trucks and trailers would arrive in the port, where they were checked into a secure holding compound.

There were no procedures in place at either terminal that required cargo information to be provided to the master prior to arrival. Information that was provided was based on the drivers' declarations as to the contents and weight of each trailer. A loading list was issued to the master, however the weight information was frequently not provided, and on the voyage in question the loading list had no weights included **(Annex 7)**.

Due to the flexible nature of the service, there were occasions where trailers declared on the loading list were substituted by other trailers. The loading list provided at Warrenpoint for this voyage, included four such trailers that were replaced by other units. However, there was no documentation available indicating that this information was passed to the master.

1.9.2 Requirement to weigh cargo

Riverdance was limited to carrying no more than 12 passengers and was categorised as a Class VII ro-ro cargo vessel. Current UK legislation[4] requires the weighing of cargo in UK ports to be loaded on UK registered Class II and ClassIIA ro-ro passenger vessels only. Cargo scheduled to be loaded on UK registered Class VII ro-ros is not required to be weighed. Similarly, cargo destined to be loaded at UK ports on any foreign registered ro-ro, such as *Riverdance*, is not required to be weighed under UK law.

The Merchant Shipping (Mandatory Surveys for Ro-Ro Ferry and High Speed Passenger Craft) Regulations 2001 (SI 2001/152) implement European Directive 1999/35/EC. Annex IV of the Directive provides guidelines for "qualified inspectors" when carrying out the routine surveys required by this legislation. Under the heading "Loading and Stability Information", the inspectors are guided to verify:

> *b…That measures are taken to ensure that the ship is not overloaded…That the loading and stability assessment is carried out as required. That goods vehicles and other cargo are weighed where required and the figures passed to the ship for use in the loading and stability assessment."*

[4] The Merchant Shipping (Weighting of Goods, Vehicles and Other Cargo) Regulations 1998

The drivers of the trailers loaded on *Riverdance* provided a declaration as to the weight of his/her unit, but these were often based on estimates. It was therefore usual for Seatruck to assign a standard weight of 6 tonnes and 30 tonnes to empty and loaded trailers respectively.

These procedures meant that accurate cargo information was seldom provided to the vessel prior to arrival in either port. The cargo plan was also subject to modification at any time during the operation, right up to the closing of the stern ramp. If a unit arrived before the vessel was ready to sail, and there was space, every attempt would be made to ship it.

Although a provisional loading sheet was given to the chief officer on arrival in each port **(Annex 7)**, the information included on this sheet was of limited value to a ship's officer as the weights were often vague, or omitted altogether, and the stowage position referred only to stowage on the upper or main deck. The loading list also included space for the trailer ID number and length, but this information was not routinely provided.

The planned stowage position of the trailers on the upper deck or the main deck was based on the declared weight and height of the trailer. However the actual stowage was decided during the loading when the unit passed the chief officer on the ship's stern ramp. He would then confirm to the driver where the trailer was to be stowed, based on the height of the unit (heights under the accommodation block being restricted) and how heavy it appeared. If the tractor unit seemed to be labouring while pulling the trailer, the chief officer knew it could be heavier than declared, and on occasions would stop such units from being sent to the upper deck.

During loading operations, *Riverdance* was kept close to upright using a counter heeling system. This system automatically transferred permanent ballast between two heeling tanks, using a high volume, reversible pump. Occasionally, the chief officer actively looked out for heavy trailer units that he could use to adjust the vessel's trim and list, especially if the heeling tank levels were approaching their operational limits, which could be identified by reference to the tank content level indicator lights.

1.9.3 Cargo securing

Seatruck's terminal check-in procedures included a visual inspection of the trailer load and any external securing arrangements. The security of the contents of curtain sided trailers (taughtliners[5]) was not checked. However, if there was clear external evidence of existing cargo shift, such as bulging of the curtain side **(Figure 10)**, shipping could be refused.

During loading operations at Warrenpoint on 31 January, several trucks were refused passage on *Riverdance* due to concerns raised about the expected poor weather conditions during the crossing to Heysham.

5 There are five basic kinds of trailers in use. They are 1) taughtliner 2) tipper 3) flatbed 4) tanker 5) box.

Figure 10

Examples of tautliners with bulging sides prior to shipment

Before *Riverdance* left her berth at Warrenpoint, trailers were secured in accordance with the vessel's cargo securing manual, with extra lashings provided because of the expected poor weather conditions.

The trailer lashings were then re-checked at 30 minute intervals while *Riverdance* was on passage, with only minor tightening required. Most of the lashings held securely even when *Riverdance* was listed over to extreme angles **(Figure 11)**.

Figure 11

Trailers still secured on the main deck after the grounding

1.10 BALLAST AND BILGE SYSTEM

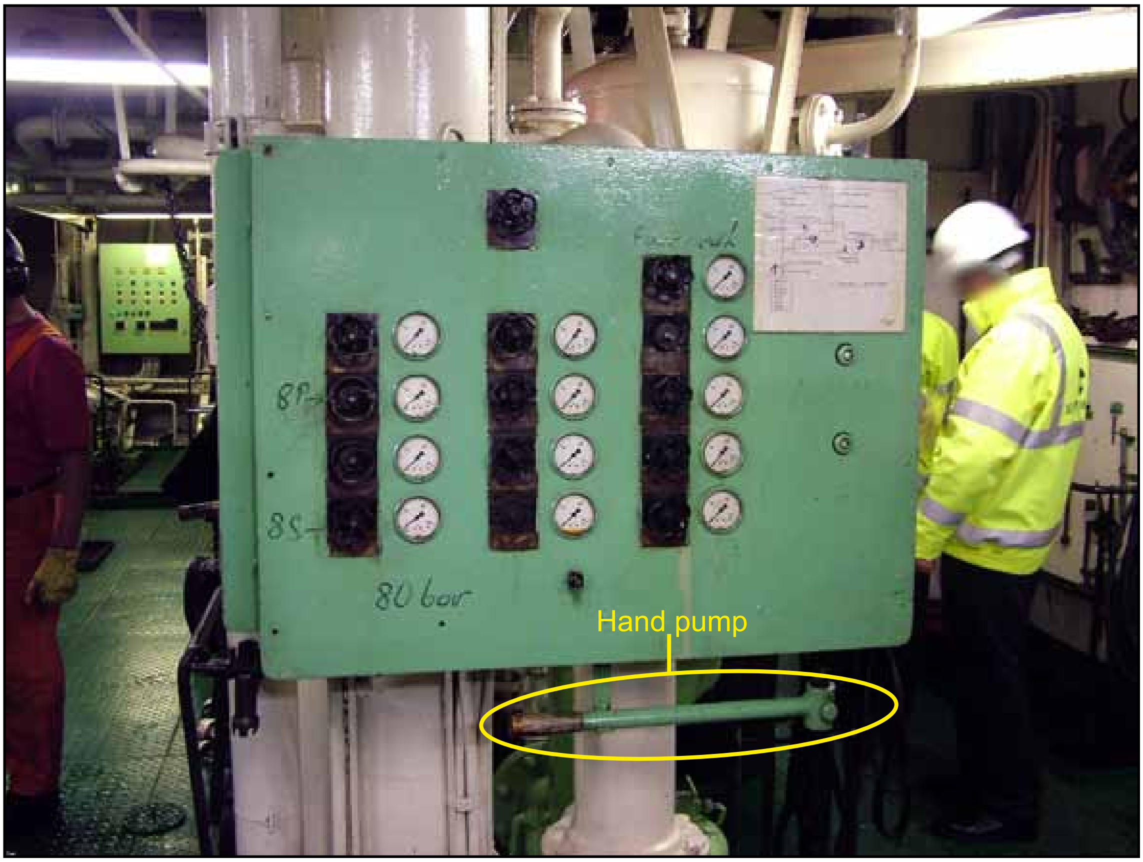
1.10.1 Ballast valve operation

Riverdance was still fitted with the original ballast valve operating system as installed at new build in 1977. This included a hydraulic storage tank which held about 30 litres of oil **(Figure 12a)**. Oil was routed to the required tank ballast valve through a combination of control valves **(Figure 12b)**; each individual tank valve consisted of the valve body and an actuator which incorporated a spring-loaded plate. The system provided no mimics at the control station to indicate the states of the valves. The only indication that the valve was fully open was when the in-line pressure gauge indicated a rising pressure and it became difficult to continue pumping as the valve actuator became hard up against its open "stop".

Figure 12a

Hydraulic storage tank

Figure 12b



Ballast distribution control panel

1.10.2 Routine ballast operations

The ballast condition on board *Riverdance* was seldom altered. The routine ballast condition was to have number 3, port and starboard tanks full and all other ballast tanks empty. In this configuration 158 mt of ballast was carried on board and number 3 tanks were effectively considered to be “permanent ballast”, and were left unchanged.

In contrast, her sister vessel, *Moondance*, routinely carried 539 tonnes of ballast which was mostly contained within her fore peak tank **(Annex 18a)**. Another sister vessel, which also operated in the Irish Sea, carried 490 tonnes of ballast which was more evenly distributed throughout the vessel **(Annex 18b)**.

1.10.3 Operation of the heeling tank system

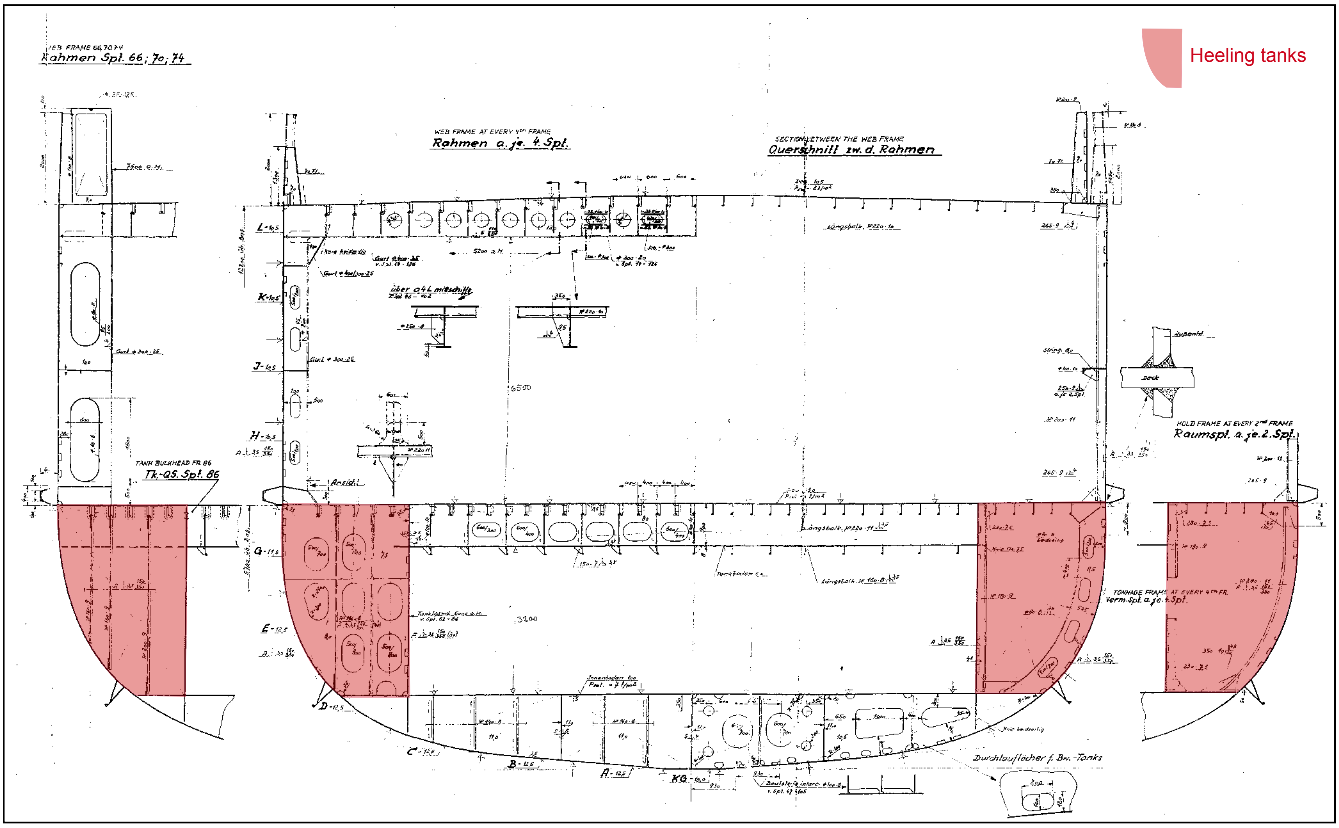
In every port during cargo operations, the heeling tank system was used in its automatic mode, to counter the lists caused as the trailers were loaded or discharged. The system was designed so that, under normal operating conditions in port, there could be no backflow or cross-flooding between the tanks.

The heeling system consisted of two heeling tanks, designated 13 port and 13 starboard, which were directly connected with a 300mm (12”) cross-over pipe **(Figures 13a and b)**. Within this line was a reversible pump **(Annex 8)** which had a rated capacity of 600 m^3/hr, and allowed ballast to be shifted quickly to whichever side it was needed to counter lists developed during loading, or unloading, operations.

However, when stopped, the in-line pump offered minimal resistance to water flow in either direction. To avoid the heeling tanks cross-flooding or levelling each time the pump stopped, non return valves were installed in the suction and discharge lines in the tanks, and manual block valves fitted in the cross-over pipe and located within the engine room workshop. The manual valves were kept closed at sea.

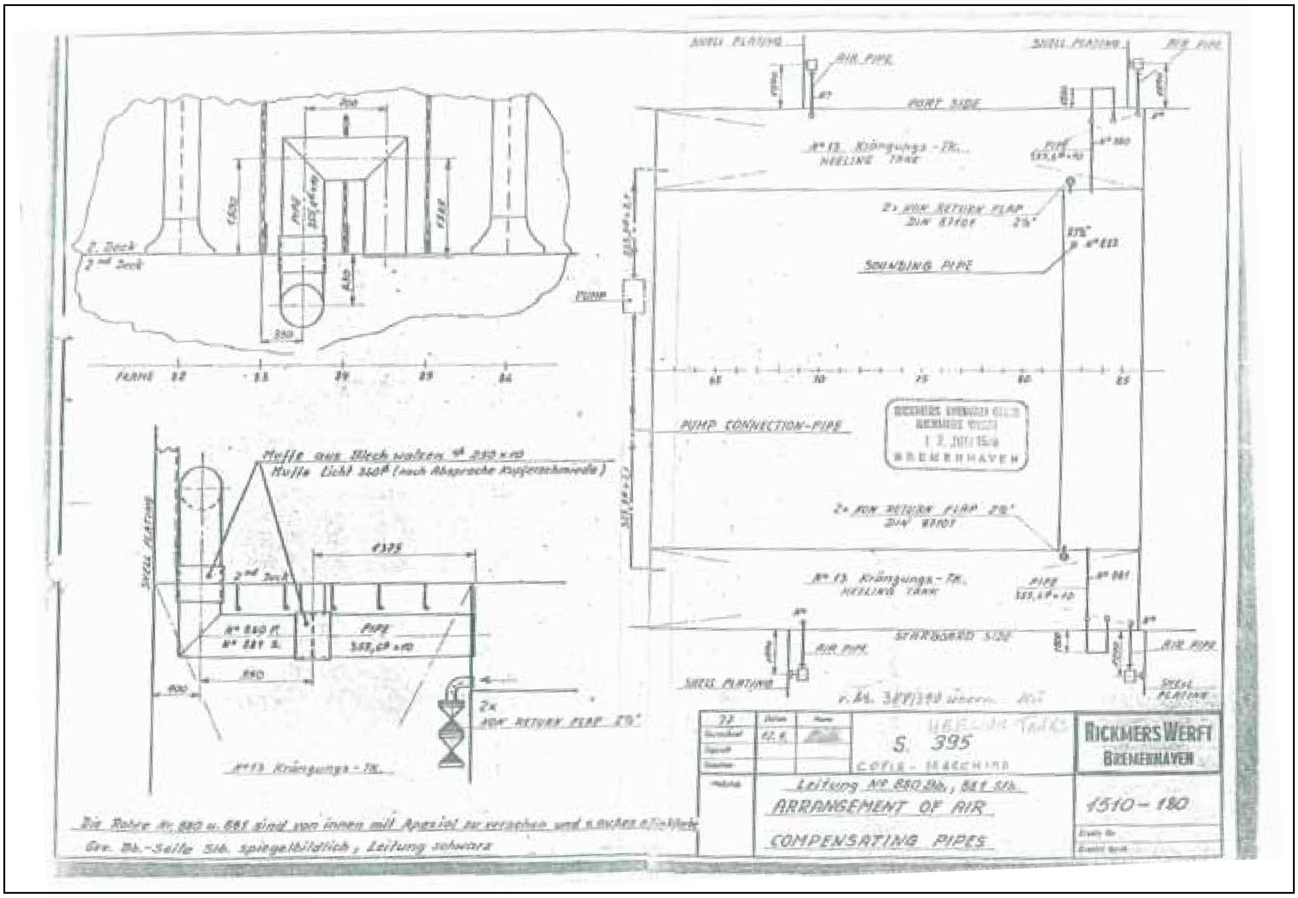
During the vessel’s demolition process on Cleveleys Beach, some 6 months after the grounding, the non return valves were inspected and both of the upper, discharge side valves were found to be seized in the open position **(Figures 14a and b)**.

Figure 13a



Midship section through *Riverdance*'s heeling tanks

Figure 13b



Pipeline design of heeling system

Figure 14a

Port non return valve not sealed

Figure 14b

Starboard non return valve

The pre-arrival procedures were described in checklist E002 **(Annex 3)** and it was intended that the system would be made ready for operation during the stand-by period as *Riverdance* approached her berth, after the end of passage. At this time, the manual valve on the cross-over line would be opened, and the heeling pump breakers switched on ready for the cargo officer to take control. However, on the day of the accident, the valves on the heeling system's cross-over line were opened, earlier than was usual, shortly after the duty engineer had been given 1 hour's notice for stand-by. This was around the same time that the vessel experienced her most noticeable rolls.

1.10.4 Bilge alarms

Riverdance was fitted with bilge alarms in the engine room, lower hold, bow thruster room and the steering compartment. These triggered audible and visual alarms in the engine control room when activated.

The alarm for the lower hold and bow thruster room was on a common electrical circuit. When the alarm operated, the actual space in alarm could not be identified without a visual inspection of the compartments.

The lower hold bilges had a capacity of about 100 litres, and the bilge alarm for this space was known to activate frequently.

1.11 STABILITY ISSUES

1.11.1 Stability Calculations and Worst Case Scenario

It was a requirement of the company SMS for the vessel's stability to be calculated before every departure, but this procedure was not routinely followed on board *Riverdance*. The officers regarded the vessel as sturdy and stable in all possible loading conditions, and this had been verified, to the satisfaction of the managers, by the production on board of a "Worst Case Scenario" (WCS) stability condition **(Annex 9)**. It was considered that the vessel's reserve of stability would be in excess of the WCS under all foreseeable loading conditions.

The only value produced by the WCS that was felt to be of importance, was the size of the GM. Although the calculation had been approved by Seatruck, the data and calculations underpinning the WCS had not been fully verified or checked against the full range of the stability requirements of the 1968 Load Line regulations.

The WCS was kept on board *Riverdance* alongside the approved copy of the trim and stability documentation. Unfortunately, there were no duplicate calculations or other supporting documentation held ashore in Seatruck's offices, and stability information was unavailable to the CMT.

1.12 SAFETY MANAGEMENT SYSTEM PROCEDURES

1.12.1 General

The requirement for management companies to establish a Safety Management System (SMS) is laid out in the International Safety Management (ISM) Code. The Code is contained in Chapter IX of the Convention for the Safety of Life at Sea (SOLAS), 1974, and came into force on 1 July 1998. Amendments to the Code came into force on 1 July 2002.

The Seatruck Ferries' SMS had gradually evolved through a number of ship management changes. In 1996 Crescent Ship Management Ltd was the ship manager and was responsible for developing the SMS. A number of company mergers followed within the Crescent group and the SMS responsibilities also changed until, in February 2006, after a change of ownership of the Crescent group, Seatruck Ferries assumed full responsibility for maintaining and developing the SMS.

1.12.2 External ISM auditing

On 21 July 2006, Det Norske Veritas (DNV), on behalf of the vessel's flag State, issued Seatruck with an ISM Document of Compliance to operate "other cargo ships (ro-ro ferries)". The first annual verification was completed on 10 September 2007. Although there were no non conformities identified, seven observations were noted **(Annex 10)**.

DNV last conducted an ISM Code Certification audit on *Riverdance* on 22 May 2006. The audit report confirms that no non conformities were identified and the vessel was then issued with a Safety Management Certificate, which was valid at the time of the accident.

1.12.3 Internal SMS audits

From February 2006 three internal SMS audits of *Riverdance* were carried out by two company superintendents and a serving chief officer. The last internal ISM audit was conducted on 18 December 2007 while the vessel was on passage from Heysham to Warrenpoint **(Annex 11)**. During these three audits, a total of four non conformities were raised. The fact that ship's staff were not calculating the stability in accordance with the requirement of the SMS, was not identified.

1.12.4 Guidance on cargo / ballasting operations

Cargo operations are covered in the SMS at section DP07 **(Annex 12)**.

A shipboard procedure **(Annex 13)**, approved by the vessel's previous managers, was included in the ship specific section of the SMS. This acknowledged that under normal operating procedures, ballast conditions would remain the same. However, it further stated that ballast may have to be adjusted for a number of reasons, but consideration of the need to take extra ballast whenever heavy weather was expected was not specifically identified.

1.12.5 Guidance on operating in heavy weather

Guidance in the SMS required the chief officer to take into account the prevailing and predicted weather when securing cargo. Additional consideration was also required to be given to the securing of cargo units known to be prone to movement.

Advice and guidance provided to the vessel's master on operating in conditions of heavy weather was limited to general comments about "giving consideration to the current state of the weather when preparing a passage plan". The SMS made no mention of the guidance provided in the IMO MSC.1/Circ.1228 **(Annex 14)**. Guidance was included in the ship's Trim and Stability Booklet under "Instructions to the Master" **(Annex 15)** which stated:

> "*Compliance with the stability criteria indicated in this booklet does not ensure immunity from capsize regardless of the circumstances and does not absolve the Master from his responsibilities. The Master should therefore exercise prudence and good seamanship having regard to the season of the year, weather forecasts and the navigational zone and should take the necessary action as to course and speed warranted by the prevailing conditions.*"

1.13 ONBOARD MANAGEMENT

1.13.1 Familiarisation procedures for new joiners

Senior officers joining *Riverdance* were routinely provided with comprehensive handover notes by their outgoing counterparts. In addition, the company SMS required all new joiners to undergo a structured programme of familiarisation and training. There was no requirement for written handover notes to be provided for incoming junior officers. For example, on *Riverdance*, a newly recruited third engineer was given a 3-day handover period with the outgoing officer, but no notes were left for him to refer to after the outgoing officer left the vessel and he assumed his responsibilities.

1.14 RESCUE OPERATIONS

1.14.1 Coastguard response

Following the initial "Mayday" at 1956 the coastguard mobilised three helicopters, two lifeboats and numerous mobile shore patrol units. It also placed other emergency services on alert, and Blackpool International Airport was placed on stand-by to receive possible survivors from *Riverdance*.

Tug availability in the area was checked, but none were capable of rendering assistance in the poor weather conditions. The coastguard therefore requested assistance from two oil rig support vessels in the Irish Sea, and co-ordinated the attendance of another five surface craft.

1.15 DAMAGE SUSTAINED

Prior to, and during the first grounding, *Riverdance* sustained little actual damage other than to rails on the port quarter as a result of green seas on deck and a trailer lost overboard. The initial heavy heel to port resulted in an unknown, but limited, number of trailers shifting. However, the majority of the trailer lashings held, and it was mainly cargo within the trailers that moved, leading to a residual list to port.

When attempts were made to refloat *Riverdance* on the rising tide, the helm and engines were used for a considerable period of time, and the master accepted that the need to get the vessel safely afloat outweighed the likelihood of damage being sustained. It was most probably during this period that damage to the propellers occurred and the starboard rudder became detached **(Figure 15)**.

Consequently, when *Riverdance* finally came to rest on the beach at Cleveleys, her hull appeared intact and sound **(Figure 16)**. However, the effects of bad weather, during the following days as the vessel lay on the beach, together with the continual pounding and effects of wave action on the hull, eventually laid her open to the sea.

Although salvage operations continued in earnest, it became increasingly unlikely that they would be effective in refloating the vessel, and progressive damage and flooding occurred to the entire hull, including the engine room. *Riverdance* gradually settled into the sand until her list increased to an angle of over 100º to the beach, and she was declared a constructive total loss. The decision was taken to demolish the vessel in situ.

Image courtesy of Brookes Bell

Figure 15

Damage sustained to *Riverdance*'s CPP and starboard rudder

Image courtesy of MCA

Figure 16

Vessel aground with no apparent damage to ship's port side or hull

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 FATIGUE

The possibility of fatigue was examined. The hours of work and rest for the officers were discussed during interviews, and the work patterns complied with the STCW requirements for rest. Even in the bad weather being experienced, officers and crew were able to get adequate rest of a reasonable quality.

Fatigue is therefore not considered to have been a contributory factor to this accident.

2.3 ENVIRONMENTAL DATA

2.3.1 Wave data

Accurate and detailed data for wind and swell was available from several sources for the area around the Lune Deep. There were monitoring stations in Liverpool Bay, Morecambe Bay Gas field 13.5 miles to the west, on Shell Flats 2.7 miles to the south, and at Barrow wind farm 4.0 miles to the north.

Wind and wave height data collected from these sources was combined with hindcast data from the Meteorological Office **(Table 1)** to generate a detailed picture of the environmental conditions in the area during the time of the accident.

Time UTC	Wind Speed Knots	Wind Direction ° True	Resultant Wave height M	Resultant Wave period (s)	Resultant Wave direction ° True	Wind sea height m	Wind sea period (z) (s)	Wind sea direction ° True
0001	30	216	2.9	6.2	233	2.9	6.7	233
0300	42	220	3.7	6.5	242	3.7	7.1	242
0600	43	224	3.9	7	235	3.9	7.4	235
0900	35	261	3.6	7	256	3.5	7.3	256
1200	37	264	3.7	6.9	260	3.7	7.3	260
1500	38	257	3.6	6.8	258	3.6	7.2	258
1800	40	260	3.8	7.1	258	3.8	7.3	258
2100	43	252	4	7.2	256	4	7.4	256

Table 1 - Data from the MET office for 31 January

Significant wave heights in the Morecambe Bay area were recorded as up to 6.5m, which would have resulted in wave packets, within the wave trains, in excess of 7m in height with a zero crossing period, (z), of 6-7 seconds. This combination of wave height and periodicity would have resulted in a very steep seaway.

Conditions very similar to those recorded were confirmed by reports from vessels operating in this area, including reports from lifeboats that responded to the "Mayday" from *Riverdance*.

In parallel with the collection of weather data, the expected wave spectra in the area of the accident were investigated. Wave spectra are affected by parameters such as the wind speed and direction, wave fetch and water depth. A JONSWAP[6] spectrum is often used in hydrodynamic studies to represent the conditions of inshore waters with a limited fetch.

A summary of the environmental study can be found in the QinetiQ report at **(Annex 1, Section 2.2)**.

2.3.2 Tidal data

Tidal data was obtained from a measuring station located at Heysham. High tide was at 1715, and at the time of the accident the tide was ebbing in a direction of 250º at 0.7kts.

2.4 STABILITY

2.4.1 Availability of information

During the initial stages of the MAIB investigation, extensive efforts were made to accurately recreate the stability condition of *Riverdance* on her departure from Warrenpoint. Several problems were encountered.

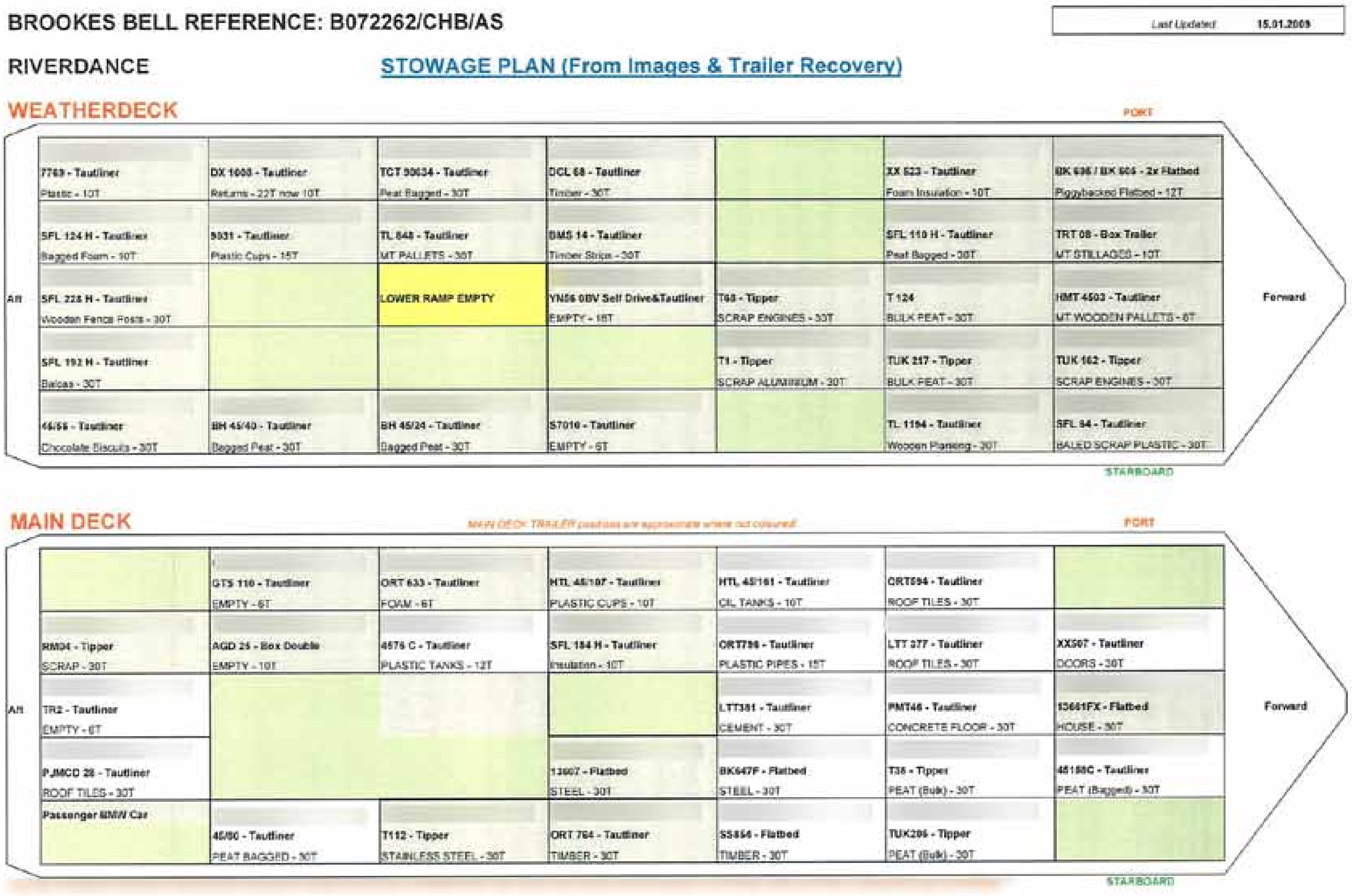
1) Lack of accurate cargo information

   Cargo information was provided to MAIB in the form of a loaded "final ship's manifest" **(Annex 16)**. The accuracy of the weights was unknown, and the actual stowage position of the trailers on the decks was not recorded. It was a considerable time after the accident that an accurate cargo stowage plan could be reconstructed **(Figure 17)** based on information from aerial photographs of the upper deck **(Figures 18 and 19)**, and records of the main deck made during the salvage and demolition operations.

   It was later discovered that the loading list provided to the vessel at the start of cargo operations at Warrenpoint referred to four trailers which were not subsequently loaded but were substituted by other trailers.

[6] JONSWAP - The "Joint North Sea Wave Project" wave spectrum has been developed to model limited fetch, shallow water wave conditions

Figure 17



Best estimate of cargo stowage

Figure 18

Figure 19

Two stills from RAF video showing majority of trailers still held in, or close to their original position

2) Ballast and bunker information

Soundings of ballast and bunker tanks were taken on a weekly basis and recorded in logs kept on board *Riverdance*. Although Seatruck required a bunker statement to be sent to them at the end of each month, this report did not refer to individual tank quantities. As most onboard documentation was lost during the salvage, the bunker quantities and disposition at the time of the accident had to be recalled from memory by those on board.

The ballast distribution was easier to confirm because the only ballast tanks in use were number 3 port and starboard. Although water was also carried in the heeling tanks system, the levels in these tanks were not normally recorded or considered a significant issue by ship's staff under routine operating conditions unless one of the tanks was reaching its operational limit. For calculation purposes, the tank levels attributed to the heeling system were based on the recollection of the crew that the system level indicator lights were equal at the time of departure from Warrenpoint.

3) Trim and Stability (T&S) booklets

Updated Trim & Stability booklets, approved by DNV, were provided by the shipyard to Seatruck and placed on board *Riverdance* in June 2000. Following the accident, Seatruck was unable to locate a copy of this document. It is therefore likely that the only "approved" copy of the T&S booklet held by the owners was lost during the salvage operation.

Initially only a single copy of a "preliminary" version of the *Riverdance* T&S booklet was available, and this had been made available to SMIT[7] as salvors. It was not until later that the "approved" T&S booklet was provided to investigators, by DNV, the vessel's classification society. Other calculations were made using the approved T&S booklet from the sister vessel *Moondance*, which, although generally the same as the "approved" *Riverdance* T&S booklet, contained subtle - but significant - differences in the information provided **(Annex 1, Sections 2.6.12 to 2.6.14 and Annex 17)**.

2.4.2 Operation of *Riverdance* and *Moondance*

Seatruck operated *Riverdance* and her sister vessel, *Moondance*, between Heysham and Warrenpoint. They were considered to be substantially identical, despite the differences in lightweight and longitudinal centre of gravity (LCG) stated in the "approved" T&S booklets of each vessel.

As both vessels were operated on the same route, by the same company, it was surprising to note there was a significant difference in the amount and distribution of ballast carried during normal operation: *Riverdance* routinely carried 158 mt of ballast, while *Moondance* carried 539 mt **(Annex 18a)**. Notwithstanding the differences, calculations conducted following the accident

[7] SMIT Salvage BV, Rotterdam – appointed as initial salvors for the vessel

to *Riverdance* indicate the ballast configurations resulted in similar stability conditions on both vessels. The differing practices were rationalised by the vessel's managers by attributing them to their masters' individual preferences. Nevertheless, the significantly greater number of incidents of heavy weather damage experienced by *Riverdance* compared to *Moondance* (see Section 2.12), and the anecdotal descriptions of *Riverdance*'s motion at sea being "nice and easy" or "lazy rolling" should have prompted them to question whether the vessel's reserve stability was sufficient to take more action to understand the apparent operational differences between the two sister vessels.

2.4.3 Reliance on the Worst Case Scenario

There was a requirement within the Seatruck SMS for ship's staff to calculate the vessel's stability prior to every departure. However, on *Riverdance* this was done infrequently. Instead, substantial reliance was placed on the WCS calculation that had been produced on board, and the experience of the vessel's officers. Although Seatruck's managers were aware that this WCS document existed, and was relied on by ship's officers, they had not independently reviewed it, and no copy was held in the company offices for reference.

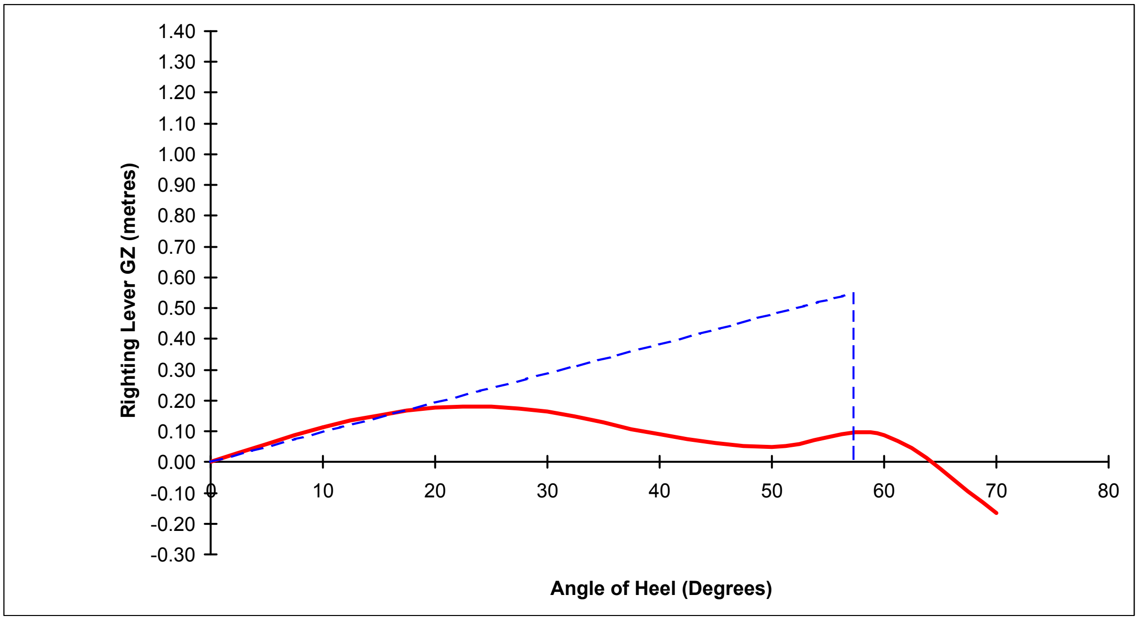
Copies of *Riverdance*'s WCS were lost with the vessel. Consequently, the document used on *Moondance* was referred to during this investigation **(Annex 9)**. The conditions were largely similar for both vessels because they were created on board from the same basic information. From examination of the WCS calculation spreadsheet, using *Riverdance*'s 2000 "approved" hydrostatic and lightship data, the actual values for stability criteria were found to be non-compliant with the 1968 Load Line regulations in a number of areas **(Figure 20a and b)**.

Figure 20a

Worst Case Scenario Summary of Stability			
Criteria, based on the 1968 Load Line Regulations	**Rule Minimum**	**WCS Value**	**Compliant?**
Area Under Righting Lever (GZ) to 30°	0.055 m rads.	0.068 m rads.	Yes
Area GZ from 30° to lesser of 40° and X	0.030 m rads.	0.023 m rads.	NO
Area Under Righting Lever (GZ) to 40°	0.090 m rads.	0.091 m rads.	Yes
Maximum Righting Lever (GZ)	0.20 m	0.176 m	NO
Angle of Heel at which Maximum Righting Lever (GZ) Occurs	Not less than 25 and preferably greater than 30°	23° approx	NO
Transverse Metacentric Height (GM_{fluid})	0.15 m	0.547 m	Yes
Angle of Downflooding (X)	-	-	

Moondance WCS recalculated using *Riverdance*'s approved trim and stability data

Figure 20b



GZ curve for the *Moondance* WCS using *Riverdance*'s approved trim and stability data

The difference between the WCS calculated GM of 0.73 m **(Annex 9)** and the calculation as above, of 0.547, was found to be due to errors within the WCS spreadsheet cells, where formulae had been replaced by manual entries. This meant that the weights and moments for stores and crew were not added to the summary of totals. The WCS calculation was also based on an old value for lightweight that had been extant before modification of the vessel.

Officers on *Riverdance* placed substantial reliance on the results of the WCS, and it is probable that this contributed to a level of complacency regarding stability issues in general, both ashore and on board. This, combined with the inherent difficulty of obtaining reliable and accurate figures for cargo weights, led to the SMS requirement for calculating the vessel's stability prior to sailing falling into abeyance.

This, in time, led to the actual stability of the vessel generally being unknown, because it was assumed that it would always be compliant. As a result, it was initially difficult to state, with any certainty, the vessel's condition and stability at the time of the accident. This became a factor after *Riverdance* grounded because ballast was rearranged without access to accurate information regarding her initial stability condition.

2.4.4 Master's decision to sail

Based on the information available to the master, at the time, and his experience with the vessel, the decision to sail from Warrenpoint was not unreasonable. However, if additional guidance for navigating in heavy weather had been provided in the SMS, or if the master had access to the further guidance included in the IMO Circ.1228 **(Annex 14)**, his choice of route and speed to Heysham might have been different.

Riverdance was thought to have sufficient GM in all conditions, and was described as a *"good sea ship".* Nonetheless, if the master had been aware of this guidance, and had accurately calculated the full range of *Riverdance*'s stability, he might have reviewed the ballast configuration and considered taking additional ballast for passages where severe weather was expected.

More guidance was provided in the "Instructions to The Master" section of the T&S booklet **(Annex 15)**, specifically -

> "*3 Compliance with the stability criteria indicated in this booklet does not ensure immunity from capsize regardless on the circumstances and does not absolve the Master from his responsibilities. The Master should therefore exercise prudence and good seamanship having regard to the season of the year, weather forecasts and the navigational zone and should take the necessary action as to course and speed warranted by the prevailing conditions*." [sic]

> "*7 All hatches, manholes and portable plates leading to spaces below the main deck are to be closed and secured watertight before the ship leaves port and are to be kept closed during navigation.*" [sic][8]

If Seatruck's SMS had included a heavy weather checklist, or if advice had been provided to masters for the precautions to be considered when heavy weather was expected, it is possible that attention would have been drawn to the need to properly close the weather deck openings while the vessel was at sea.

2.5 SCENARIOS FOR THE CAUSE OF THE INITIAL LIST

2.5.1 Cargo shift

The effect of transferring cargo weights, both by considering shifting of the cargo on the trailers alone and of the shifting of cargo and trailers together, was examined in detail and is covered in QinetiQ's report **(Annex 1, Section 3.4)**.

2.5.1.1 Upper deck

From photographic evidence of the trailers secured on the upper deck, both from the rescue helicopter while on scene **(Figure 21)**, and of *Riverdance* when aground **(Figure 22)**, it was clear that the lashings had held most of the trailers securely in place.

There were examples of cargo shifting within the trailers, and total loss of cargo from several trailers. However, only one trailer was lost overboard.

[8] There was no common term used for the upper and main decks on *Riverdance*. Ship's plans refer to deck 1 and 2, Trim & Stability booklet to the 1st deck as the main deck. The crew referred to the upper weather and main cargo decks.

Figure 21

Still from RAF video, showing upper deck cargo disposition

Figure 22

Upper deck looking aft

2.5.1.2 Main deck

Although MAIB inspectors were unable to gain access to *Riverdance* to accurately assess the amount of cargo shift that had taken place on the main deck, it was apparent from witness statements that most trailer lashings had held. In fact, several trailers remained securely lashed even when the list increased during the salvage operation and *Riverdance* was laid over to large angles on her side **(Figure 23)**.

Figure 23

Aft deck - trailers remain secured at large angle of heel

The few photographs available of the main deck after the final grounding also show little evidence of trailers shifting or of cargo having been lost from the trailers themselves **(Figures 11, 24a and b)**. Most show taughtliners still in the stowed positions, with no indication of cargo having broken through the curtain sides.

During the final breaking up of *Riverdance,* a significant number of trailers were removed from the main deck, substantially intact **(Figure 25)**. It would appear that within the confines of the main deck, any trailers that did break free were prevented from moving very far, by the adjacent trailers or parts of the ship's structure. This would have limited the amount of weight that could have shifted to cause the vessel to list.

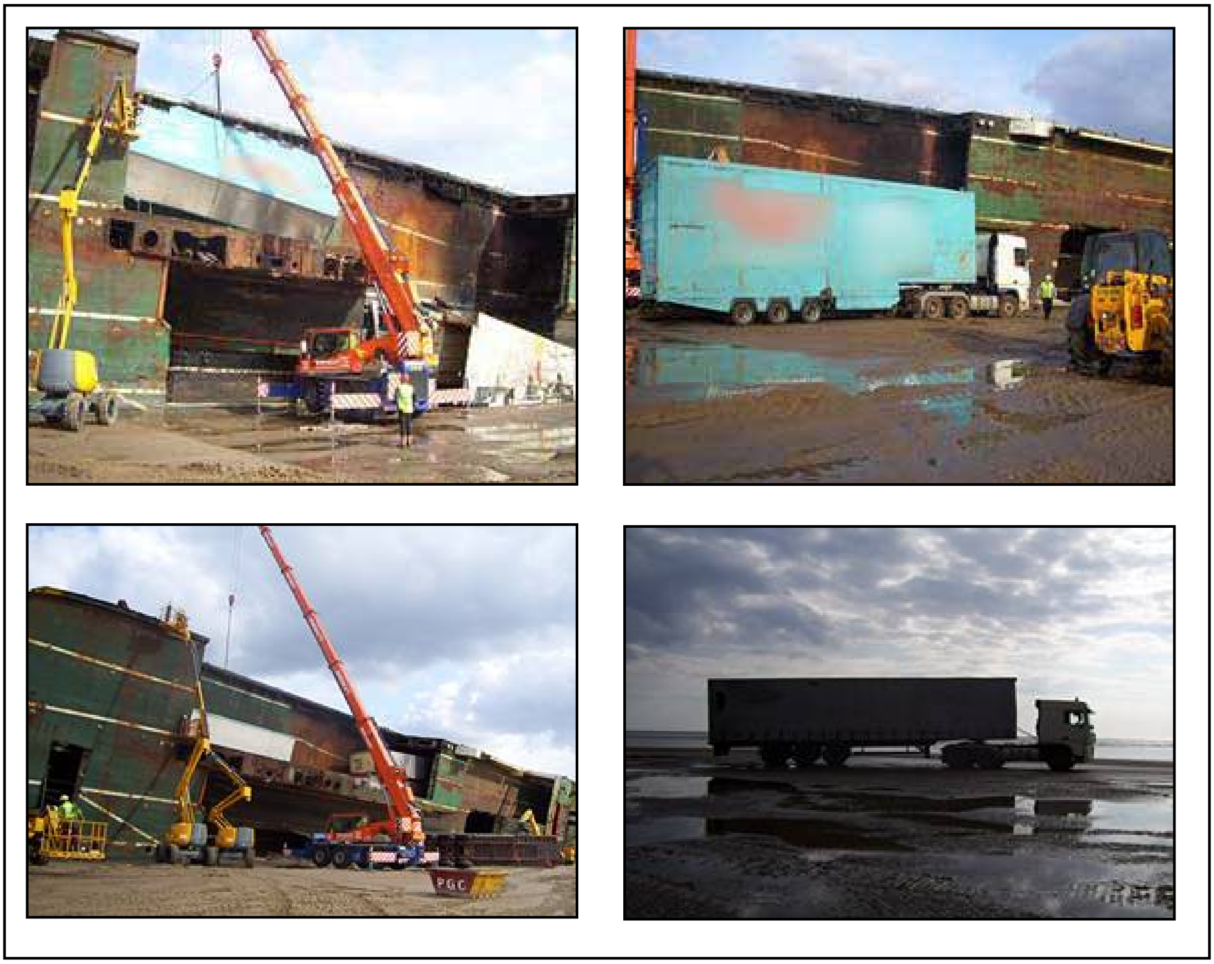
Figure 24a

Taughtliner by the stern ramp on the main deck after grounding
still secured and in position

Figure 24b

Trailers still secured on the main deck after grounding
- note the flatbed with load still secured (circled)

Figure 25



Photographs taken during demolition showing trailers being removed substantially intact

2.5.1.3 Effect of cargo shift

Although it is not possible to ascertain precisely how much cargo shifted at this time, the QinetiQ study **(Annex 1, Section 3.4.3)** calculated the possible effects. Their results indicate that an angle of list of 10º could be obtained with a moderate, but not excessive, cargo shift. This cargo shift would have been equivalent to the contents of 27 of the trailers shifting by 1.92 m to port, or any of the following combination of variables:

Percentage cargo	No. Trailers	Distance moved by trailers (m)	Distance moved by contents (m)
100%	54	0.70	0.96
50%	27	1.40	1.92
33%	18	2.12	2.91
25%	14	2.80	3.84
10%	5	7.00	9.59

Table 2: Extract from QinetiQ report, Section 3.4.3 – Estimated cargo shift required to produce 10º of list.

It was, however, clear from the calculations that the shifting of the cargo alone would not have been sufficient to cause the larger angles of list and heel experienced by the vessel through the later stages of the accident **(Annex 1, Section 3.6.4 and 3.10.3)**.

2.5.2 "Freak" waves

During the initial reports made to the coastguard, it was suggested that the initial list was due to *Riverdance* being struck by a "freak" (i.e. abnormal) wave. However the area around Lune Deep is notorious for large, steep faced swells, and in the weather conditions experienced at the time of this accident, large and unpredictable swells could have been reasonably foreseen. Waves experienced by *Riverdance* might well have been excessive, with swell waves reported to be up to 7.0m. They would also have been intensified, and been made steeper, as a result of the ebb tide from Morecambe Bay. However, this could not be considered to be "freak", especially within this area.

2.5.3 Loss of GM

Wave forms generated during storm force winds generally travel in the same direction as the wind, although wave trains can build up with their own direction and velocity. In this case, where the wind was westerly for a considerable period of time, the waves had built up to a speed of close to 18 kts **(Annex 1, Section 3.1)**. When this wave movement was compared to *Riverdance*'s movement, the waves were calculated to be travelling slightly faster than the vessel. This may lead to several effects: pure loss of stability, surf riding, broaching and loss of directional stability. These effects are described in detail in IMO MSC.1/Circ.1228 **(Annex 14)**.

The dangers of navigating in following seas (running before the wind) are generally well known in deep sea conditions, especially in fuller form container vessel hulls, and include poor handling, loss of directional stability, wave surfing and uncontrollable broaching[9]. However these effects have not previously been generally considered to be significant in shallow or sheltered waters.

A wave travelling close to the same speed as the vessel can cause an effective loss of GM as it passes along the vessel, the greatest effect being at the position of greatest variation in overall waterplane area, usually when the crest is at midships. The effect is greater as the difference in speeds is reduced and the vessel "hangs" on the wave for longer. The effective loss of GM depends on several variables; wave height relative to the draught, and wave length relative to vessel length being the most notable.

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[9] The following documents are concerned with the dangers of navigating in following seas;

MSC/Circ.707 19 October 1995 GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN FOLLOWING AND QUARTERING SEAS superseded by IMO MSC.1/Circ.1228, 2007

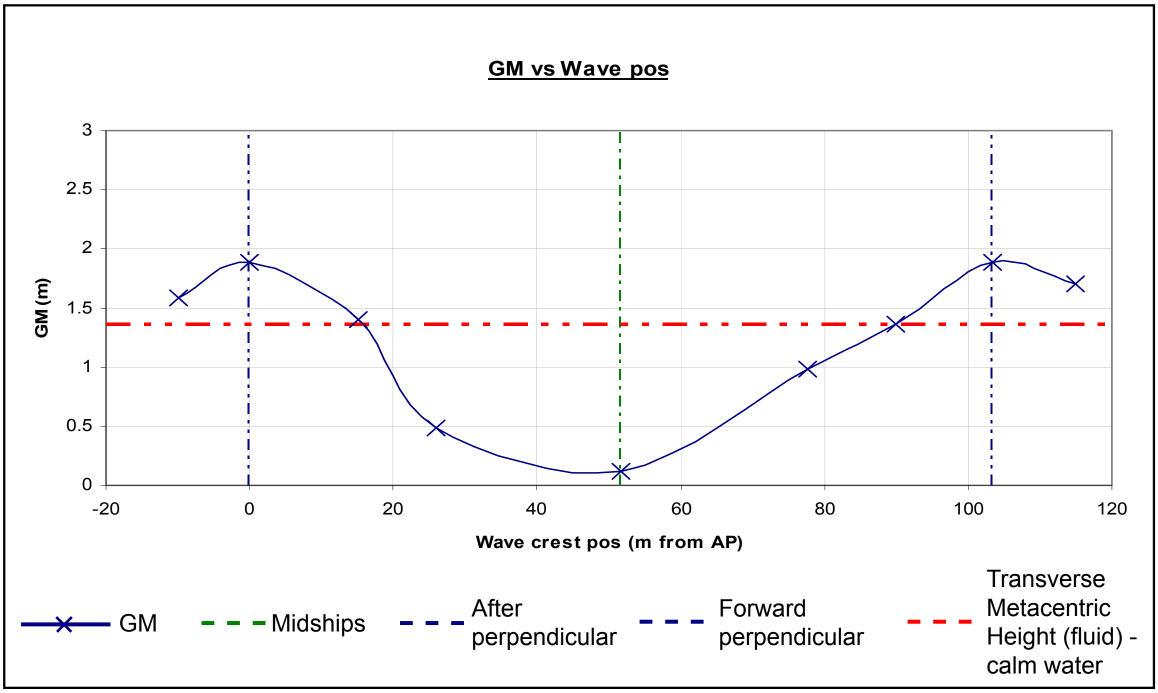
IMO Resolution A749 (18) CODE ON INTACT STABILITY FOR ALL TYPES OF SHIPS COVERED BY IMO INSTRUMENTS Chapter 2.5 November 1993

IMO Review of the intact stability code SLF 45/6/7 31 May 2002

QinetiQ Report (Annex 1, Section 4.1.14)

As can be seen in **Figure 26**, in the case of *Riverdance* there would have been a very large reduction in the GM as the wave passed amidships.

Figure 26



Loss of GM on a wave crest **(extract from Annex 1 - QinetiQ report, Section 3.2.11)**

Based on the departure stability condition of *Riverdance,* it was calculated that the GM could be reduced to 0.10 m or even less, during the passage of the waves.

The practical effect of the reduction of effective GM on *Riverdance* would have been to allow the application of any external force to result in a disproportionally large and slow, even hanging, roll. Recovery from the resulting angle of heel would be slow. Effective stability would not be regained until the GM began to increase as the wave passed forwards of amidships.

A wave, or train of waves, passing the vessel would result in a succession of slow rolls to either side, increasing in magnitude. In the worst case there would be insufficient righting lever, allowing the vessel to hang over to the one side, until the righting lever began to increase and be effective.

2.5.4 Ballast configuration

From the estimated departure condition, *Riverdance*'s stability was in compliance with the 1968 Load Line Regulations. However, the ballast configuration routinely adopted on board the vessel was probably inappropriate for the severe weather expected, and a more seamanlike precaution might have been to take additional ballast before sailing from Warrenpoint.

However, ballast was seldom adjusted or transferred within *Riverdance* during normal operations, and there is no evidence to suggest that ballast was being transferred before or during the periods of heavy rolling.

2.5.5 Use of heeling tanks

In addition to the designated ballast tanks, *Riverdance* was fitted with a heeling tank arrangement (see Section 1.10.3). This was not used for ballasting in the accepted meaning of ballast, i.e to adjust the vessel's draught or trim, but was provided solely to control and counter heels caused during loading/unloading operations in port by trailers as they were being positioned on the vessel.

It was routine for the system to be made ready for use during the arrival stand-by. On this occasion, the cross-over valves had been opened shortly after 1830, when the engineer on duty was given 1-hour's notice of stand-by; this did not follow the suggested timing indicated in the company's pre-arrival checklist. There was also a suggestion that *Riverdance* had a slight list, and that the duty engineer had been instructed to correct it. As the ballast tanks were not usually adjusted, it is probable that any correction of list would have been made using the heeling tank system.

When operating in port, at normal levels of heel, water was prevented from migrating between the heeling tanks by non return valves fitted within them. However, these valves could become ineffective in preventing ballast transferring between the tanks when the vessel was rolling to large or very large angles. The effectiveness of this arrangement would have been further reduced if the upper (discharge) non return valves in both heeling tanks had been seized in the partially open position, as noted during the inspection during demolition. It is considered that the valves were most likely to have been in this state during the incident as the similar style suction valves, located in the same space were inspected during the demolition and found to be fully functional.

2.5.6 Probable causes of the list to port

After *Riverdance* had suffered the large hanging roll, due to the loss of effective GM, some trailers and/or cargo from the trailers, either broke loose or shifted bodily to port. This is likely to have resulted in a residual list angle of about 10º to port, with rolling substantially in excess of this **(Annex 1, Section 3.4)**. Shortly after this, the master instigated a rapid turn to starboard.

In order to explain the severe list to port which subsequently occurred, MAIB examined the probable effect of the two most likely scenarios:

1) The effect of the turn to starboard and downflooding

   The rapid turn to starboard could have been sufficient to cause the vessel to broach as she turned, causing her port list to increase. If not broached, then *Riverdance* would have heeled further to port as she made her rapid turn to starboard. In either case, the larger port list which resulted would have been further increased due to the effect of the strong winds acting on her starboard hull and accommodation as she turned through the wind. Simulations of the likely resulting angle of heel produced by these scenarios concurred with witness reports where angles of up to 50º to port were reported. This magnitude of heel would have led to the port edge of the upper deck being submerged.

There were then a number of ways that water could have entered the vessel **(Annex 1, Sections 3.6.9 and 3.6.10)**:

(i) If it had not been possible to close the port weather door to the main deck due to it being blocked by cargo before waves started to break onto the port side deck (or if it had not been fully secured after closing and then re-opened) water could have entered through this doorway onto the main deck and then slowly drained down to the lower hold. However it is acknowledged that this door remained closed at this time, and water is unlikely to have entered the vehicle decks through this opening.

(ii) Although the vents to the lower hold were fitted with watertight flaps, these had not been closed and, at the extreme heel angles experienced in the turn, these vents would have been fully immersed, allowing water to downflood directly into the lower hold. Indeed, video footage from the rescue helicopter just prior to commencing winching operations shows these vents still being submerged by waves breaking, from time to time, over the portside deck edge.

(iii) Two further vents to the main deck and lower hold were located under the forward accommodation and these were also unsecured. However their height above the deck means they were unlikely to have become immersed.

Witness accounts indicated that there was some water in the lower hold, main deck aft and in the bow thruster room during the accident, although the amount is uncertain. Since it was claimed that these spaces did not contain water prior to the accident, this water must have entered the vessel at some stage during the listing and rolling.

2) The effect of the turn to starboard, and cross-flooding, involving the heeling tanks.

A) By gravity

Before the accident, *Riverdance* was said to be rolling slowly up to 15º - 20º. She then hung over to port at an angle of 20º to 30º, probably under the effect of reduced GM caused by the passing of a succession of wave trains. Also, during the turn to starboard, the vessel reportedly experienced angles of heel of up to 50º.

The result of such angles of heel would be to raise the level of the starboard heeling tank above that of the port tank. Since the isolating valves in the system cross-over pipeline were open at this time, this could then have allowed cross-flooding from the starboard heeling tank into the port heeling tank **(Annex 1, Section 3.8)**. Although there was a transfer pump fitted within the pipeline, this type of pump would offer minimal resistance to the flow of water, and in view of the size of the cross-over pipe (300 mm), would have allowed a significant amount of water to flow between the tanks in a short time.

On departure from Warrenpoint, the water level was reported to have been about the same in each of the two tanks, giving some 78 mt in each tank. At the angle of heel experienced during the rolling and turn, a large proportion of the contents of the starboard tank could have flowed by gravity to the port side tank. The effect of this shift of water within the vessel, combined with cargo shift, could have been sufficient to result in the angle of heel experienced when *Riverdance* came out of the turn.

B) By operation of the heeling pump

There is also the possibility that the heeling system was intentionally operated to correct an existing list. As the duty engineer had only recently joined *Riverdance,* he might have been surprised by the speed that the transfer pump operated **(Annex 19)**; with a capacity of 600 m^3/hr, the entire 78 mt of water in the starboard tank could have been transferred within 10 minutes. For this to have been a real possibility, the duty engineer must have operated the system incorrectly and pumped the wrong way, i.e from starboard to port. Therefore, although in theory, possible, this is considered highly unlikely.

The effect on *Riverdance* of either of these possibilities, combined with the initial cargo shift, would have been sufficient for the vessel to come out of the starboard turn with the angle of list to port of around 30º to 40º **(Figure 27 and Annex 1, Section 3.8.25)**.

2.5.7 Cause of the list to port

It is not possible to establish with certainty the precise reasons why *Riverdance* experienced the excessive lists on 31 January 2008. However, it is probable that a combination of the scenarios discussed above existed that night. What is known is that the list of 35º experienced on the exit from the sudden turn to starboard is unlikely to have been caused by the effect of cargo shift alone **(Annex 1, Section 3.10.3)**.

Accredited clone copyright MOD 31/01/2008: RAF SAR Force

Figure 27

RAF video showing median list of 30 to 40°

2.6 REFLOATING AND THE FINAL LIST TO STARBOARD

2.6.1 Preparation to refloat

Although the situation was still critical, once *Riverdance* had grounded, both the master and the members of the CMT were confident that she was now stable and that she would be refloated on the next tide. In fact, little had changed for the better: the wind and sea were not expected to reduce; no tugs were available; the stability of the vessel was unknown; and both main engines had stopped.

Although there had been discussions between the master and the CMT, the decision to refloat and the details of any plan were left to the master. No calculations on the vessel's stability had been made either on board or ashore. While still aground, the use of anchors could have helped bring the vessel into the wind and sea once afloat, and stopped the vessel being carried further onto the beach. This option was not taken although it was reportedly considered.

2.6.2 Cause of the final grounding and list to starboard

With no stability calculations undertaken, when the decision was taken to move ballast within the vessel, the decision on how much ballast to alter was taken based on the master's estimation. In the final event, due to problems encountered in operating some of the ballast tank valves, only number 3 port and number 8 starboard tanks were reballasted; this was assumed to be sufficient, even though it was less than originally planned.

Once afloat, unsurprisingly, *Riverdance* could not be manoeuvred head to sea, so the wind and tide set her further up the beach, turning her beam on to the elements. The master then suspended his attempt to refloat the vessel pending a further rise in the tide. Even at this stage, with proper contingency planning, *Riverdance*'s anchors could have been used to attempt to prevent the vessel being carried closer to shore on the still rising tide, or she could have been ballasted heavily to stabilise the situation. This would have given time to arrange for a full check on stability, and to arrange for tugs to be standing-by ready to render assistance, before starting further attempts to refloat *Riverdance.*

As *Riverdance* lay parallel to the beach line, she was still rolling under the influence of wind and sea, and her rolls began to be progressively more towards the starboard side. Finally, there was a swifter roll that resulted in her listing heavily to starboard, i.e. against the wind and sea, which was accompanied by the sound of cargo shifting across the vehicle decks from port to starboard. When the effect of the redistribution of ballast was subsequently calculated, even though it was less than planned, it was evaluated that, if floating freely, there would have been a resultant list of about 30º to starboard **(Annex 1, Section 3.10.8)** (excluding any effects of cargo shifting back to starboard).

2.7 SAFETY MANAGEMENT SYSTEM

2.7.1 Provision of guidance

There was little guidance offered to masters in the navigational (passage planning) section of the Seatruck SMS **(Annex 20)**, and no specific advice for operating in heavy weather. Seatruck's masters were experienced in operating in the Irish Sea, were familiar with the handling of their vessel, and were considered better placed to make operational decisions than those based in the office ashore. However, none of the bridge team on *Riverdance* was aware of the guidance available to masters from IMO for avoiding dangerous situations in following or quartering seas, **(Annex 14)**, and little consideration appeared to be given to the warnings and guidance given in the T&S Booklet **(Annex 15)**.

2.7.2 Stability requirements

The SMS contained references to the need for stability calculations to be completed prior to departure, yet on board *Riverdance* this procedure had largely been ignored since the development of the WCS.

The vessel's SMS had not been changed to reflect this change of procedure, and the anomaly was not detected during internal audits of the vessel.

2.7.3 Audits

Internal SMS audits are carried out to verify that ships are operated safely and in accordance with the instructions contained within the relevant SMS manual. The audits are also intended to verify continued compliance with the ISM Code. During the most recent internal audits of *Riverdance,* a number of omissions and contradictions relating to the SMS and deck department practices were identified. However, the findings of the last internal audit conducted on *Riverdance* were promulgated via an internal office memo **(Annex 11)** rather than utilising the designated SMS reporting forms. Accordingly, the issues raised during this audit were never formally entered as non conformities into the company's SMS records.

It is important, wherever possible, that auditors are sufficiently detached from the vessel to avoid bias, and that they are suitably trained and experienced to carry out the task. In the case of *Riverdance,* due to the size of the company, it was difficult to ensure that auditors assigned to conduct audits were sufficiently independent of the day to day operation of the vessel.

Each of the audits conducted on *Riverdance* was carried out by a different auditor, including serving sea staff, with the most recent audit being conducted by an experienced chief officer. However, he was not a trained ISM auditor. This might have resulted in an unwillingness to raise, formally, non conformities against procedures considered to be contrary to the SMS procedures.

In the external DNV audit for the annual endorsement of the DOC, which was conducted on 10 September 2007 **(Annex 10)**, the absence of a procedure to track non conformities and incident reports was highlighted. A further observation suggested that "root cause" identification should be made for each and every incident/accident.

2.7.4 Incident reporting

During the 11 years *Riverdance* operated between Heysham and Warrenpoint, she reported a total of 111 incidents, of which 11 involved cargo shifts and/or involving large lists, including an almost identical event in April 1998 (see Section 2.12). During the same period, *Moondance* reported a total of 66 incidents, 3 of which involved cargo shift. The difference in this level of reports indicates that either *Riverdance* was experiencing a much higher level of cargo incidents, or that there was a difference in the two vessels' reporting culture.

The company analysis of the cargo related incidents consistently blamed cargo shift as the root cause. No further consideration was given to the possibility that the different incident rate might have been because the two vessels were operating in different ways. Consequently, no measures were considered to reduce the frequency of such incidents on *Riverdance*. In particular, the 1998 incident might have been a key indicator to a serious problem.

2.8 CRISIS MANAGEMENT TEAM

Seatruck's SMS required the establishment of a Crisis Management Team (CMT), consisting of senior Seatruck managers and superintendents, to respond to any emergency arising involving a company vessel. The procedures within the SMS required the Crisis Manager (CM) to take into consideration the following:

> *"In formulating his plan of action, the Crisis Manager should consult the emergency checklists, crisis management emergency checklist and flowchart, bearing in mind the need to adapt to the particular incident"*

The CMT procedures had been established in October 2007, and Seatruck conducted an exercise to practise the procedures on 21 January 2008, only 10 days prior to this accident.

After the accident, Seatruck's CMT was assembled and was informed that *Riverdance* had suffered a serious cargo shift. Guidance for the CMT, covering this scenario, was provided in the company's SMS by a specific checklist **(Annex 6)**. Initial action called for by this guidance included confirmation of the vessel's watertight integrity and stability.

Later, when *Riverdance* had grounded, further guidance was available to the CMT in the form of another checklist entitled Grounding/Stranding **(Annex 5)**. This form included a requirement to verify the watertight integrity of the hull, that all tanks had been sounded, and to fully assess any damage.

A number of other precautionary measures were detailed on both forms.

During this period, the role of the CMT was to assist and provide guidance to the master, making suggestions and checking that the items required in the checklists had been considered and methodically worked through. This included, but was not limited to, the proposed plan to attempt to refloat on the next tide and the intended redistribution of ballast prior to refloating.

Unfortunately, due to a lack of ship's documentation available to it, and no access to the vessel's loaded condition during the crisis, the CMT was heavily reliant on the master's estimate of how much ballast needed to be redistributed.

The initial plan proposed by the vessel, and endorsed by the CMT, was to de-ballast number 3 port and fully ballast numbers 2 and 8 starboard tanks, while also transferring the whole contents of the heeling system from port to starboard.

In the absence of detailed stability information for *Riverdance,* the CMT was unable to determine, with any accuracy, the likely outcome of the proposed ballast plan.

It is clear that, if there had been access to accurate stability information, the CMT would have been better placed to understand and influence the situation.

During this operation difficulties with the hydraulic system prevented the use of No 2 starboard. This reduced the amount that could be ballasted by about 70 mt. Again, the CMT was unable to determine the effects of this change to the intended plan.

Most classification societies, and many leading marine consultancies, provide an Emergency Response Service (ERS) designed to provide assistance to ship-owners, managers and masters when their vessels run into an emergency situation, such as that experienced by *Riverdance* that night. Indeed, such a “back up” service is mandatory under the requirements of MARPOL Annex I for tankers over 5,000 tonnes deadweight. Under such services ship operators are, typically, provided with computerised models to assess their vessels’ stability and residual strength. ERS shore-based teams are made available to assist and support the masters’ decision making during what are likely to be highly stressful and arduous situations.

The pre planning and support provided by an ERS could have greatly enhanced the ability of the CMT and the master to analyse the potential risks to *Riverdance* throughout the incident, and to identify the optimum course of action.

2.9 INFORMATION PROVIDED BY THE TERMINALS

2.9.1 Port operation

The port operations at both Heysham and Warrenpoint were highly focused on the shipping of trailers quickly and effectively. Check-in procedures were cursory, relying substantially on the declaration of the driver, without any controls to verify the information provided.

2.9.2 Loading

Shipping charges were based on the length of the trailer rather than the weight of the unit, so there was little incentive for Seatruck to develop procedures to confirm the weights of trailers. Another indication of a lack of concern in this area was evident by the continued assumption that a trailer’s maximum weight would be 30 mt. In fact, loaded trailers, within the UK, may legally weigh up to 36 mt. This could allow the driver of a 36 mt trailer to correctly state at check-in that he had a full load, and the terminal staff would assume this statement to mean the trailer weighed 30 mt.

This style of terminal operation did not lend itself to providing detailed pre planning or pre allocation of stowage of the trailers. Only the basic division between upper and main deck stowage was provided to the master on arrival at the terminal. Since the weights were based only on the driver’s declaration, the plan was often modified when ships’ officers identified trailers that appeared too heavy for stowage on the upper deck, as they drove on board.

2.9.3 Verification of cargo weight

It is a requirement under SOLAS Chapter VI Carriage of Cargoes (Regulation 2) that:

> *The shipper provides the master or his representative with appropriate information on the cargo sufficiently in advance of loading to enable the precautions which may be necessary for proper stowage and safe carriage to be put into effect.*

This should ensure that the master has accurate knowledge of the weight of the intended cargo to be shipped on his vessel to allow him to ensure that his vessel has adequate reserves of stability. Under the procedures followed by the terminals on this service, both of which were operated by Seatruck, and possibly others which do not routinely weigh trailers, this information was not readily available.

The procedures adopted by the terminals on this service appeared to be focused more on providing a service to the road haulage customers, than on ensuring the master was provided with accurate information to calculate the vessel's condition before departure.

After the accident MAIB, in co-operation with the port authorities in Heysham, made two spot-checks. The first checks were of 50 random trailers from the trailer park. This check revealed inaccuracies in the declared weights that cumulated in an under-declared weight of 112 mt (17.5%).

A second check was made of the cargo carried on a randomly selected voyage of *Moondance*. Again, there were inaccuracies, and the total under declared weight of cargo on this occasion was 71.7 mt (7.8%). Also, during this second check, four of the trailers loaded according to the ship's manifest, could not be positively matched to any of the trailers actually loaded; as the total number of trailers shipped was in agreement with the manifest, this would seem to indicate that four incorrect trailers were shipped.

2.9.4 Cargo information

It is a requirement of the Merchant Shipping (Weighing of Goods Vehicles and Other Cargo) Regulations 1988, as explained in MSN 1393 **(Annex 21)**, for trailers to be weighed when carried on UK registered Class II and Class IIA ro-ro passenger ferries, serving UK ports. There is no similar requirement to do so for cargo ro-ro's carrying fewer than 12 passengers. As *Riverdance* was a Class VII cargo vessel, there was no requirement to weigh trailers, so no procedures had been developed within the terminal to do this. Although there was a weighbridge at Heysham, it was not regularly used to spot-check, or otherwise verify, trailer weights. Consequently, the only information that was available to the master was based on the driver's declaration when checking in the trailers at the terminal.

A direct result of inaccurate cargo information is that accurate stability calculations cannot be conducted. On *Riverdance* cargo information was occasionally confirmed to be inaccurate when draught checks were conducted, and substantial differences between observed and calculated displacements were sometimes noted. Prior to the accident the calculated displacement of *Riverdance* agreed substantially with the observed draughts at Warrenpoint; this served to confirm only the total weight of trailers, not the distribution or that each trailer's weight was accurately declared.

It appears illogical that UK regulations require only trailers which are destined to be loaded onto Class II and IIA ro-ro passenger vessels to be weighed. SOLAS Chapter VI is equally applicable to Class VII ro-ro cargo vessels.

2.10 SECURING ARRANGEMENTS WITHIN TRAILERS

The securing (lashing) of cargo trailers on the vessel was of great importance to Seatruck. However, the arrangements used to secure loads onto the trailer were only checked if inspection could be easily achieved. Taughtliners (closed or curtain sided trailers) and customs sealed trailers were rarely inspected unless there was clear evidence, such as bulging curtain sides, of cargo shift prior to loading onto the vessel **(Figure 10)**. The internal securing systems provided in taughtliners **(Figure 28)** are designed to restrict lateral movement of the load which might be expected during normal road transport. The location of the securing straps does not provide an easy means to secure the load downwards onto the trailer bed as the lashings are secured to a top rail inside the unit. This is not ideal for resisting the forces that may occur during a sea passage.

As a result of the previous cargo shifting and listing incidents, Seatruck had circulated guidance to its regular clients on how to secure cargo for sea transport. However, Seatruck had found great difficulty in convincing shippers that lashings needed to be firmly secured and additional securing was needed when shipping by sea.

Industry guidance has been provided by both the IMO and the (UK) Department for Transport, for hauliers and shippers, regarding securing cargoes effectively for shipment by sea **(Annex 22)**. However, it has been an acknowledged, industry-wide problem, that many hauliers do not fully understand the forces to which trailers and their cargoes are subjected during a sea passage.

There is a clear need for further work to be done to ensure that shippers and hauliers recognise the importance of stowing and securing the contents of trailers destined to be transported by sea and adhere to the available guidance on this issue.

Figure 28

Securing arrangement within a “taughtliner”
Note: cargo is not secured down onto the trailer deck

2.11 RO-RO SAFETY

The stability of a vessel is fundamental to its safety.

This investigation has highlighted a widespread acceptance of ro-ro vessels being operated without the weight or distribution of the cargo being known. This attitude appears analogous to that already found during MAIB investigations into accidents which have occurred within the container shipping industry. Containers shipped by sea are rarely weighed and ships’ stow plans are invariably based upon shippers’ declared weights. In commenting on the absence of cargo information provided to the master of *Annabella* (MAIB report No 21/2007), it was noted that:

> *Notwithstanding any cargo planning carried out ashore, the master has ultimate responsibility for the safety of his vessel. He must therefore be given the tools and the time to satisfy himself of the safety of the planned cargo*.

The SOLAS regulations[10] require "*…that the master shall be supplied with such information...as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service.*"

In the absence of specific and accurate information on the disposition and weight of cargo on board his vessel, it is difficult to rationalise how any master can be expected to verify the stability of his vessel, especially when, like the master of *Riverdance*, he is faced with the need to take emergency measures such as counteracting the effects of sudden cargo shift or water ingress.

Further concern over attitudes to cargo safety in the ro-ro industry has been raised during another current MAIB investigation in which a large articulated vehicle broke free from its cargo lashing. Early findings from this investigation indicate that a significant majority of goods vehicles shipped onboard ro-ro vessels are not fitted with appropriate lashing points, and that the lashing points provided on cargo decks of some ro-ro vessels operating from UK ports are not sufficient to allow such vehicles to be adequately secured. As a result, when chocks and lashings are applied, they are often used in an ad-hoc way, that rarely optimises their effectiveness.

In the *Riverdance* case, the trailer lashings were extremely effective; however the cargo still shifted due to it not being properly secured within the trailers. Despite efforts by Seatruck, hauliers and shippers still do not recognise the importance of stowing and securing the contents of trailers destined to be transported by sea.

Taken together, it becomes clear that there has been a widespread acceptance of unsafe practices with relation to stability within ro-ro vessels. Fundamental requirements, from accurate knowledge of the weight and distribution of cargo to allow stability calculations to be made, through to the ability to properly chock and lash a trailer, and the securing of cargoes within trailers, have all become eroded with time. As a consequence, there is an urgent need for a study of the means by which masters of all ro-ro vessels operating to and from UK ports should ensure the safety of their vessels.

2.12 INTERNATIONAL MARITIME ORGANIZATION

The IMO has produced guidance to masters on the operation of vessels in heavy weather **(Annex 14)**, and to masters and shippers on the securing of cargo for transport by sea **(Annex 22)**. It is evident, however, that this information is not effectively promulgated to the intended recipients.

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[10] SOLAS Chapter II-1 Resolution 22

Poor promulgation of IMO information was one of the findings of the New Zealand Transport Accident Investigation Commission investigation report into a heavy weather incident in the Cook Straight in March 2006, involving the ferry *Aratere*[11], which also experienced heavy rolling and cargo shift.

2.13 SIMILAR ACCIDENTS

Riverdance and her sister vessel *Moondance* had both experienced previous incidents involving severe listing and cargo shifts. The following extracts are from Seatruck's incident reports:

Riverdance

Nov 06 – in south-south-east Beaufort 9, *Riverdance* experienced very heavy rolling resulting in three trailers slipping off trestles and the contents of two trailers shifting.

Jan 06 – in southerly Beaufort 9/10, *Riverdance* experienced heavy rolling, resulting in cargo shifting within a curtain-sided trailer and breaking out of the trailer.

Apr 05 – in south by west Beaufort 7, in rough seas, two trailers shifted. It was suggested that one of them was "very heavy".

Jan 05 – in west-south-west Beaufort 8, *Riverdance* experienced very heavy rolling, resulting in the collapse of the trestle, due to a possible shift of cargo within the trailer.

Jan 05 – in south-west Beaufort 10/11 (in a position 4 miles from the accident on 31 January 2008), *Riverdance* rolled and pitched heavily when cargo within seven trailers shifted.

Feb 04 – in south-west Beaufort 8, cargo in several trailers shifted due to lack of internal securing. All ship's lashings held.

Oct 00 – in south-south-east Beaufort 7, while rolling and pitching heavily, cargo shifted within three trailers due to insufficient internal lashing.

Nov 99 – in south-south-west Beaufort 9/10, while rolling and pitching heavily, cargo shifted within five trailers due to insufficient internal lashing.

Nov 99 – in west-south-west Beaufort 9/10, the vessel experienced a heavy roll into a deep trough. Cargo broke loose within two trailers due to insufficient internal lashing; several of the lashings on these trailers and one other then failed.

[11] *Aratere* - New Zealand Transport Accident Investigation Commission investigation Report 06-201

Oct 98 – in southerly Beaufort 6/7, the vessel experienced heavy rolling while approaching Hellyhunter Buoy. Lashing points on two tipper trucks broke free.

Apr 98 – in north-east Beaufort 9, *Riverdance* experienced two successive waves on the starboard quarter, causing her to roll heavily to port and slew to starboard. This caused cargo shift on both the main and weather decks. Although the ship's lashings all held, there was cargo shifting within trailers.

Moondance

Dec 03 – in north-west Beaufort 8, during heavy rolling, an articulated vehicle fell on its side due to internal cargo shift.

Feb 07 – In southerly force 9 (very rough sea and heavy swell). Vessel experienced 3 heavy rolls in sequence. On the weather deck one trailer broke free due to 2 lashing pots failing.

Mar 07 – in west-south-west Beaufort 8, during heavy rolling, internal cargo shift caused a trailer to shift off the trestle and rest on the bulwark, pulling two lashings out of deck fittings and one chain to snap.

Other similar accidents:

Aratere

In March 2006 a New Zealand ro-ro ferry navigating in the Cook Strait experienced periods of extreme rolling, and had difficulty in maintaining her heading. This incident was investigated by the New Zealand Transport Accident Investigation Commission. One of the conclusions noted in the investigation report states that this accident resulted from navigation in following seas. The master was unaware of the IMO guidance to masters in MSC.1/Circ.1228.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

1. Fundamental requirements, from accurate knowledge of the weight and distribution of cargo to allow stability calculations to be made, through to the ability to properly chock and lash a trailer, and the securing of cargoes with trailers have all become eroded with time. [2.11]

2. The only trailer weight information was based on the driver's declaration. A direct result of inaccurate cargo information was that accurate stability calculations could not be conducted. [2.9.4]

3. It appears illogical that UK regulations require only trailers which are destined to be loaded onto Class II and IIA ro-ro passenger vessels to be weighed. SOLAS Chapter VI is equally applicable to Class VII ro-ro cargo vessels. [2.9.4]

4. The role of the CMT was to assist and provide guidance to the master. If there had been access to accurate stability information the CMT would have been better placed to understand and influence the situation. [2.8]

5. The use of an Emergency Response Service, such as that provided by most classification societies, would have greatly enhanced the ability of the Crisis Management Team and ship's staff to analyse the potential risk to *Riverdance* and identify the optimum course of action. [2.8]

6. The internal cargo securing systems provided in taughtliners are not ideal for resisting the forces that may occur during a sea passage. [2.10]

3.2 OTHER SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

1. The IMO has produced guidance, both to ships and shippers, on securing of cargo for transport by sea. There was also the guidance to masters for navigation in heavy weather, however it is evident that this information was not effectively promulgated to the intended recipients. [2.5.3, 2.10, 2.12]

3.3 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED

1. The weather conditions at the time of the initial heeling accident were very poor and could have led to difficulties in steering, broaching or loss of effective GM. [2.3, 2.5.3]

2. The SMS was found to be deficient in a significant number of areas. [2.4.3, 2.4.4, 2.7.1, 2.7.2, 2.7.3]

3. Although each of the audits conducted on *Riverdance* was carried out by a different auditor, the most recent auditor was inexperienced and unqualified in audit procedures. [2.7.3]

4. Over reliance was placed on the results produced in the Worst Case Scenario stability calculation, which indicated the condition complied with the 1968 Load Line Regulations when, in fact, it was non-compliant. [2.4.3, 2.7.2]

5. The condition selected as the Worst Case Scenario was not checked by Seatruck, and contained errors. [2.4.3]

6. Officers on *Riverdance* placed substantial reliance on the results of the Worst Case Scenario. This, combined with the inherent difficulty in obtaining reliable and accurate figures for cargo weights, led to the SMS requirement for calculating the vessel's stability prior to sailing falling into abeyance. [2.4.3, 2.7.2]

7. No consideration was given to taking on board additional ballast in preparation for the expected severe weather. [2.4.4, 2.5.4]

8. The master decided to sail based on his knowledge and experience. However, there was no checklist or guidance in the SMS on how Seatruck wished its vessel to be operated in heavy weather, and the master was unaware of the guidance contained in IMO Circ.1228 to masters, on operating in heavy weather. [2.4.4, 2.7.1]

9. Although the trailers were well secured, some cargo shifted from within them. [2.5.1, 2.10]

10. Although there was a requirement in the trim and stability booklet, "instructions to the master" to secure "*hatches, manholes and portable plates leading to spaces below the main deck"* the air vents to the lower hold were not secured. [2.4.4, 2.5.6]

11. Actions to redistribute ballast, prior to refloating, were taken without accurate assessment of the situation, and the results of these transfers were not checked prior to transfer, either on board or ashore by the Crisis Management Team. [2.6.1, 2.6.2, 2.8]

12. Spot-checks of 50 random trailers from the trailer park, and on a randomly selected voyage by *Moondance,* revealed inaccuracies in the declared weights, with cumulative under declared weights of 112 mt and 72 mt respectively. [2.9.4]

13. Due to the size of the company, it was difficult to ensure that auditors assigned to conduct ISM audits were sufficiently independent of the day to day operation of the vessel they audited. [2.7.3]

14. Proper procedures to conduct the audits and report findings were not implemented by Seatruck during the auditing process. [2.7.3]

15. There was an absence of procedure to track non conformities and incident reports. "Root cause" analysis should be made for every incident. [2.7.3]

SECTION 4 - ACTION TAKEN

4.1 MARINE ACCIDENT INVESTIGATION BRANCH has:

1. As a result of this accident, and the grounding of MV *Moondance*, the Chief Inspector of Marine Accidents has issued the following urgent safety recommendations to **Seatruck Ferries Shipholding Limited**:

   S2008/171 Take immediate action to verify the safe operation of all Seatruck vessels and ensure, in particular, that such vessels operate at all times with adequate reserves of stability, which satisfy the Load Line Convention.

   S2008/172 Conduct an urgent review of the fundamentals of the existing Seatruck Safety Management system, to ensure these are adequate for the purpose in the short term, until a full review of the system can be completed.

2. Following an investigation into an accident involving the sister vessel *Moondance* in Warrenpoint Harbour, Northern Island, 29 June 2008 (MAIB report No 5/2009) made the following recommendations to:

   *The **Bahamas Maritime Authority** to:*

   2009/109 Take urgent action to review the validity of Seatruck Shipholding Limited's Safety Management Systems to ensure they are sufficiently robust for safe operation of its vessels.

   ***Seatruck Ferries Shipholding Limited** to:*

   2009/110 Provide guidance to suitably trained internal ISM auditors on the scope of their responsibilities, including assessment of crew knowledge, departmental management and inter-departmental communications.

   2009/111 Undertake a review of the onboard risk assessment procedures to ensure its vessels comply with Seatruck Ferries Shipholding Limited's policy.

3. Produced a flyer containing lessons to be learned from this accident. It will be distributed to the industry when this report is published.

4. Has developed an MOU with salvors to ensure appropriate access in the aftermath of future accidents.

4.2 SEATRUCK FERRIES SHIPHOLDING LIMITED has:

1. Accepted and complied with the intent of MAIB recommendations S2008/171; S2008/172; 2009/110 and 2009/111.
2. Commenced an internal review of the company's existing safety management system, following a full independent audit carried out by Det Norske Veritas on 5 September 2008.
3. Carried out a review of the SMS, involving masters and third party experts.
4. Identified a number of masters and chief engineers who are considered suitable for receiving training as internal auditors, and further work is ongoing to identify appropriate ISM audit training courses.
5. Provided guidance to internal ISM auditors on the scope of their responsibilities, including assessment of crew knowledge, departmental management and inter-departmental communications.
6. Produced notices to hauliers (handout/letters/website) regarding securing cargo within a unit, to raise awareness of ensuring cargo lashing adequacy.
7. Carried out spot-checks on declared cargo weights.
8. Reviewed the safe operation of vessels with regard to stability.
9. Produced guidance to masters concerning
   - Adverse weather conditions
   - Stability.
10. Commissioned new stability programs for *Moondance.*
11. Commenced trials of a revised trestle system.
12. Planned to introduce weighbridge facilities at all Seatruck terminals by 2013.

4.3 BAHAMAS MARITIME AUTHORITY has:

1. Undertaken to commission a full, independent, audit of Seatruck's SMS following completion of Seatruck's own internal review, currently underway.

SECTION 5 - RECOMMENDATIONS

The **Department for Transport** and the **Maritime and Coastguard Agency** are recommended to:

2009/153 Conduct an urgent study into stability and operational issues which impinge on the safety of ro-ro vessels operating from UK ports. In particular, the study should identify how the stowage plan should be produced and implemented, how masters can establish the stability of their vessel before sailing, and under varying conditions of service, the securing of trailers, and the securing of cargo within trailers to prevent their movement whilst at sea.

The **Road Haulage Association** and the **Freight Transport Association** are recommended to:

2009/154 Provide guidance to shippers on the additional securing of cargo onto trailers intended for shipping by sea to withstand the dynamic forces that may be experienced.

The **Maritime and Coastguard Agency** and the **Bahamas Maritime Authority** are recommended to:

2009/155 Ensure proper and effective methods exist to promulgate and disseminate safety information produced by IMO, and other relevant organisations, to ship operators.

The **International Chamber of Shipping** is recommended to:

2009/156 Review existing guidance to owners on "Emergency Preparedness" and promote careful consideration of the merits of using Emergency Response Services.

Interferry and the **International Chamber of Shipping** are recommended to:

2009/157 Promulgate to ship owners/managers the MAIB Safety Flyer describing this accident and the principal lessons learned from it.

September 2009
Marine Accident Investigation Branch

Safety recommendations shall in no case create a presumption of blame or liability