Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Ministry
of Transport and Digital Infrastructure

Investigation Report 12/16

Serious Marine Casualty

Collision between the Rendsburg transporter bridge and freighter EVERT PRAHM with subsequent grounding of the EVERT PRAHM on 8 January 2016

25 March 2020

This investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Act – SUG). According to said Law, the sole objective of this investigation is to prevent future accidents. This investigation does not serve to ascertain fault, liability or claims (Article 9(2) SUG).

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 34(4) SUG.

The German text shall prevail in the interpretation of this investigation report.

Issued by:
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Table of Amendments

Page	Amendment	Date
3	Insertion of a table of amendments on an additional page. This changes the total number of pages.	10.02.2021
33	Figure 28: “portside wing” replaced by “starboardside wing”	10.02.2021
53	Subsection. 3.4.5: „see Figure 45“ replaced by „see Figure 47“	10.02.2021
101	The text: “When the transporter bridge's operator docked on the northern bank on the morning of the accident after Ship A had passed, the EVERT PRAHM's masthead light was already visible in the video when the signal lights on the transporter bridge went on (see Figure 84, red arrow = EVERT PRAHM's masthead light). The storm hook was released within six seconds of this happening, whereupon the purple bridge light extinguished. Within another five seconds the transporter bridge moved away from the dock and thus directly toward the EVERT PRAHM.” was replaced by “When the transporter bridge's operator docked on the northern bank on the morning of the accident after Ship A had passed, the EVERT PRAHM's masthead light was already visible in the video when the signal lights on the transporter bridge went on after the storm hook was released (see Figure 84: red arrow = EVERT PRAHM's forward masthead light). Within six seconds, the violet illumination of the bridge pier went out. Within another five seconds the transporter bridge moved away from the dock and thus directly toward the EVERT PRAHM.”	10.02.2021
117	„Figures 25 bis 29, 31 bis 46, 74: BSU“ replaced by „Figures 25 bis 29, 31 bis 36, 38 bis 46, 74: BSU“.	10.02.2021

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1 SUMMARY

The German-flagged coaster EVERT PRAHM transited the Kiel Canal westbound on 8 January 2016 during her voyage from Liepaja in Latvia to Husum in Germany. The bridge was manned by the chief officer and a cadet. A canal pilot was also on the bridge. A 2-3 Bft south-easterly wind which was slowly turning to the south-west blew in the early hours of the morning. *Inter alia*, snow and black ice warnings had been issued for the Rendsburg-Eckernförde area. There was snow and freezing rain during the night. Wind forces of 4-5 Bft with gusts of 6-7 Bft were measured at Rendsburg after 0600[1]. The air temperature stood at about 3 °C and there was light rain.

The EVERT PRAHM approached the railway bridge at Rendsburg in darkness at 0635. Her speed over ground (SOG) was about 8.8 kts. The transporter bridge suspended below the railway bridge was on the northern bank of the Kiel Canal at the time. In addition to the operator, there was also a passenger on the transporter bridge. The EVERT PRAHM kept to the middle of the fairway and was just short of the railway bridge when the transporter bridge set off toward the southern bank. Despite the EVERT PRAHM executing a full astern manoeuvre combined with hard to port, it was not possible to prevent the collision. The transporter bridge struck amidships against the hatch, was briefly snagged, rotated, and then released again. It then struck the starboard wing before scraping over the wheelhouse, dragging the antenna, radar and stern mast with it in the process. The EVERT PRAHM sailed gently onto the southern embankment at canal kilometre 62.5. She freed herself unassisted by means of a stern manoeuvre. She then sailed into the Kreishafen of Rendsburg and made fast there at 0715.

As a result of the accident the Kiel Canal and the railway bridge at Rendsburg were closed to maritime traffic and to rail traffic respectively.

The transporter bridge was severely damaged due to the collision and partially torn out of the rail track. It was stuck over the middle of the Kiel Canal. The operator was seriously injured due to the collision. The only passenger on the transporter bridge was also injured. With the assistance of the canal ferry MEMEL, both people could be rescued from the transporter bridge and taken to hospital. The emergency responders managed to re-engage the transporter bridge and move it to the southern side of the canal by about midday.

[1] All times shown in this report are local = UTC+1.

2 FACTUAL INFORMATION

2.1 EVERT PRAHM

2.1.1 Photograph of the ship

© Hasenpusch Photo-Productions

Figure 1: Photograph of the EVERT PRAHM

2.1.2 Ship particulars

Name of ship:	EVERT PRAHM
Type of ship:	General cargo ship
Nationality/Flag:	Germany
Port of registry:	Leer
IMO number:	9138757
Call sign:	DQRI
Owner:	Karl Meyer Shipping International GmbH & Co. KG[2]
Year built:	1996
Shipyard/Yard number:	Koetter-Werft GmbH/90
Classification society:	DNV GL[3]
Length overall:	78.25 m
Breadth overall:	11.65 m
Gross tonnage:	1,598
Deadweight:	2,398 t
Draught (max.):	4.50 m
Engine rating:	1,320 kW
Main engine:	S.K.L. 6VD29/24AL-2

[2] Karl Meyer Shipping International GmbH & Co. KG manages shipping operations for Hammann & Prahm Reederei GmbH.

[3] Classification society at the time of the accident.

(Service) Speed:	11 kts
Hull material:	Steel
Minimum safe manning:	5

2.1.3 Voyage particulars

Port of departure:	Liepaja, Latvia
Port of call:	Husum, Germany
Type of voyage:	Merchant shipping, international
Cargo information:	1,903 t maize
Manning:	7
Draught at time of accident:	4.1 m
Pilot on board:	Yes
Canal helmsman:	No
Number of passengers:	0

2.2 Transporter bridge

© Bartzsch/Geißler/Schmachtenberg

Figure 2: Photograph of the transporter bridge

2.2.1 Transporter bridge particulars

Entry into service:	2 December 1913
Location:	Rendsburg, canal kilometre 62.644
Operator:	Waterways and Shipping Office (WSA) Kiel-Holtenau

	(duty station: Rendsburg)
Length:	14 m
Breadth:	6 m
Maximum load capacity:	7.5 t
Suspension system:	Four vertical suspension cables, eight diagonal tension cables
Weight of gondola:	About 37 t
Weight of suspension system:	350 kg per cable
Weight of superstructure:	About 41 t
Diameter of suspension cables:	38.2 mm
Maximum speed:	5 km
Distance crossed:	120 m
Propulsion:	Four 21 bhp electric motors installed in four arms with two iron wheels each
Diameter of the wheels:	1 m
Duration of crossing:	About 2 minutes
Power supply:	400 V AC via conductor line
Height above water:	About 3 m
Material:	Steel
Operating personnel:	1

2.2.2 Marine casualty information

Type of marine casualty:	Serious marine casualty; collision with physical injury
Date, time:	8 January 2016, 0638
Location:	Kiel Canal
Latitude/Longitude:	φ 54°17.61' N λ 009°40.96' E
Ship operation and voyage segment:	Estuary trading
Place on board:	Ship's side amidships (starboard), superstructure
Consequences:	Two casualties and material damage

Extract from Official Navigational Chart No 3009 (detailed chart), (BSH)

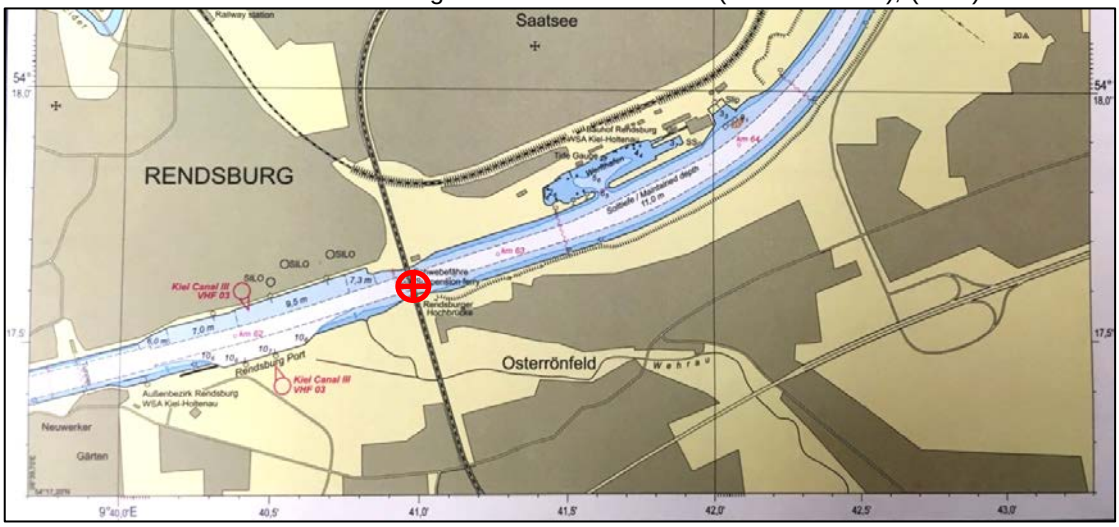


Figure 3: Extract from navigational chart showing the scene of the accident

2.3 Shore authority involvement and emergency response

Agencies involved:	Waterway Police (WSP) Kiel, Rendsburg Police, Kiel Fire Service, Rendsburg Fire Service, Eckernförde Volunteer Fire Service, Rendsburg-Eckernförde Dangerous Goods District[4] Firefighting Unit, Rescue Service, German Red Cross, WSAs Brunsbüttel and Kiel-Holtenau
Resources used:	Canal ferries MEMEL and NOBISKRUG, workboat SEHESTEDT, tug NOK1, emergency vehicles of shore-based emergency responders
Actions taken:	Partial closure of Kiel Canal to maritime traffic and the railway bridge at Rendsburg to rail traffic; casualties rescued from the transporter bridge; transporter bridge re-engaged and secured on the southern side of Kiel Canal
Results achieved:	Casualties rescued; Kiel Canal cleared for use by shipping after the transporter bridge was secured and the EVERT PRAHM was freed

MEMEL	SEHESTEDT	NOBISKRUG
 Nightflyer, Memel NIK 1373, CC BY 3.0	 © WSA Kiel-Holtenau	 Nightflyer, Burg, Fähre über den Nord-Ostsee-Kanal NIK 0326, CC BY 3.0
WSA Kiel-Holtenau's ferry with pointed bow and stern for crossings between Schacht-Audorf and Nobiskrug equipped with a water cannon	WSA Kiel-Holtenau's work and inspection ship, Rendsburg outer district equipped with a crane	WSA Kiel-Holtenau's (reserve) ferry with folding ramps at bow and stern (moored at Hochdonn)

[4] The Dangerous Goods Firefighting Unit has been set up by the Rendsburg-Eckernförde administrative district and supports local volunteer firefighting units in missions involving dangerous substances and goods.

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident

On 8 January 2016 the EVERT PRAHM transited the Kiel Canal from east to west in a convoy with two other seagoing vessels (Ship A and Ship B) during her voyage from Liepaja in Latvia to Husum in Germany. Ship A was sailing ahead and Ship B astern of the EVERT PRAHM. Ship B also had a canal pilot deployed on board, as well as a canal helmsman.

The EVERT PRAHM's bridge was manned by the chief officer and a cadet. The officer had taken over the watch at 0350. A canal pilot was also on the bridge. A 2-3 Bft south-easterly wind which was slowly turning to the south-west blew in the early hours of the morning. Inter alia, snow and black ice warnings had been issued for the Rendsburg-Eckernförde area. There was snow and freezing rain during the night. The transporter bridge's operator started work on the Kiel Canal's southern bank at 0425. He made his first crossing at 0427. Before his next crossing he allowed a seagoing vessel approaching from the east to pass at a safe distance at 0440 and then set off for the southern bank.

Wind forces of 4-5 Bft with gusts of 6-7 Bft were measured at Rendsburg after 0600. The air temperature stood at about 3 °C and there was light rain. Visibility was good.

The pilot on the EVERT PRAHM instructed the cadet (acting as helmsman) to head for the middle light on the railway bridge at Rendsburg.

After the vessel leading the convoy (Ship A) had passed the bridge at 0633 (see Figure 4), the transporter bridge crossed from the southern to the northern bank (see Figure 5). The crossing took 1:32 minutes.

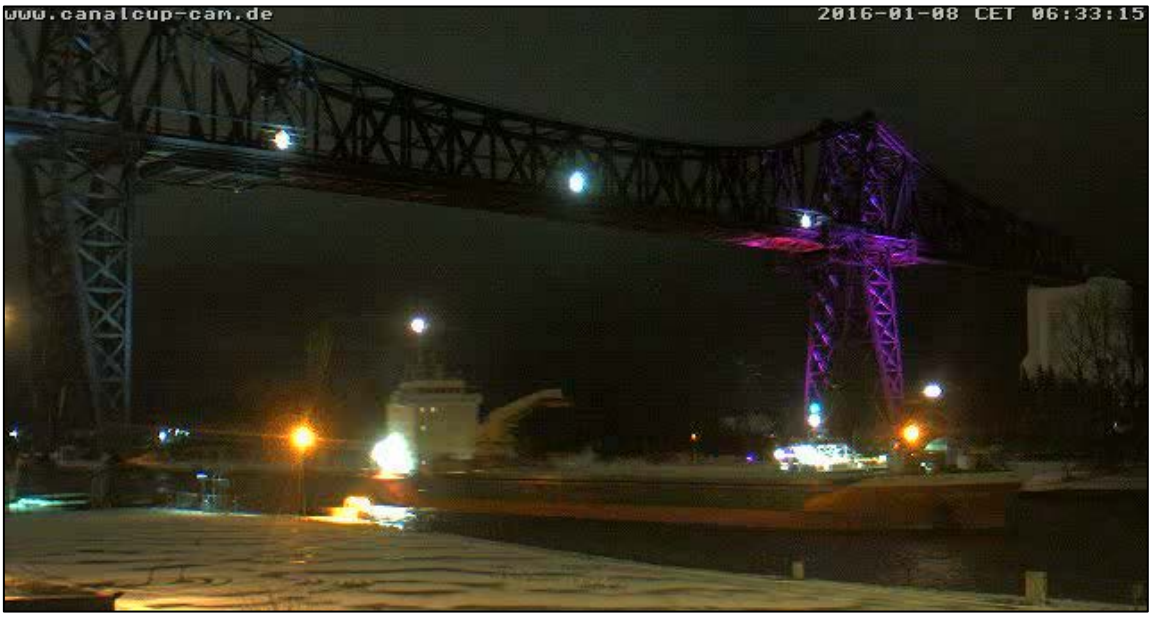


Figure 4: Ship A in the convoy passes the transporter bridge (08/01/2016, 0633)

Figure 5: The transporter bridge makes fast on the northern bank (08/01/2016, 0635)

The EVERT PRAHM approached the railway bridge at Rendsburg in darkness at 0635. Her SOG was about 8.8 kts. The transporter bridge suspended below the railway bridge was still made fast on the northern bank of the canal. The signal lights were off and the Rendsburg railway bridge's coloured lighting indicated that the transporter bridge was made fast on the northern side (see Figure 6).

Figure 6: The transporter bridge made fast on the northern bank (08/01/2016, 0637)

In addition to its operator there was also a passenger on the transporter bridge. The EVERT PRAHM kept to the middle of the fairway in accordance with the pilot's recommendation and was just short of the railway bridge when the transporter bridge's signal lights went on (Figure 7; see Subsection 3.4.9 below for information regarding the bridge pier's violet lighting).

Figure 7: The transporter bridge turns on the signal lights (08/01/2016, 0637)

The bridge lighting went off a few seconds later (see Figure 8).

Figure 8: Bridge lighting on the northern bank is turned off (08/01/2016, 0637)

The transporter bridge set off for the southern bank at 063727. The officer on watch and the cadet (acting as helmsman) on the bridge of the EVERT PRAHM noticed the transporter bridge's departure almost simultaneously. The cadet drew the pilot's attention to the moving transporter bridge with an exclamation, at which the pilot ordered full astern and hard to port. The full astern manoeuvre was performed by the chief officer at the control lever and the hard to port manoeuvre by the cadet at the helm. By this time neither was sufficient to prevent a collision with the transporter bridge. There was no audible warning on the tyfon.

The transporter bridge struck the hatch of the EVERT PRAHM amidships (see Figure 9), snagged briefly on the hatch, rotated, was dragged over the hatch cover and then released.

Figure 9: Collision (08/01/2016, 0638)

It then struck the starboard wing before scraping over the wheelhouse, dragging the antenna, part of the funnel and stern mast with it. At the same time, the transporter bridge was catapulted upward and swung violently (see Figures 10 and 11).

Figure 10: Transporter bridge catapulted upward (08/01/2016, 0638)

Figure 11: Transporter bridge swinging after the collision (08/01/2016, 0638)

The severely damaged transporter bridge was stuck over the middle of the Kiel Canal after the collision. The two people on the transporter bridge were injured during the accident. The transporter bridge's superstructure on the Rendsburg railway bridge was derailed but thankfully – given that a train crossed the bridge immediately after the accident at 063842 – did not project into the railway track.

The collision and hard to port manoeuvre caused the EVERT PRAHM to turn to port and she approached the southern embankment. Her crew and the canal pilot remained unharmed. The pilot recommended hard to starboard and then full astern, which the cadet executed. Despite this the EVERT PRAHM sailed gently onto the southern embankment at canal kilometre 62.5 at 0640. The chief officer stopped the engine. The vessel traffic service (VTS) was notified on VHF radio. Following that the chief officer put the vessel back to astern. The EVERT PRAHM refloated at 0646 (see Figure 12). The master went onto the bridge shortly after.

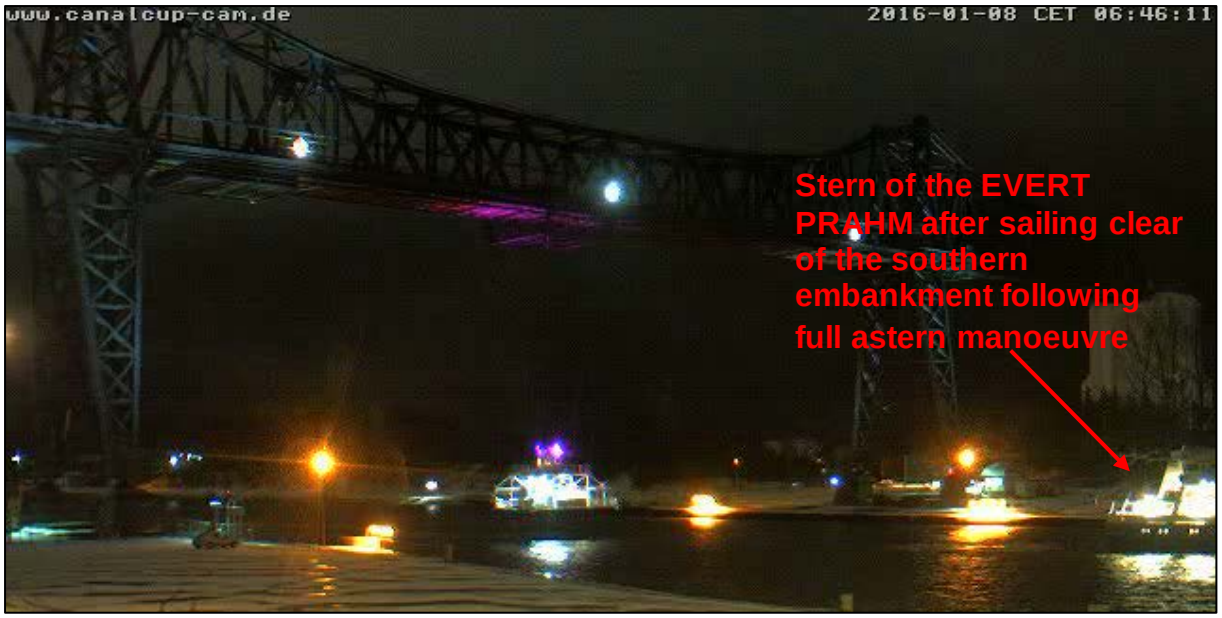


Figure 12: The EVERT PRAHM refloats after sailing onto embankment (08/01/2016, 0646)

Although the EVERT PRAHM had been severely damaged, the wheelhouse's interior was essentially still intact. The controllable pitch propeller, rudder and bow thruster all worked properly. Parts of the navigation lighting had been torn off, however. Moreover, a radar and the VHF radio failed due to the antennas being torn off. The EVERT PRAHM therefore shifted to the nearby district port of Rendsburg, making fast there at 0705. After a survey by the Ship Safety Division (BG Verkehr) she was granted permission to call at a shipyard in the immediate vicinity unassisted in daylight and in good visibility.

3.2 The rescue and recovery operation

VTS Kiel Canal received several reports immediately after the accident. The VTS informed WSA Kiel-Holtenau about the accident at 0643. The VTS received preliminary information with details of the collision and notification of two casualties on the transporter bridge on VHF radio at 0640 from the transporter bridge's seriously injured operator. The transporter bridge's operator had injured his back, fractured a leg and was suffering from shock. The passenger hit his head during the collision but fortunately was wearing a bicycle helmet. He injured his knee and had numerous bruises, for example. The actual extent of the injuries was not known at this point. At the same time as the operator of the transporter bridge, the injured passenger made an emergency call with his mobile phone. The pilots assigned to the EVERT PRAHM and Ship B, which was following the EVERT PRAHM in the convoy, also notified the VTS.

The VTS notified WSP Kiel, the German Joint Situation Centre Sea[5], the Ship Safety Division (BG Verkehr) and the BSU. Kiel Fire Service and Rendsburg Fire Service were already proceeding to the scene of the accident after being alerted by the control centre. The Central Command for Maritime Emergencies (CCME) was also notified and assisted WSA Kiel-Holtenau in commanding the operation.

The first emergency responders from Rendsburg Fire Service arrived on the northern bank at 0650 but were unable to reach the transporter bridge to begin with. At this point the responders did not know how many casualties there were or whether people were in the water. The accident was observed on the bridge of Ship B, which was following the EVERT PRAHM in the convoy, and she stopped immediately. On Ship B it was expected that people were in the water. When it was established that the first emergency responders at the scene were unable to reach the transporter bridge, a decision was made to use the crew as lookouts on the starboard wing and pass the scene of the accident at minimum speed with the assistance of the bow thruster (see Figure 13).

Figure 13: Ship B in the convoy passes the scene of the accident (08/01/2016, 0657)

Nobody was found in the water and this was reported to the VTS immediately. The latter then asked Ship B to continue her voyage. The Kiel Canal was closed at 0700 between the Schülp (eastwards) and Audorf (westwards) sidings. The Deutsche Bahn's emergency control centre in Hannover was also informed and any rail traffic scheduled to cross the railway bridge at Rendsburg was suspended at the same time for the duration of the rescue and recovery operation. The rail connections between Hamburg and Flensburg (from Husum to Kiel and Kiel to Rendsburg) were affected.

[5] The Joint Situation Centre Sea (GLZ-See) in Cuxhaven is a combined institution of the federal government and the five coastal states. It pools the technical expertise of the Federal Waterways and Shipping Administration, coastal state WSP services, the Federal Police, the Customs, the German Navy, the CCME and the Federal Office for Agriculture and Food and its objective is to promote maritime safety.

Neighbouring VTSs and the Elbe pilots were also informed about the accident and the associated partial closures to maritime traffic.

The canal ferry MEMEL picked up several rescue vehicles and individual emergency responders from the fire service on the northern bank and headed for the scene of the accident. Staff of WSA Kiel-Holtenau and the outer district in Rendsburg had also been informed in the meantime and were heading for the scene of the accident.

The fire service set up an aerial access platform with floodlights on a turntable ladder in the direction of the transporter bridge (see Figure 14) at 0705 on the northern bank to give emergency responders a better view of the situation. Communication between the fire service and casualties was initially not possible. The VTS informed the operator of the transporter bridge on VHF radio that emergency responders would soon arrive at the scene.

Figure 14: Start of the rescue operation by the fire service (08/01/2016, 0708)

At 0718 emergency responders were able to approach the damaged transporter bridge by means of an inflatable boat (see Figure 15) and thus make contact with the injured passenger.

Figure 15: Rescue operation – contact established by means of inflatable (08/01/2016, 0718)

The inflatable boat stayed with the transporter bridge until the arrival of the MEMEL at 0729 and then remained on standby (see Figure 16). The NOBISKRUG, the SEHESTEDT and the NOK1 were also requested to assist with the rescue operation. The fire service requested additional lifeboats so as to be able to respond faster if the transporter bridge fell into the water. The lifeboats remained on standby. In addition, Eckernförde Volunteer Fire Service was subsequently alerted with its diving unit.

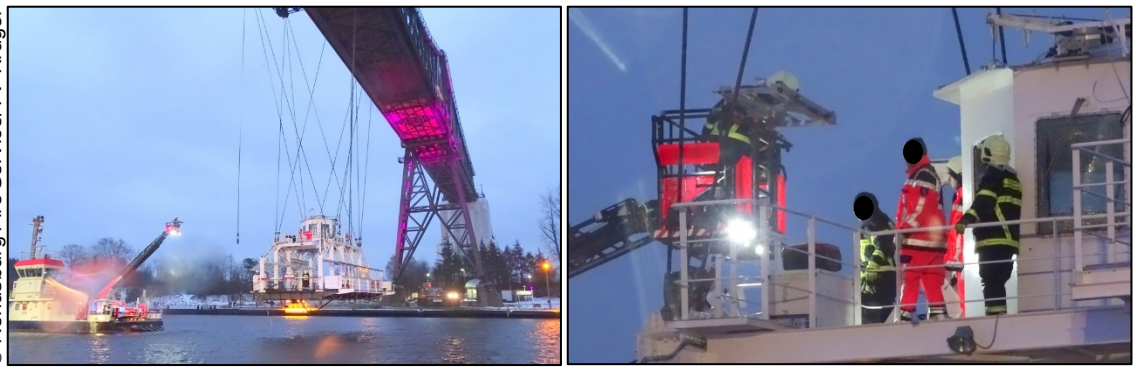
Figure 16: Rescue operation – MEMEL arrives at the scene of the accident (08/01/2016, 0729)

Two fire engines from Rendsburg Fire Service had been loaded onto the MEMEL in the meantime. At 0736 emergency responders were able to cross from the MEMEL to the transporter bridge on the turntable ladder of one of the fire engines and begin treating the casualties (see Figures 17 to 19). To begin with the strength of the wind

made it impossible to mount a ladder safely, meaning that although emergency responders could get onto the transporter bridge it was initially not possible to carry the transporter bridge's injured operator from it to the MEMEL safely.

© Rendsburg Fire Service/TV-Krüger

Figure 17: Rescue operation – emergency responders climb across to the transporter bridge



© Rendsburg Fire Service/TV-Krüger

Figure 18: Rescue operation – emergency responders on the transporter bridge

The injured passenger was able to leave the transporter bridge at 0739 via the turntable ladder. Rescuing the transporter bridge's operator proved difficult because the steps to his cabin had been so badly damaged by the collision that this route could not be used. The operation was complicated further by the transporter bridge's severed 400 V conductor line, which sprayed sparks on the upper deck and therefore had to be switched off ashore first so as not to endanger anyone.

Figure 19: Rescue operation – Fire engines on the MEMEL and treatment of casualties on the transporter bridge

It took just under an hour before the transporter bridge's operator could also be moved onto the MEMEL at 0832 in a litter via the turntable ladder. The casualties were transferred to ambulances waiting on the northern bank and driven to a hospital for further treatment.

The rescue operation was formally ended at 0855 and the fire service operation at 1100. Some 80 emergency responders were involved in the rescue and recovery operation.

The transporter bridge was severely damaged due to the collision and partially torn out of the rail track. It was stuck over the middle of the Kiel Canal (see Figure 20).

Figure 20: Position of the transporter bridge in daylight after the accident

Attempts at re-engaging the transporter bridge's superstructure had already been ongoing since the early hours of the morning and succeeded at about midday. However, the battery-assisted emergency drive could not be used and the transporter bridge had to be pulled to the southern side manually using chain hoists.

Inspection engineers responsible for the WSA's bridge structures assessed whether the bridge had also been damaged by the collision at the same time. The inspection engineers did not detect any damage to the structure to begin with and this was reported during a briefing arranged for 1300 near the scene of the accident. This assessment was subsequently revised.

From 1318 onwards it was possible to pull the transporter bridge to the southern bank metre by metre. The recovery took just under three hours, after which the transporter bridge could be made fast on the southern bank and no longer posed an obstacle to navigation (see Figure 21).

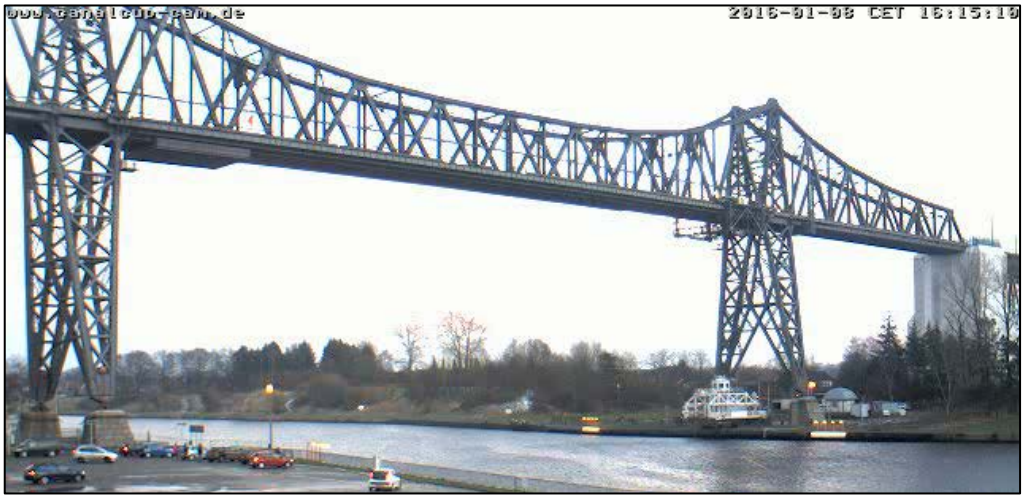


Figure 21: Recovery of the damaged transporter bridge (08/01/2016, 1615)

The Kiel Canal was reopened to shipping at 1615. However, the closure for rail traffic continued because additional works were necessary on the Rendsburg railway bridge (i.e. on the transporter bridge's superstructure).

The BSU initially and WSP Kiel afterwards secured the transporter bridge for the investigation.

3.3 Disassembly of the transporter bridge

The transporter bridge (consisting of the gondola weighing some 37 t, the suspension system with 12 steel cables each weighing 350 kg, and the superstructure weighing some 41 t) was disassembled after the accident and transported to the WSA's dockyard near the railway bridge.

Figure 22: The transporter bridge being unloaded at the WSA's dockyard

3.4 Investigation

The Waterways and Shipping Administration (WSV) notified the BSU on the morning of the accident at 0728. An investigation team arrived in Rendsburg at 1115. At this point the transporter bridge was still stuck over roughly the middle of the canal. The investigation began on board the seagoing vessel involved in the accident, the EVERT PRAHM.

3.4.1 EVERT PRAHM

The EVERT PRAHM's crew and owner cooperated fully. Documentation made available for the safety investigation included the deck log book, pilot card, ship's certificates and crew's timesheets for January 2016.

The EVERT PRAHM is a coaster of medium age. The SKL Motoren- und Systemtechnik AG diesel engine has a power output of 1,320 kW. A right-handed controllable pitch propeller is used for propulsion. This enables the ship to reach a speed of 11 kts. According to the pilot card, the EVERT PRAHM reaches a speed of 9.5 kts when laden and sailing full ahead. The full ahead to full astern switchover time is specified as 180 seconds. The pilot card indicates 30 seconds for switching from hard-over rudder to hard-over rudder. The maximum rudder angle is specified as 40°.

Figures 23 and 24 below provide an overview of the wheelhouse. They were not taken on the day of the accident.

Figure 23: Wheelhouse of the EVERT PRAHM, control position

The navigation equipment includes a GPS system, sea radar apparatus from Sperry Marine, radar apparatus from Racal-Decca used for rivers, an echo sounder, a VHF radio installation, a Navitron autopilot and the latest paper navigational charts and sailing directions. A laptop with ECS[6] software was also in use on the day of the accident.

6 ECS: Electronic chart system (a digital chart system used to assist with navigation).

Figure 24: Wheelhouse of the EVERT PRAHM, chart table

At the time of the first inspection of the EVERT PRAHM's bridge after the accident by WSP Kiel, it was found that the sea radar apparatus was switched to standby, 1.5 nm. The river radar was switched to the setting 0.5 km.

Since the EVERT PRAHM has a gross tonnage of less than 3,000 her carriage requirements do not include a voyage data recorder (VDR/S-VDR). Consequently, VDR data were not available for the reconstruction of the course of events leading up to and during the accident. In particular, audio recordings of conversations on the bridge were thus not available.

Conditions on the EVERT PRAHM were challenged twice during seven port State controls in the five years before the accident (see Spreadsheet 1). The deficits found included minor oversights in the documentation.

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IMO, Na

Sweden	Norrköping	22/03/2016	N	Paris MoU	Initial inspection	
Poland	Szczecin	21/05/2015	N	Paris MoU	Initial inspection	
Denmark	Kolding	16/07/2014	N	Paris MoU	More detailed inspection	2
Denmark	Randers	16/08/2013	N	Paris MoU	More detailed inspection	
Finland	Pori	03/07/2012	N	Paris MoU	Initial inspection	
Netherlands	Amsterdam	29/08/2011	N	Paris MoU	Initial inspection	3
Finland	Uusikaupunki	26/10/2010	N	Paris MoU	Initial inspection	

Spreadsheet 1: Summary of port State controls on the EVERT PRAHM

During the first inspection of the ship's certificates and test reports for the radar sets by WSP Kiel on the day of the accident it became apparent that tests for both radar sets were overdue. The investigation did not reveal any evidence of possible malfunctions of the equipment, however.

3.4.1.1 Crew

The EVERT PRAHM was manned by a master, a chief officer, three able seafarers deck and two sea cadets.

The chief officer has served at sea for seven years, the last two of those as chief officer. He has been employed by the owner since 18 December 2015 and on board the EVERT PRAHM ever since. On the day of the acdent he was on the bridge from 0200, taking over the watch from the master at 0350.

The cadet, who had the role of helmsman at the time of the accident, was completing his second work placement from the maritime school. He had been on board the EVERT PRAHM training in bridge service since 28 October 2015. At the time of the accident he was steering with the joystick (see Figure 25).

Figure 25: The EVERT PRAHM's control position, joystick control, taken on 08/01/2016

Crew testimonies provided for the BSU's safety investigation are listed under Subsection 3.4.3.1.

3.4.1.2 Damage

The EVERT PRAHM was heavily damaged during the accident. The transporter bridge struck the hatch cover amidships, resulting in deformations and paint abrasion (see Figure 26).

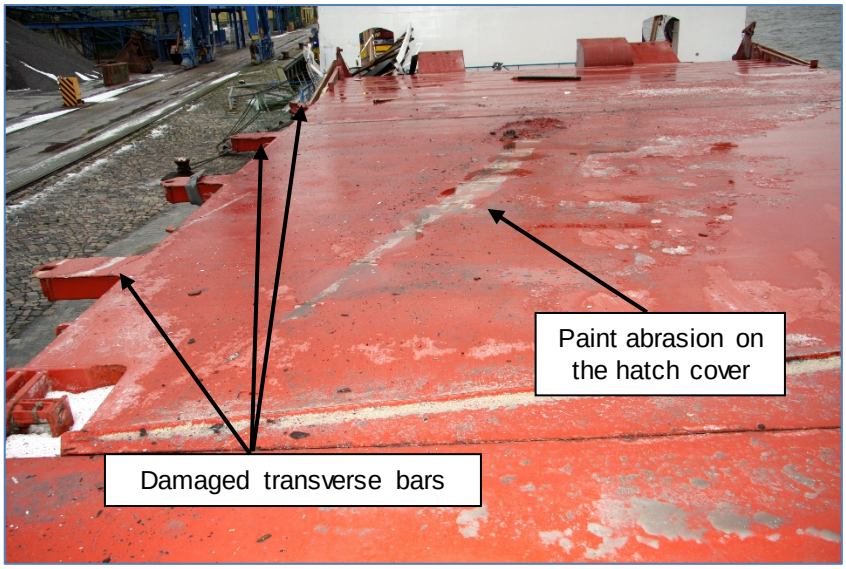


Figure 26: Damage to the EVERT PRAHM's hatch cover

The starboard bridge wing was severely buckled inwards and similar to the wheelhouse generally deformed (see Figures 27 and 28).

Figure 27: Overview – damage to the EVERT PRAHM's superstructure

Figure 28: Damaged starboard wing on the EVERT PRAHM

The lighting was partially defective. Due to the impact and the transporter bridge snagging on the wheelhouse, the stern mast had been knocked down and several antennas on the observation deck (including the X-band radar antenna, GPS and AIS) were damaged (see Figure 29).

Figure 29: Damage to the EVERT PRAHM's superstructure, view from astern

The Ship Safety Division (BG Verkehr) surveyed the damage and issued a prohibition on continuing. The EVERT PRAHM later received permission to sail to the shipyard under certain conditions to have the necessary repairs carried out.

3.4.2 Transporter bridge

The transporter bridge has connected the municipality of Osterrönfeld with the town of Rendsburg since it entered service at the end of 1913. It is used to transfer passengers and cars up to 7.5 t. Up until the day of the accident it was one of the few remaining transporter bridges in the world and unique in terms of design and operation (suspended from a railway bridge over a navigable waterway).

It transported about 520 vehicles and 1,700 passengers daily.

On 12 January 2016 Kiel Public Prosecutor's Office secured the transporter bridge as evidence for further investigations in consultation with the BSU and WSP Kiel.

3.4.2.1 Design

The transporter bridge was suspended on a superstructure by means of four vertical suspension cables each with a diameter of 38.2 mm and eight diagonal tension cables (see Figure 30).

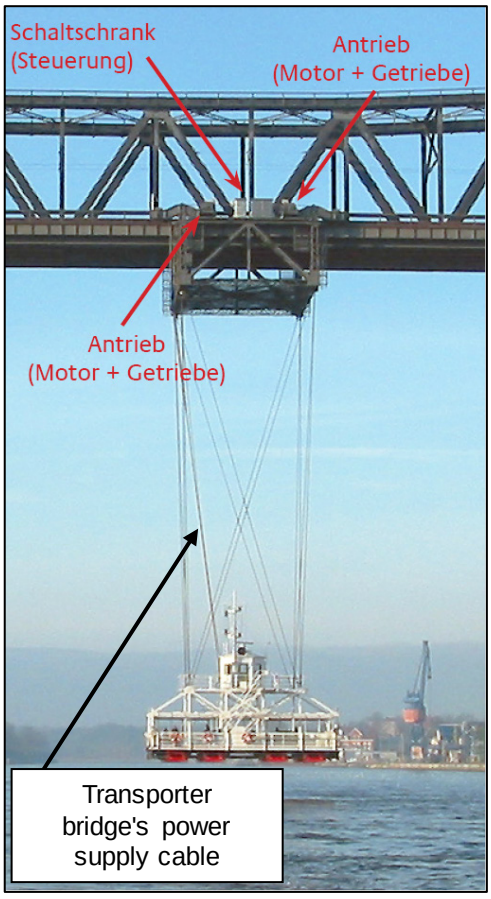


Figure 30: Transporter bridge and superstructure

The superstructure was suspended beneath the 45-metre-high Rendsburg railway bridge. Its main propulsion system was electric with four three-phase motors, each driving every second wheel with 1 kW (corresponding to 16 bhp). The so-called conical rotor brake motors (type: Demag KB) were powered by a conductor rail. There was also a battery-powered emergency drive (see Figures 31 and 32). The control boxes that implemented manoeuvres and actions performed on the consoles in the transporter bridge's control position were located on the superstructure on the bottom chord of the bridge.

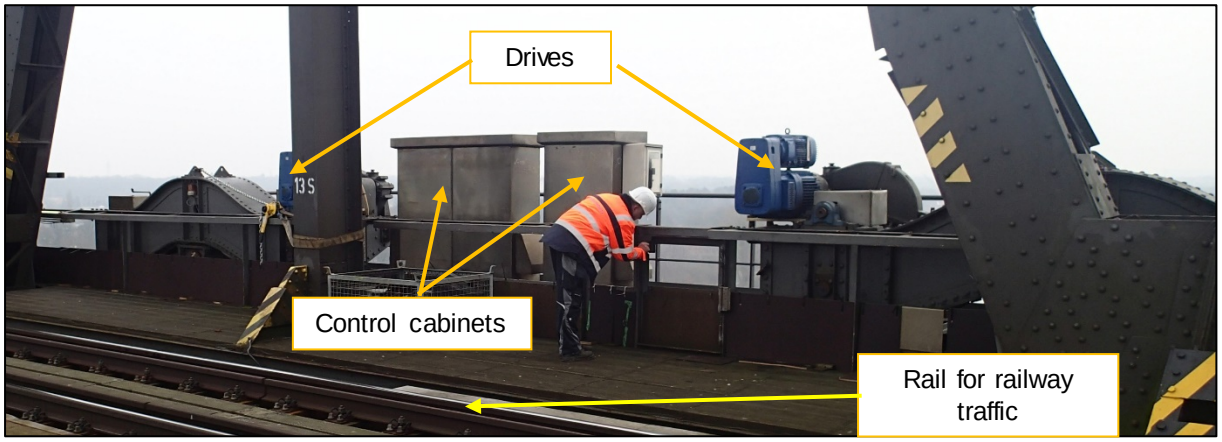


Figure 31: Control cabinets and drives of the superstructure

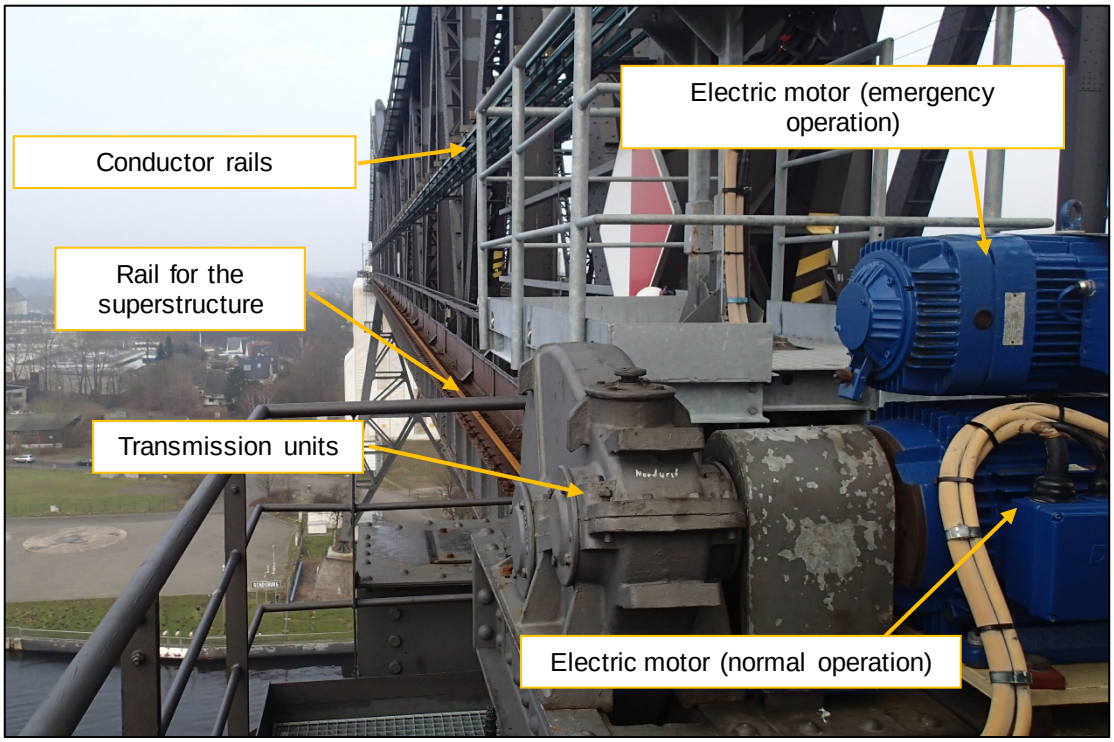


Figure 32: Part of the superstructure (drive system on north-western side)

Batteries were installed on the transporter bridge for the DC motors. They were activated by operating a switch for the power supply on the control panel. The switch

was set to emergency operation (see Figure 33) when the BSU and WSP Kiel surveyed the control position.

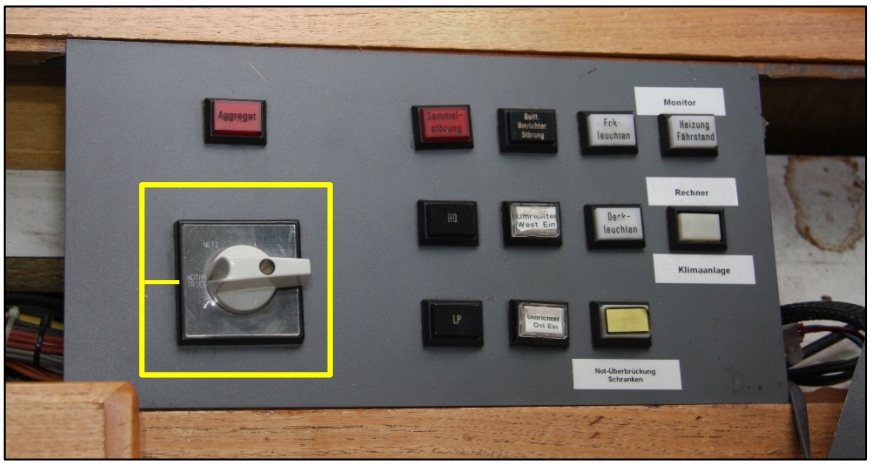


Figure 33: Mode selector switch set to emergency operation

Windscreen wipers were installed on three sides of the octagonal structure. One windscreen wiper was installed on each of the windows in both directions of travel. In contrast to the straight pane on the western side, the straight pane on the eastern side does not have a windscreen wiper because of the entrance door located there (see Figures 34 and 35).

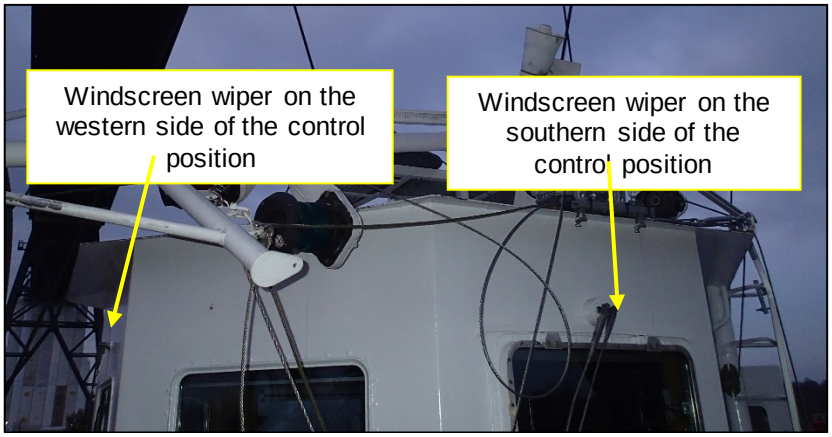


Figure 34: Windscreen wiper on the southern and western side

Figure 35: Door on the eastern side and windscreen wiper on the northern side

The transporter bridge had been completely overhauled in 2015.

3.4.2.2 Operation of the transporter bridge

WSA Kiel-Holtenau is responsible for the operation and maintenance of the transporter bridge. Rendsburg outer district is responsible for the operation. The Rendsburg construction yard oversees the electrical and mechanical engineering facilities on behalf of the outer district and carries out scheduled maintenance on these facilities. The outer district is responsible for the structural maintenance of the installation. Cooperation between the BSU's investigation team, the WSA responsible for operation and the construction yard was carried out via the Kiel office of the Directorate-General for Waterways and Shipping (GDWS), which is responsible for technical supervision, and ran smoothly.

The transporter bridge was operated as one-man operation. Prior to October 2004, a second employee had been responsible for loading/unloading the transporter bridge and operating the barriers. Accordingly, the switch to one-man operation had already taken place several years before the accident. Since then, the transporter bridge's operator has been responsible for both the loading/unloading operation and the crossing.

WSA Kiel-Holtenau notified the transporter bridge's operators in a letter dated 16 November 2004 of the then new transporter bridge service and operating instructions dated 10 November 2004. Extracts of relevance to the safety investigation follow.

Section 1 – Transporter bridge operating times

The transporter bridge operates during the summer months (April to September) from 0500 to 2300 and during the winter months (October to March) from 0500 to 2200.

Departure times are scheduled as follows and publicised on notice boards in the waiting areas:

From the southern side (Osterrönfeld) at
0500, 0515, etc. every 15 minutes until 2245 or 2145.
From the northern side (Rendsburg) at
0507, 0522, etc. every 15 minutes until 2252 or 2152.

These times must be observed, when crossing is not obstructed by shipping in the canal or other disruptions. During special occasions or times of exceptionally high pedestrian and cycle traffic, crossings shall be made more frequently without adhering to specific crossing times if operating conditions so permit.

Section 2 – Watchkeeping

Operating personnel shall provide the service in two watches of 8.5 or 9 hours each. The handing over of watches is provided for by the duty roster established by WSA Kiel-Holtenau.
Longer handover times required in specific cases must be recorded in the operating log.

The watch making the handover shall notify the watch making the takeover of any deficiencies or irregularities found during operation of the transporter bridge.
The takeover of the watch is confirmed by entering the name in the available operating book.

Section 3 – Duties of operating personnel

The ferry machinist is responsible for the following.

1. Local supervision of the transporter bridge, its appendages and access routes.

2. Putting the transporter bridge into service each day in accordance with the regulations. On the respective day and prior to the first crossing, this shall include an inspection of the
   a) position lights;
   b) roadway and footpaths;
   c) liferafts;
   d) lifebuoys;
   e) lifejackets;
   f) fire-extinguishing appliances, and
   g) traffic, warning and information signs.

Any defects found must be reported to the field officer or the management of the facility immediately.

3. Managing the transporter bridge during crossings.

4. Taking the transporter bridge out of service on the southern bank when daily service comes to an end. This includes [...].

5. Supervision of the proper use of safety appliances and ensuring that passengers comply with canal police rules and regulations.

6. Immediately reporting to the field officer or manager of the facility any major defects or damage and entry of the results into the operating log.

7. Observance of the transporter bridge operating regulations, as amended.

[…]

Section 5 – Regulation and security of transporter bridge traffic

1. […]

2. In the event of frost, black ice or snow, the transporter bridge and access routes must be sprinkled with sand/grit as an urgent measure. Furthermore, the winter road clearance service must be notified by phone.

3. The barriers on land must be illuminated in darkness.

4. […]

5. […]

6. VTS NOK II must be notified immediately of any emergency that may affect maritime traffic.

7. […]

Section 6 – Detailed rules for the crossing

1. Prior to departure the ferry machinist must keep a careful lookout for ships approaching the crossing. In foggy weather particular attention must be given to identifying vessels making their presence known by means of signals 3.1 in Annex II to the *Seeschifffahrtsstraßen-Ordnung (SeeSchStrO)* [German traffic regulations for navigable maritime waterways] (ships proceeding from the west one prolonged blast and from the east two prolonged blasts). Crossings must not be started if a vessel has approached up to 800 m or if signal 2.2 (short – prolonged) has been issued.

2. The ferry machinist must give notice of each crossing by means of the bell.

3. […]

By way of derogation from the safety distance of originally 800 m stated in Section 6 of these service and operating instructions, WSA Kiel-Holtenau issued the following written instructions:

Date	Contents of the instruction
20/02/2014	Increase safety distance to 900 m after reduction of the main propulsion speed from 6.49 km/h to 5.84 km/h
23/11/2015	Increase safety distance to 1,200 m if a malfunction of the emergency drive is suspected
15/12/2015	Reduce safety distance to 1,000 m after the emergency drive has been checked and classed as operable

Spreadsheet 2: Operating instructions for transporter bridge safety distances

The safety distances were indicated by bars on the radar in the transporter bridge's control position (see Subsection 3.4.8). There was no audible warning when a ship entered the safety area.

The classification society DNV GL had prepared a 66-page illustrated transporter bridge operating manual, which WSA Kiel-Holtenau had made available to the transporter bridge operating personnel with the note (dated 15 April 2015) 'for information and attention' appended.

A normal crossing manoeuvre of the transporter bridge proceeded as follows:

- when the transporter bridge was secured on the bank by means of automatic locking with a storm hook, its operator had to open the barriers on land, on board and the pedestrian gate by pressing the *Landschranke AUF* [open barrier on land], *Schranke AUF* [open barrier on board] and *Tor AUF* [open pedestrian gate] push-buttons and thus allow passengers access to the transporter bridge. The corresponding illuminated push-buttons had to be operated from the control panel on the northern bank when making fast on the northern side or that on the southern back when making fast on the southern side;

- after the transporter bridge was loaded, four switches on the control panel on the land side had to be operated before its traction current was supplied. Accordingly, the transporter bridge could only depart when
  - the barrier on the bank was closed (illuminated push-button *Landschranke ZU* [barrier on land closed]);
  - the barrier on board was closed (illuminated push-button *Schranke ZU* [barrier closed]);
  - the pedestrian gate was closed (illuminated push-button *Tor ZU* [pedestrian gate closed]), and
  - the storm hook for wind protection was unlocked, which was signalled by the illumination of the *Entriegelt* [unlocked] lamp if the procedure was

completed successfully. When the lock was released, the transporter bridge's signal lights illuminated automatically.

- the transporter bridge's operator then changed control position from land side to canal side and put the control lever in the ahead position. The lever remains in this position, meaning it does not return to a neutral position automatically when released. This mode of operation aims to enhance the safety of the transporter bridge, as it should not come to a standstill in the canal with transiting maritime traffic if the operator is impeded unexpectedly during a crossing. The transporter bridge would continue crossing were this to happen. The speed of the transporter bridge in the docking area would be automatically reduced by associated circuitry before the movement is switched off via the limit position at the docking area. The storm hook also locks automatically.

The transporter bridge's three-phase drives have a 'drop anchor' so that the motors block immediately in the event of a three-phase power failure or an emergency stop triggered via the respective control panel. The transporter bridge's advance distance varied between 0.5 m and 1.5 m, depending on load.

Emergency stop buttons (functioning described in the operating manual) for the main drive were located on the side next to the respective control panel for a crossing to the northern or to the southern bank (see Figure 36).

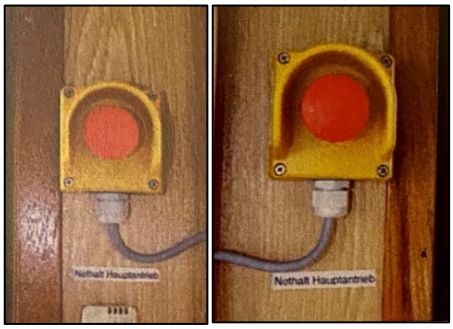


Figure 36: Emergency stop button in the transporter bridge operator's cabin

The transporter bridge was also equipped with a signal horn (see Figure 37). According to the operating manual, this could be sounded by pressing the signal horn button on the respective control panel in order to issue sound signals (e.g. attention) to warn maritime traffic.

Figure 37: Transporter bridge's signal horn

For the operation of the transporter bridge a risk assessment in accordance with EN ISO 12100 (safety of machinery) was prepared by DNV GL in addition to the operating manual (see Subsection 3.4.9.1 below).

3.4.2.3 Damage

The BSU's investigation team and WSP Kiel jointly surveyed the severely damaged transporter bridge on the day of the accident after it had been pulled to the southern side. Load-bearing components of the transporter bridge's structure were damaged and deformed. Moreover, the bolts on two suspension cables were fractured. Components of the transporter bridge (from the liferaft brackets, in particular) were left on board the EVERT PRAHM after the collision.

A rough description of the damage to the transporter bridge (see Figures 38 to 43) follows:

- the platform for the passengers and its roof was almost completely destroyed on the side of impact (eastern side);
- the steps to the control position were destroyed on the eastern side;
- the signal mast was broken;
- the transporter bridge's barrier on the southern side was destroyed, and
- the solid liferaft brackets below the platform were destroyed.

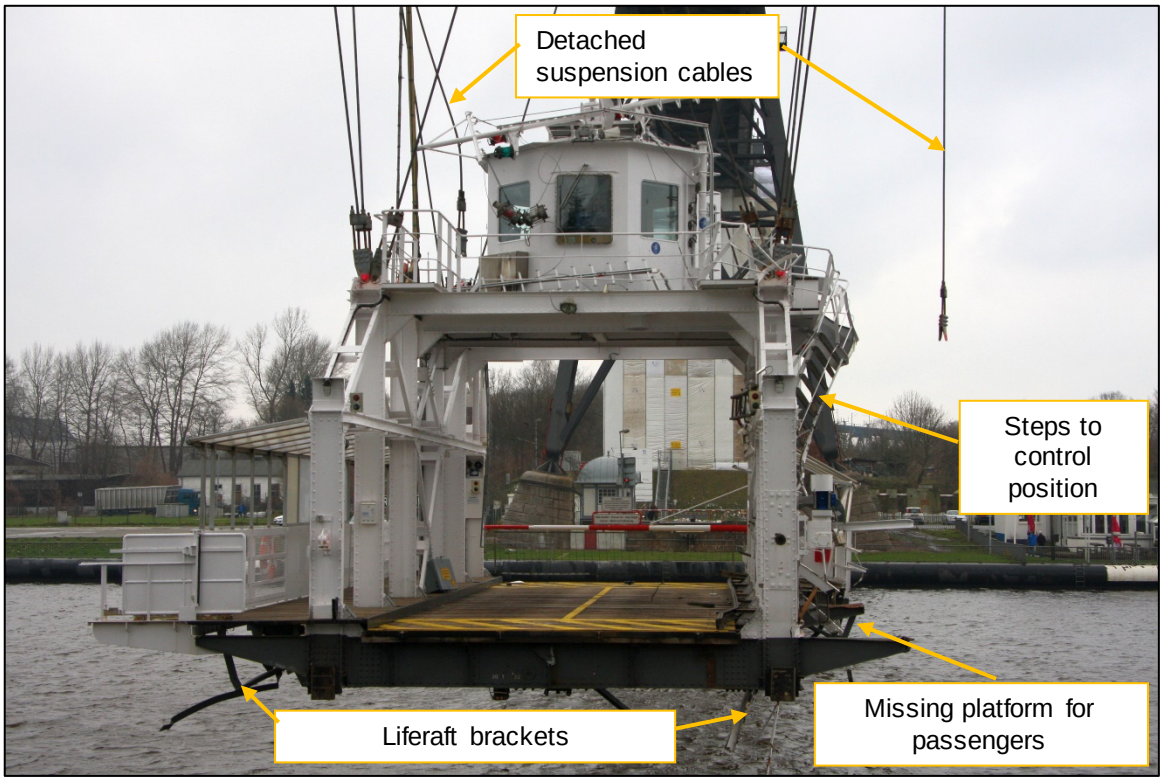


Figure 38: Transporter bridge viewed from the southern side

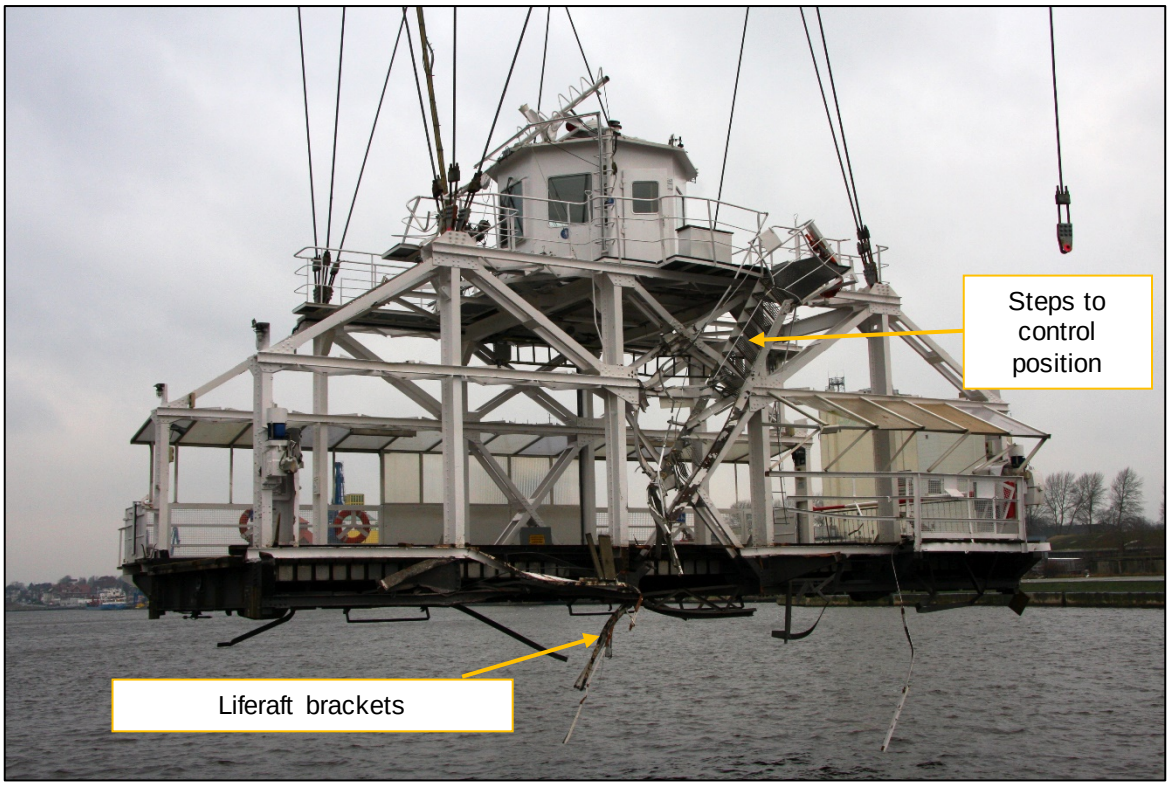


Figure 39: Transporter bridge viewed from the eastern side

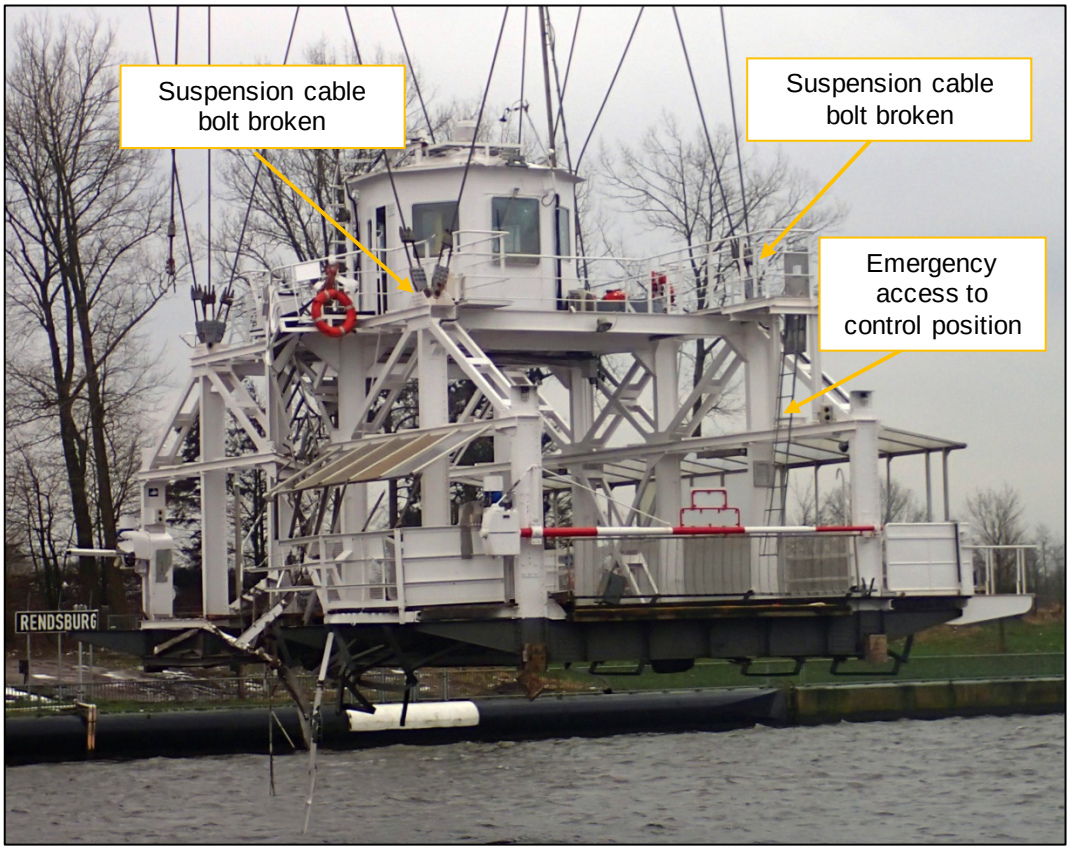


Figure 40: Transporter bridge viewed from the northern side

Figure 41: View of the destroyed passenger platform and steps to the control position

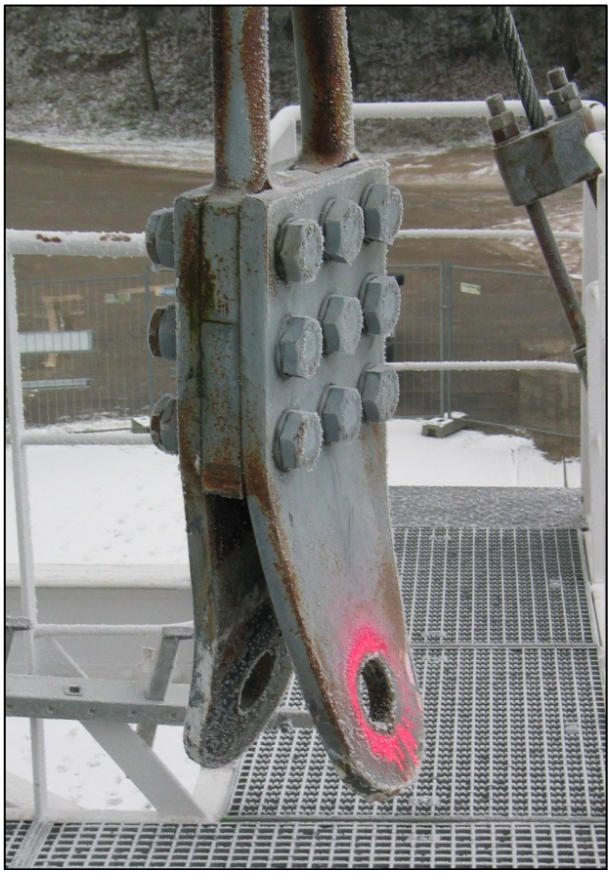


Figure 42: Broken suspension from the north-western side

Figure 43: Cable attachment point on the north-western side

The control position was severely affected (see Figure 44).

Figure 44: View into the control position from the door

The window on the northern side of the transporter bridge's control position was shattered (see Figure 45). The window to the southern side was intact but the sunblind was rolled down.

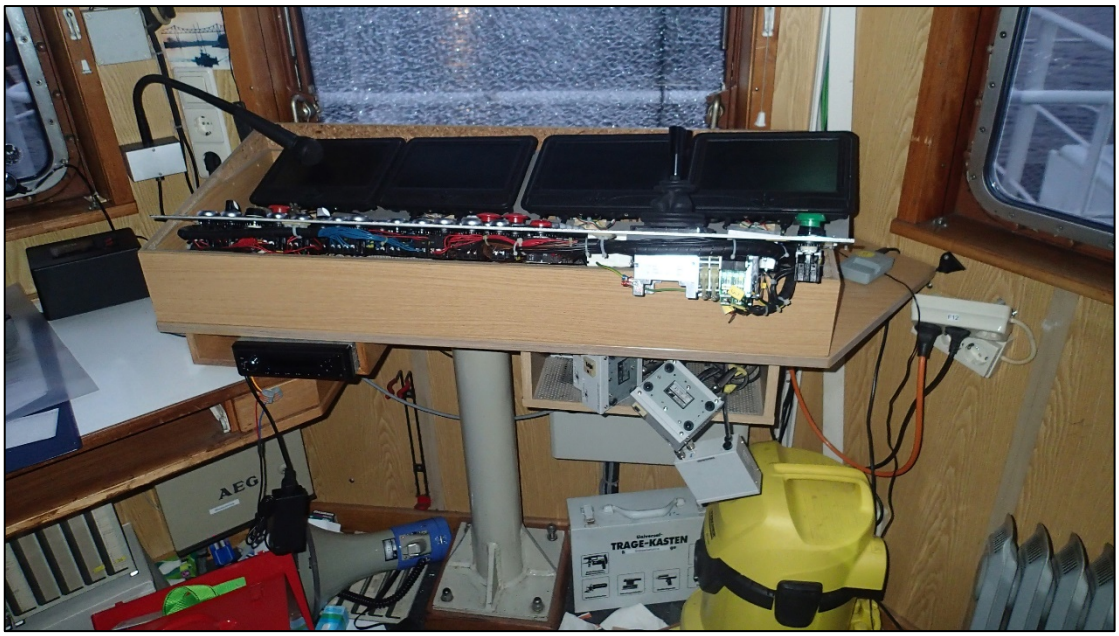


Figure 45: View of the control panel on the northern side

The damage to the transporter bridge and the bridge structure was estimated at more than EUR 1 million, corresponding to a constructive total loss in respect of the transporter bridge.

3.4.3 Witnesses

3.4.3.1 Canal pilot and crew of the EVERT PRAHM

The canal pilot assigned to the EVERT PRAHM cooperated with the BSU and provided his detailed ship accident report for the investigation. The crew also cooperated with the BSU, providing for the investigation detailed written statements on the course of events leading up to and during the accident. The statements of the crew and the pilot are consistent in content and therefore summarised below.

The statements indicate that the canal pilot boarded the EVERT PRAHM in the Kiel-Holtenau roadstead for the voyage to Rüsterbergen. After the master had finished his briefing, the EVERT PRAHM entered the lock and made fast there at 0320 to take on fresh water and provisions. Both steering pumps were reportedly switched on and there were reportedly no malfunctions during the voyage.

The VTS's situation report transmitted on VHF radio reportedly indicated that a short stop would have to be made in the Groß-Nordsee siding but that otherwise no oncoming traffic should reportedly be expected. The EVERT PRAHM reportedly sailed out of the lock at 0350 after the chief officer had taken over the watch. The master reportedly stayed on the bridge and continued steering until Nordhafen. The master then reportedly left the bridge and rested. The officer in charge of the navigational watch reportedly operated the rudder himself for a brief period before the cadet entered the bridge and took over the helm. Both the chief officer and the canal pilot were satisfied with the cadet's execution of steering recommendations.

The voyage reportedly progressed quietly with few oncoming vessels to begin with. As notified, the EVERT PRAHM reportedly had to wait in the Groß-Nordsee siding about 30 minutes for a larger oncoming vessel. They reportedly sailed out of the Groß-Nordsee siding at about 0515 and then proceeded at canal speed without stopping again. Visibility was reportedly good when the EVERT PRAHM turned from the right-hand bend at Saatsee onto the straight canal stretch up to the Rendsburg railway bridge. The transporter bridge was reportedly made fast on the northern side without lighting. The EVERT PRAHM reportedly sailed in approximately the middle of the canal and the canal pilot reportedly recommended that the cadet head for the illuminated middle of the bridge (see Figure 4). Since a ship was moored in the Kreishafen the canal pilot reportedly inquired about the speed and the ensuing reading reportedly stood at just over 8 kts.

Shortly before the EVERT PRAHM reportedly reached the bridge, the lights of the transporter bridge were reportedly switched on suddenly and it reportedly started to move immediately afterwards. The canal pilot reportedly recommended a blast of the tyfon, the helm command hard to port and the engine command full astern. The cadet and the officer in charge of the navigational watch reportedly executed both commands. However, the EVERT PRAHM had reportedly only turned a few degrees to port when the collision occurred.

After the collision the EVERT PRAHM reportedly turned toward the southern embankment. To avoid grounding on the embankment, instructions to set the rudder to hard to starboard and execute a kick ahead with the engine were reportedly issued. The engine was then set to full astern. The ship then reportedly grounded on the southern embankment at canal kilometre 62.5. Her remaining SOG was 3 kts.

It was claimed that the engine was reportedly first stopped and a report made to the VTS on Kiel Canal III. After reportedly briefly ensuring that there were no casualties on board the EVERT PRAHM, instructions to set the propeller to astern with increasing output were reportedly issued. After two to three minutes the ship was reportedly afloat again and stopped immediately to prevent another collision with the transporter bridge, which was stuck over the middle of the canal. The ship then reportedly headed for the Kreishafen of Rendsburg.

3.4.3.2 Transporter bridge operator

The operator of the transporter bridge was seriously injured during the collision. He was the focus of criminal proceedings after the accident and therefore also significantly affected personally. During the survey of the transporter bridge on 18 February 2016 his legal counsel advised on his behalf that visibility through the transporter bridge's window panes was severely restricted on the day of the accident due to ice and snow. However, beyond that he was not available to either the BSU or the WSP as a witness because he did not want to give any further details about the accident.

Consequently, in addition to documents from WSA Kiel-Holtenau, the BSU referred to other witness testimonies and the remarks made by the transporter bridge's operator on VHF radio after the accident for the investigation.

The transporter bridge's operator had started his training as an aspirant at WSA Kiel-Holtenau on 3 March 2014 and received instruction in the navigational and operational rules and regulations from the official navigator responsible. The theoretical and practical examination was carried out on 11 April 2014 by the management of the facility and the official navigator in the presence of the staff council's representative. According to his examination papers, the transporter bridge's operator demonstrated good theoretical and practical knowledge of

- putting into service and traffic management of the transporter bridge;
- use of the transporter bridge for assistance – ambulance transport;
- operating and service instructions of WSA Kiel-Holtenau, and
- navigational knowledge with regard to the use of sound signals (according to the regulations of the SeeSchStrO)

and was engaged as a transporter bridge operator in the two-watch service from then on. He is in possession of the VHF radio operator's certificate.

3.4.3.3 Passenger on the transporter bridge

WSP Kiel questioned the transporter bridge's injured passenger as a witness. The statement was provided to the BSU for the maritime safety investigation. The BSU also evaluated statements that the witness had made to the press. These indicated that the 31-year-old police officer from Rendsburg had been going home on his bicycle after finishing a night shift. He regularly used the transporter bridge for his journey to and from his place of work and had travelled on it even when he went to school. He boarded the transporter bridge with his bicycle at 0635 to cross over to Osterrönfeld. He saw the approaching freighter when the transporter bridge departed but thought nothing of it to begin with. It was only shortly before the collision that he reportedly realised that the transporter bridge would not allow the freighter to pass. The collision, which threw the witness to the ground, occurred when he became aware of the danger. His bicycle helmet prevented more serious head injuries.

When the transporter bridge started to spin because of the collision, the passenger slid back and forth over the deck before he was able to hold on to something to avoid falling into the water. When the transporter bridge swung out, the passenger made an emergency call to the control centre with his mobile phone.

After the emergency call, he reportedly heard a recurring sound signal, similar to a fog bell. The transporter bridge's operator then reportedly went from his control position on the upper deck to the guard rail and reportedly inquired about the witness and possible other passengers. In addition, the transporter bridge's operator had reportedly informed him that he too had notified the emergency responders. The transporter bridge's operator then reportedly lowered an emergency ladder but the injured passenger thought it too unsafe to use. The transporter bridge's operator then reportedly returned to the control position. Later on, when the recovery operation got underway, the passenger reportedly called out in an attempt to ask for the transporter bridge operator's mobile phone number for communication with emergency responders at the request of the fire service. However, it reportedly seems that the transporter bridge's operator did not understand his request.

The passenger had suffered head and knee injuries due to the collision and was admitted to a hospital in Rendsburg for further treatment and monitoring. He was unfit for work for one and a half weeks.

3.4.3.4 Canal pilot and canal helmsman on Ship B

Ship B was sailing behind the EVERT PRAHM in the convoy and was manned by a canal pilot and a canal helmsman, both of whom gave extensive testimony when questioned as witnesses by WSP Kiel. The BSU was provided with the interview reports for the maritime safety investigation.

After many years of service as a master, the canal pilot has served as a pilot on the Kiel Canal (*inter alia*) since 1993. The canal helmsman has served on the Kiel Canal for 25 years. They stated the following with regard to events on the morning of the accident.

The weather was reportedly poor on the morning of the accident. The wind was reportedly strong and gusty. Snow and sleet showers reportedly made it necessary to sail with windscreen wipers on permanently. It is reportedly always very bright in the area of the Rendsburg railway bridge, meaning increased concentration is reportedly required in such weather conditions.

The canal pilot was reportedly surprised when the transporter bridge crossed from the southern to the northern bank between two ships in a convoy (Ship A and the EVERT PRAHM). From the perspective of the ship following the EVERT PRAHM it reportedly looked relatively tight. After staying on the northern bank for one to two minutes the transporter bridge reportedly set off again, prompting the canal pilot to reportedly comment to the canal helmsman "He's in a hurry today." It reportedly seemed as if the transporter bridge was intending to pass just aft of the EVERT PRAHM's stern when it reportedly suddenly first flew up and then back and forth. The people on the bridge of Ship B were reportedly astonished. The distance to the EVERT PRAHM was reportedly only 500-700 m, which is why the machine was reportedly set to full astern immediately as an emergency manoeuvre. The chief officer, who was in charge of the navigational watch, reportedly called the master to the bridge. It had been possible to stop Ship B. The VTS was reportedly informed on VHF radio. Due to the many years of service on the Kiel Canal and knowledge of the capacity of the transporter bridge, it was assumed on Ship B that there were several people in the water and possibly also fatalities due to the severity of the collision. When they reportedly saw that the first emergency responders to arrive could not reach the transporter bridge, the canal pilot reportedly asked the master to instruct his crew to act as lookouts on the starboard wing, to pass the scene of the accident at minimum speed and to look for people in the water in the process. However, only one person was reportedly seen on the transporter bridge when they passed the scene of the accident.

On being questioned it was reported that no tyfon signal was heard before the accident, although it had reportedly been stormy and the doors to Ship B's wheelhouse had been closed.

3.4.3.5 Transporter bridge's operator from the previous day

During the investigation WSP Kiel also questioned the transporter bridge operator's colleague, who was on duty on the evening of 7 January 2016. The interview report was made available to the BSU.

As regards the training of transporter bridge operators, the witness stated that it was reportedly similar to a driving test and divided into a theoretical and a practical component. The theoretical component reportedly mainly concerns navigation rules, information on traffic group (TG) classification in the Kiel Canal and a VHF radio certificate. The practical component reportedly includes training on the control position by colleagues, a safety briefing on distances to be maintained from transiting shipping and training on using radar apparatus. There is reportedly no radar training similar to that given to inland waterway vessel skippers, for example, because the transporter bridge does not use radar for moving but always follows the same route. Transporter bridge operators reportedly usually set the radar to a range of 1,200 m or 1,600 m, where 1,200 m is reportedly favoured. In the westerly direction this setting reportedly reaches up to the bend at Saatsee.

Trainees are also encouraged to listen to the canal radio, in particular messages from the VTS. The training concludes with an examination organised by the official navigator. A note on successful completion of the examination is kept in the personal file. The transporter bridge operating manual is reportedly the only documentation on operation given to transporter bridge operators.

The witness did not find any technical defects on the transporter bridge during operation on the evening before the accident.

He stated that there was reportedly only one radar set at the control position. This reportedly has a pre-configured fixed safety area marked by two bars (to the west and to the east) on the radar image. The safety area at the time of the accident was reportedly set to 900 m, which is the distance from the transporter bridge in both directions of the Kiel Canal. The transporter bridge is reportedly not allowed to set off if a ship is moving toward it within the safety area. However, not adhering to the safety distance is reportedly acceptable when passing a ship at the stern.

When asked about the challenges of crossing at night, the witness explained that the many shore-based lights reflected very strongly on the windows of the operator's control position. The visibility is reportedly very limited when crossing in the dark, meaning it is reportedly necessary to keep a concentrated lookout through the windows.

When asked about a blind sector between the windows of the control position, the witness stated that everything was reportedly fine if you looked out of the windows to the left and right before crossing.

3.4.3.6 Other witnesses

WSP Kiel also interviewed other witnesses. Since none of these witnesses had seen the accident personally or were particularly familiar with the operation of the transporter bridge, their statements have not been included in this investigation report.

3.4.4 Surveys

On the day of the accident the BSU's investigation team boarded the EVERT PRAHM and inspected the damage, spoke with the crew and gained a general overview of the conditions on the bridge (including visibility ahead, navigation equipment, etc.).

After the transporter bridge had been pulled to the southern side and secured there, it was also subjected to a preliminary survey by the investigators. Since the power on the transporter bridge was switched off at the time of the survey, it was not possible to ascertain whether the radar apparatus had been switched on or off.

Kiel Public Prosecutor's Office secured the transporter bridge on 12 January 2016 in consultation with the BSU and WSP Kiel. WSP Kiel and representatives of the WSV carried out an inspection on that same day. WSP Kiel provided the survey report to the BSU. During the inspection of the control position, it was noted that the control lever of the southern control panel was in the front position. In the neutral position, operating the main switch in the western control panel would also have acted like an emergency stop switch on the three-phase motors. During the inspection the switch was set to emergency operation. A WSV representative present at the meeting justified this, as well as the position of the control lever on the southern control panel, with the fact that after the accident an attempt was made to move the transporter bridge from the middle of the canal during the recovery work.

An emergency stop switch above the control panel had not been engaged and was therefore not operated. WSP Kiel pressed the switch for test purposes, at which it engaged. In the event that the emergency stop switch above the southern control panel had not been operable on the day of the accident, there was also an emergency stop button on the opposite control panel. This was also found to be unengaged.

The transporter bridge was then searched thoroughly. No medication, drugs or alcohol were found on board.

It was agreed (on the basis of circuit and electrical diagrams) in the presence of WSP Kiel and a representative of the WSV at a meeting at the scene on 13 January 2016 that the AEG readout device should be removed from the control position's western control panel, as this would contain a corresponding recording if an emergency stop was triggered. The Flensburg-based Bilfinger GreyLogix foodtec GmbH, which had installed the system on the transporter bridge originally and upgraded it over the ten years prior to the accident, was commissioned with removing the device.

Said company carried out the removal of the readout device. Arrangements had been made to read out the data at the company's premises in the presence of the BSU and WSP Kiel on 18 January 2016. For the analysis of the data the readout device was connected to a battery, at which it became apparent that the alarm archive's RAM could not be read due to the long power interruption. The device only displayed two dates (the current date (18 January 2016) and one from 2011). The device was then disconnected from the power supply and packaged so as to have the lost data possibly recovered by the device's manufacturer, which was ultimately unsuccessful, however.

On 22 January 2016 the BSU's investigation team surveyed the transporter bridge in Osterrönfeld at the southern docking area. The survey was carried out jointly with representatives of WSP Kiel and technical experts from DNV GL, which Kiel Public Prosecutor's Office had commissioned. The experts inspected the cabling, including that of the emergency stop buttons. The normal emergency stop position and the active position were noted so as to allow for a comparison with recordings made on the day of the accident. The superstructure was without power on the day this survey was carried out, meaning that the functionality of the emergency stop could not be tested. The position of the emergency stop buttons for the southern (for crossing to the southern bank) and northern (opposite direction) control panels was noted (see Figure 46).

Figure 46: Position of the emergency stop button to the left above the southern control panel

Another survey of the transporter bridge was made on 18 February 2016. This survey was attended by WSP Kiel, experts from DNV GL, numerous representatives of the WSV and Deutsche Bahn, the EVERT PRAHM's legal counsel with expert and the transporter bridge operator's legal counsel. In addition to the survey of the transporter

bridge, a joint inspection of the Rendsburg railway bridge was also made. To begin with, the control system of the transporter bridge's drives, which are positioned on the transporter bridge's superstructure, was surveyed. The emergency stop functions were tested there, this time with power supplied. The emergency stop function was operable during this test.

During the joint survey on 18 February 2016 works carried out on the deck of the transporter bridge's control position on the day before the collision were also discussed. Representatives of the WSV advised that a mechanic from the WSV had mounted a GPS antenna on the roof. Works on the transporter bridge's electrical system had not been carried out. Accordingly, all parties involved rated the works as not relevant to the accident. Following the survey, it was unanimously stated that the transporter bridge reportedly complies with the state of the art and that a technical failure of the emergency stopping device (*inter alia*) should be ruled out. In consultation between the BSU, WSP Kiel and DNV GL's experts, it was decided after the survey that there was no further need for the transporter bridge to be secured. The previously removed AEG readout device for alarms was handed over to the WSV.

After two alterations in the investigation management at the BSU due to changes in personnel, another survey of the transporter bridge took place on 6 April 2018. The investigation team measured the viewing angles in the operator's cabin during this survey (see Subsection 3.4.11).

3.4.5 Data from VTS Brunsbüttel

In addition to the VHF radio recordings (Kiel Canal III) from the day of the accident, VTS Brunsbüttel provided the BSU with visibility measurements in the Rendsburg area, the traffic control system route diagram (see Figure 47), as well as raw AIS data for the EVERT PRAHM and other seagoing vessels sailing in the convoy for the reconstruction of the course of events leading up to and during the accident.

3.4.5.1 Kiel Canal route diagram

VTS Kiel Canal uses an automatically generated route diagram for traffic planning. In particular, this makes it possible to ensure that encounters in the canal only occur between ships of permitted TGs. The route diagram from the day of the accident was available for the safety investigation.

The BSU has rendered anonymous the names of uninvolved ships. The ships listed on the left-hand side sail from east to west and those on the right-hand side in the opposite direction. The ships ahead and astern of the EVERT PRAHM in the convoy are marked in red. The positions of the EVERT PRAHM plotted by the traffic control system in the VTS stop at the time of the accident after the antennas on the superstructure were torn off (see red border in Figure 47). The signal loss is actually not identical with the position of the bridge in this diagram. An exact representation of the ship's position is not the purpose of the diagram, however.

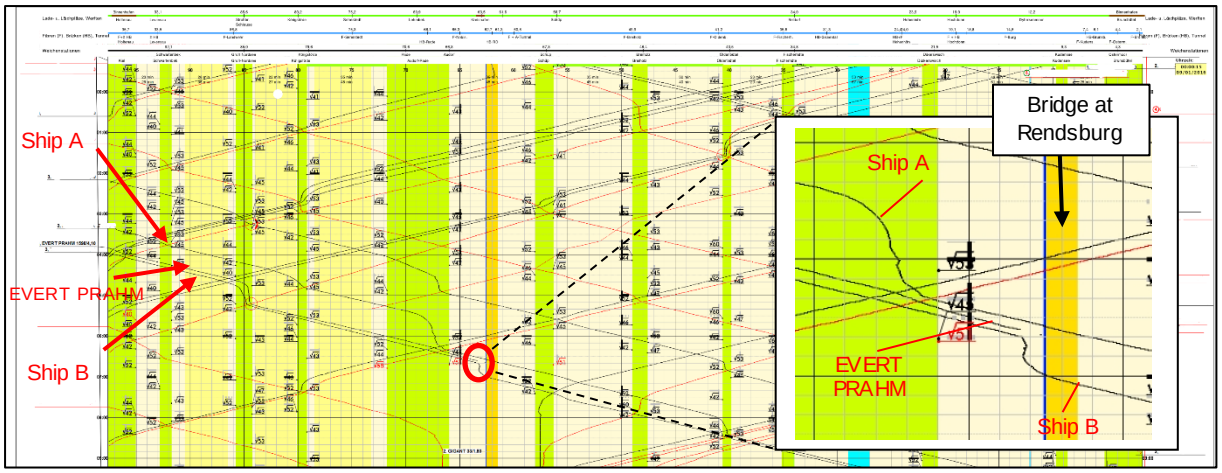


Figure 47: Extract from the route diagram for the Kiel Canal on the day of the accident

3.4.5.2 VHF radio communication

The recordings of radio traffic on VHF channel Kiel Canal III were analysed after the accident for the investigation. This VHF channel is a so-called duplex channel, i.e. the shore-based radio station (VTS) can only communicate with one maritime radio station at any given time. Maritime radio stations do not hear the messages of other maritime radio stations.

WSP Kiel transcribed the following radio traffic:

Time	VTS	Transporter bridge	Ships
063956		This is the transporter bridge.	
	EVERT PRAHM, Kiel Canal III.		
		An accident on the transporter bridge. It is […] in the middle of the fairway […] there was an accident, the transporter bridge, have collided with a ship.	
	EVERT PRAHM, you had a collision?		
		Transporter bridge had a collision with a ship.	***EVERT PRAHM*:** Yes, we just had a collision with the transporter bridge and are now south on the embankment near canal […]
		Help.	*EVERT PRAHM*: […] at 62.5.
	At 52.5. One moment. Ship B, Kiel Canal III.		
			***Ship B*:** Yes.

Time	VTS	Transporter bridge	Ships
	Well, from what I understand the EVERT PRAHM has just collided with some vehicle.		
		With the transporter bridge from Rendsburg.	
	(To Ship B) You must stop, I think with the transporter bridge, if I heard correctly.		
			Unknown 1: Yes, I am in the corner here, I cannot answer here, we have the [*with?*]
		The transporter bridge is now stopped here, virtually in the middle, and uh [...]	
			EVERT PRAHM: Yes, we are on the embankment. I guess we will probably first make fast at the Kreishafen shortly, but we will see.
	Yes, okay. The transporter bridge, Kiel Canal III.		
			Non-involved party: Kiel Canal III, [name]. The transporter bridge, I think it was a really violent collision. We should definitely send emergency responders there.
	Yes, we will do it right away.		
064233	Ship B, Kiel Canal III.		***Ship B***: Yes, this is Ship B.
	Yes, well, now if I understand correctly the EVERT PRAHM is on the embankment. You stay in the Kreishafen. The transporter bridge was in a violent collision.		
			How am I supposed to get to the Kreishafen? I am still lying east of the Kreishafen. I will have to see if I can pass first.
	Oh, now I understand, okay. Thank you. And can you see if there were people on board or was the transporter bridge empty?		

Time	VTS	Transporter bridge	Ships
			I am looking there with the glass now. I have stopped him for now. It was a very violent collision.
	Many thanks for the information. Okay. We will send ambulances there.		
064335			***EVERT PRAHM*:** Kiel Canal III, EVERT PRAHM, morning.
	Yes, morning, can you say if there were any injuries because of the collision?		Uh, we have, I do not know, there was a cyclist on it and I do not know what is wrong with the [...] with the [...], here with the operator from the transporter bridge. Well, someone is standing up on the transporter bridge right now, otherwise I cannot see.
	Yes, did you have no contact with the transporter bridge after the collision?		No.
	Okay, so you will stay in [Schülp]? So, the vessel is running normally, no engine damage or anything else?		Yes, I think we will briefly make fast in the Kreishafen to begin with.
	Yes, if you can get there, that is fine, then make fast to begin with. And damage, can you say anything for the ship?		Yes, the transporter bridge is damaged, severely buckled inwards at the front, yes?
	Okay, and no physical injuries.		No, there are no injured people here.
	In that case I understand, thank you. Can you say anything about the collision, exactly what happened?		

Time	VTS	Transporter bridge	Ships
			***Ship B*:** Kiel Canal, Ship B, can I get in for a minute?
	Just a moment, then Ship B first, [...] stay [...] yes.		
			Well, I see a person walking back and forth on the transporter bridge and the transporter bridge is still hanging. I intend to try to pass on the southern side because I cannot stay here like this.
	Okay, I understand, you are trying to stay on the southern side of the Kreishafen for now. Liaise with the transporter bridge, too, try to make contact with it at any event. When you reach it, send it to [Canal] 3. I would like to know if anyone was hurt, or not. I have sent an ambulance there as a precaution.		
			The ambulance is here, uh, can anyone be reached now on the transporter bridge? I have no contact with it. I will try to edge up to it now but I cannot stay here like this, either.
	Yes, then do it in accordance with the safety and efficiency. Make fast if you can and let us know when you are finished. Unfortunately, I cannot reach the transporter bridge by phone, either.		

Time	VTS	Transporter bridge	Ships
			***Ship B*:** Yes, but I do not need to make fast. When I have passed, I can continue.
	Yes, of course, if you can manage to, then you can do that, of course. You will have to assess that now. Unfortunately, I cannot see that from here.		
			No, I will manage on my own.
	All right. Just for information, the EVERT PRAHM is currently making fast in the Kreishafen, yes?		
		Kiel Canal, this is the transporter bridge.	
	Yes, transporter bridge, I have been trying to reach you. Yes, go ahead, what happened?		
		I could not find the phone. I do not know where she came from all of a sudden. I was looking on radar. She was there all of a sudden and then we collided. I have two people on board. Me and another one downstairs, maybe injured. I do not know if my leg is fractured, no idea.	
	Yes, how many casualties are on board?		
		I am in the middle of the Kiel Canal.	
	Take your time now, one tiny moment please, exactly how many casualties are on board?		
		I will look again. One moment, please.	
	Yes. The ambulance is already here.		

Time	VTS	Transporter bridge	Ships
064727		Kiel Canal III, transporter bridge.	
	Yes, transporter bridge, Kiel Canal.		
		Two casualties.	
	Two casualties on board.		
		Yes.	
	Okay. The ambulance is already at the scene. Are you coming to the northern or southern side?		
		I cannot get anywhere with the transporter bridge. It is stuck. Ropes are torn, cables are torn. I will see what it looks like from the outside. I cannot assess that right now. Just a moment please.	
	Yes, take your time and see. Otherwise I will send another ferry to you with the ambulance.		

Spreadsheet 3: Kiel Canal III VHF radio recordings after the accident

3.4.6 Weather on the day of the accident

Germany's National Meteorological Service (DWD) prepared a report on the weather in the area of the Kiel Canal (canal kilometres 50-70) during the period of relevance to the accident between 0600 and 0800 on 8 January 2016 on behalf of WSP Kiel. Extracts from the report, which was made available to the BSU for the investigation, follow.

The weather map displayed a storm front with a core pressure of 985 hPa (see Figure 48) over the German Bight, which tracked eastward over the northern part of Schleswig-Holstein and the western part of the Baltic Sea as the day progressed. Polar air over the region was displaced by the depression, resulting in precipitation gradually changing from snow or freezing rain to rain.

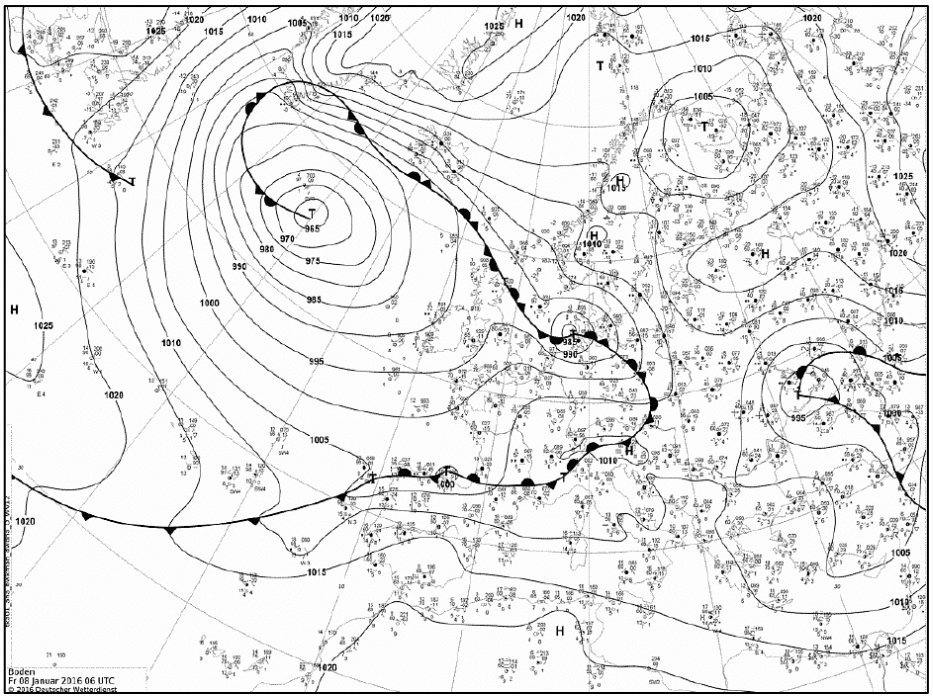


Figure 48: DWD's ground pressure and frontal analysis at 0600 UTC on 08/01/2016

The DWD stated the following with regard to the weather in the area of the accident.

Mean wind and gusts (at a height of 10 m above the water surface):
Measuring stations in the vicinity indicate that a southerly wind of 12-18 kts (4-5 Bft) prevailed at the scene of the accident during the period specified. It veered westward by midday, temporarily increasing to 27 kts (6-7 Bft) in the process. Rawinsondes displayed increasingly unstable atmospheric stratification, allowing stronger wind speeds from higher layers to be deflected downward. Gusts of up to 33 kts (7-8 Bft) were recorded in the corresponding period, for example.

Weather and visibility:
The satellite image (see Figure 49) displays a compact cloud spiral over the region, which is to be seen in conjunction with the depression. There was also precipitation, which initially fell to the ground as freezing rain. The rainfall became increasingly prevalent toward the end of the period. Visibility stood at 5-10 km.

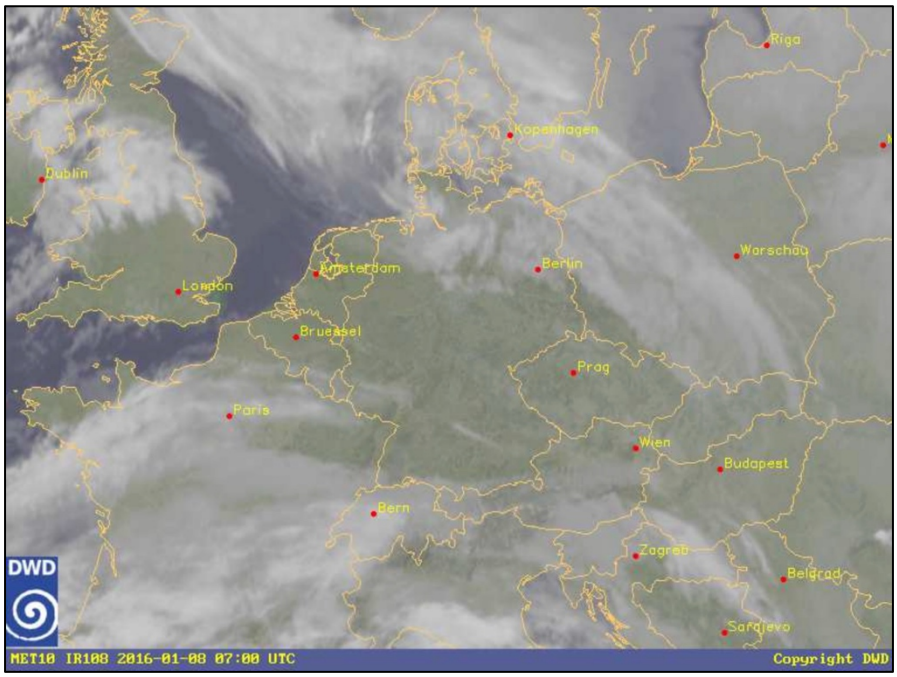


Figure 49: Extract from the MET10 satellite image in the infrared spectral channel of 08/01/2016, 0700 UTC

Temperature:
The air and water temperature exhibited values of about plus 3 °C.

The BSU and the GDWS commissioned the DWD with the preparation of a weather report from 0400 on the day of the accident until the time at which the accident occurred (about 0640). This was to focus on visibility, temperatures and precipitation during said period, in particular.

The remarks of the DWD are consistent with video recordings of the web camera set up at the scene of the accident (see Subsection 4.1.2.1), on which snow cover is visible on the banks in the period from before until after the accident (see Figure 50).

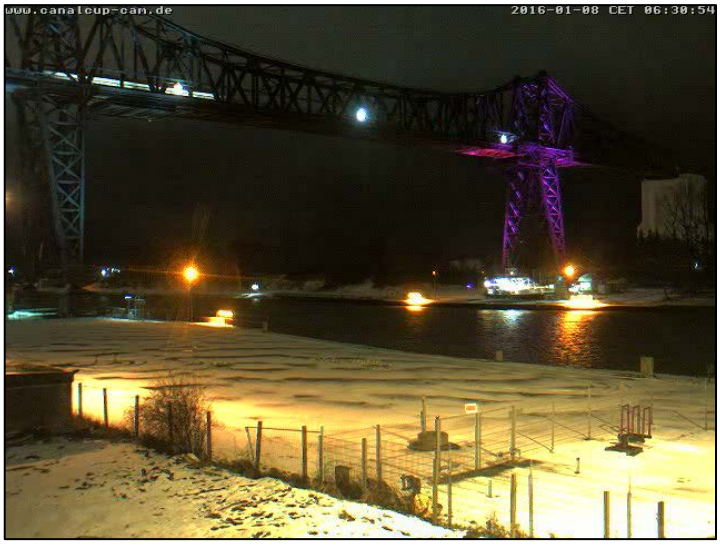


Figure 50: Snow cover on the banks, scene of the accident, (08/01/2016, 0630)

The wind stood at 6-7 Bft according to the crew of the EVERT PRAHM. Visibility was reportedly more than 1,000 m at all times, even in snowfall. On the other hand, the bridge team on Ship B, which was following the EVERT PRAHM in the convoy, reported that visibility was restricted due to snow grains.

3.4.7 AIS recordings

The BSU was sent AIS recordings of the course of events leading up to and during the accident from various sources for the safety investigation.

3.4.7.1 AIS recordings from WSA Brunsbüttel

WSA Brunsbüttel provided the BSU with screenshots from the WSV's own AIS media player for the investigation. Two screenshots per minute cover the period 063336 to 063842.

The times on the AIS media player differ by about ten seconds from the times on the web camera recordings. This difference is within the usual tolerance for recordings from different sources. To facilitate comprehensibility, the times from the AIS media player are used to correlate information about the speeds and courses of the ships mapped.

The first ship in the convoy, Ship A, passes the Rendsburg railway bridge at 0633 at a SOG of 7.8 kts[7] (see Figure 51). She was followed by the EVERT PRAHM (8.7 kts, course over ground (COG): 230.0°, heading (HDG): 234°) and the last ship in the convoy, Ship B, at 8.4 kts. The recording exhibits a synchronisation deviation in that the speed of the EVERT PRAHM is indicated as 8.7 kts in the detail bar displayed to the right, while the detail bar next to the ship symbol indicates 8.8 kts.

[7] All SOGs shown below are in kts.

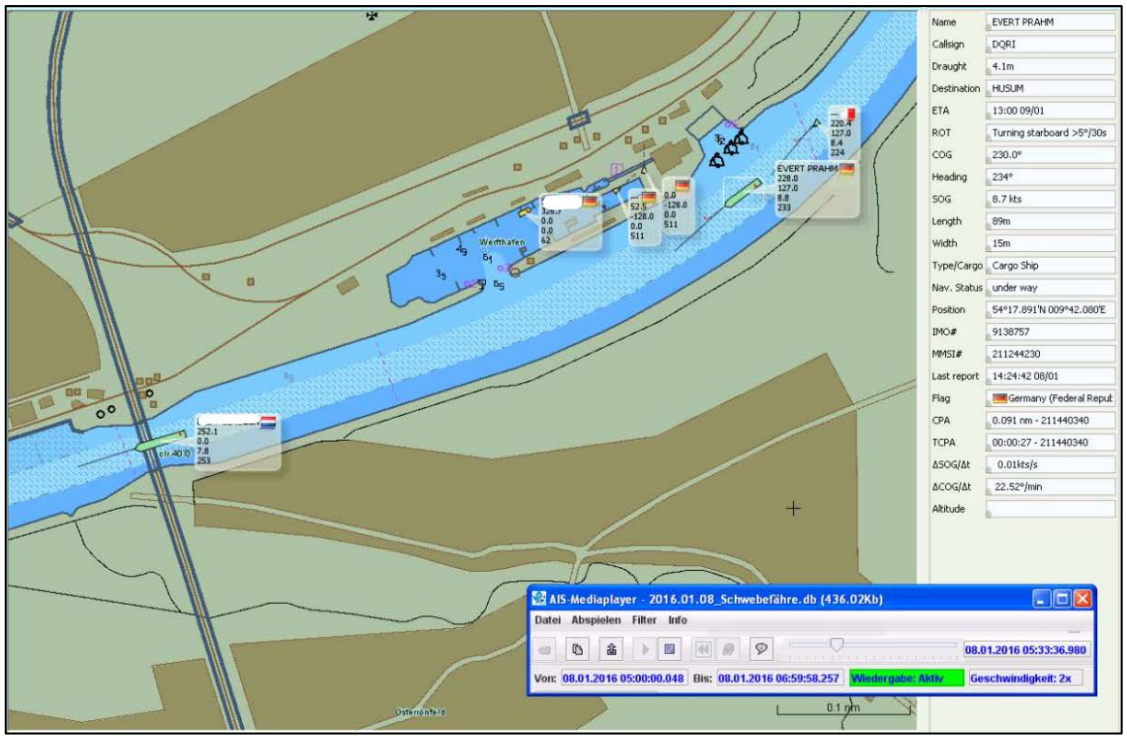


Figure 51: Ship A passes bridge before the accident (08/01/2016, 063336)

Ship A has passed the bridge and thus also the transporter bridge, reducing her speed further to 7.4 kts (see Figure 52) in the process. The EVERT PRAHM is at the end of the right-hand bend in the canal keeping roughly to the middle of the fairway at a speed of 8.7 kts. Ship B follows her at 8.4 kts.

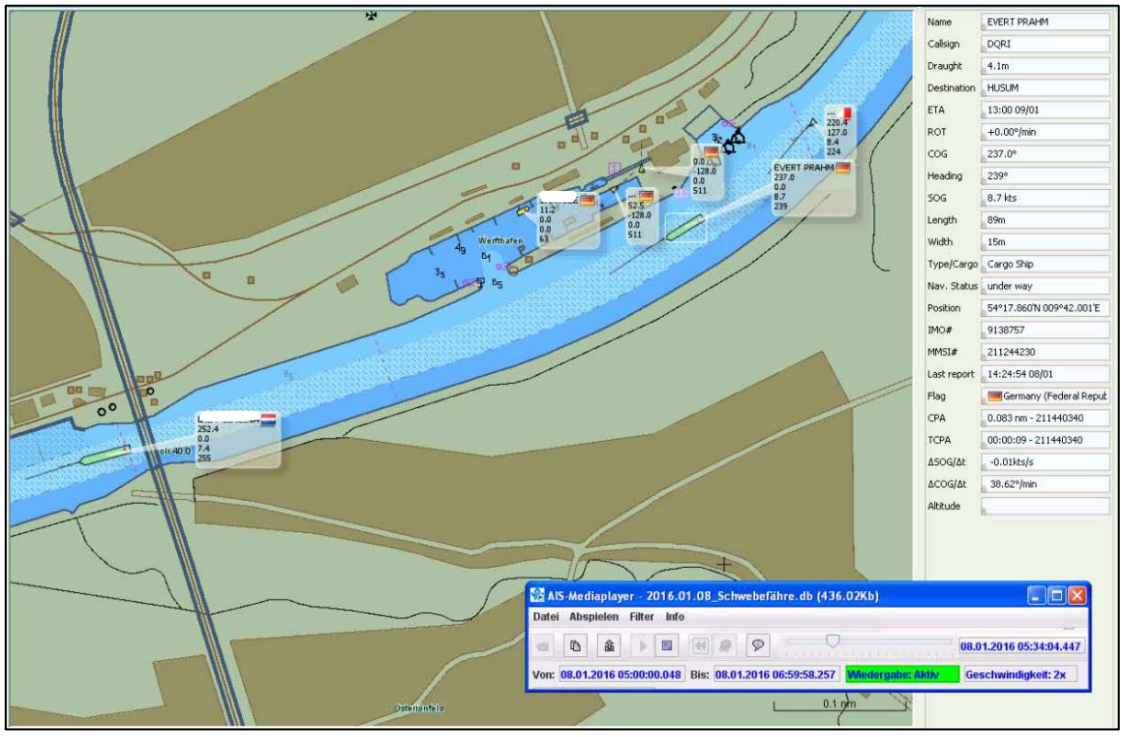


Figure 52: Ship A has passed the bridge (08/01/2016, 063404)

After Ship A passed the bridge and the transporter bridge her speed reduced further to 7.2 kts. At the same time, the EVERT PRAHM enters the straight section of the canal in front of the bridge at a speed of 8.7 kts. The speed of Ship B following her remains unchanged at 8.4 kts (see Figure 53).

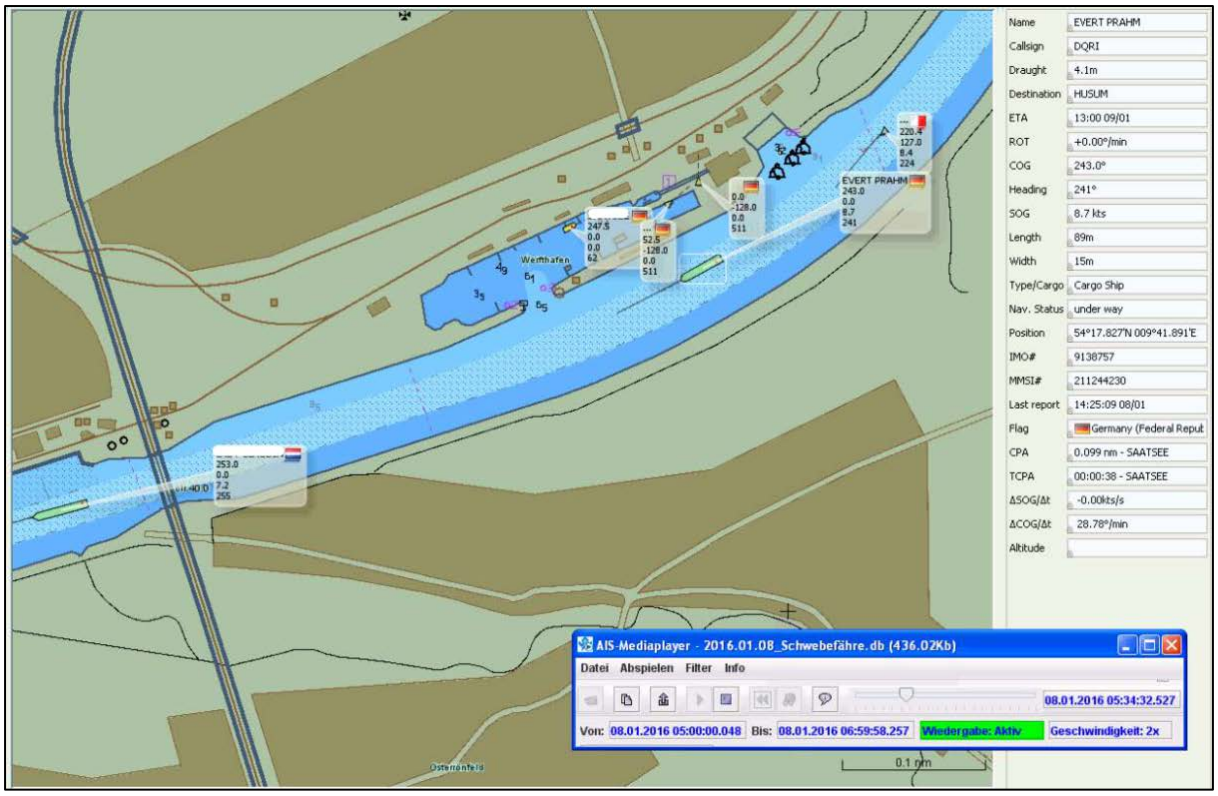


Figure 53: The EVERT PRAHM approaches the bridge (08/01/2016, 063432)

Ship A sails away from the bridge at 7.1 kts. Meanwhile, the EVERT PRAHM approaches the bridge at 8.8 kts (COG: 244.0°, HDG: 239°) sailing on the right-hand side of the fairway. Ship B continues to sail at a constant speed of 8.4 kts (see Figure 54).

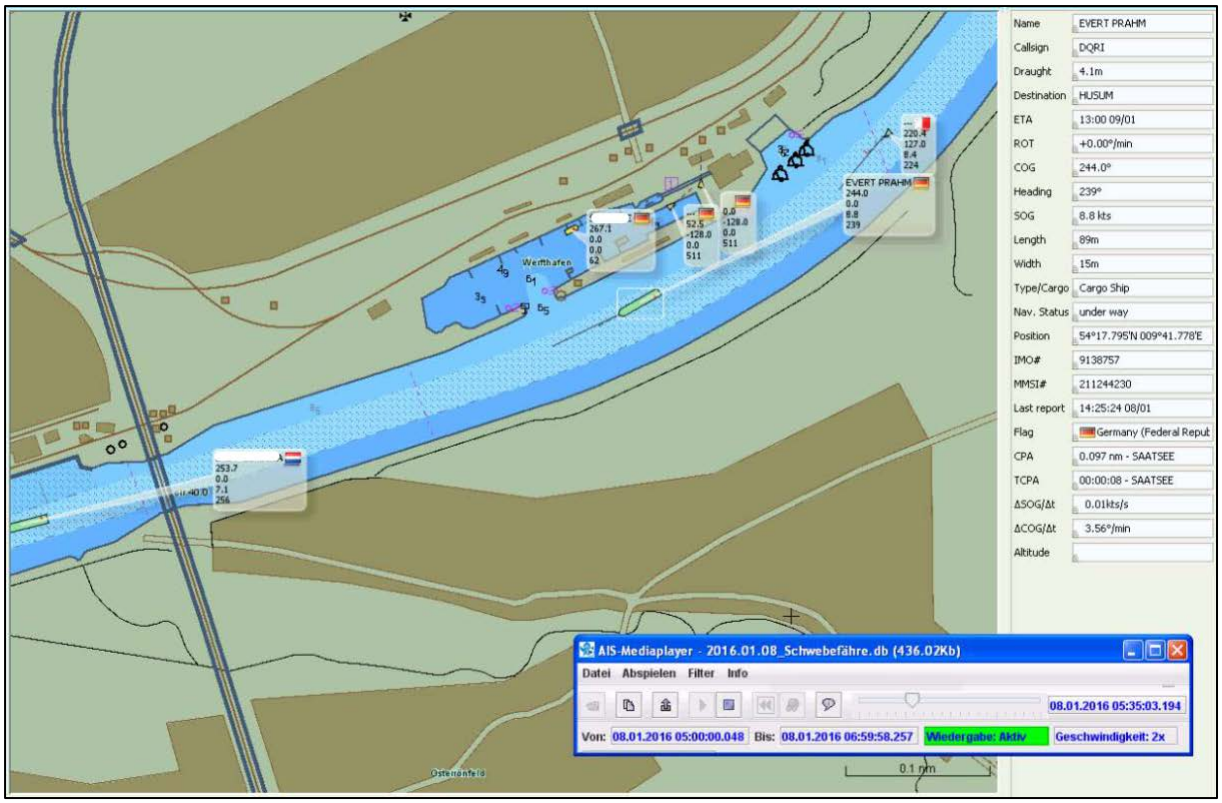


Figure 54: The EVERT PRAHM approaches the bridge (08/01/2016, 063503)

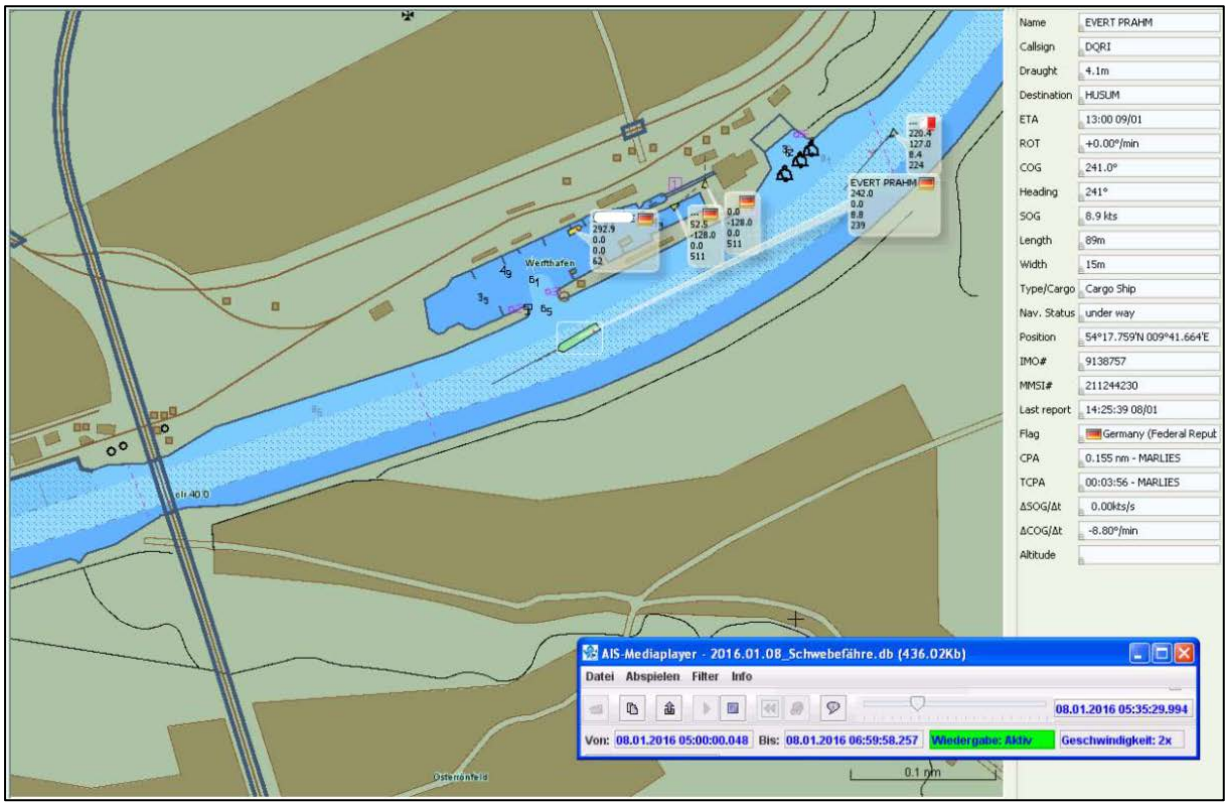


Figure 55: The EVERT PRAHM approaches the bridge (08/01/2016, 063530)

Figure 56: The EVERT PRAHM approaches the bridge (08/01/2016, 063603)

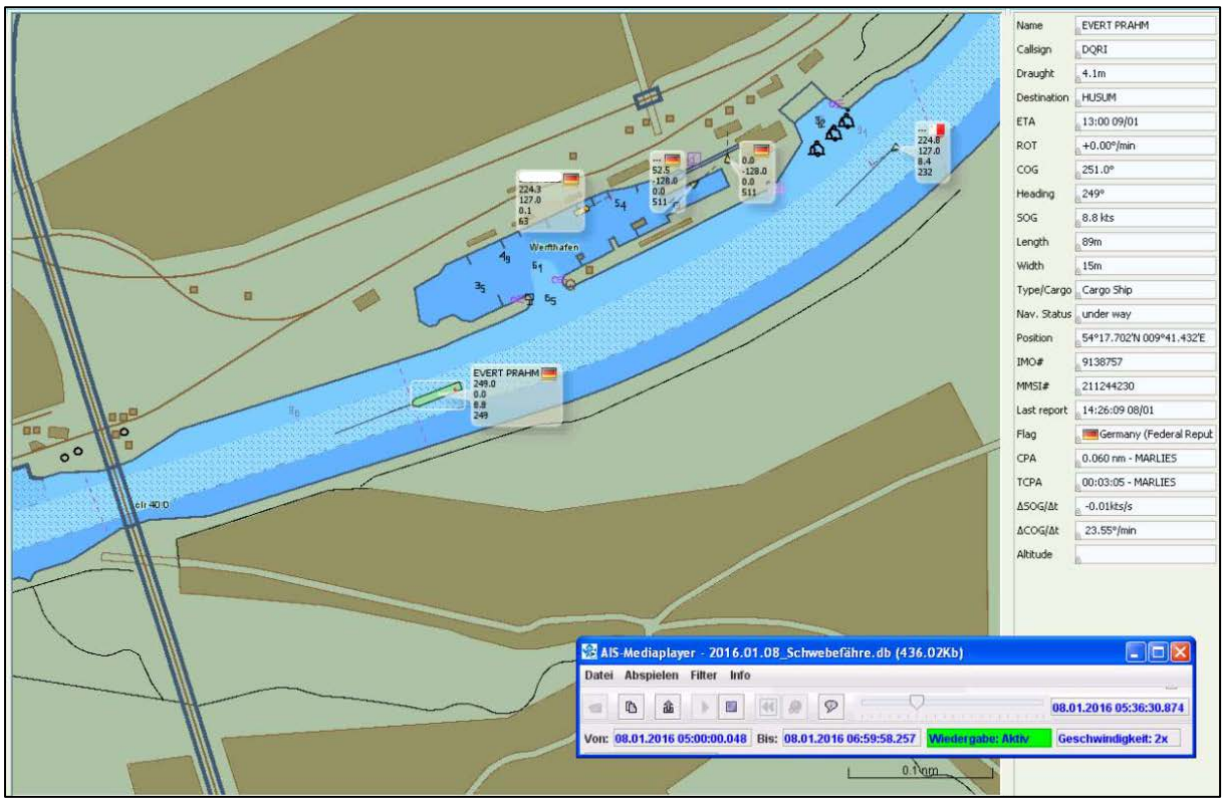


Figure 57: The EVERT PRAHM approaches the bridge (08/01/2016, 063630)

The EVERT PRAHM's speed is indicated at a constant 8.8 kts.

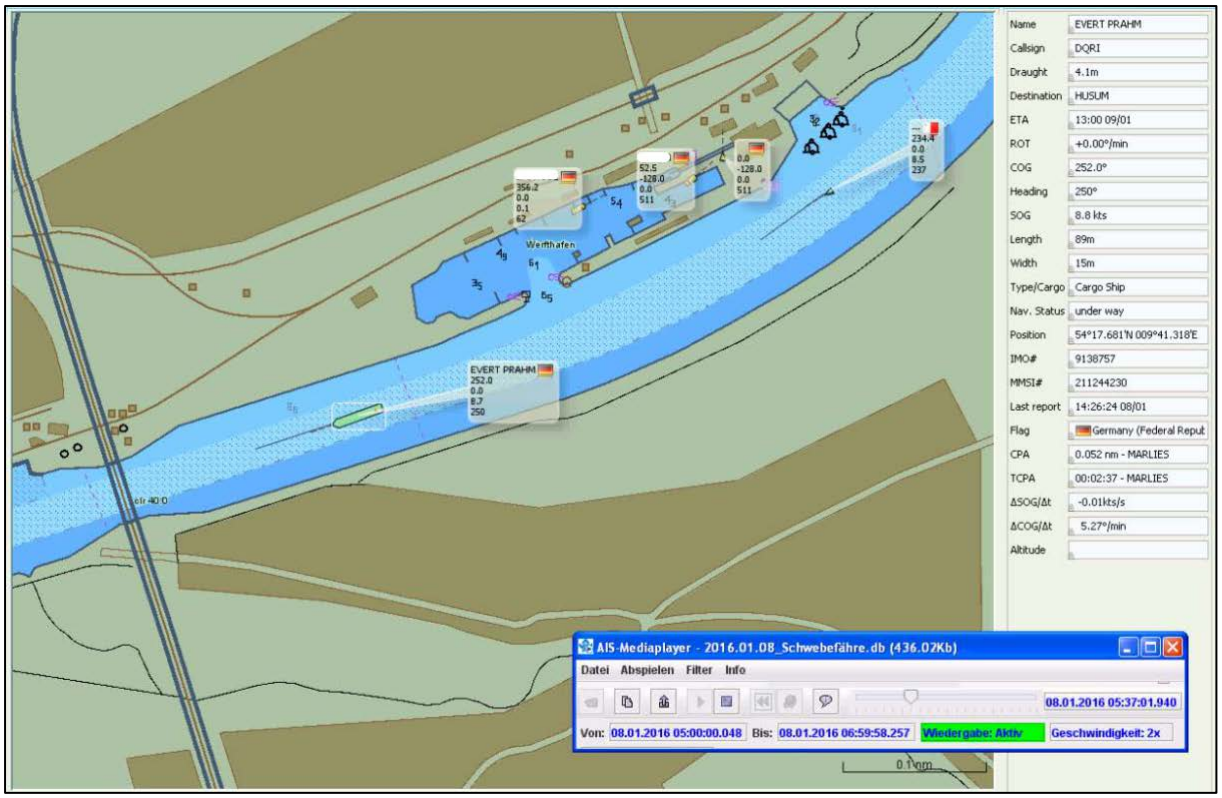


Figure 58: The EVERT PRAHM approaches the bridge (08/01/2016, 063701)

Figure 59: The EVERT PRAHM approaches the bridge (08/01/2016, 063730)

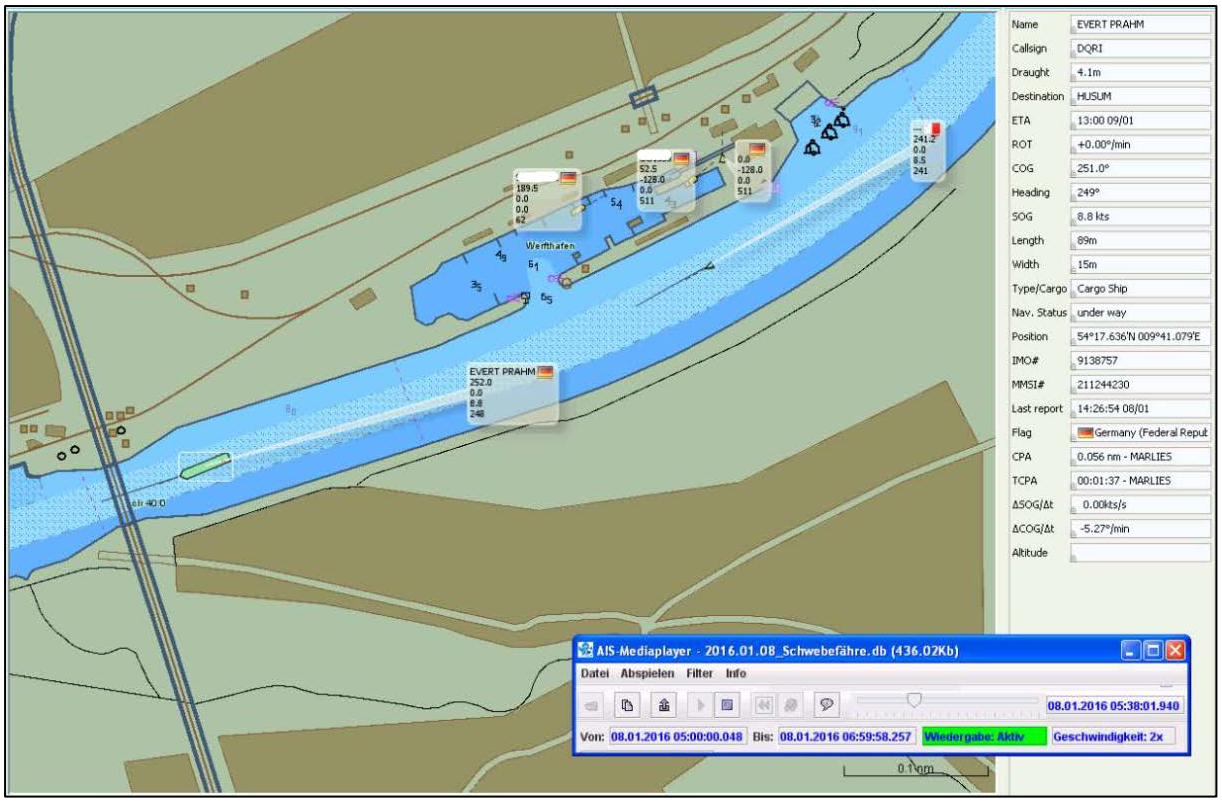


Figure 60: The EVERT PRAHM approaches the bridge (08/01/2016, 063801)

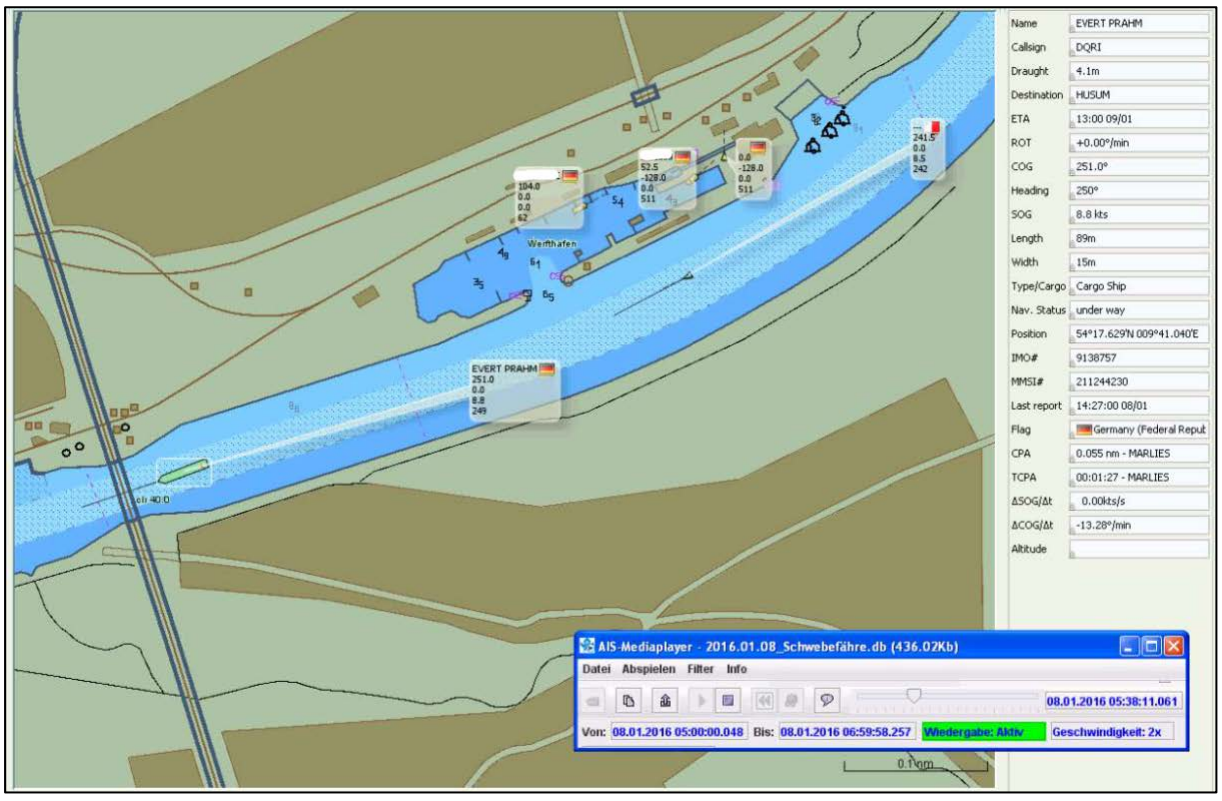


Figure 61: The EVERT PRAHM approaches the bridge (08/01/2016, 063811)

The EVERT PRAHM's COG and HDG remain almost unchanged during the approach to the bridge crossing. The speed is also indicated at 8.8 kts immediately before passing beneath the bridge. The collision with the transporter bridge occurred between the previous and following figures.

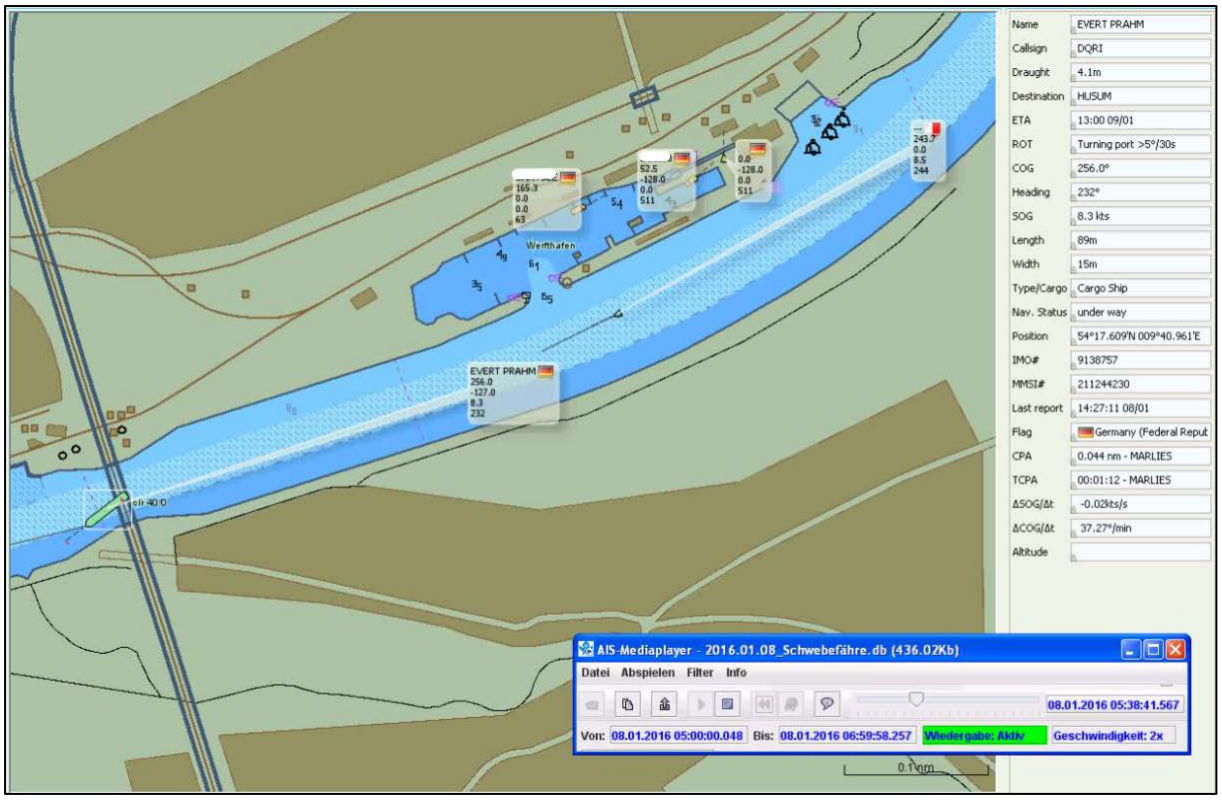


Figure 62: The EVERT PRAHM after the collision (08/01/2016, 063841)

3.4.7.2 AIS recordings from the WSP control centre

The Joint Control Centre of the Waterway Police of the Coastal States in Cuxhaven compiled the AIS plots of the course of events leading up to and during the accident at the request of WSP Kiel. This compilation was made available to the BSU.

The recordings indicate that the EVERT PRAHM approached the bridge crossing at 063506 at a COG of 244.0°, a HDG of 239° and a speed of 8.8 kts. These figures are consistent with WSA Brunsbüttel's recordings for 063503.

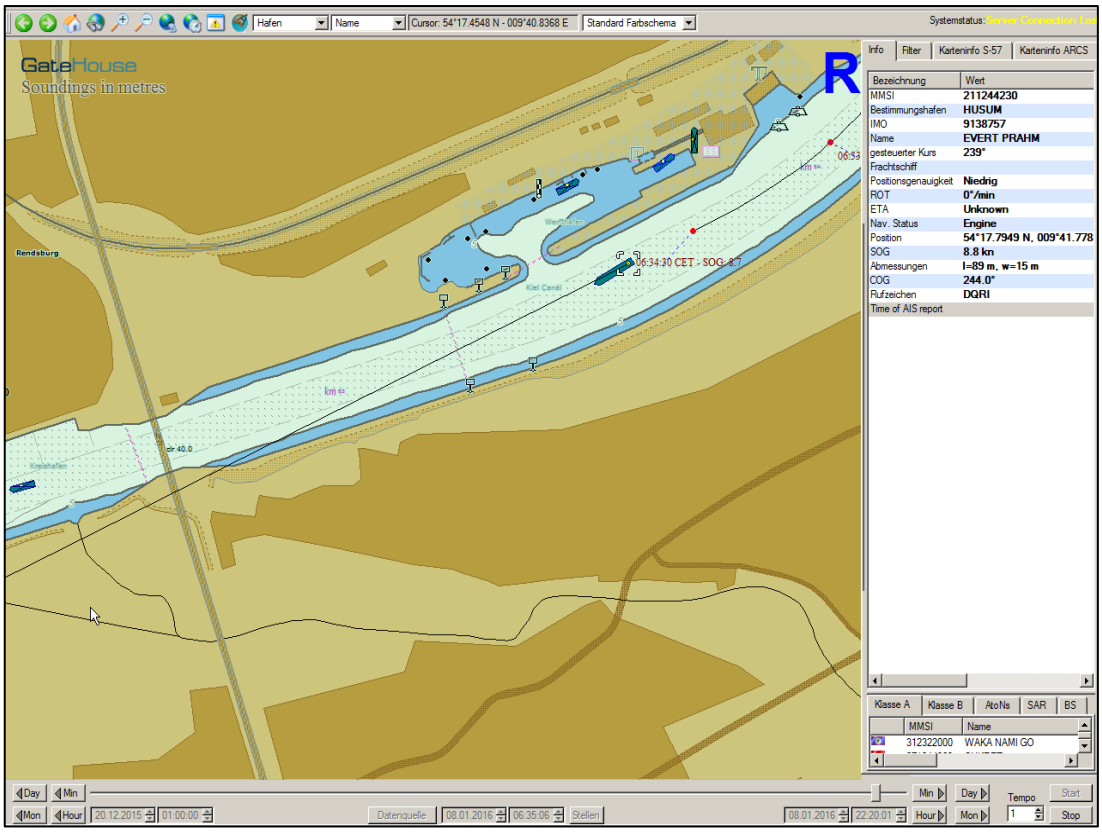


Figure 63: The EVERT PRAHM approaches the bridge (08/01/2016, 063506)

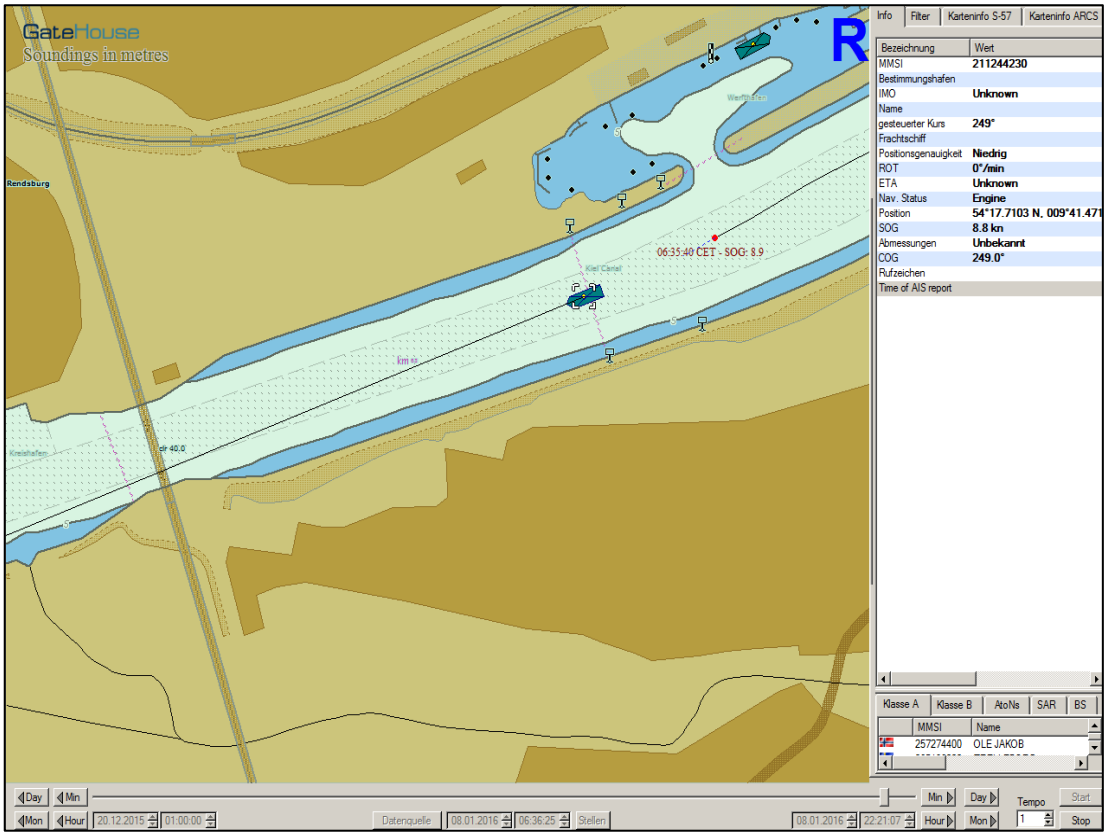


Figure 64: The EVERT PRAHM approaches the bridge (08/01/2016, 063625)

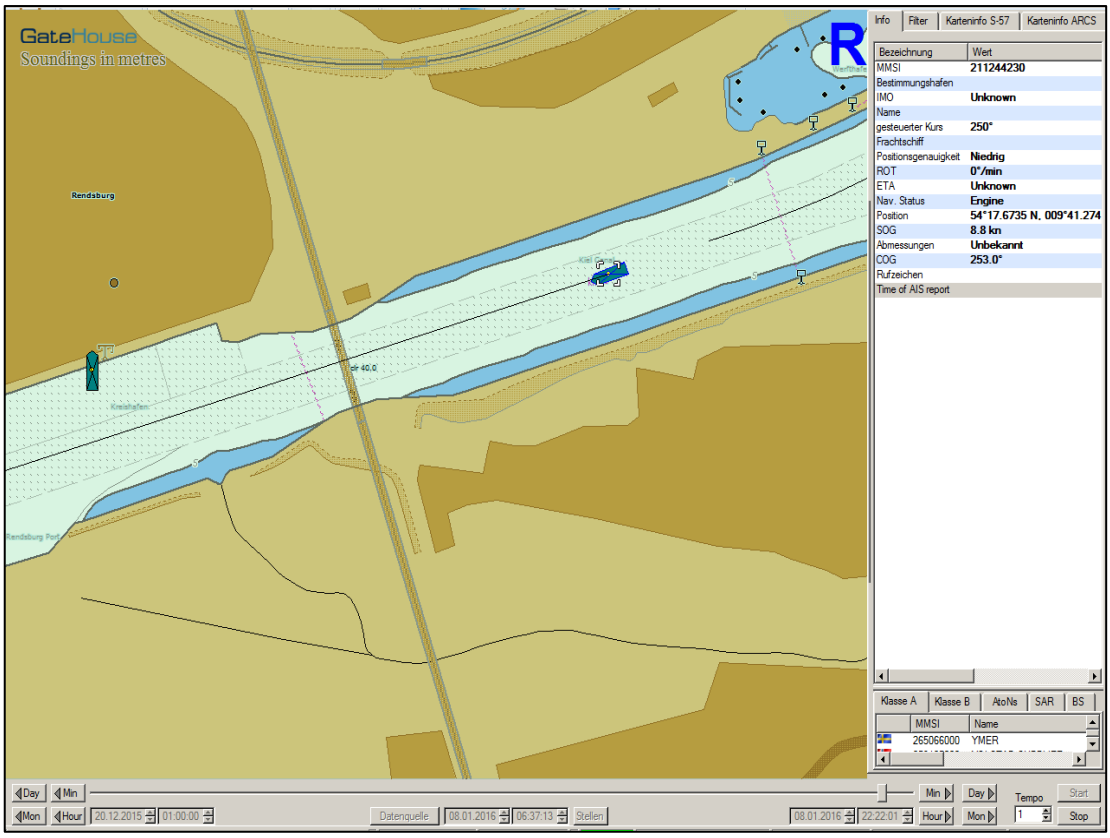


Figure 65: The EVERT PRAHM approaches the bridge (08/01/2016, 063713)

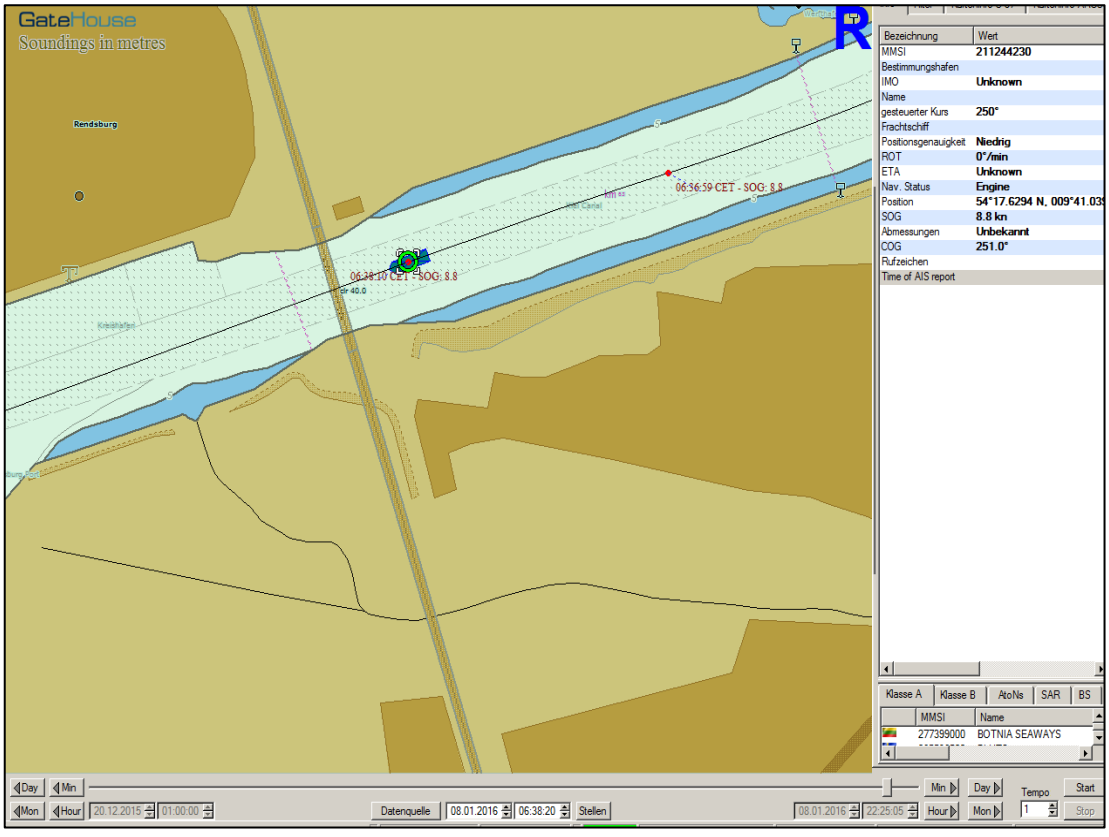


Figure 66: The EVERT PRAHM approaches the bridge (08/01/2016, 063820)

The recordings from the WSP control centre also indicate that the EVERT PRAHM sailed at an almost constant COG and HDG until immediately before the bridge crossing. The speed is indicated at a constant 8.8 kts. In the next plot recorded (063836) the accident has already occurred (see Figure 67).

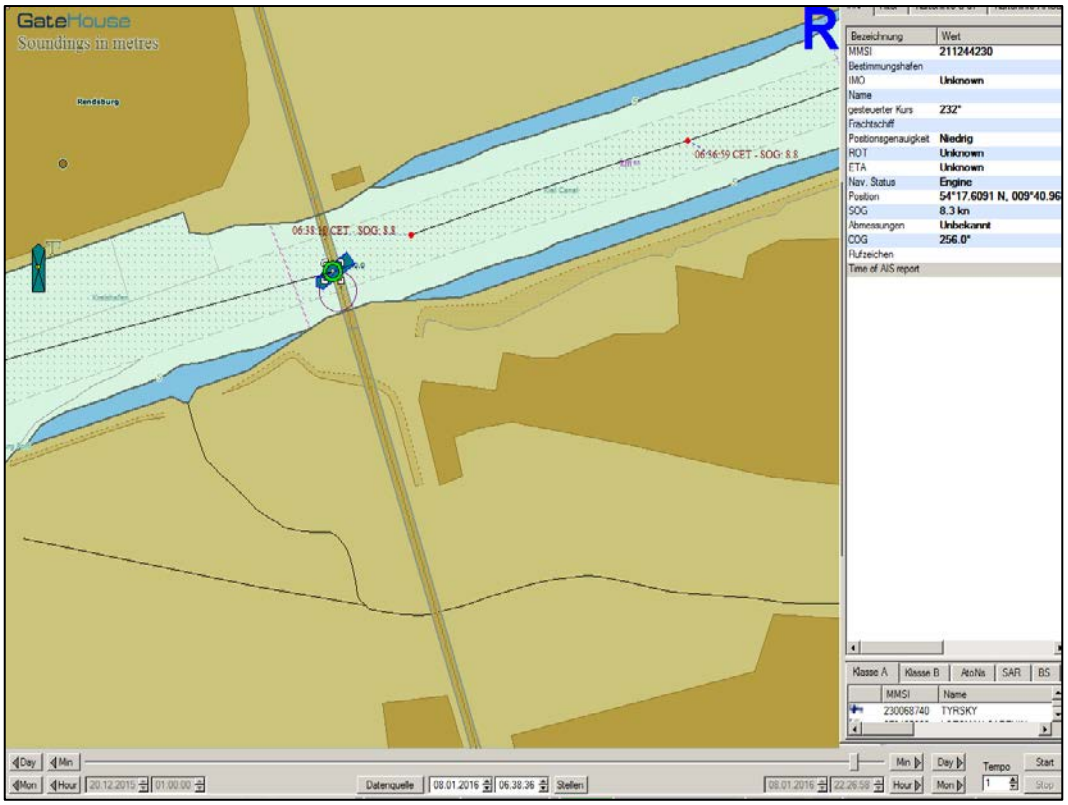


Figure 67: The EVERT PRAHM after the collision (08/01/2016, 063836)

The WSP control centre also documented the interruption of the EVERT PRAHM's AIS signal after the collision with the transporter bridge (see Figure 68).

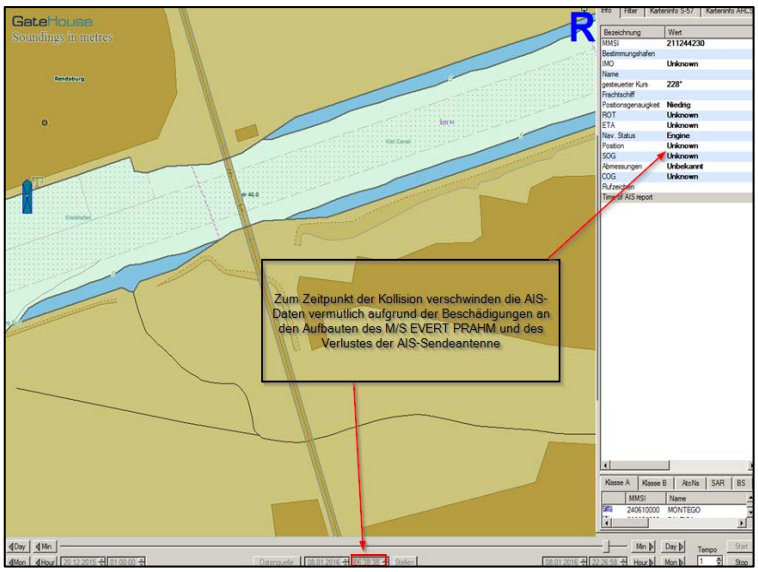


Figure 68: Interruption of the EVERT PRAHM's AIS signal (08/01/2016, 063838)

3.4.8 Testing of the transporter bridge's radar set

WSP Kiel tested the transporter bridge's radar set and found no indications of a malfunction.

The two distance markers of the safety area to be maintained from transiting shipping are clearly visible (red arrow markings) on the radar image used for illustration (see Figure 69). Since the radar set was found to be without power when the first survey after the accident was made, it was not possible to determine retrospectively whether it had been in operation on the morning of the accident.

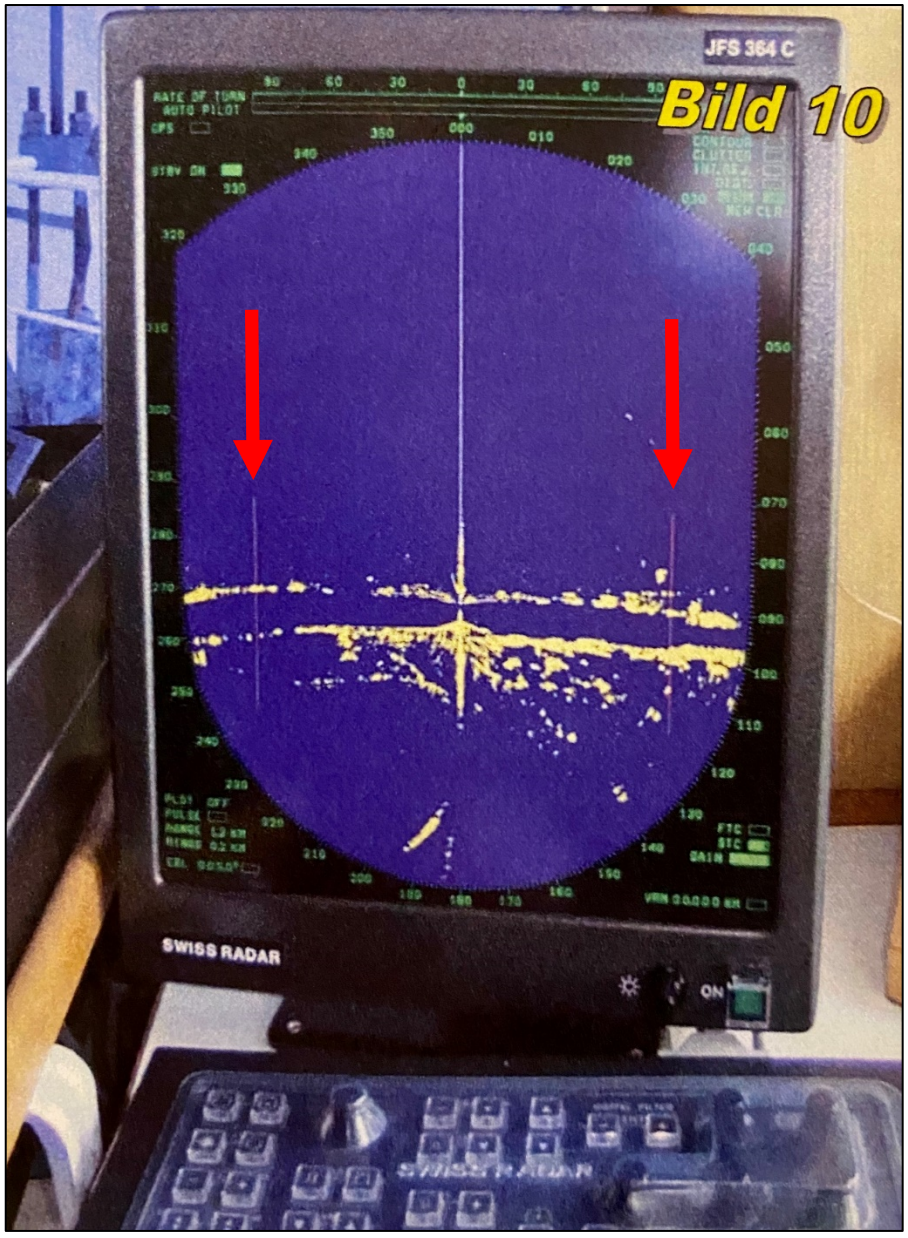


Figure 69: Transporter bridge's radar set (photograph taken on 20/12/2012, image from DNV GL's expert opinion on emergency stopping devices)

3.4.9 Expert opinion on emergency stopping devices, standby systems

DNV GL prepared an expert opinion on 1 April 2016 on the technical condition of the transporter bridge's braking and emergency stopping system on behalf of Kiel Public Prosecutor's Office. The BSU was provided with the opinion for the safety investigation.

The task of the experts was to examine the transporter bridge and to assess and document the technical condition – that of the braking and emergency stopping system, in particular. Following that, the question as to whether the technical condition of the transporter bridge was a causal factor in the collision with the EVERT PRAHM had to be answered.

The team of experts inspected the platform (gondola) and the operator's cabin on 22 January 2016, broadening the inspection to include the complete transporter bridge with superstructure in a second survey on 18 February 2016.

Extracts from the opinion follow.

"The transporter bridge has a battery-powered emergency drive, which can be activated via a mode selector switch and an illuminated push-button. The emergency drive function serves exclusively as a diversified backup to the main operating system to enable the completion of a crossing in the event of a power failure or similar. […]"

With regard to operation under main propulsion, the opinion states that after the completion of unloading/loading the barriers had to be closed first, i.e. before the transporter bridge's operator was required to check that the waterway was clear. "After completing this check, the *Entriegeln* [unlock] button on the canal-side control console must be pressed. This releases the storm hook and clears the transporter bridge for crossing. The transporter bridge is then set in motion by setting the drive lever. If the movement command is not given within six seconds of [...] *Entriegeln* [unlock] and the associated opening of the storm hook, then the storm hook will lock the transporter bridge again and starting is prevented by the control system and mechanically."

The expert opinion goes on to state that the storm hook can only be unlocked when the loading barrier is closed.

For the sake of completeness it should be mentioned at this point that during darkness it is the violet illumination of the bridge girders on the respective side of the canal that notifies shipping transiting the Kiel Canal of the locking of the storm hook (see Figure 50 above). However, the town of Rendsburg does this in the interest of tourism, i.e. it is not a signal for shipping.

The opinion describes a normal crossing as follows.

"When the lever is set in the direction of travel, the crossing is initiated and the transporter bridge starts to move. [...] The transporter bridge then accelerates evenly

over an acceleration ramp[8] to the speed corresponding to the position of the lever. The control lever remains at its position independently, i.e. it is not automatically set to neutral when released. However, both this and a reversal of the direction of travel is possible at any time through the intervention of the transporter bridge's operator. If the transporter bridge's operator does not intervene in the movement of the transporter bridge during a crossing, then the crossing will be continued and completed with it until docking. The transporter bridge's speed is automatically reduced in the docking area, movement is switched off via limit switches at the dock and the transporter bridge is locked with the storm hook. The *ferry maintaining connecting lines* navigation mark is disabled [...]." The opinion states that normal crossings are completed in just under two minutes.

With regard to the emergency stop function (see emergency stop button in Figure 46), the experts determined that pressing the button would have caused the electrical supply to be disconnected from the current path responsible for propulsion of the transporter bridge. The transporter bridge would then have been slowed down by friction and thus stopped. The inspection of the emergency stop circuit in the operator's cabin as well as on the two carriages revealed that the immediate shutdown system was operable and not defective.

The experts analysed the web camera recordings and concluded that the accident happened about 30 seconds after departure, i.e. after manual initiation of the crossing. They also assume that pressing the emergency stop button within the first 15 seconds could have prevented the accident. The opinion does not contain any information or calculations regarding the distance covered by the transporter bridge or the advance distance and duration of the stop.

The opinion closes with the following observations:

- the emergency stopping device was operable and met all norms and applicable standards[9];
- the emergency stop button would have made it possible to stop the transporter bridge quickly;
- the transporter bridge's operator had four options for stopping the transporter bridge:

    - pull back the control lever;
    - press emergency stop;
    - set mode selector switch to emergency operation (emergency operation function in the event of a power failure or similar), or
    - switch off the AC inverters for the main east and west drive systems. Switching off the inverters is equivalent to stopping the main drive systems.

[8] Electronic control system to accelerate the transporter bridge to its defined speed smoothly and quickly.

[9] EN 60204-1: Safety of machinery – Electrical equipment of machines; ISO 13849-1: Safety of machinery – Safety related parts of control systems.

3.4.9.1 Risk assessment for the transporter bridge

On 16 April 2014 DNV GL prepared verification documents for the transporter bridge risk assessment in accordance with EN ISO 12100 based on the aspect of the mechanical and electrical safety of machinery. The risk assessment was provided for the safety investigation.

Directive 2006/42/EC on machinery states that machinery manufacturers are required to carry out a hazard analysis to determine any hazards associated with the machine. The risk assessment is a sequence of logical steps that permit the systematic investigation of hazards posed by machinery (EN ISO 14121 – Safety of machinery – Risk assessment).

The risk assessment estimated that without further modification the transporter bridge's service life would be another 15 years (i.e. until 2029).

One of the hazard scenarios assessed in the risk assessment was a collision between a ship and the transporter bridge. The protection objective and measures were formulated as follows.

> "Preventing a collision between a ship and the transporter bridge.
> Technical protection measures:
> - defined safety area within which no ship must be located when the transporter bridge departs;
> - safety area configured for speed in emergency operation;
> - verification of safety distance visually and with radar.
>
> Structural protection measures:
> - control lever without automatic reset function. Movement continues automatically;
> - the transporter bridge's operator has periodic health checks.
>
> Structural technical protection measure:
> - redundant emergency drive with daily operational check.
>
> Control system protection measure:
> - audible signal for emergency operation."

The remaining risk was classified as follows.

- "Remaining risk arising from carelessness of the transporter bridge's operator or maritime traffic exceeding the speed limit. Generally low remaining risk.
- Remaining risk arising from unintentional adjustment of the control lever, e.g. during a fall, resulting in automatic continuation of movement no longer being ensured. Remaining risk can be reduced by other technical measures (e.g. automatic signalling when the transporter bridge is at a standstill and outside the limit positions).
- Remaining risk arising from failure of the emergency drive. Generally low remaining risk."

Inter alia, the following hazard groups/consequences were also identified.

- "Exposure to noise → Discomfort, loss of consciousness, impaired balance, permanent hearing loss, tinnitus, stress and all other problems arising from a disruption of speech communication.
- Exposure to vibration → Diseases of the lower spine, bone joint damage, spinal injury, discomfort, vascular disease, neurological disease.
- Ergonomic hazards → Discomfort, fatigue, musculoskeletal disorders, stress, all other problems arising from human error.
- Risks related to the workplace → [...] insufficient visibility from the working position, unsuitable lighting, unsuitable seating, noise at the workplace, vibration at the workplace."

In summary, the recommendations included

- provide an emergency stopping device;
- create an operating manual, and
- convert the control lever to one with locking in the selected position.

The recommended measures were implemented before the accident.

3.4.10 Expert opinion of the GDWS

As the leading authority for technical supervision of WSA Kiel-Holtenau, which is responsible for operation of the transporter bridge, the GDWS in Kiel commissioned an expert opinion on the navigational behaviour of the ship's command of the EVERT PRAHM.

The opinion was prepared by Professor of Nautical Science Sander Limant from the Faculty of Mechanical Engineering, Process Engineering and Maritime Technologies at Flensburg University of Applied Sciences and reviewed by Professor Pawel Ziegler from the Institute of Nautical Science and Maritime Technologies at the Maritime Centre of Flensburg University of Applied Sciences. The opinion was provided to the BSU on 16 November 2016 for the investigation.

The objective of the opinion was to examine the navigational behaviour of the ship's command of the EVERT PRAHM and put this in the context of shipping legislation. The expert's assignment did not include assessing the transporter bridge's role in causing the accident.

The assessment of the navigational behaviour of the ship's command of the EVERT PRAHM was to a large extent based on various collision simulation scenarios carried out at the Maritime Centre of Flensburg University of Applied Sciences. The simulations were based on specially prepared 3D models of the Kiel Canal in the area of the railway bridge at Rendsburg and dynamic objects, such as the surrounding traffic, taking into account the weather and visibility on the morning of the accident.

The expert, Professor Limant, did not receive digital data on the ship's structure for modelling the EVERT PRAHM from the owner. Accordingly, for the digital reproduction of the EVERT PRAHM in the ship handling simulator, Professor Limant had to refer to photographs taken on board the EVERT PRAHM on 13 January 2016 during a damage assessment by another expert advising the GDWS, Dr.-Ing. Hark Ocke Diederichs.

The opinion includes a distance-time assessment of the transporter bridge. To achieve this, a compilation of web camera recordings published on the Internet by the press after the accident was slowed down digitally and then analysed. Based on the times displayed (taking into account time delays of +/- 2-3 seconds) a time difference of 45 seconds was calculated between the departure of the transporter bridge (063716) and the collision (063801). The time data referenced on the web camera images have been included in the opinion with a general note appended that the camera time index is reportedly "not to be regarded as absolute due to a time delay in the transmission and/or time storage of the internal timer" and reportedly allows for a "time difference only in the range of +/- 2 seconds".

Furthermore, it was found that the transporter bridge's superstructure had reportedly moved about 3-4 m further after the collision between the transporter bridge and EVERT PRAHM. The total distance covered by the transporter bridge to the final position of the superstructure was specified as 65 m.

Following on from these findings, the opinion looks at the question of the possible reaction time of the navigators on the EVERT PRAHM. Various rules of the Regulations for Preventing Collisions at Sea (COLREGs) are presented, including Rule 7 (Risk of collision) and Rule 8 (Action to avoid collision). After researching literature on estuary trading in reduced visibility, the expert arrives at two possible reaction times for the EVERT PRAHM's bridge team. One is referred to as a *conservative* reaction time of 17 seconds (15 seconds plus a safety margin of 2 seconds) and the other is referred to as a *required* reaction time of 12 seconds (10 seconds plus a safety margin of 2 seconds).

In the opinion, two manoeuvre points are then derived from AIS position data and speed data from the EVERT PRAHM (see Figure 70).

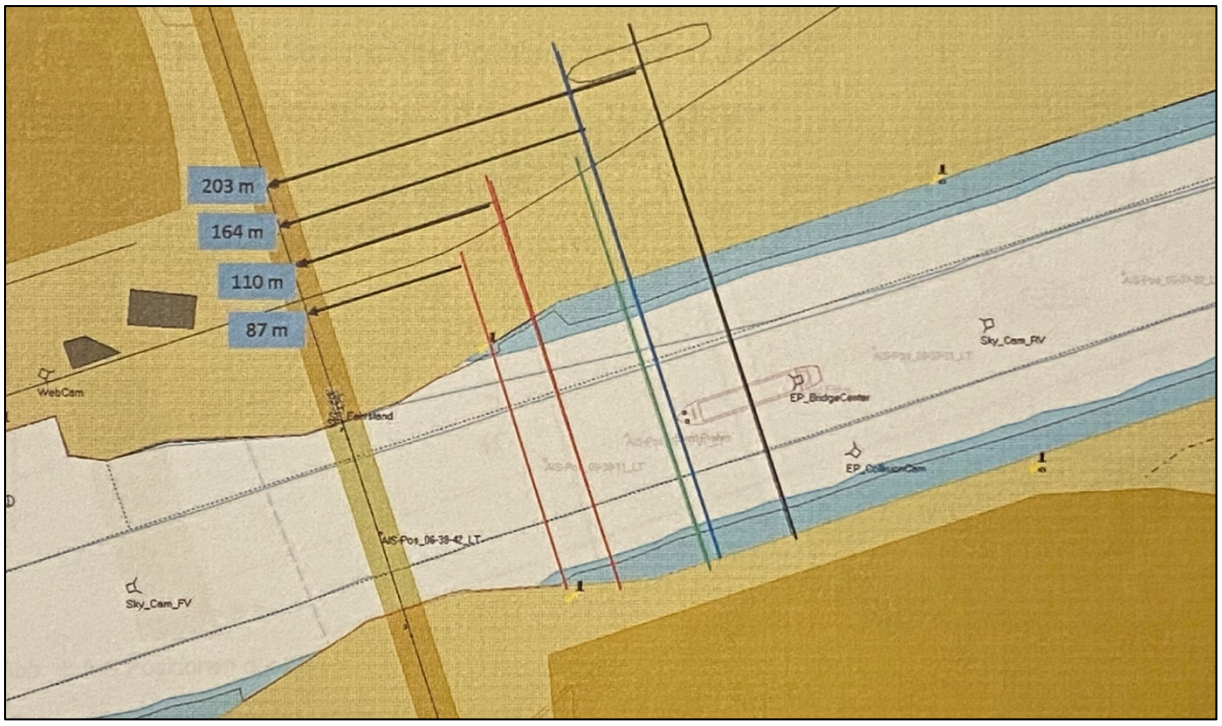


Figure 70: Manoeuvre points of the EVERT PRAHM from the GDWS opinion

The red line (manoeuvre point) at 87 m would therefore reportedly correspond to a reaction time of 12 seconds, while the red line at 110 m would reportedly correspond to a reaction time of 17 seconds. According to the opinion, the blue line indicates the position of the EVERT PRAHM's bow when the transporter bridge starts moving (164 m distance, 45 seconds before collision) and the green line the position two seconds after the transporter bridge starts moving.

The opinion provided for static and dynamic modelling of the EVERT PRAHM on the ship handling simulator of the Maritime Centre of Flensburg University of Applied Sciences. This simulation was based on incomplete data, as the EVERT PRAHM did not provide any documents for simulation calculations. The opinion compensated for the missing documents in places by referring to data from comparable ships and existing photographic material.

The opinion then models various manoeuvres based on the assumption that the transporter bridge is also a vessel in accordance with point 12 of Section 2(1) SeeSchStrO and that the EVERT PRAHM is thus subject to obligations to give way under the COLREGs:

- stop manoeuvre: engine telegraph on stop;
- crash stop: engine telegraph on full astern;
- hard to port and full ahead: rudder hard to port;
- hard to port and full astern: helm hard to port and then engine telegraph to full astern after rotation starts;
- hard to starboard and full ahead: helm hard to starboard;

- hard to starboard and full astern: helm hard to starboard and then engine telegraph to full astern after rotation starts;
- full astern and port anchor: engine telegraph on full astern and then after a further 13 seconds reaction time port anchor with one chain length;
- full astern and port and starboard anchor: engine telegraph on full astern and then after a further 13 seconds port anchor with one chain length and after a further ten seconds starboard anchor with one chain length;
- best practice: rudder hard to port, check rotation with rudder hard to starboard and stabilise return.

With the exception of one manoeuvre (best practice), none of the above manoeuvres can prevent a collision with the transporter bridge or contact with the embankment by the EVERT PRAHM in the simulation performed. In the simulation, the best-practice manoeuvre prevents the collision with a closest point of approach (CPA) of about 1 m from the transporter bridge to the EVERT PRAHM's superstructure and stern.

Following the simulation of evasion manoeuvres, the opinion focuses on a legal assessment of the navigational practices on the EVERT PRAHM's bridge. The ship's command of the EVERT PRAHM reportedly infringed the regulation on safe speed according to Sections 26(1) and 26(3) SeeSchStrO in conjunction with Rule 6 COLREGs. Instead of the 8.1 kts permitted[10] in the Kiel Canal, the EVERT PRAHM reportedly sailed at 8.8 kts. The opinion does not state whether this played a role in causing the collision. With regard to the provisions of the COLREGs on keeping a proper lookout (Rule 5) and action to avoid collisions (Rule 8), the expert notes:

> "It is clear to the undersigned that the alternative or cumulative violation of these two regulations by members of the ship's command in charge of navigation on the EVERT PRAHM, which are cardinal duties, caused the collision with the transporter bridge. The transporter bridge's role in causing the accident was not a subject of this report."

3.4.11 Second opinion of the EVERT PRAHM

On 10 January 2018 the legal counsel of the EVERT PRAHM's owner commissioned Captain Dennis Brand of brand MARINE CONSULTANTS GmbH with the preparation of a statement in response to the GDWS opinion. The object of the assignment was to check the initial values and calculations on which the GDWS opinion was based and assess the extent to which it would actually have been possible in practice to make the only simulated manoeuvre which would theoretically have been suitable for narrowly avoiding the collision (best practice, see Subsection 3.4.10).

[10] See GDWS (Outstation North) Notice 12.4.2.2 regarding Section 26(3) SeeSchStrO (dated 7 August 2018; at the time of the accident the same provision was provided for in 12.13.1.2): 15 km/h (8.1 kts) over ground in the Kiel Canal.

The second opinion arrives at the following conclusions regarding the GDWS opinion by Professor Limant, *inter alia*:

- the assumptions for the transporter bridge are reportedly incorrect. The opinion reportedly contradicts itself with regard to the maximum speeds of the transporter bridge to be applied;
- the initial values are reportedly incorrect. As regards the web camera images, the time interval between two images is reportedly up to five seconds, not the two to three seconds indicated;
- the underlying calculations are reportedly wrong. The distance covered by the transporter bridge up to the collision was reportedly not proven, incorrectly specified and was then subject to further calculation and rounding errors;
- the expert was reportedly therefore not able to know where the transporter bridge was located at any given time;
- as a consequence, it is reportedly not possible to assess which manoeuvre could have prevented a collision;
- arbitrary reaction times have reportedly been set. Underlying judgments are reportedly misrepresented or irrelevant;
- since the manoeuvre points defined in the GDWS opinion are based on the arbitrary reaction times, the result of the simulation is reportedly also incorrect;
- regardless of that, the 'best-practice' manoeuvre is reportedly not possible in practice;
- contributory negligence of the navigation personnel on the EVERT PRAHM in the collision could reportedly not be proven.

With regard to possible reaction times of the ship's command of the EVERT PRAHM, the second opinion states after consultation with chronobiologist Dr. med. Dieter Kunz of the Berlin Charité that a blanket assumption is reportedly not possible without taking into account seasonal or diurnal rhythms. However, the GDWS opinion reportedly did not take into account that the collision occurred in the early hours of the morning in winter, meaning that a reaction time should reportedly be increased.

With regard to the EVERT PRAHM's assumed speed of 8.8 kts according to AIS recordings, the author of the second opinion stated that a tolerance should reportedly generally be allowed for, which was not the case with the GDWS opinion. Furthermore, the assumption that switching on the visual signs for night-time for a "Ferry underway and maintaining connecting lines with one or both banks respectively embankments" (one all-round green light positioned above one all-round white light – see Figure 71) pursuant to the SeeSchStrO is reportedly equivalent to departing is rejected. According to Rule 3(i) COLREGs in conjunction with Section 1(4) SeeSchStrO, the word 'underway' reportedly means that "a vessel is not at anchor, or made fast to the shore, or aground". "Accordingly, 'underway' does not mean that it is actually making speed through water, but only that it is potentially capable of doing so." In setting the visual

signs for night-time the transporter bridge therefore reportedly only made clear that it was ready to depart.

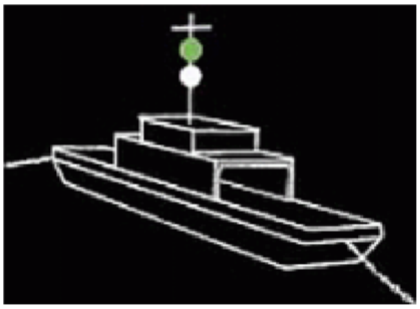
5.1	Nicht freifahrende Fähren in Fahrt	
	Bei Nacht: ein grünes Rundumlicht über einem weißen Rundumlicht.	

Figure 71: Visual sign for a "Ferry underway and maintaining connecting lines with one or both banks respectively embankments" pursuant to the SeeSchStrO

The author of the second opinion rates the evasion manoeuvre executed by the ship's command of the EVERT PRAHM (port manoeuvre and engine telegraph to full astern) as being in accordance with good seamanship and an appropriate reaction:

> "In this respect, it is important to remember that the canal tapers at this point and is visually constricted vertically by the railway bridge. Besides the prevailing darkness, this led to additional stressors in the decision-making process of the ship's command, which also had to comprehend the – absurd – departure of the transporter bridge. In addition, members of the ship's command in charge of navigation on the EVERT PRAHM were not able to estimate the actual speed of the transporter bridge, as it was still in an acceleration phase and therefore its speed was changing constantly.
>
> [...] against this background it is all the more commendable that the ship's command of the EVERT PRAHM correctly recognised that there was more room on the port side than on the starboard side and consequently decided in favour of a port manoeuvre and thus passing in front of the transporter bridge, especially since the natural reaction of every navigator is to first consider a starboard manoeuvre so as to sail behind a crossing object."

Finally, the author of the second opinion questions the applicability of the COLREGs to the transporter bridge and the legal classification of the latter as a ferry according to point 12 of Section 2(1) SeeSchStrO.

3.4.12 Measurement of the field of view in the transporter bridge operator's cabin

The examination of the visibility of an approach of the EVERT PRAHM from the transporter bridge operator's cabin was of considerable relevance when investigating the cause. A team of investigators from the BSU surveyed the transporter bridge again on 6 April 2018 and measured the field of view. At this point the transporter bridge was located at WSA Kiel-Holtenau's Rendsburg site.

The transporter bridge operator's cabin is installed in the middle of a separate smaller platform, which in turn is positioned centrally above the base platform used for transporting passengers and vehicles. A steel structure connects the lower and upper platforms. The transporter bridge's suspension cables are fixed to the upper platform. The operator's cabin stands freely on the upper platform, meaning it can be walked around easily (see Figure 72).

Figure 72: Transporter bridge before the accident – view from the direction of the EVERT PRAHM

The operator's cabin has an octagonal floor plan (see Figure 73). Each of the eight sides has a window with the two windows in the immediate direction of travel being the largest (84 x 100 cm). Five other windows are only slightly smaller (77 x 100 cm). The smallest window is installed in the only door (48 x 60 cm).

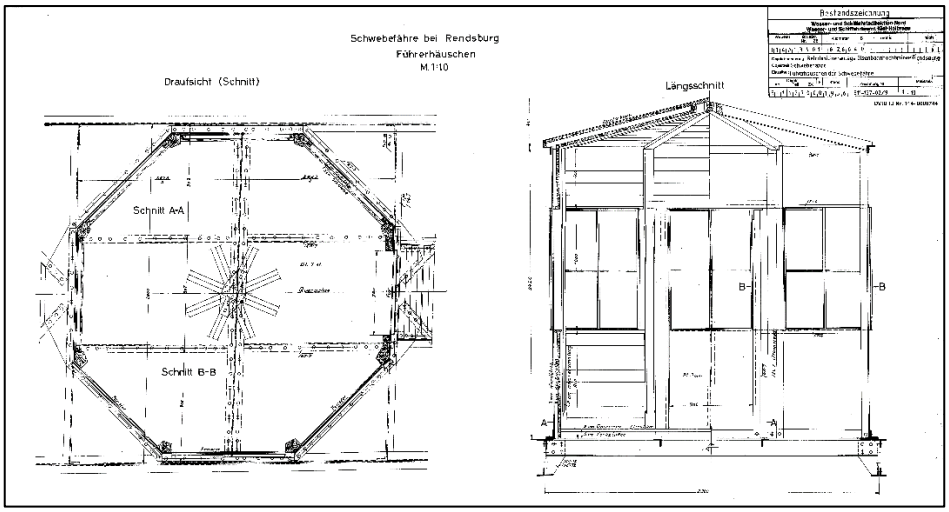


Figure 73: Floor plan of the transporter bridge operator's cabin

To reconstruct the viewing angles during the voyage under investigation from the northern to the southern bank, the floor plan was rotated so as to approximately correspond to the orientation of the transporter bridge over the relevant section of the Kiel Canal (see Figure 74).

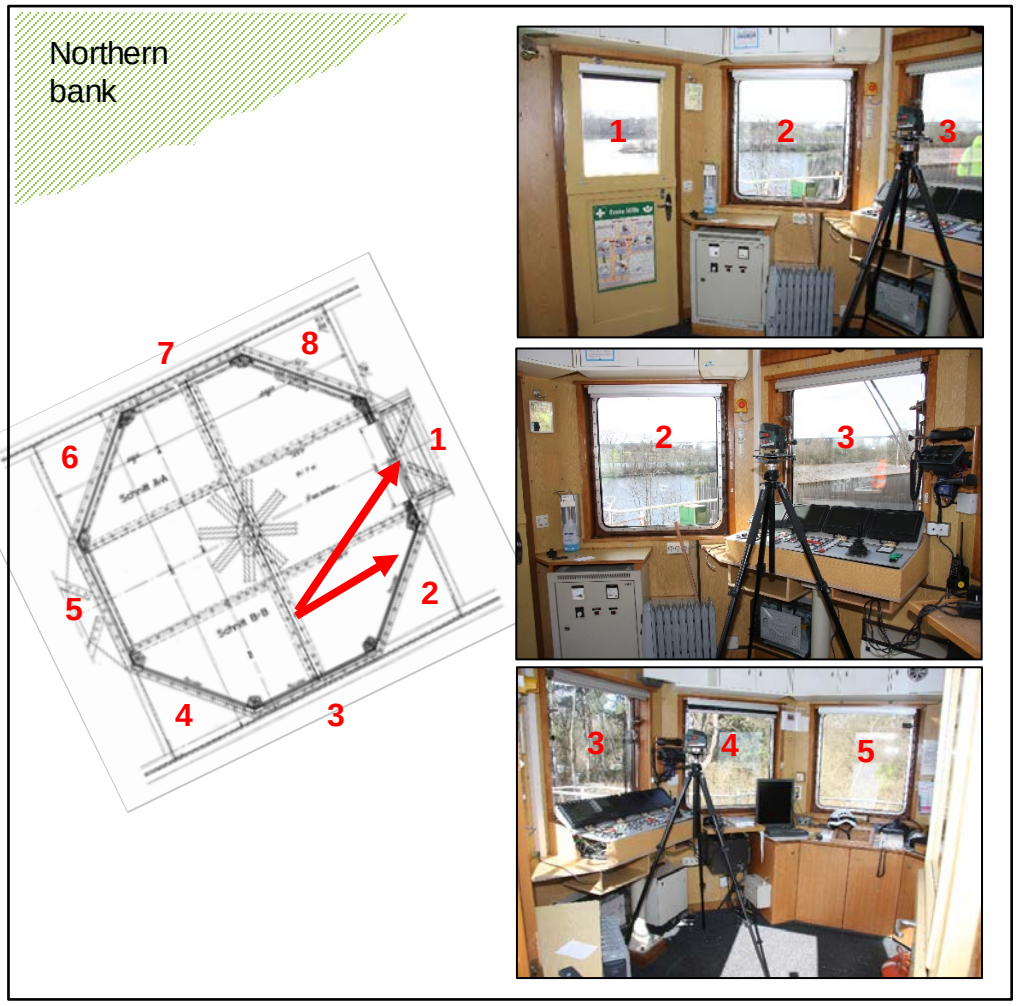


Figure 74: Window arrangement in the transporter bridge operator's cabin

There were only two windows (1 and 2, see red arrows in Figure 74) through which the approach of the EVERT PRAHM could theoretically have been observed. This statement does not take into account the weather on the night of the accident, as the measurement of the field of view only determines that permitted by the structural arrangement of the windows.

Windows 3 and 7 in the immediate directions of travel (see Figure 74: 3 for crossings to the southern bank and 7 for crossings to the northern bank), as well as 5 are each equipped with one windscreen wiper. A sun shield is fitted to the inside of each window. None of the eight windows has its own heating system with filaments.

The measurement was based on the transporter bridge's operator being positioned in front of the control panel for the direction of travel from the northern to the southern bank. The control lever for the direction of travel or speed was located at an ergonomically appropriate distance (arm's length). Ultimately, this resulted in a position centrally in front of the southern control panel (see Figure 75, blue marking corresponds to the estimated position).

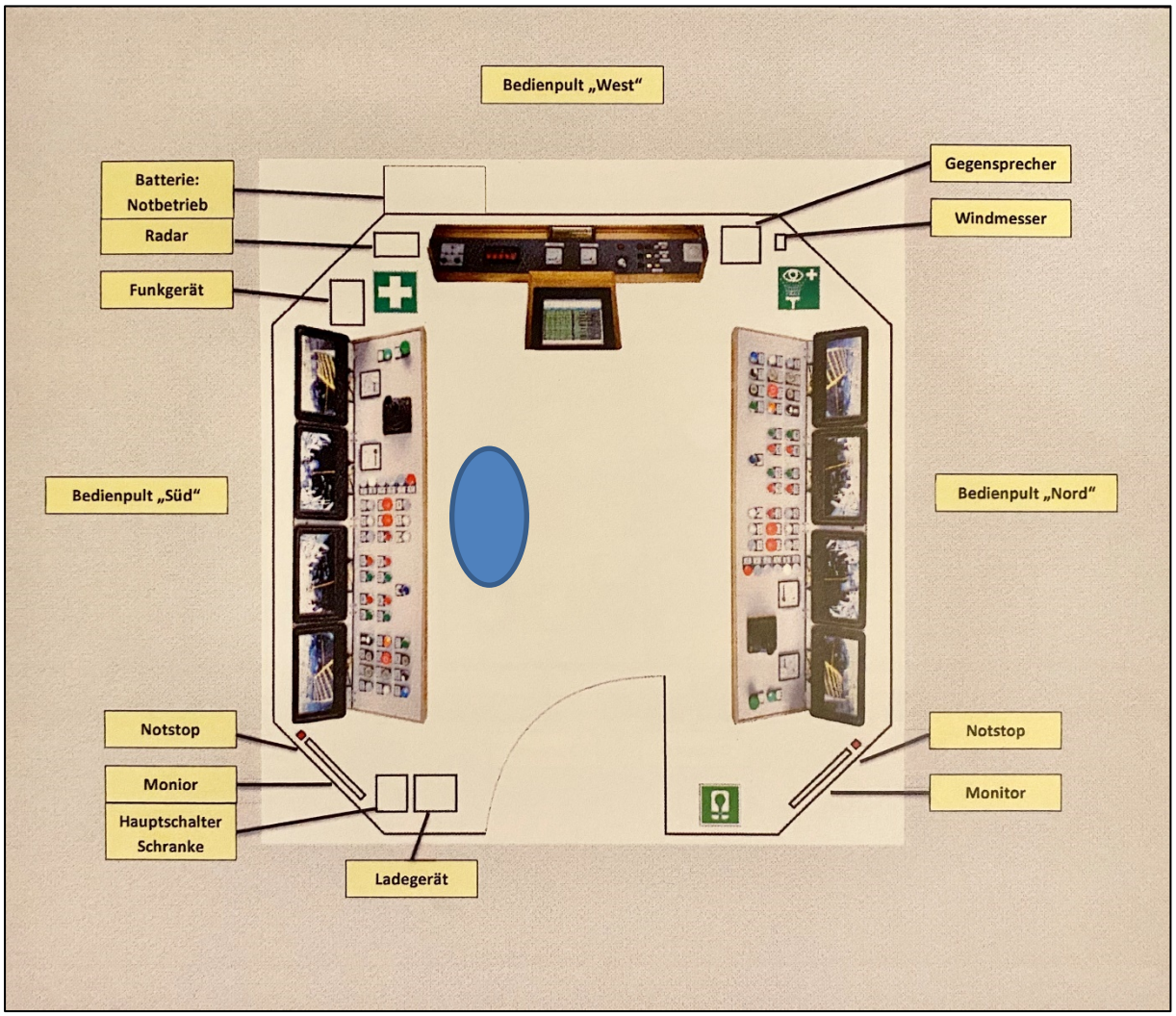


Figure 75: Arrangement of the control panels in the operator's cabin – taken from the operating manual

The measurements were limited to the viewing angles relevant to the collision with the EVERT PRAHM. These were determined with the aid of a laser beam level and a 360° bearing plate mounted on a stand (see Figure 76).

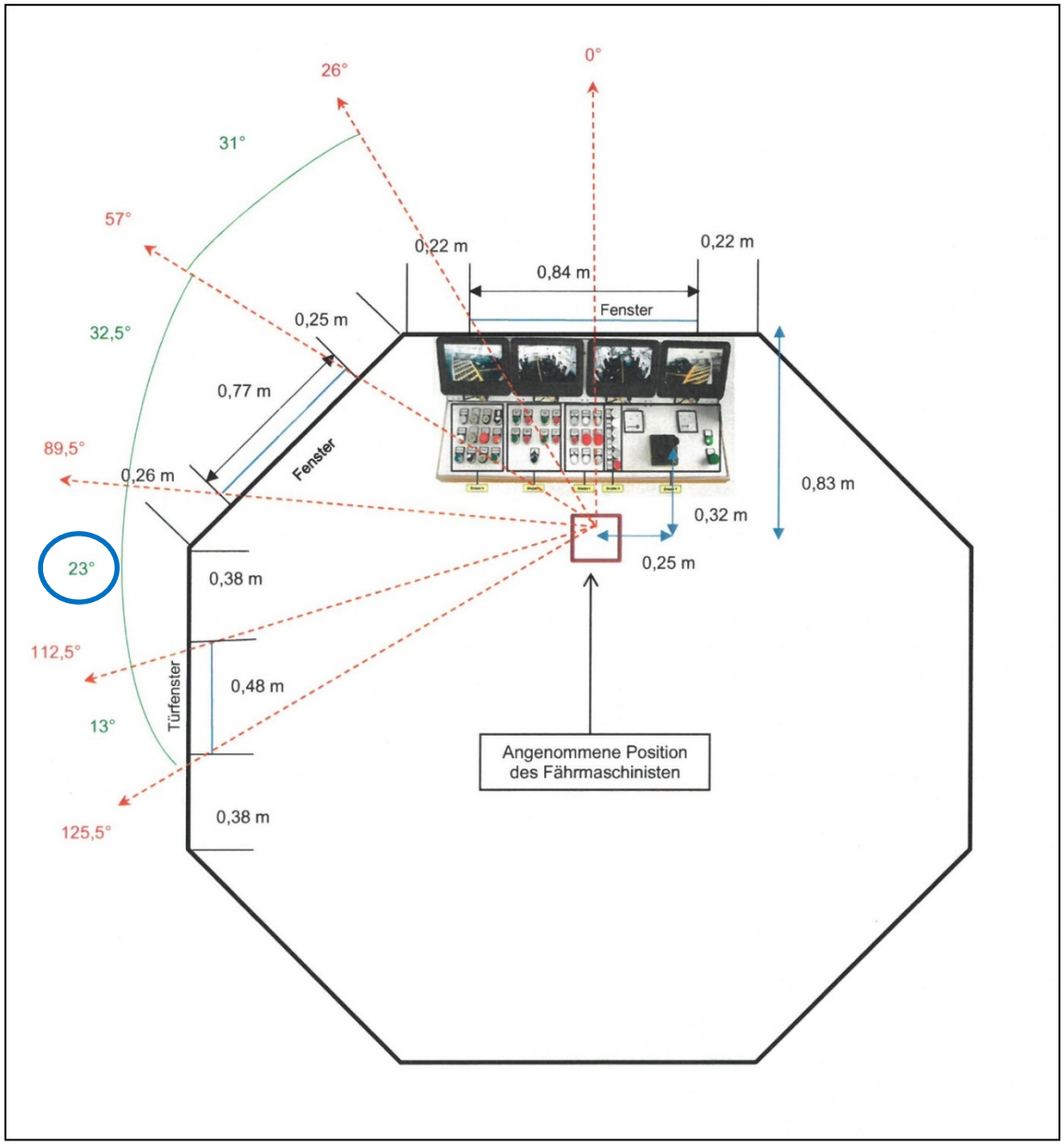


Figure 76: Viewing angles

The following figure transposes the measured angles to the navigational chart at the time at which the first ship in the convoy (Ship A, green dot in Figure 77) passes. The EVERT PRAHM is marked as a red dot and the ship following her in the convoy (Ship B) as a blue dot. The door frame and the wall between windows 1 and 2 create a blind sector of 23° (see blue circle in Figure 76).

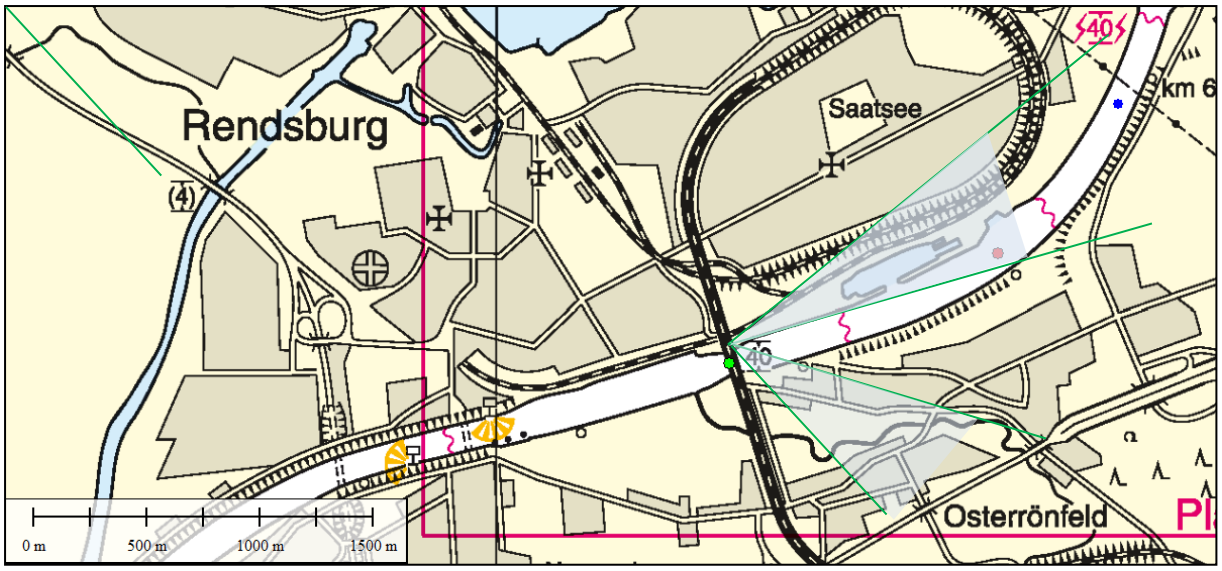


Figure 77: Viewing angle when the first ship in the convoy passed

The measurement of the field of view and determination of the viewing angle derived from that revealed that theoretically the structural conditions in the transporter bridge operator's cabin permitted a view of the EVERT PRAHM when the first ship in the convoy passed. However, it should also be noted that a large part of the Kiel Canal – the immediate vicinity of the transporter bridge when looking east-north-east, in particular – was in the blind sector if the position of the transporter bridge's operator remained unchanged.

4 ANALYSIS

That a collision had occurred between a seagoing vessel and one of only eight transporter bridges still in operation in the world was not the only factor that made this marine casualty an unusual event even for the BSU. What was especially unusual was the fact that a large part of the investigation concerned the transporter bridge and thus not a seagoing vessel. In terms of subject matter, the BSU broke new ground in this regard. This added to the complexity of the investigation significantly and combined with two unavoidable changes in the investigation's management team explains its unusually long duration.

According to its objectives and scope of application, the Seesicherheits-Untersuchungs-Gesetz[11] (SUG) enables determination of the circumstances of the marine casualty beyond just the seagoing vessel concerned. Rather, it should also take in any factors that directly and indirectly caused the accident – therefore also the transporter bridge and any factors affecting it of relevance to the accident.

The parties involved in the investigation provided extensive expert opinions and statements for evaluation. The parties responsible for the operation of the EVERT PRAHM and the operation of the transporter bridge were in dispute throughout the entire period of the investigation, at times also in court. At the same time, the transporter bridge's operator faced criminal proceedings. It was therefore all the more important for the BSU to emphasise the principle of the investigation under the SUG, according to which an investigation is not about the attribution of errors or the determination of fault, liability or claims, but rather focusing solely on lessons that can be learnt from the course of events leading up to and during the accident, so as to avoid similar accidents wherever possible. The duration of the investigation did not detract from the relevance of findings and assessments, as at the time of drafting this report construction of the new transporter bridge is planned. It is therefore reasonable to assume that a reproduction of the transporter bridge will be put into operation in the same place.

4.1 Legal classification of the transporter bridge

Classifying the transporter bridge in legal terms proved a central point of the investigation. The representatives of the EVERT PRAHM and the parties responsible for operation of the transporter bridge did not agree on this classification, including in the context of the following questions.

- Is the transporter bridge really a ferry (maintaining connecting lines with one or both banks respectively embankments) pursuant to the SeeSchStrO?
- Are the SeeSchStrO and COLREGs applicable to the transporter bridge in whole, in part or not at all?

[11] Maritime Safety Investigation Act.

- What duties of conduct were applicable to the EVERT PRAHM and the transporter bridge?

To answer the questions raised, it was first necessary to clarify the transporter bridge's legal status.

The transporter bridge's status was not clearly defined in legal terms by the managing authority, WSA Kiel-Holtenau. The transporter bridge displayed signal lights and issued sound signals similar to a ferry maintaining connecting lines with one or both banks respectively embankments pursuant to the SeeSchStrO. The SeeSchStrO does not define the term ferry but references the general definitions of Rule 3 COLREGs, *inter alia*, in Section 2(1).

Rule 3(a) COLREGs states: "The word 'vessel' includes every description of water craft, including non-displacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water."

The transporter bridge was clearly a means of transportation. However, there was no agreement on the classification as 'water craft'. The GDWS in Kiel classifies the transporter bridge as a 'nondisplacement craft' and thus takes the view that both the COLREGs and the SeeSchStrO apply to it. The BSU takes a different view. The transporter bridge was not used on but above the water. Moreover, it could not have been used on the water as required by the wording of Rule 3(a) COLREGs. In the opinion of the BSU it was also not a 'nondisplacement craft'. This refers in particular to hovercrafts or structures that partially float on air cushions above the water. The transporter bridge was clearly not a WIG craft, either. In contrast to a transporter bridge, the latter two categories must – and this alone explains the legal or factual reference to the traffic regulations applicable on the water – by their very nature physically interact with the water surface to function.

The argument put forward by the GDWS that if classification of the transporter bridge as a craft were to be denied, third-party protection norms like the COLREGs would be restricted in their scope of application, thereby creating legal uncertainty for all traffic participants on the Kiel Canal, is not persuasive, either. The mere desire to close any regulatory gaps that may exist is not sufficient for the (analogous) application of the COLREGs to the transporter bridge. In particular, the explicit inclusion of WIG craft, seaplanes and nondisplacement craft (hovercrafts) makes it clear that an unintended regulatory gap (that can be applied by analogy) does not exist.

Finally, it is important to consider that legal uncertainties arise solely from the way in which the transporter bridge is actually built and operated. For example, if the transporter bridge were theoretically to be operated at a height above the canal that

would preclude contact with ships or if technical precautions were taken during operation to ensure the transporter bridge could not set off if a vessel approached within a certain radius on the Kiel Canal, then no dangerous situation whatsoever and certainly no legal uncertainty for third parties would arise. Accordingly, the parties responsible for the operation of the transporter bridge have it within their power to remove potential legal uncertainties from the outset by means of safe construction and operation concepts.

On the other hand, were the arguments of the GDWS to be regarded as valid, the COLREGs would have to be consistently applied in the event of a collision between a seagoing vessel and moving container gantry crane projecting over the pier (e.g. when the vessel is berthing or casting off). The BSU considers this to be outlandish, which brings it to the logical conclusion that the transporter bridge is not a water craft, at least not within the meaning of the COLREGs and therefore not a vessel within the meaning of the SeeSchStrO. Moreover, whether the transporter bridge was to be classified as an overhead railway under the *Haftpflichtgesetz* [Germany's Law on liability] did not need to be clarified by the BSU, as liability interests are not relevant to the safety investigation.

The legal basis for the evaluation in the context of the safety investigation was as follows:

- the BSU considers that the rules of the COLREGs concerning the interaction of two vessels are not applicable to this marine casualty. In particular, this applies to Section II COLREGs – Conduct of vessels in sight of one another;

- the application of the SeeSchStrO, the COLREGs and other shipping-related regulations was to be limited solely to the EVERT PRAHM as a seagoing vessel (in particular with regard to the rules concerning lookouts, safe speed, basic rules of conduct in traffic under the *Verordnung zu den Kollisionsverhütungsregeln* [Germany's Ordinance on the regulations for preventing collisions at sea], etc.).

4.2 Lights displayed by the transporter bridge

Since the BSU was of the opinion that the transporter bridge was not a vessel for the purposes of the SeeSchStrO, it follows that lights displayed by the transporter bridge (see Figure 7) were a voluntary installation by WSA Kiel-Holtenau because they were not stipulated by the SeeSchStrO.

On the other hand, the GDWS claims that as a prominent safety criterion according to the rules of the SeeSchStrO and the COLREGs, the transporter bridge's lighting had to be fully respected to ensure the safety of maritime traffic. The BSU does not follow this assessment but rather assumes that the transporter bridge must be kept clear of

vessels transiting the Kiel Canal whatever the circumstances, so as not to impair the safety and efficiency of maritime traffic. In the same context, WSA Kiel-Holtenau's instructions to transporter bridge operators with regard to increasing or decreasing safety distances to be maintained from vessels in the Kiel Canal are regarded as necessary and appropriate.

There was disagreement not only about the general display of lighting but also about the actual consequences of that. The main objective was to answer the questions as to whether the display of the signal lights meant the transporter bridge was 'underway' in a legal sense and whether the actual departure of the transporter bridge was always associated with this.

The transporter bridge's signal lights were linked to its automated locking system when docking on the northern or southern bank. The signal lights extinguished once the lock was activated and displayed when it was manually deactivated.

For the definition of the term 'underway' the SeeSchStrO again refers to Rule 3 COLREGs. Rule 3(i) COLREGs reads

> "The word 'underway' means that a vessel is not at anchor, or made fast to the shore, or aground."

Rule 35(b) COLREGs reads in part:

> "A power-driven vessel underway but stopped and making no way through the water [...].

It therefore follows from the COLREGs that the term 'underway' does not necessarily mean 'making way through the water'. Accordingly, a vessel does not necessarily have to move in order to be 'underway'. It is sufficient that the vessel is not generally prevented from moving by other means (anchor and lines, etc.). This finding was of interest for the safety investigation because it follows that the EVERT PRAHM's bridge team would not have had to assume the transporter bridge would start to move when the signal lights were displayed, even if the SeeSchStrO were applicable to it.

4.3 Video analysis by the BSU

Both the GDWS's expert opinion and the second opinion of the EVERT PRAHM were based on a short recording of a sequence of web camera images, which was available for download on the Internet and depicted the course of events leading up to and during the accident in the time period 063702 to 063814 on 8 January 2016, as referenced by the time stamp on the images. Both the GDWS's expert opinion and the second opinion of the EVERT PRAHM considered this very short video. In the opinion of the BSU's investigators, the calculations and comments on reaction times and evasion manoeuvres were largely of little help. It seems to the BSU's investigators that the attempt to limit the EVERT PRAHM bridge team's possible reaction time to a certain

number of seconds and then to measure that against extremely sparse case law is too academic and remote. The video of the accident clearly shows that the transporter bridge's early departure was the main cause of the accident. Viewing the video also makes it clear how little time the EVERT PRAHM ultimately had left for an evasion manoeuvre. Whether 15 seconds, 20 seconds or 30 seconds of reaction time remained after recognition of the risk of collision on the bridge is immaterial from the point of view of the BSU, since the specific circumstances of the case (e.g. sailing at night, bright bridge lighting, unusual situation with a high element of surprise) must be taken into account and the AIS recordings showed that even if it was ultimately unsuccessful, an evasion manoeuvre was at least made. After viewing the video material the BSU is in no doubt that if this accident could have been prevented at all, then it would have been by the transporter bridge with an advance distance of up to 1.5 m, but realistically not by the EVERT PRAHM, however.

Both experts provided further revisions of their opinions for the legal dispute and the BSU's investigation. However, the BSU felt compelled to pursue its own evaluation taking a different approach.

The BSU takes the view that although the short video recording was a good starting point for clarifying the circumstances, since usually no video recordings of the course of events leading up to and during an accident are available, it was already clear at an early stage of the investigation that access to other and significantly longer periods recorded would be necessary to clarify urgent questions. With that in mind, the investigators contacted the operator of the web camera, Canal-Cup Projekt GmbH, which installed it mainly to market a rowing event in the Kiel Canal. Its IT service provider gave the BSU access to web camera data from several months prior to the accident up to current data for the safety investigation.

In particular, the following questions were to be answered by means of the video analysis.

- What operating behaviour did the transporter bridge display on a day-to-day basis before the accident?
- Were the safe CPAs stipulated by WSA Kiel-Holtenau observed?
- Did the transporter bridge's individual operators display any differences in operating behaviour?
- Were there any earlier instances – and if so, how many – of the transporter bridge departing slowly even though a seagoing vessel was just passing?
- How did the transporter bridge's daily operation look in terms of workload and frequency of crossings?

The data provided made it possible to answer the above questions but required a comprehensive evaluation by the BSU, which had to be conceptualised first for reasons of comprehensibility and impartiality.

4.3.1 Data sourced from the web camera

The web camera is an outdoor camera continuously connected to the Internet and automatically uploads frames generated to a server, making them available on the Internet as live images. The camera is mounted with the direction of view eastward onto the Rendsburg railway bridge, meaning it is also directed at the transporter bridge's former and (when put back into service) future workplace. The Rendsburg-based Deutsche Ruder-Marketing GmbH is responsible for data processing on the operator's website. The camera's image resolution makes it impossible to identify individual people or car number plates, for example.

The films are in flash format and stored on a daily basis. Each film records the videos in the form of a time lapse and has a playing time of about 30 minutes per video/day. Recording begins at 0300 and ends at 0300 on the following day (24-hour recording intervals – see Figure 78).

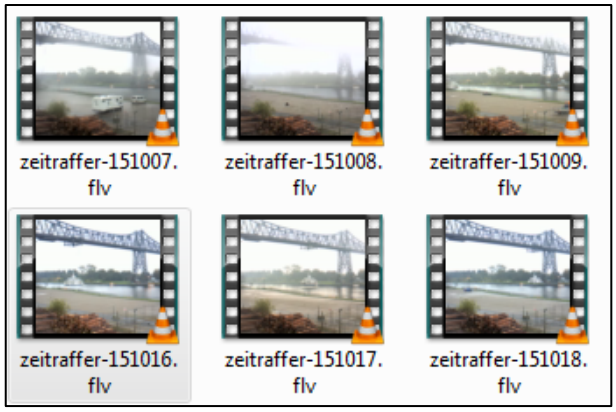


Figure 78: Storage format of web camera recordings

4.3.2 Period analysed

Various factors were considered when determining the period to be analysed:

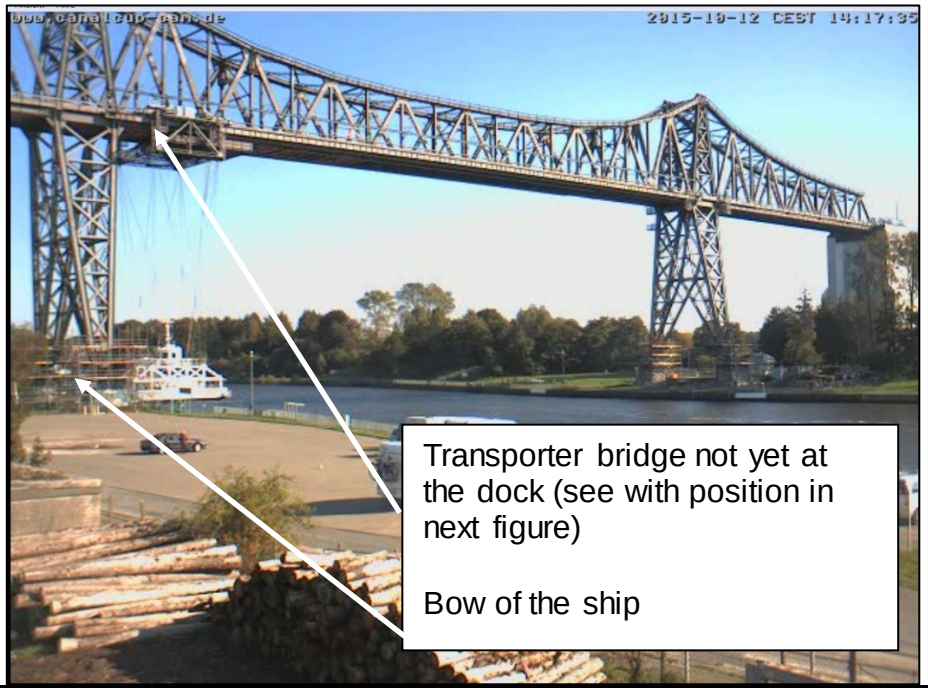
- it should be a representative period for conclusions on day-to-day operation;
- the period should permit conclusions on the normal operation of the transporter bridge, i.e. special circumstances like the public holidays shortly before the accident should be taken into account. Accordingly, the period for the retrospective analysis had to extend well beyond December;
- since each video was to be analysed individually by qualified personnel, the amount of work involved had to be manageable.

Taking these factors into account, the investigation team decided to analyse the period 1 October 2015 until midnight on 9 January 2016. A total of 101 videos were individually viewed and analysed.

4.3.3 Methodology applied

Each day and thus each video in the time period selected was viewed individually and the findings were entered into pre-made logs. A separate log was created for each video, for which the crossings of the transporter bridge to be evaluated were to be classified in five different categories:

Category	Description
A	Average traffic and no obstructions, free movement
B	Clear distance from passing maritime traffic; it may be necessary to wait for passing traffic
C	No clear distance from passing maritime traffic; a pass is made at the stern but departure takes place only after the ship has passed (in compliance with the operating instructions) 

D	'Creeping', i.e. departing despite passing maritime traffic within the safety distance but approaching the passing vessel slowly and briefly stopping if necessary before passing at the stern 
X	Crossing just before a passing ship 

	
T	Miscellaneous (e.g. test or maintenance run, hesitant operation, extremely slow or fast operation, sudden stopping and forward or reverse operation, operation without docking and loading/unloading)

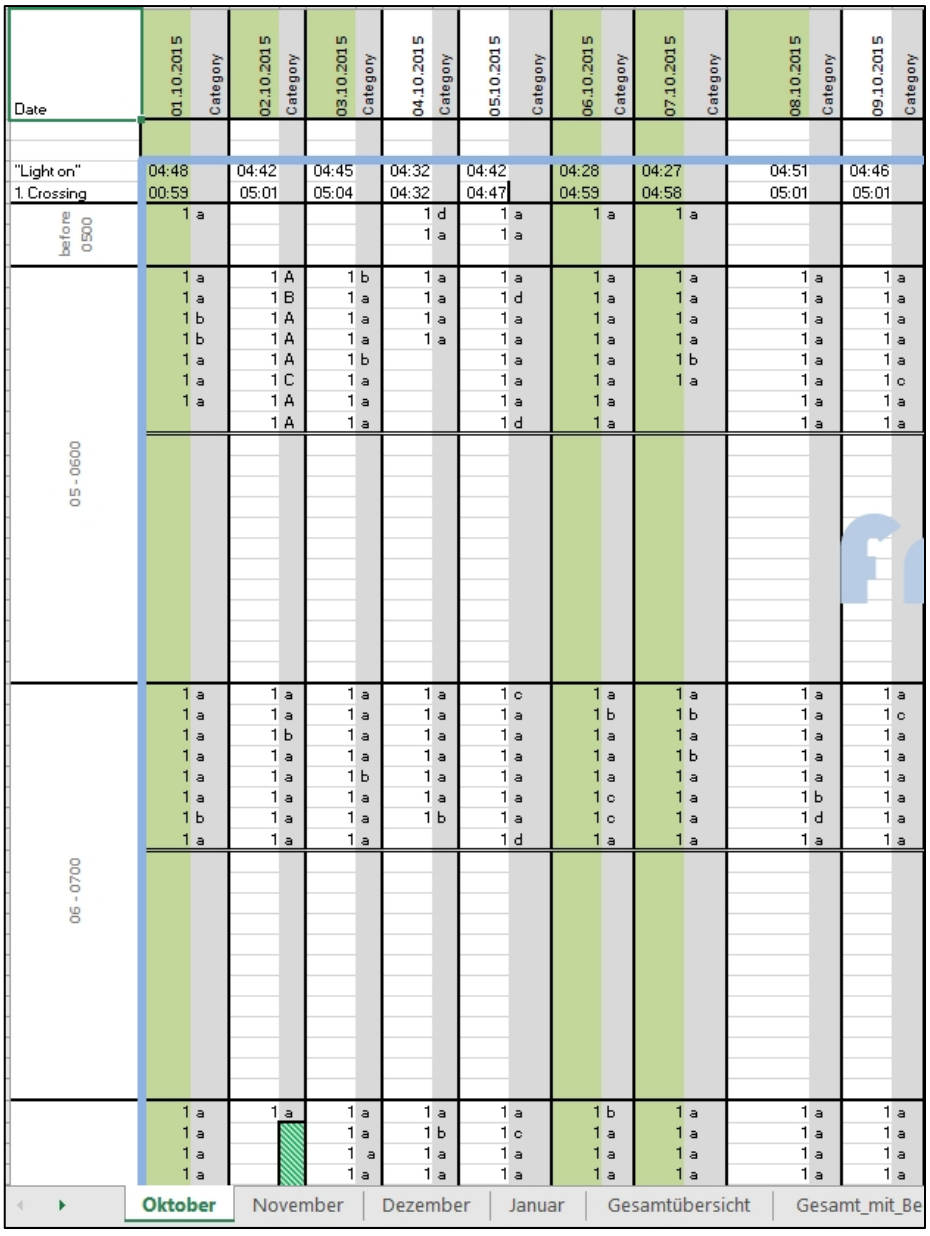
Spreadsheet 4: Categories for the retrospective analysis of the web camera videos

Categories A, B and C comply with WSA Kiel-Holtenau's operating instructions, while categories D and X clearly contravene the safety distance requirements. On the other hand, Category T is as a collective category for any crossings that are neither clearly compliant nor manifestly non-compliant.

In the application of these categories the daily logs contain the following information:

- date of the recording;
- time from when the transporter bridge was illuminated (signal lights on);
- time of the start of the first crossing;
- total number of crossings;
- exceptional Category B, C, D, X or T crossings;
- time of the start of last crossing, and
- time from when the transporter bridge was unlit (signal lights off).

All data contained in the daily logs were then inserted into the corresponding monthly data sheets (October, November, December and January). As with the daily logs, the monthly data sheets are divided into time intervals (see Figure 79).



Date	01.10.2015	Category	02.10.2015	Category	03.10.2015	Category	04.10.2015	Category	05.10.2015	Category	06.10.2015	Category	07.10.2015	Category	08.10.2015	Category	09.10.2015	Category
"Light on"	04:48		04:42		04:45		04:32		04:42		04:28		04:27		04:51		04:46	
1. Crossing	00:59		05:01		05:04		04:32		04:47		04:59		04:58		05:01		05:01	
before 0500	1	a					1	d	1	a	1	a	1	a				
							1	a	1	a								
05 - 0600	1	a	1	A	1	b	1	a	1	a	1	a	1	a	1	a	1	a
	1	a	1	B	1	a	1	a	1	d	1	a	1	a	1	a	1	a
	1	b	1	A	1	a	1	a	1	a	1	a	1	a	1	a	1	a
	1	b	1	A	1	a	1	a	1	a	1	a	1	a	1	a	1	a
	1	a	1	A	1	b			1	a	1	a	1	b	1	a	1	a
	1	a	1	C	1	a			1	a	1	a	1	a	1	a	1	c
	1	a	1	A	1	a			1	a	1	a			1	a	1	a
			1	A	1	a			1	d	1	a			1	a	1	a
06 - 0700	1	a	1	a	1	a	1	a	1	c	1	a	1	a	1	a	1	a
	1	a	1	a	1	a	1	a	1	a	1	b	1	b	1	a	1	c
	1	a	1	b	1	a	1	a	1	a	1	a	1	a	1	a	1	a
	1	a	1	a	1	a	1	a	1	a	1	a	1	b	1	a	1	a
	1	a	1	a	1	b	1	a	1	a	1	a	1	a	1	a	1	a
	1	a	1	a	1	a	1	a	1	a	1	c	1	a	1	b	1	a
	1	b	1	a	1	a	1	b	1	a	1	c	1	a	1	d	1	a
	1	a	1	a	1	a			1	d	1	a	1	a	1	a	1	a
	1	a	1	a	1	a	1	a	1	a	1	b	1	a	1	a	1	a
	1	a			1	a	1	b	1	c	1	a	1	a	1	a	1	a
	1	a			1	a	1	a	1	a	1	a	1	a	1	a	1	a
	1	a			1	a	1	a	1	a	1	a	1	a	1	a	1	a

Oktober | November | Dezember | Januar | Gesamtübersicht | Gesamt_mit_Be

Figure 79: Extract from a monthly data sheet

Each crossing was listed and assessed individually. If there were no exceptional Category B, C, D, X or T crossings, then the crossing was automatically classified to Category A. Special events (e.g. repair works) and the shifts of the transporter bridge's operator from the day of the accident were colour highlighted in the monthly data sheets according to the shift schedule provided by WSA Kiel-Holtenau.

A summary of the day with totals of the mapped A, B, C, D, X and T crossing evaluation categories exists at the end of each day. The grand total can be found in the 'Sum of all evaluations' column. The last row shows the total number of crossings, regardless of category, under 'Crossings per day'. This row is for control purposes. The day is correctly calculated and nothing has been forgotten or entered several times only if 'Crossings per day' and 'Sum of all evaluations' are identical.

The summary contains the data from 1 October 2015 to 9 January 2016 (101 days) in a spreadsheet. Each day is considered individually. Rows contain the time intervals, columns contain the evaluation categories (see Figure 80).

	01.10.2015 Thursday							02.10.2015 Friday						
	Crossings	A	B	C	D	X	T	Crossings	A	B	C	D	X	T
before 0500	1	1	0	0	0	0	0	0	0	0	0	0	0	0
05 - 0600	7	5	2	0	0	0	0	8	6	1	1	0	0	0
06 - 0700	8	7	1	0	0	0	0	8	7	1	0	0	0	0
07 - 0800	10	9	1	0	0	0	0	1	1	0	0	0	0	0
08 - 0900	8	8	0	0	0	0	0	0	0	0	0	0	0	0
09 - 1000	8	7	1	0	0	0	0	0	0	0	0	0	0	0
10 - 1100	8	6	2	0	0	0	0	0	0	0	0	0	0	0
11 - 1200	9	9	0	0	0	0	0	8	5	3	0	0	0	0
12 - 1300	8	4	3	0	1	0	0	9	7	2	0	0	0	0
13 - 1400	7	5	1	1	0	0	0	7	4	2	0	1	0	0
14 - 1500	8	5	3	0	0	0	0	8	8	0	0	0	0	0
15 - 1600	8	7	1	0	0	0	0	8	5	1	1	1	0	0
16 - 1700	7	4	3	0	0	0	0	8	6	2	0	0	0	0
17 - 1800	9	9	0	0	0	0	0	9	8	0	1	0	0	0
18 - 1900	9	7	2	0	0	0	0	7	5	2	0	0	0	0
19 - 2000	8	7	0	0	1	0	0	8	8	0	0	0	0	0
20 - 2100	8	7	0	0	1	0	0	9	8	1	0	0	0	0
21 - 2200	9	7	1	0	1	0	0	8	8	0	0	0	0	0
22 - 2300	8	6	2	0	0	0	0	7	6	1	0	0		
		120	23	1	4	0	0		92	16	3	2	0	0
Total														
All crossings	148							113						
All criterias	148							113						
Carry over	148							113						
Average number of crossings per hour *1	8,2							*2						

*1= the period "before 0500 am" is not taken into account
*2=all days with "no view on the ferry" and/or repairs with ferry standstill or public holidays are not evaluated

Figure 80: Extract from the summary

The number of crossings per category and time was linked from the corresponding monthly data sheet as a total. Control calculations are located in the bottom rows here, too. 'Sum of all crossings' is the total number of individual crossings in the 'Crossings' column, 'Sum of all evaluations' is the grand total from columns A, B, C, D, X and T and 'DB month carried forward' is the amount carried forward from the respective monthly data sheet. These rows are only used to check the accuracy and completeness of the entries. The average 'Number of crossings per hour' was calculated in the bottom row as the mean average of all totals from the 'Crossings' column. Crossings made before 0500, any days on which the transporter bridge was not visible due to the weather, repair days with the transporter bridge out of service and public holidays were not taken into account.

4.3.4 Findings

A total of 6,648 transporter bridge crossings made in the period 1 October 2015 to 9 January 2016 were analysed. Since the shift schedules of the transporter bridge operators deployed were taken into account in the analysis, it was possible to establish from a general view of operating behaviour according to the above categories that the transporter bridge operator's behaviour on the day of the accident did not differ from that of his colleagues (see Figure 81).

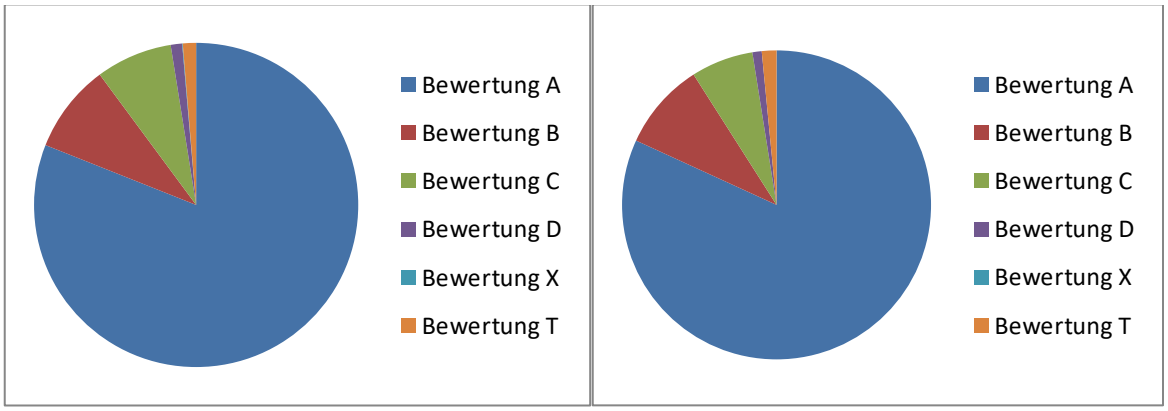


Figure 81: Comparison of operating behaviour – graphic evaluation

The chart to the left shows the operating behaviour of the transporter bridge operator on the day of the accident in the overall period analysed and the chart to the right shows that of his colleagues. The percentage analysis also reveals that the differences in cumulative operating behaviour are marginal at most (see Spreadsheet 5).

Transporter bridge operator on the day of the accident Total/Month Oct-Jan	in %	**Other transporter bridge operators** Total/Month Oct-Jan	in %
Percentage of crossings as per A	81.0	Percentage of crossings as per A	81.8
Percentage of crossings as per B	8.8	Percentage of crossings as per B	9.14
Percentage of crossings as per C	7.6	Percentage of crossings as per C	6.52
Percentage of crossings as per D	1.1	Percentage of crossings as per D	0.97
Percentage of crossings as per X	0.1	Percentage of crossings as per X	0
Percentage of crossings as per T	1.3	Percentage of crossings as per T	1.53

Spreadsheet 5: Comparison of operating behaviour – percentage analysis

The analysis revealed that the operating behaviour described by the canal pilots questioned (Category D, 'Creeping') could be seen in about 1% of transporter bridge crossings. The transporter bridge departed despite the maritime traffic and headed for the ship so as to then cross to the other bank directly at the stern. Expressed in number of cases, the operator of the transporter bridge on the day of the accident displayed this operating behaviour 37 times and his colleagues 33 times. These very clear violations of WSA Kiel-Holtenau's instructions regarding safe distances to be maintained were spread over the respective month, occurring at different times of the day and night. This operating behaviour became something that could be observed in the Kiel Canal regularly, sometimes even on a daily basis (see Figures 82 and 83).

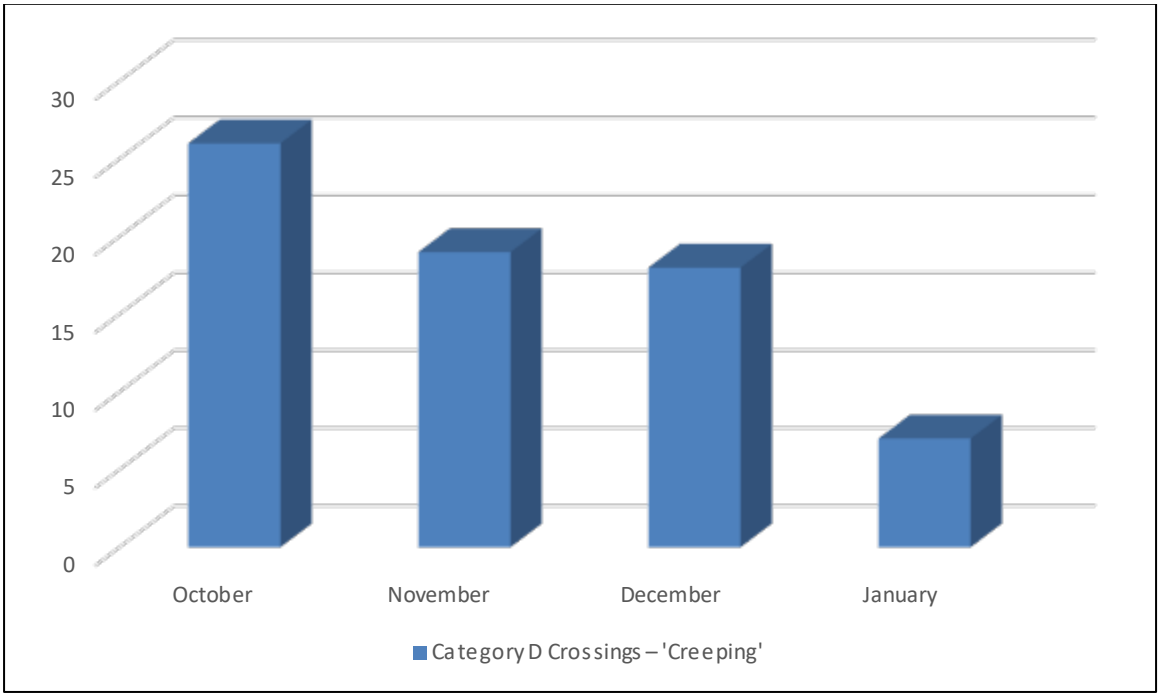


Figure 82: Transporter bridge crossings with a significant deficit in the safety distance

Since the month of January 2016 was not fully recorded due to the accident being at the beginning of the month, there is only an apparent downward trend here.

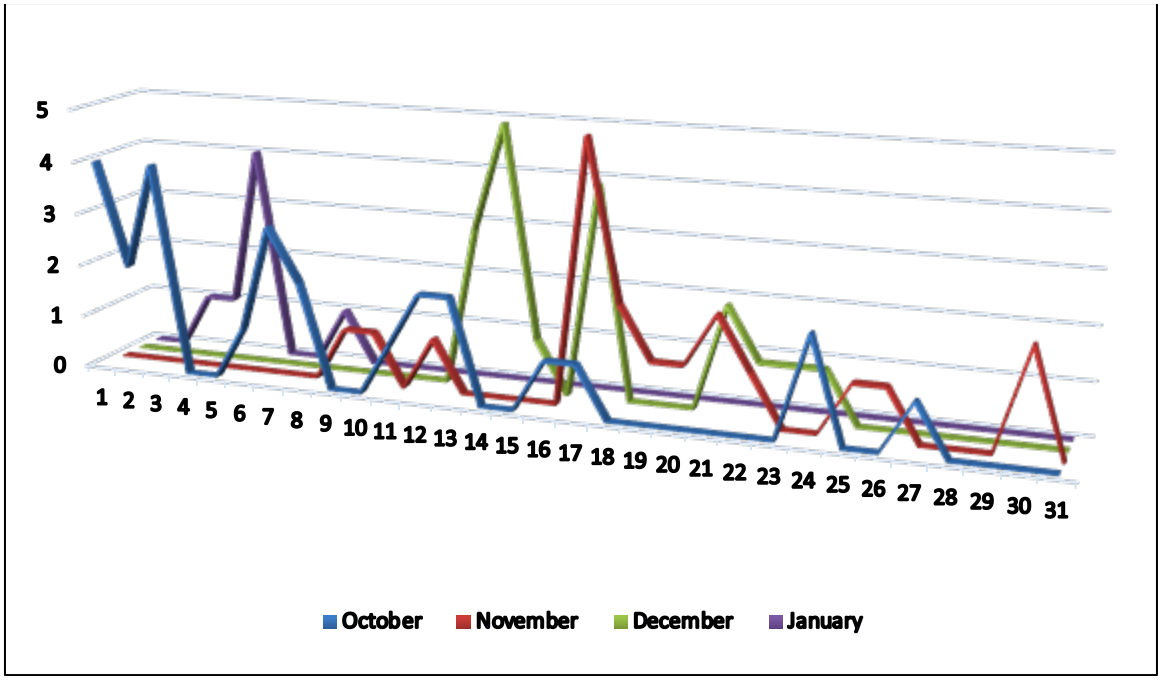


Figure 83: Distribution of infringements across the days of each month

In each case, crossings with a clear deficit in the safety distance were distributed across the whole month. There was no indication that deficits in the safety distance were more frequent on certain weekdays (e.g. Mondays) than on others. Based on these evaluations it can be stated that the transporter bridge's departure on the morning of the accident, despite the fact that maritime traffic was passing at the same time, was neither a novelty nor at least unusual. Parties transiting the Kiel Canal on a regular basis would be able to witness this operating behaviour by the transporter bridge sooner or later. The analysis therefore substantiates the testimony of the pilots on the EVERT PRAHM and the ship following her in the convoy, according to which the departure of the transporter bridge alone did not lead to the assumption of a risk of collision. Rather, the BSU assumes that the transporter bridge regularly crossed in such a conspicuous manner and that inasmuch an element of habituation may have developed among merchant shipping.

When the transporter bridge's operator docked on the northern bank on the morning of the accident after Ship A had passed, the EVERT PRAHM's masthead light was already visible in the video when the signal lights on the transporter bridge went on after the storm hook was released (see Figure 84: red arrow = EVERT PRAHM's forward masthead light). Within six seconds, the violet illumination of the bridge pier went out. Within another five seconds the transporter bridge moved away from the dock and thus directly toward the EVERT PRAHM.

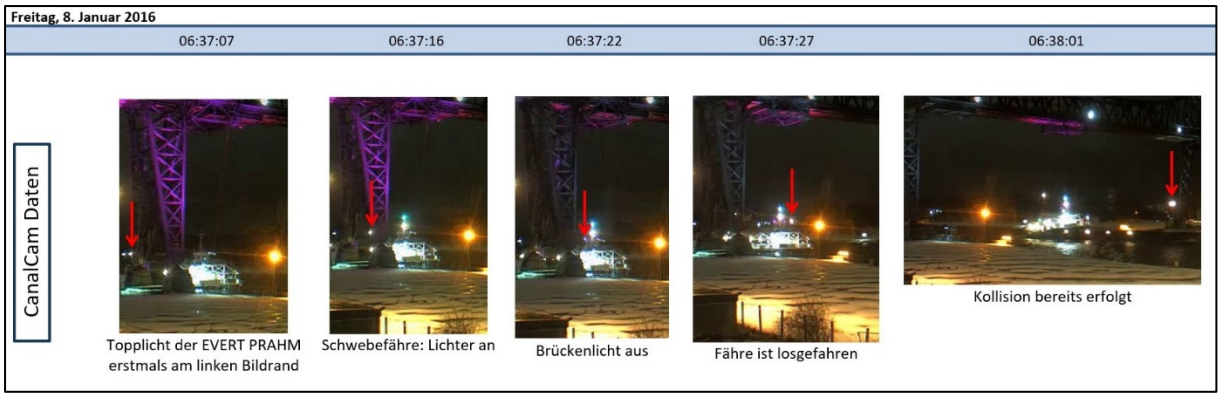


Figure 84: Video showing accident sequence

The analysis of this accident sequence, together with the assumptions and findings made by the BSU, according to which

- the windows of the transporter bridge operator's cabin were in all likelihood covered by ice and partly snow. Moreover, they did not have windscreen wipers in the direction of the approaching EVERT PRAHM;
- the radar apparatus on the transporter bridge and the emergency stop function were free of defects;
- the transporter bridge's operator was sufficiently trained, physically fit, familiar with the operation of the transporter bridge and informed about safety distances to be maintained;
- the operating behaviour of the transporter bridge's operator did not reveal any anomalies compared to that of his colleagues,

demonstrated that the accident was mainly caused by the transporter bridge operator's failure to notice the EVERT PRAHM for reasons that remain unclear. The BSU's investigators regard the chronological sequence of the video showing the accident and the comments of the transporter bridge's operator after the accident on VHF

> ("I do not know where that came from all of a sudden. [...] She was there all of a sudden and then we collided.")

as sufficient evidence for the assumption that the transporter bridge's operator did not intend to approach the EVERT PRAHM slowly and then pass at her stern, but rather that he completely overlooked the seagoing vessel. Had he stepped out of the cabin to check for surrounding traffic he would have seen the EVERT PRAHM. Given the weather on this early winter morning, it seems quite natural that he stayed in the cabin instead. Depending on position, the proven blind sector may have made it easier to overlook the approaching seagoing vessel. The transporter bridge's operator would have had to change his position, i.e. look out of the windows (which were iced up anyway), for example. After the accident he stated on VHF radio that he did not see the EVERT PRAHM on the radar. Since the investigation did not deliver any evidence of malfunctions, the BSU rates this as an attempt to justify his behaviour.

A glance at the radar apparatus and stepping out of the cabin would have been the best way to avoid the risk of collision. Instead, the transporter bridge did not move hesitantly but rather set off at normal speed immediately, as if no ship were in the vicinity.

The transporter bridge's operator thus violated the obligation in Section 6 of the operating instructions, according to which he was required to keep a careful lookout before departure. In addition, he was required to keep the transporter bridge clear of maritime traffic and maintain a safety distance of 1,000 m. Whether or when he noticed his momentary failure before the collision could not be determined.

Regardless of these findings, the number of daily crossings was evaluated for the analysis of the working conditions on the transporter bridge. According to the operating instructions, the transporter bridge's timetable provided for 142 crossings per day in the summer timetable (71 departures from each bank) and 134 crossings per day in the winter timetable (67 departures from each bank). Accordingly, eight crossings were required per hour to adhere to the timetable. Assuming there were no complications and the crossing time was two minutes, about five and a half minutes remained for loading/unloading passengers and vehicles on the bank. Maritime traffic posed a particular challenge for the transporter bridge operators. It was necessary to wait for every passing ship. The analysis of the recordings revealed that the transporter bridge regularly had to wait for several minutes in a loaded condition before it could cross the canal in compliance with the safety distance rules when vessels sailed in a convoy. Each hold-up caused a delay in the timetable, which was then made up for by reduced loading and unloading times. During peak hours (e.g. 1400 to 1500), up to 20 crossings were recorded per hour, reducing the time for loading or unloading the transporter bridge to about one minute. Such an increase in the frequency of crossings was explicitly ordered in Section 1 of the operating instructions.

The analysis shows that although fewer crossings were always made at weekends than on weekdays, the eight crossings per hour target was consistently met. The arithmetic mean of all crossings in the months analysed is a constant eight crossings per hour (see Figure 84 – the red line represents the mean of eight hours per day).

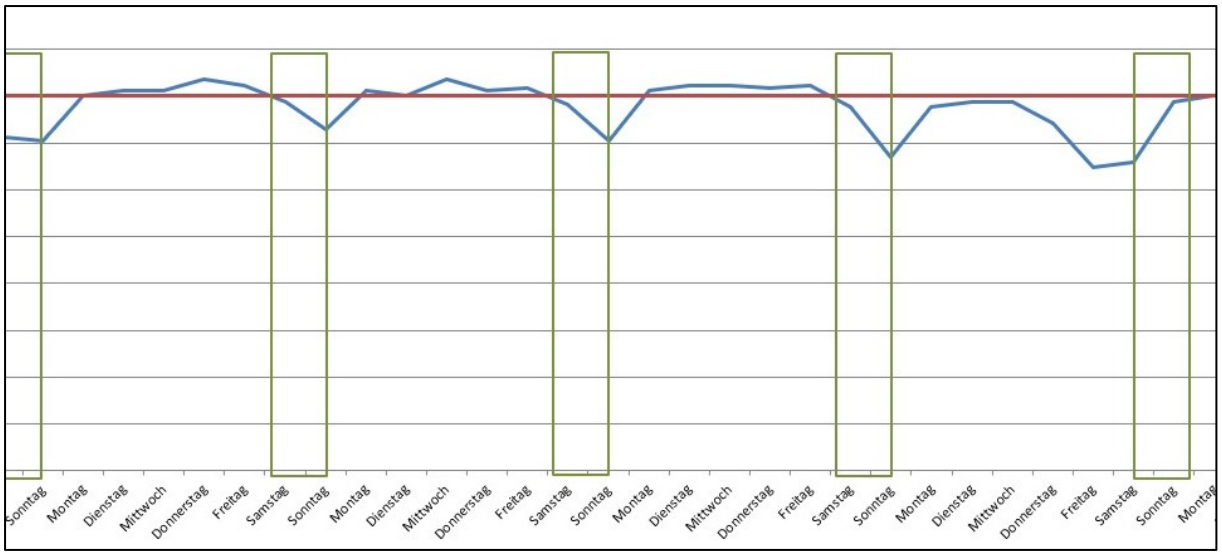


Figure 85: Extract from the analysis of the daily number of crossings by the transporter bridge

The number of crossings per day varied:

- October 2015: 113 to 148 crossings daily;
- November 2015: 73 to 142 crossings daily;
- December 2015: 122 to 142 crossings daily;
- January 2016: 65 to 136 crossings daily.

Days with fewer crossings usually followed a public holiday.

The 2-shift system of the transporter bridge's operators is as follows according to the analysis of the recordings:

- the early shift generally started at about 0430. The lights of the transporter bridge did not go on until about 0450 on the odd occasion. On the morning of the accident the light on the transporter bridge went on for the first time at 0425. The first crossing was at 0432, i.e. just under half an hour before the timetable started. It was generally noted that the transporter bridge also carried passengers and vessels before 0500 if required;

- the change of shift was generally at about 1330. At this point in time the early shift had been working for eight and a half to nine hours without regular or fixed breaks being apparent from the timing of the crossings;

- the late shift ran from 1330 to 2155 (winter timetable).

The analysis of the video recordings revealed the overall picture of a workplace with a high workload, where maritime shipping was an almost unpredictable and yet decisive factor for the success of the transporter bridge connection in terms of adherence to the timetable.

4.4 Operation of the transporter bridge

The operational organisation of the transporter bridge was the responsibility of WSA Kiel-Holtenau, which provided numerous documents and statements for the safety investigation in response to questionnaires. This gave the BSU the impression of a routine-oriented workplace involving a high degree of responsibility due to the transportation of passengers. The measures taken by WSA Kiel-Holtenau and the GDWS in Kiel, which is responsible for technical supervision, to make the risks of the workplace manageable are considered sufficiently effective after analysis of the documents. Nevertheless, the BSU believes there is still a need for improvement, especially against the background of the planned commissioning of a new transporter bridge in the future. After all, the risk of carelessness of the operator, which was classified as 'low' in the risk analysis, did materialise. Reviewing the marine casualty provides an opportunity to draw lessons from the course of events leading up to and during the accident and to consider them in the future operating concept. It is thanks to fortunate circumstances that there was only one passenger on the transporter bridge at the time of the accident and that the consequences of the accident were not more serious. The probability of extremely serious injuries would have been much higher if the accident occurred one hour later.

4.4.1 Workflows and equipment

WSA Kiel-Holtenau described and documented the workflows in the transporter bridge operator's cabin in sufficient detail. A fault management system was in place, which involved the entry of any faults into a fault log (that was separate from the operating log) indicating appropriate reporting channels to the shift personnel taking over and the managing authority. The BSU assumes that the transporter bridge was fully operable on the day of the accident and that the radar set and the emergency stop function in particular were not restricted by technical issues. The testimony of the transporter bridge operator from the previous evening, the lack of entries in the fault log and the inspections and performance tests carried out after the accident support this assumption.

The technical equipment of the transporter bridge with the radar was necessary and sufficient. Two distance markings defined the safety distances to be maintained by transiting shipping with sufficient clarity. Various options for initiating an emergency stop or moving the transporter bridge in emergency operation are available. Based on experience gained from this marine casualty, the BSU believes with regard to the construction of a new transporter bridge that it is advisable to consider whether appropriate additional or more effective technical aids than the radar apparatus can be used to assist the transporter bridge's operator. Even if the radar (in contrast to the radar apparatus on the former transporter bridge) were to be equipped with an ARPA[12], it would hardly be possible to set up effective alerting in the event of deficits in the safety distance because the surrounding land area and numerous radar obstacles (e.g. masts and pillars) would trigger alarms constantly.

[12] ARPA: Automatic radar plotting aid.

This would be different if an AIS were used, in which CPA[13] and TCPA[14] limits could be set. The BSU believes that an AIS receiver would be sufficient here, as the GPS reception required for an active device may not be continuously guaranteed under the railway bridge.

Regardless of the possibilities offered by technical aids, the BSU believes that it would be important for the managing authority to question whether the daily workload arising from the timetable could not be better handled by a 3-shift system instead of the previous 2-shift system. It is important to acknowledge here that there have been no major accidents or disturbances involving the transporter bridge prior to this marine casualty, despite the high number of daily crossings. The documents disclosed by WSA Kiel-Holtenau and feedback from the transporter bridge's operators do not provide any evidence that the managing authority would have been notified of an overload due to the tight timing of crossings or length of shifts. The BSU was not aware of any health problems of the staff as a possible consequence of considerable stress or a continuous overload, either.

WSA Kiel-Holtenau carried out traffic counts on the transporter bridge every 15 days to analyse the development of traffic. Adherence to the timetable and the regularly occurring additional crossings were therefore known. From the BSU's perspective it is a workplace in which repetitive workflows play a major role, despite the variables of transiting maritime traffic. Experience gained from other marine casualties and international studies on repetition at the workplace show that recurring activities combined with vast experience can be typical factors in the development of an accident.[15] The many years of successful and most importantly almost trouble-free operation of the transporter bridge are proof that WSA Kiel-Holtenau's original shift schedule actually worked. After the accident and with the knowledge gained from it, the issue of repetition, as well as alternative shift schedules and systems should nevertheless be included in the new operating concept. Even minor adjustments could help to reduce the workload of the staff substantially and thus the risk of stress, fatigue and errors arising from repetition on the transporter bridge.

4.4.2 Work ergonomics

In principle there are numerous regulations relating to work ergonomics designed to improve the working conditions for employees and thus not only have a positive influence on the work result, but also make an important contribution to maintaining health. The relevant legal framework for work ergonomics is the *Arbeitsstättenverordnung (ArbStättV)* [Germany's Ordinance on workplaces], which aims to "ensure the safety and health of workers when workplaces are being set up and operated" (Section 1(1) ArbStättV). However, it applies only to a very limited extent to workplaces in public transport, such as that of a transporter bridge operator in the present case.

[13] CPA: Closest point of approach.
[14] TCPA: Time to closest point of approach.
[15] See the BSU's Investigation Report 28/06, for example.

According to point 2 of Section 1(2) ArbStättV, only the regulations on the protection of non-smokers and on health and safety labelling are applicable to means of transportation used in public transport.

However, the following provisions are not applicable:

- protection against noise;
- sanitation and hygiene facilities;
- rest areas;
- sufficient space for changes to working posture and movements;
- anti-glare and anti-reflection display screens and other work equipment.

Since the managing authority is part of the federal administration, numerous ergonomic approaches were made to adapt the workplace to the needs of the transporter bridge operators, despite the inapplicability of most of the aforementioned provisions of the ArbStättV to the transporter bridge:

- risk assessments and safety briefings were carried out;
- the transporter bridge operator's cabin was equipped with heating and air conditioning;
- the transporter bridge operator's cabin was equipped with a refrigerator and a kettle for refreshments during a break.

Despite the administration taking such measures, the BSU's investigators could not see how the transporter bridge's operators could take a break of only 15 minutes, for example, when the timetable hardly facilitates this and as a workplace the transporter bridge does not even have a toilet. Based on the video analysis the BSU assumes that it is hardly possible to take genuine breaks in the transporter bridge operator's cabin. In one-man operation the transporter bridge operator is responsible for many tasks that have to be performed manually and sometimes simultaneously (barrier operation, supervision of passengers, crossings, etc.). Under these circumstances there is no real opportunity to take an undisturbed break, even if in structural terms the cabin is in an elevated position and thus cannot be seen into by passengers.

4.4.3 Special structural characteristics

The measurement of the field of view revealed a blind sector of 23° in the position in which the operator would typically stand during the crossing manoeuvre. This means that the operator must be aware of this and take the necessary measures to compensate for this structural disadvantage, i.e. vary his position regularly before departure so as to obtain the necessary overview of the prevailing traffic situation by looking out of the windows.

The fact that only three out of eight windows are equipped with a windscreen wiper and none of them can be heated must be regarded as a handicap. On the night of the accident it had snowed and was icy. Following the analysis of the witness testimonies, the BSU concludes that even without winter weather conditions the view from the windows can be seriously impaired at times, especially during crossings at night by the bridge lighting and associated reflections. Visibility may be impaired to such an extent

when the windows are frozen that traffic observation is only possible by stepping out of the operator's cabin or looking at the radar. The BSU considers it appropriate to expressly draw the attention of prospective and existing transporter bridge personnel to these conditions or to remedy the situation in a new construction by making technical modifications, such as heated windows with a sufficient number of windscreen wipers.

4.4.4 Operating personnel

The transporter bridge is controlled by one operator in a 2-watch system. The BSU believes that a second person on board is not necessarily needed to ensure smooth operation. The increased staffing that used to be on board (two people) has been sufficiently compensated for by the technical emergency stopping and emergency operation systems, video monitoring of the transporter bridge's entrances and main deck, as well as the radar apparatus. The transporter bridge's years of successful operation support this fact. It can also be assumed that the transporter bridge's operator on the day of the accident was basically equal to the task. According to information given by the GDWS, the transporter bridge's operator could not be accused of any behaviour that was questionable in terms of safety up until the accident on 8 January 2016. Any impairments caused by alcohol were shown to have not contributed to the accident. A test carried out by the WSP on the day of the accident was negative. The BSU believes that an assumed momentary failure can never be ruled out completely. In this context it was important to evaluate the managing authority's risk mitigation measures in respect of the training given to transporter bridge operators and performance of the duty of supervision and care, however.

4.4.4.1 Training and qualifications

Although the transporter bridge's operators are commonly referred to as ferry machinist, their qualifications are not comparable to those of an machinist employed on a ship. A navigating certificate is not needed to operate the transporter bridge. In the opinion of the BSU, this is not necessary to carry out the tasks of a transporter bridge operator, either. Rather, the party responsible, WSA Kiel-Holtenau, stated that it selects suitable employees who have been with the WSA for a long time and who are then trained and qualified by the WSA to operate the transporter bridge. Trainees must obtain the *UKW-Sprechfunkzeugnis für den Binnenschifffahrtsfunk* [German certificate for VHF radiotelephone operators on inland waterways] before training begins. The training by the WSA then takes place on the transporter bridge over a period of about six weeks on a full-time basis. The transporter bridge operator involved in the accident had completed the training successfully and proven himself in practical terms over years of service.
The BSU believes the scope and duration of the training are sufficient to meet the daily demands during transporter bridge operation. It is important that WSA Kiel-Holtenau ensures that the technical aids provided are actually used. All in all, the BSU assumes that the transporter bridge operators also used the radar apparatus in principle. It was not possible to reconstruct why this did not happen before the accident or why the EVERT PRAHM may have been overlooked.

4.4.4.2 Supervision and care by the WSA

The party responsible, WSA Kiel-Holtenau, carried out and documented a risk assessment for the workplace of the transporter bridge operators using the guidelines (version 3.1) of the *Unfallkasse des Bundes* [federal accident insurance fund]. The *Handlungshilfe zur Beurteilung der Arbeitsbedingungen in der Bundesverwaltung sowie in Betrieben und Einrichtungen der Länder und Kommunen* [guidelines for assessing working conditions in the federal administration as well as in companies and institutions of the federal states and municipalities] is an electronic tool for carrying out risk assessment in accordance with the *Arbeitsschutzgesetz* [Germany's Act on safety and health at work]. The supervisory authority has at its disposal numerous workplace- and activity-related checklists, as well as modules relating to type of hazard, which can be put together as required and also customised for the workplace being assessed.

Following this risk assessment, the *G25: Fahr- und Steuertätigkeit* [German occupational health examination for driving and control work] was defined as an operational aptitude test. In addition to this periodic health check, the transporter bridge operators are also instructed on occupational safety each year.

The transporter bridge operators' workplace was inspected both with the involvement of external bodies and by WSA Kiel-Holtenau as the managing authority. The last workplace inspection before the accident in the presence of the federal accident insurance fund was made on 12 October 2011. The last workplace inspection before the accident by an expert for occupational safety and the medical officer was made on 14 August 2012. No deficiencies were found at the workplace. In response to an enquiry from the BSU's investigators, the WSA stated that it maintained frequent, irregular and unannounced contact with the transporter bridge operators on site but did not give details of the average frequency of such checks prior to the accident. Since the routine checks should be documented, the BSU believes there is a need for improvement here. The same applies to feedback from the transporter bridge operators, which should be obtained as regularly as possible and could help to identify weak points and thus make it possible to recognise potential overload situations in good time.

The safety distance instructions – changing several times – were comprehensible. However, compliance with these safety distances should be checked more effectively. In particular, the installed web camera with a direct view of the transporter bridge's workplace makes this easily possible. However, even without the camera, regular unannounced on-site contacts could help to make the personnel of the transporter bridge more aware of the urgency of maintaining safety distances.

4.5 EVERT PRAHM

The BSU believes that the EVERT PRAHM's bridge team was confronted with an almost unsolvable risk situation when the transporter bridge set off regardless of their approach.

4.5.1 Bridge team

The bridge was not properly manned on the night of the accident. Apart from the officer in charge of the navigational watch, no other crew member qualified to form part of the watch, in particular no qualified lookout, was present on the bridge. Due to his advisory function, the canal pilot was part of the bridge team but did not belong to the crew in a legal sense. The need to man the bridge with an additional helmsman (given that automatic steering gear is prohibited on the Kiel Canal), as raised by the GDWS, qualified to form part of the watch in addition to the members of the ship's command in charge of navigation and a qualified lookout may remain unanswered, as the BSU believes it had no impact on the further course of the accident.

In the opinion of the GDWS, the improper manning of the EVERT PRAHM's bridge must be regarded as the principle causative factor in the collision with the transporter bridge. The EVERT PRAHM's bridge team unanimously stated that the cadet and the pilot reacted to the departure of the transporter bridge almost simultaneously. The analysed web camera frames clearly indicate that a lookout could probably not have recognised the situation any earlier. The BSU therefore considers that although the improper manning of the bridge is a violation of the requirements of A-VIII/2.14 et seq. of the STCW Code in conjunction with the obligation to maintain a proper lookout under Rule 5 COLREGs, it – as just discussed – did not contribute to the accident.

Notwithstanding the undermanning of the bridge, the investigation did not reveal any evidence of fatigue among the bridge team on the night of the accident. The time sheets submitted for January 2016 indicate that the stipulated rest periods were observed by all crew members.

4.5.2 Speed

Ships transiting the Kiel Canal are classified to TGs (from one to six) based on their size. Depending on the section of the canal, encounters may only occur between ships whose TGs do not exceed the number 6, 7 or 8 when added together. The WSV's traffic control system can thus ensure that the distances between ships encountering on the canal are safe. In the Kiel Canal all vessels of TGs 1-5 are subject to a speed limit of 15 km/h (or 8.1 kts). TG 6 ships or those with a draught in excess of 8.5 m may only proceed at 12 km/h or 6.5 kts.

Due to her draught of 4.1 m, the EVERT PRAHM was classed as a TG 3 ship on the day of the accident and thus subject to a speed limit of 15 km/h or 8.1 kts. The ships ahead and astern of the EVERT PRAHM in the convoy were also classed as TG 3. The BSU created a velocity profile for the EVERT PRAHM based on the AIS data (see Figure 86).

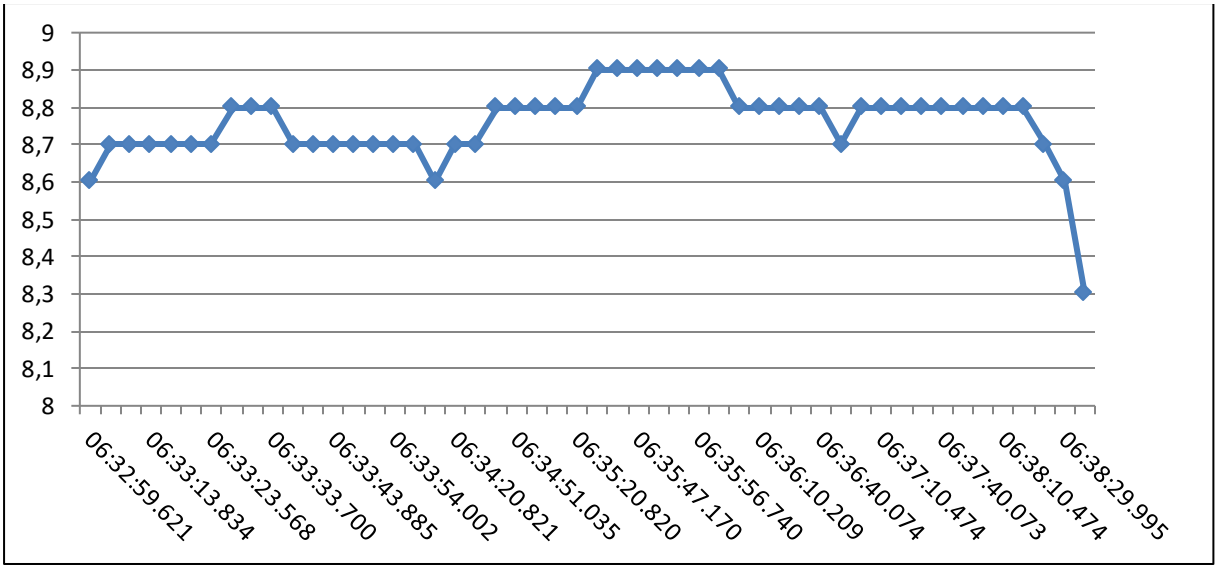


Figure 86: AIS velocity profile for the EVERT PRAHM

Irrespective of the general observation that such AIS data always involve minor deviations in the presentation (see Figure 51 – speeds of 8.7 kts and 8.8 kts displayed for the EVERT PRAHM in the same AIS plot), the recordings as a whole indicate that the EVERT PRAHM had exceeded the speed limit. However, the BSU's investigators believe this excess speed of 0.6 kts to 0.7 kts (corresponding to 0.36 m/s at 0.7 kts) had no effect on the collision. Stopping would not have been possible even if 8.1 kts had been maintained and the additional reaction time arising from sailing in compliance with the canal's speed limit would not have been sufficient for a promising evasion manoeuvre.

4.5.3 Evasion manoeuvre

The EVERT PRAHM carried out an evasion manoeuvre in a hopeless situation, which could only have been successful if the transporter bridge had also carried out an emergency manoeuvre (e.g. emergency stop) at the same time. From a navigational perspective, the manoeuvre chosen (full astern and hard to port) is understandable and the only realistic manoeuvre in the short time available. In the few seconds available an emergency anchoring manoeuvre was hardly conceivable, either. As can be deduced from her subsequent contact with the embankment, the EVERT PRAHM ran into difficulties due to the manoeuvre chosen. Her manoeuvrability was fortunately retained, meaning the canal could be used for the rescue and recovery operation without any constraints.

The BSU does not believe it reasonable to assume that an inherent risk of collision existed when the transporter bridge's signal lights went on or when the violet bridge illumination went out. There were times when the transporter bridge carried out such manoeuvres daily. Accordingly, given the practicalities of merchant shipping on the Kiel Canal, a departure alone need not entail an evasion manoeuvre. The video recordings analysed show that none of the seagoing vessels affected by an inadmissible manoeuvre of the transporter bridge due to clearly not complying with the safety distances (Category D – 'Creeping', Category X – Moving in front of the bow)

executed an evasion manoeuvre. Rather, there was evidently the assumption – beyond the scope of the SeeSchStrO and the COLREGs – that it was the sole responsibility of the transporter bridge to keep clear and thus always give shipping priority.

In the opinion of the BSU, this was not about the numerous ship's commands and advising pilots affected accepting a dangerous situation, but rather about making comprehensible decisions based on a realistic assessment of the situation and alternative courses of action. As soon as the transporter bridge approached a ship to such a short distance, an evasion manoeuvre by the ships had little chance of success due to the time lag of engine manoeuvres and confined space for an evasion manoeuvre under the bridge. Only the manoeuvring characteristics of the transporter bridge, which were fundamentally different to those of seagoing vessels, promised success in such situations. In this respect, it was quite logical for the seagoing vessels to continue their voyage unperturbed in the numerous convergences analysed, as the transporter bridge, with its advance distance of about 1 m and permanent opportunity to reverse the direction of travel at any time, had quite different options and also made use of them to avoid collisions. The EVERT PRAHM was in the wrong place at the wrong time when in this particular case the transporter bridge approached not in a controlled but rather in a careless manner and thus failed to execute any manoeuvres whatsoever.

4.5.4 Warning signals

The BSU assumes that neither the EVERT PRAHM nor the transporter bridge used warning signals. The transporter bridge's operator did not even notice the danger, meaning he did not activate the signal horn, either. Even if he had recognised the danger, the warning signal would not have saved him from the collision in this situation. On the part of the EVERT PRAHM the situation is different, however. Had she (instead of or simultaneously with the evasion manoeuvre) used the remaining, extremely short reaction time to draw attention to the dangerous situation by means of the tyfon, then the transporter bridge's operator may have been able to prevent the collision, after all, using the special manoeuvring characteristics of the transporter bridge.

The otherwise relevant Rule 34(d) COLREGs, which requires seagoing vessels to give five short and rapid blasts on the whistle, is not relevant here. However, Section 3 SeeSchStrO contains a rule which states:

> "(1) The conduct of every person taking part in shipping traffic shall be such as to ensure the safety and easy flow of shipping traffic and to avoid any other person to be exposed to any damage or detriment, to be put at risk, or to be impeded or molested any more than is inevitable in the circumstances prevailing. Every person taking part in shipping traffic shall, in particular, take any precaution as may be required by the practice of good seamanship or by the special circumstances of the case. […]"

On the morning of the accident the EVERT PRAHM, as a traffic participant, had to warn the transporter bridge, as 'other', of a danger according to the standards of good seamanship. The tyfon would have been the preferred means of achieving this and from the perspective of the BSU the only promising means. Neither the passenger on

the transporter bridge nor other uninvolved parties, such as the bridge team on Ship B in the convoy, could confirm the bridge team's claim that a tyfon signal was sounded. The passenger reported a recurring sound signal but the investigation revealed that this was a sound signal issued automatically when the transporter bridge switches from main to standby power. Accordingly, the BSU assumes that the EVERT PRAHM did not sound a tyfon signal, as would have been necessary.

4.6 The rescue and recovery operation

From the BSU's perspective, the rescue operation was planned and implemented perfectly. The early availability of diving units and smaller lifeboats would have made it possible to rescue people in the water if necessary.

The recovery operation was complicated and the closure of the canal and railway line had to be kept as short as possible because of the importance of the Kiel Canal for maritime shipping. The recovery was successful despite adverse conditions. From the perspective of the investigation, it is important to once more urge all rescue and recovery personnel to document the condition of the scene of an accident when they first arrive, if possible with photographs or video recordings, before making any changes.

In other marine casualties, such photographic documentation has proved extremely helpful when reconstructing the accident[16]. In the present case the switch positions in the transporter bridge operator's cabin had obviously been changed in the course of the recovery operation and it was no longer possible to reconstruct the original condition afterwards. Having said that, the recovery personnel can be deemed to have been under unusually high pressure to take action quickly on the day of the accident, as the transporter bridge was stuck in the middle of and obstructed the world's most heavily used man-made navigable waterway, blocking not only the shipping but also the railway lines.

[16] See Investigation Report 445/10 concerning the fire on the LISCO GLORIA.

5 CONCLUSIONS

A proper check of the traffic situation was not made on the transporter bridge before it departed for the southern bank. This meant that the EVERT PRAHM, which was heading directly for the transporter bridge in the middle of the canal, was not noticed. There was insufficient time to execute an evasion manoeuvre on the EVERT PRAHM. Moreover, emergency manoeuvres were not executed in the transporter bridge operator's cabin because the transporter bridge's operator did not recognise the imminent danger in combination with the absence of a tyfon signal by the EVERT PRAHM either at all or early enough.

It is thanks only to fortunate circumstances that nobody suffered extremely serious injuries in addition to the considerable material damage sustained by both parties. In the early hours of the morning there was only one passenger on the transporter bridge and he was wearing protective clothing.

The rescue and recovery operation ran smoothly.

Although operation of the transporter bridge was supported technically by radar apparatus in the operator's cabin, this did not have any setting options for an alarm if there were deficits in the safety distance when a moving object approached the transporter bridge. Since there are plans for a reproduction of the transporter bridge to resume service at the same location on the Kiel Canal in the future, it would make sense to provide additional technical assistance, e.g. by installing a passive AIS device so as to provide alarms if there are deficits in the distance. Other structural adjustments for the planned new construction should include windscreen wipers, as few blind sectors as possible, as well as possibly heated windows. The operating concept of the future transporter bridge should also take into account the findings gained from this accident, e.g. with regard to an adjustment of the shift system and measures for occupational health and safety.

6 Actions taken

As part of the statement on the draft report, the GDWS in Kiel and WSA Holtenau communicated various aspects which will be taken into account in the construction of the new transporter bridge. These include:

- the new construction will be equipped with an active AIS system. The safety distance specified can thus be monitored both with the radar apparatus and with the AIS unit;
- planning of the window areas will be based on DIN EN 1864 'Inland navigation vessels – Wheelhouse', *inter alia*. Blind sectors are to be minimised in the process. The equipment of seven of the eight windows with a windscreen wiper and heating is planned. The equipment of the door window with these features is not technically possible.

Given the planned measures already described, it is not necessary to address further safety recommendations to WSA Holtenau.

7 SAFETY RECOMMENDATION(S)

The following safety recommendations do not constitute a presumption of blame or liability in respect of type, number or sequence.

7.1 Owner of the EVERT PRAHM

The Federal Bureau of Maritime Casualty Investigation recommends that efforts be made to ensure that the EVERT PRAHM's bridge is always manned in accordance with the requirements of the STCW Code, especially with regard to the posting of a lookout.

7.2 Owner of the EVERT PRAHM

The Federal Bureau of Maritime Casualty Investigation recommends that the crew of the EVERT PRAHM be made aware of the fact that in dangerous situations the possibility of a warning by means of a tyfon signal should be made use of.

8 SOURCES

- Documents from the EVERT PRAHM
  - Ship certificates
  - Bridge log book
  - Pilot card and wheelhouse poster
  - Crew timesheets
  - Navigation equipment test certificates
- Investigations of the waterway police
- Written explanations/submissions
  - Ship's command
  - Owner
  - Classification society
- Witness testimony
- Expert opinion/technical papers
- Transporter bridge documents
  - Operating instructions
  - AEG readout device program documentation
  - Electrical and circuit diagrams
  - WSV bridge plans
- Navigational charts and ship particulars, BSH
- Official weather report by Germany's National Meteorological Service
- Radar recordings, ship safety services/VTSs
- Rendsburg Fire Service's mission report
- VTS NOK's operating log
- WSA Kiel-Holtenau's *100 Jahre Eiserne Lady* [100 years of the iron lady] brochure
- Figures:
  - Figure 2: M. Bartzsch/K. Geißler/R. Schmachtenberg: Die Ertüchtigung der Rendsburger Eisenbahnhochbrücke über den Nord-Ostsee-Kanal, in: Stahlbau 84 (2015), Heft 3, Seite 171. Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin.
  - Figure page 15, picture of the MEMEL: Nightflyer (https://commons.wikimedia.org/wiki/File:Memel_NIK_1373.JPG), „Memel NIK 1373“, https://creativecommons.org/licenses/by/3.0/legalcode.
  - Figure page 15, picture of the NOBISKRUG: Nightflyer (https://commons.wikimedia.org/wiki/File:Burg,_Fähre_über_den_Nord-Ostsee-Kanal_NIK_0326.JPG), „Burg, Fähre über den Nord-Ostsee-Kanal NIK 0326“, https://creativecommons.org/licenses/by/3.0/legalcode.
  - Figures 4 to 16, 20 to 21, 50, 84 and on pages 94 to 96: http://www.canalcup-cam.de.
  - Figures 22 and 30: https://www.wsa-kiel.wsv.de/Webs/WSA/WSA-Kiel-Holtenau/DE/1_Wasserstrasse/2_Tunnel-Bruecken-Faehren/2_Bruecken_Schwebefaehre/1_EHB-RD_Schwebefaehre/6_Schwebefaehre/4_Was_bisher_geschah/Was_bisher_geschah_node.htm.
  - Figures 48 to 49: From expert’s opinion of DWD.
  - Figures 25 to 29, 31 to 36, 38 to 46, 74: BSU