ANNEX 5

MAIB's interpretation of the results of the model experiments

The model experiments made an invaluable contribution to the investigation, revealing the vulnerability of even a well-found vessel such as *Gaul* to an encounter with a group of very large breaking waves.

Model experiments provide a satisfactory way to predict performance and behaviour of the full-scale vessel, although there are often inherent limitations. This is because the modelling is of necessity a simplification of the vessel and the environment, and the results must therefore, take this into account. Model experiments in steep breaking waves are the only viable way of predicting the ship's response to extreme seas.

The model used possessed greater stability (scaled) than the full-size vessel, simply because of unavoidable effects of scale. For example, the 1 millimetre thick bulwarks on the model scale to 46 millimetre full size, about six times the real thickness. The range of stability of the model was determined by experiment to be almost 180°, which meant that it was completely self-righting. This was not realistic as the full size vessel was calculated to have a range of stability of about 120° (**Figure 10 in Annex 2**). However, the calculations for the full size vessel ignored many minor items of buoyancy such as the winches and box section masts. If these items had been included, the calculated range of stability of the vessel would have increased, but not to 180°. The range of stability of the vessel probably lay between 120° and 130°. This would of course be rapidly degraded by flooding through non-closeable openings.

As a consequence of its exaggerated range of stability, the model would not have been knocked-down to as large an angle as the full size vessel, and would have recovered more quickly. In effect, a knock-down on the full size vessel would have been worse than implied by the model experiments. For this comparison it has been assumed that both the model and full size vessel are completely sealed against water ingress, which was also unrealistic. However, the experiments carried out with doors and hatches opened, showed that water would not have flooded in fast enough during a knock-down to have prevented a partial recovery of the vessel.

Also, the model was not fitted with the minor ventilators on the starboard side, which it has been estimated would have increased the rate of flooding to the factory and other spaces during a knock-down. Again, this factor would have allowed the model to recover better than the full size vessel.

The effect of cargo and gear shifting was also not represented on the model, nor the blockage of freeing ports from loose gear sliding across the trawl deck. Both these effects would have been critical to the survival of the vessel.

The model experiments are indicative of what could have occurred with the vessel, but probably exaggerated its ability to have withstood, and to have recovered from, a knock-down. Therefore, the data gleaned from the model experiments, when scaled for the full-size vessel, could be optimistic. However, the calculated large range of stability of the vessel strongly indicates that she would have made a partial recovery from the knock-down.

Nevertheless, in spite of inherent limitations of the experiments, it is concluded that if the vessel had been struck by a large breaking wave it would have been rolled to an extreme angle and this would have compromised its safety.

FIGURES 1–46

Figure 1: **Gaul – bridge deck layout**

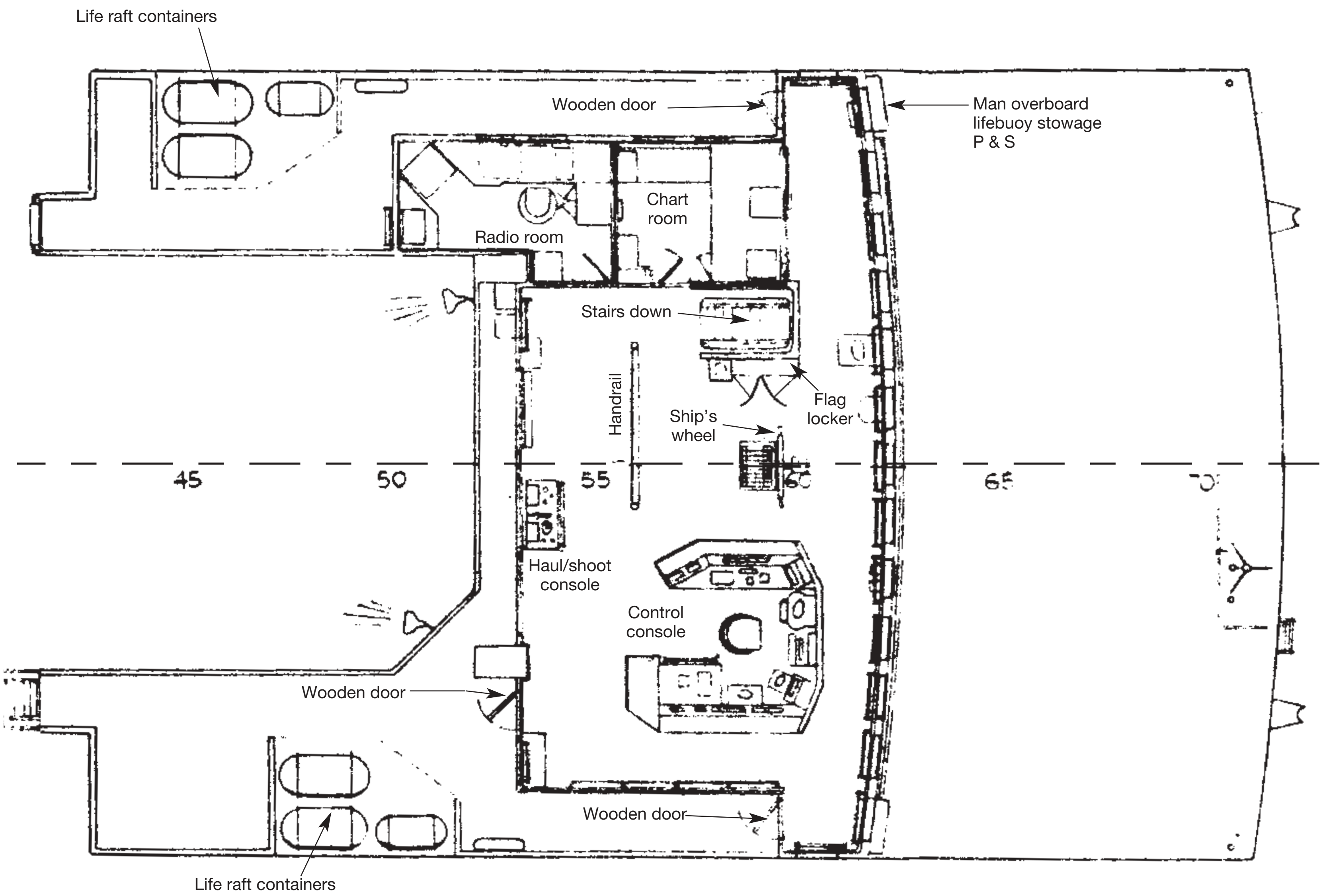


Figure 2: **Kurd – bridge interior looking to starboard**

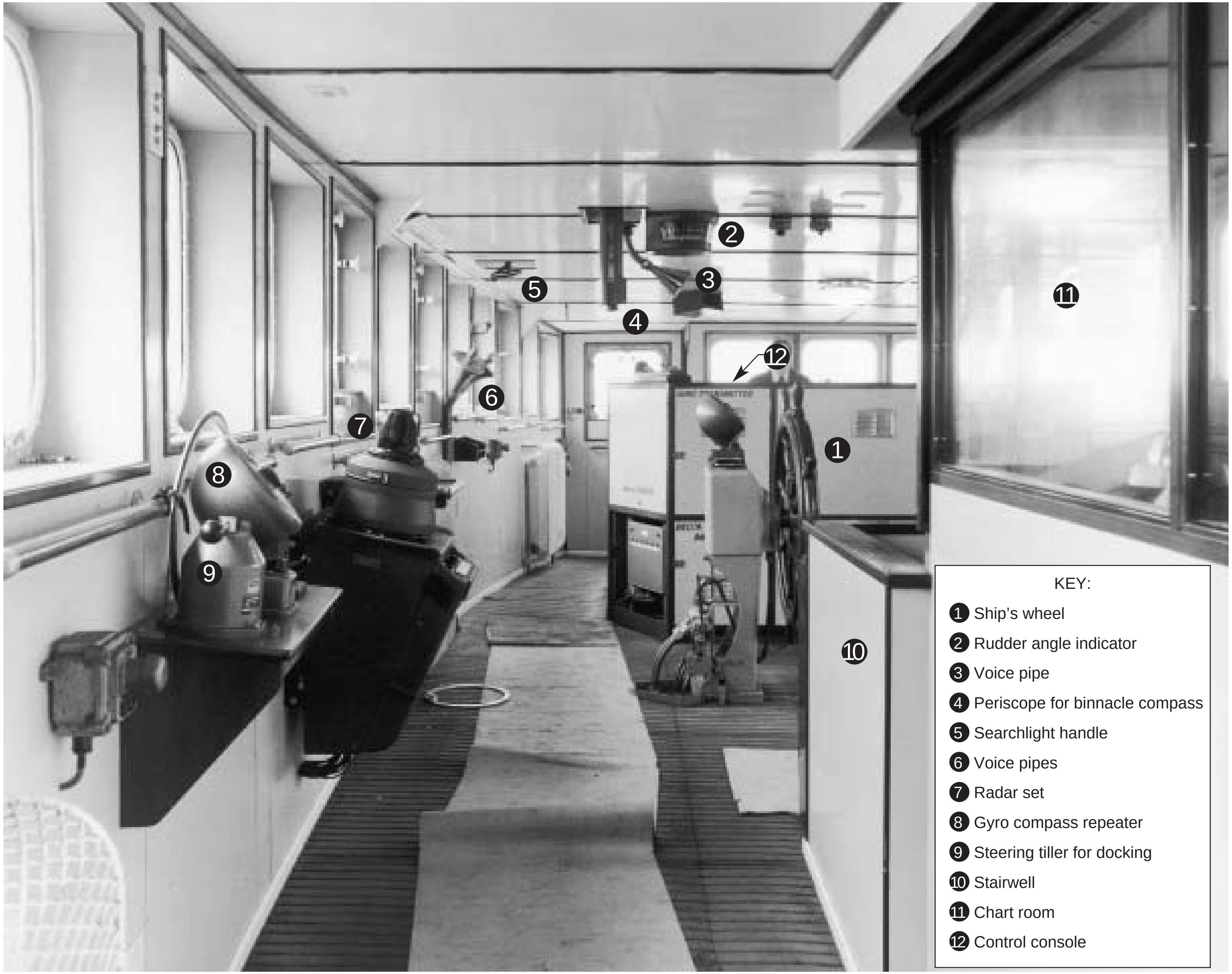


Figure 3: **Kurd – bridge interior (looking to port over control console)**

KEY:

- ❶ Haul/shoot console
- ❷ Fire alarm panel
- ❸ VHF telephone handset
- ❹ Autopilot controls
- ❺ Chart room
- ❻ Radio room

Figure 4: **Kurd – bridge interior (control console, looking forward)**

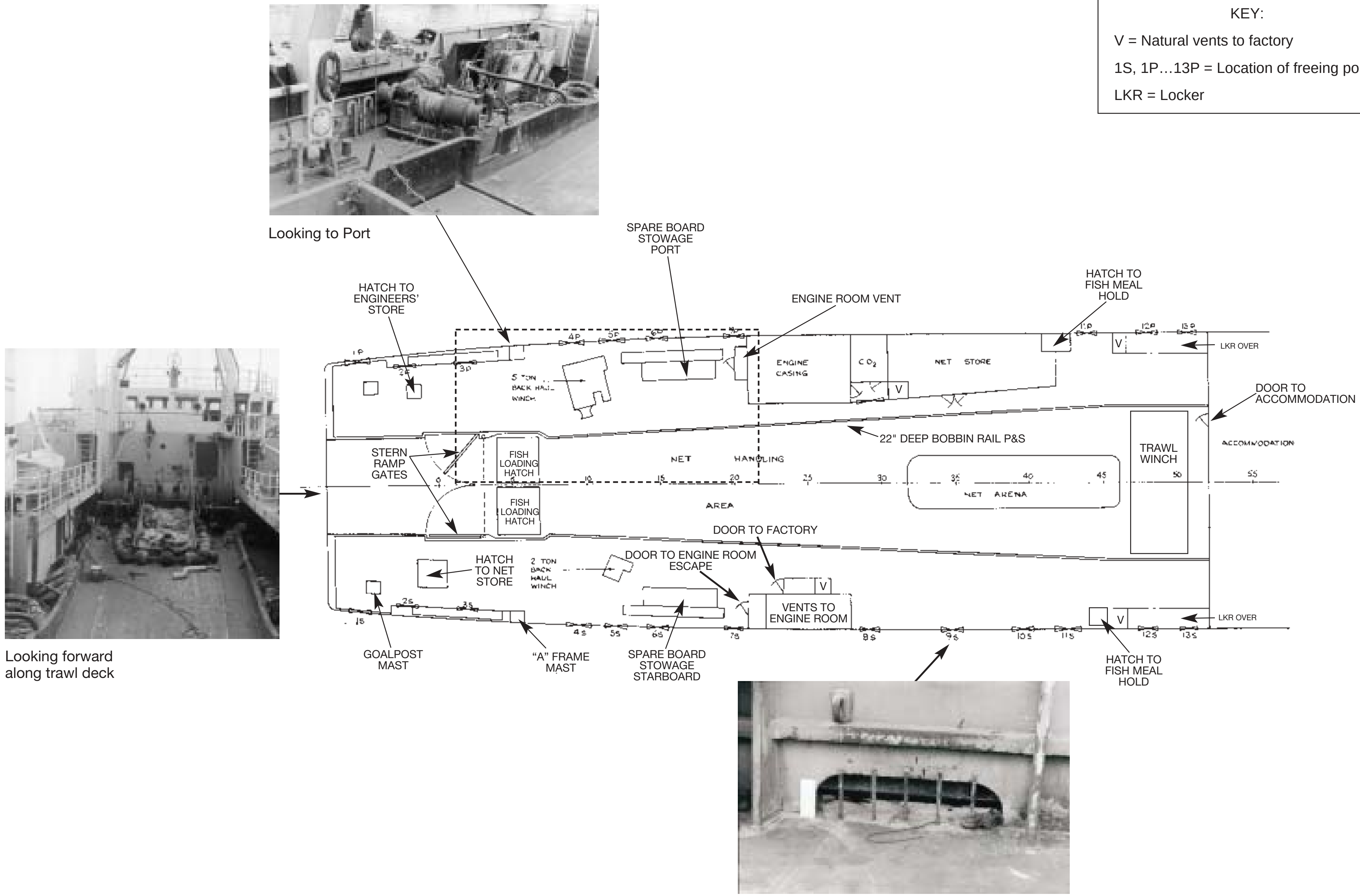
Figure 5: **Plan of trawl deck (aft)**

KEY:

V = Natural vents to factory

1S, 1P…13P = Location of freeing ports

LKR = Locker



Looking to Port

Looking forward along trawl deck

Typical freeing port

Plan and photographs courtesy of BAe Land Sea System

Figure 6: **Kurd – looking aft along trawl deck**

KEY:

1. "A" Frame mast
2. Goalpost mast
3. Net store hatch
4. Fish loading hatches
5. Stern ramp gates

Figure 7: Kurd – looking forward along trawl deck

KEY:

1. DF Aerial
2. Main mast
3. Liferafts
4. Door to accommodation
5. Net arena
6. Bobbin rail
7. Door to factory

Figure 8: **Kurd – stern ramp and gates**

KEY:

1. "A" Frame mast
2. Goalpost mast
3. Port trawl door in its stowed position
4. Hydraulically-operated stern ramp gates closed
5. Starboard trawl door in its stowed position

Figure 9: **Arab – Emergency escape door from engine room, located trawl deck starboard.**

Figure 10: **Arab – trawl deck, starboard. Door to factory**

KEY:

1. Natural ventilation inlet to factory
2. Door to factory
3. Loop used for holding door open
4. Emergency escape door from E.R. (Fig. 9)
5. Stowage rack for spare trawl doors

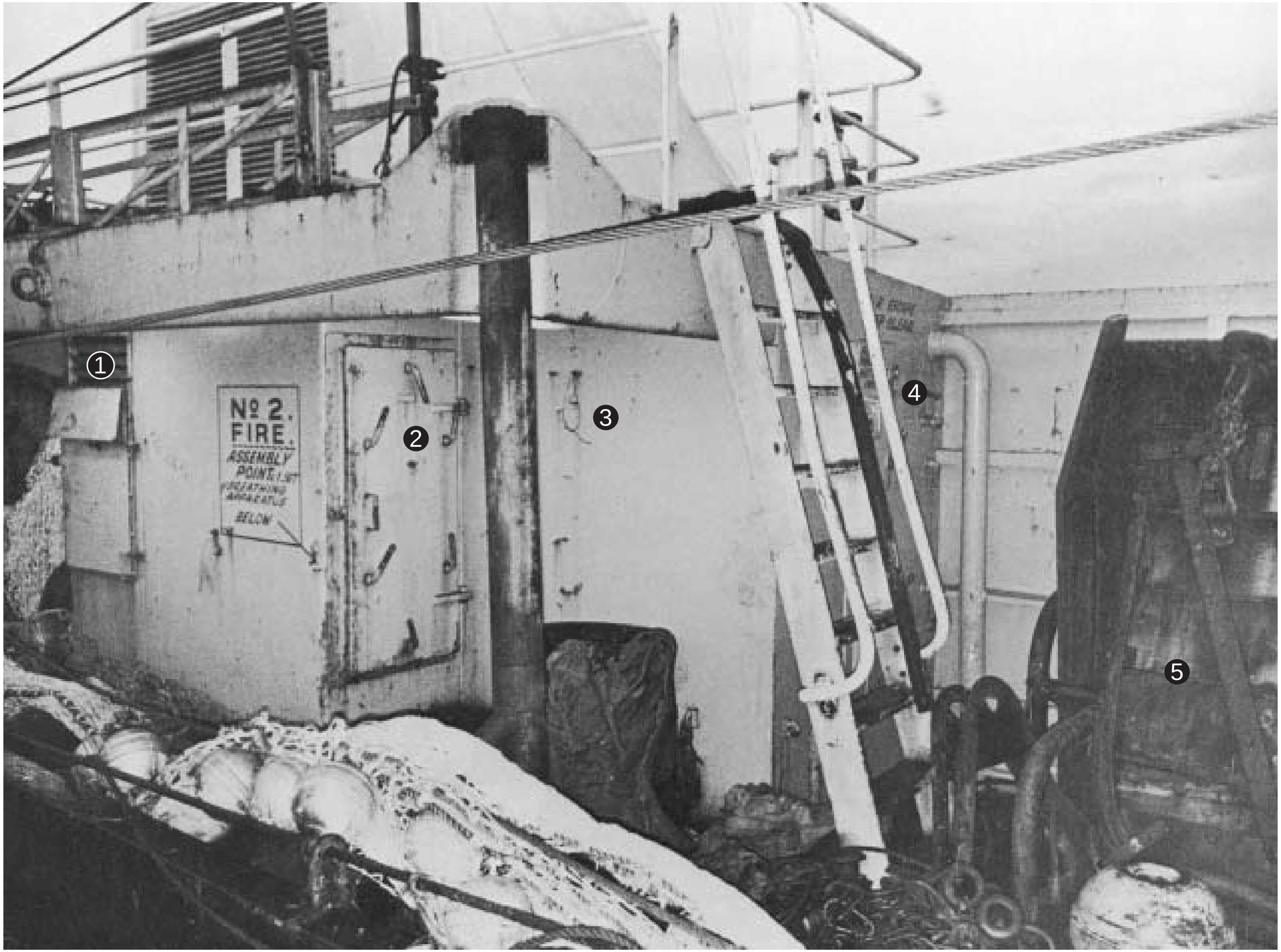


Figure 11: **Arab – trawl deck (aft), looking aft. Fish loading hatches, open**

KEY:

1. Hatch to net store, open
2. Locking pin
3. Securing clip
4. Goalpost mast

Photograph courtesy of BAe Land and Sea Systems

Figure 12: **Arab – factory deck**

Figure 13: **Description and technical specification of Sealion ROV**

SEALION

SEALION MkII (Vectored)

HEAVY WORK CLASS ROV

Designed and manufactured by Techno Transfer Industries (TTI) , and operated by Asiatic Racal Underwater Contractors, the Sealion is a multi functional Work Class ROV suitable for rapid deployment on any appropriate vessel of opportunity.

TYPICAL WORK TASKS

- Valve operation
- Cutting steel and fibre cables or ropes
- Operation of disc grinders
- Hot stabbing
- High pressure water jetting
- Removal of cuttings from wellheads
- Make and break of hydraulic connections
- Bathymetric surveys
- Installation and removal of AX rings
- Trench profiles
- Sub bottom pipe tracking
- Video observation, B/W or colour
- Still photography
- Tool skid carrying capability

The Sealion is a free swimming 100hp powered work class ROV with a depth rating of 1000 metres. The specially designed vectored thruster configuration optimises thrust to give higher forward and lateral thrust. Particular to this vehicle are the high efficiency 300mm kapalan thrusters which provide a greater thrust increase, equal in both directions.

The standard vehicle carries two 7 function manipulators, pan and tilt unit, up to 4 cameras and 4 variable intensity lights. Flexibility is a key feature in the Sealion design, enabling the installation of survey sensors, hydraulic power tools and work skids, to be added when required. Telemetry to the vehicle is via a fibre optic link or twisted pair. Video transmission is via coax or fibre optic link.

The vehicle frame, which is constructed from stainless steel hollow section, houses the following equipment: - Six hydraulic thrusters; 100hp electro-hydraulic power unit; servo valve pack; transformer housing; gyro compass and flux gate housing; electronic control pressure vessel; two manipulator arms; manipulator valve packs; pan and tilt camera unit; echo sounder; cameras and lights; sonar head and bottle.

Control of all the Sealion's function is effected from an A60 specification control cabin, certified by Lloyds Register of Shipping. The cabin is fully air conditioned, and can be Zone II or Zone I rated as required.

Sealions can be adapted to undertake work for all major offshore underwater remote task operations including Drilling, Construction, Survey, Communications and Power Cable Support as well as for Military subsea roles.

RACAL

Reproduced by courtesy of Racal

Figure 13 (continued): **Description and technical specification of Sealion ROV**

SEALION MkII (Vectored)

Specification

Physical Characteristics

Length	2.2m
Width	1.40m
Height	1.60m
Weight	1800kg
Through frame lift	5000kg
Payload(std buoyancy)	200kg
Payload(add buoyancy)	300kg
Depth rating	1000m
Power electro-hydraulic	100hp
User power	up to 5kW

Performance

Six Thrusters provides the following:-

Forward	700 kg
Vertical	500 kg
Lateral	700 kg

Note: All 6 thrusters can be driven simultaneously at 100% thrust at any time.

Speed

Forward	3.75
Lateral	2.25

Manipulators (7 function)

Reach	1.6m
Lift capacity	50kg
Rotate torque	108Nm (79lbf.ft)
Jaw gripping force	2000N (450lbf)

Cameras and Lights

The vehicle is equipped with facilities to operate up to four cameras simultaneously with three focus and zoom controls. Video can be by transmitted to the surface by fibre optic links or coax as required. 2 kW of variable intensity lighting power and 1kW of switched lighting power is available.

Pan and Tilt Unit

Motive power	Hydraulic
Control	Joy stick
Pan travel	220 degrees
Tilt travel	180 degrees
Torque	Adjustable
Speed	Adjustable

(The Pan and Tilt Unit is capable of holding two cameras with lights)

Lights

4 x variable intensity quartz halogen (2kW)

Vehicle Control System

Telemetry via a fibre optic link or twisted pair, baud rate variable, with full duplex asynchronous 8 bit data based on proprietary protocol. Control system is a real time supervisory control and data acquisition system based on a Z180 Processor on the ROV with dual Intel 486 microprocessors on the surface.

The pilots controls user friendly with a graphics interface displaying all key data user configurable set-up. An advanced diagnostic system

Digital outputs	72
Digital inputs	32
8 bit analog outputs	16
16 bit analog inputs	32
Refresh rate	30Hz

Optional tether Management System — TTI Side-entry or Top-hat type with self contained garage, up to 200m excursion umbilical.

Auto Control and Sensing Systems

Auto depth control	± 10cm
Auto heading control	± 1.5 degrees
Auto altitude control	± 10cm

Gyro Compass System

Type	King KGS 105 with flux valve or KVH DGC solid state compass with rate gyro and auto compensation.
Accuracy	± 1 degrees
Slaving rate(normal)*	3 degrees/min
Slaving rate(fast)*	14 degrees/sec

* (KGS 105 only)

Depth sensor

Transducer type	DRUCK PCDR 810
Range	0-1000m
Accuracy	0.1%
Resolution	1FSW

Echo Sounder

Type	Mesotech 807
Frequency	200kHz
Range	0.6m-30m

Control and Data Systems

The following telemetry and control circuits are available to the user:-

Down

16 x user relays, digital control 250V ac @2A

7 x 8 bit analog output channels -5 to +5V @ 0.5A

Up

7 x 16 bit analog input data channels

4 x 8 bit input flag channels

Power Requirements

380 - 500V 3 phase 50-60Hz (250kVA)

The incoming 3 phase is stepped to 1200 V by both a 6kVA single phase and an 8.7kVA 3 phase transformer to supply vehicle power via the umbilical. Incoming power is reduced to 220V to supply power for the control cabin lights, air conditioning, sockets and control electronics

Safety

Insulation resistance of the umbilical on high voltage lines is monitored with a LIM (Line Insulation Monitor), which shuts off the HT output in the event of an insulation fault.

Earth leakage circuit breakers are provided to monitor leakage of the cabin 220V and winch supplies to ensure safety of personnel

ROV Control Console

Three 19 inch rack units which can be bolted together or supplied as separate comprising:-

Pilot's control console for all vehicle and user switch functions

ROV processor control unit c/w keyboard

2 x 10 inch colour video monitors

3 x line correctors

4 x station personnel communication system c/w 3 headsets for deck use.

Emergency stop switch for HPU

Various blank panels

(Extra equipment can also be accommodated within the console)

Launch & Recovery System (LARS)

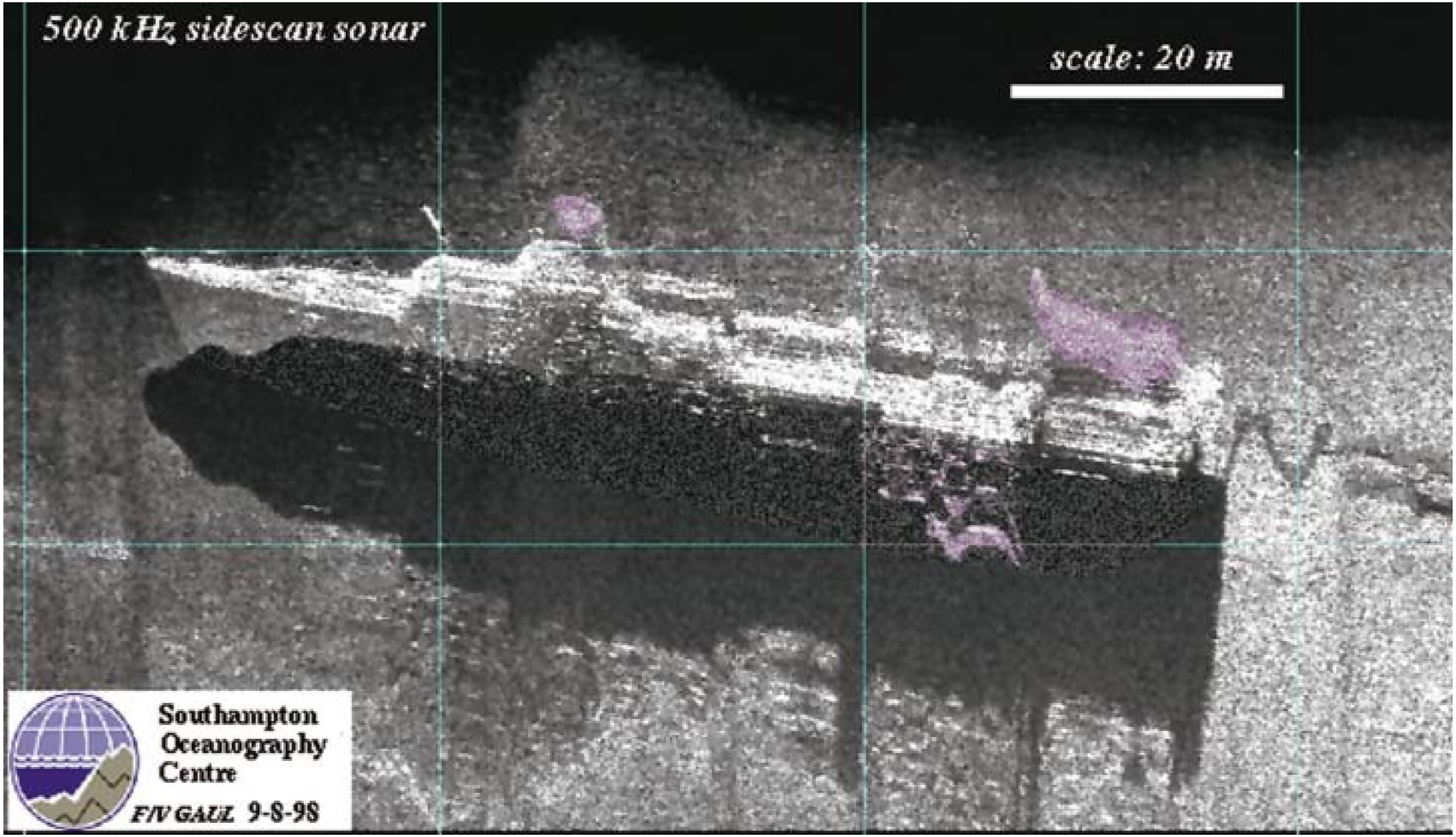
Comprises:	Umbilical lift unit, Docking mechanism and Sheave, 'A' Frame; Power pack
Control Cabin:	Air conditioned A60 Specification certified Lloyds Power & control racks, console and transformers. (85kVA, 6kVA, 7kVA.)
Umbilical	Kevlar or steel wire armoured

Specification subject to change without notice

Techno Transfer Industries Pte Ltd
45 Joo Koon Circle Singapore 629106
Tel: (65) 862 1233 Fax: (65) 861 8938

Racal Survey
The Global
Survey Company

Figure 14: **Sidescan sonar image of wreck**



Note: 1) Areas shaded in purple are fishing nets caught in the wreck.

Figure 15: **Side scan sonar survey tracks**

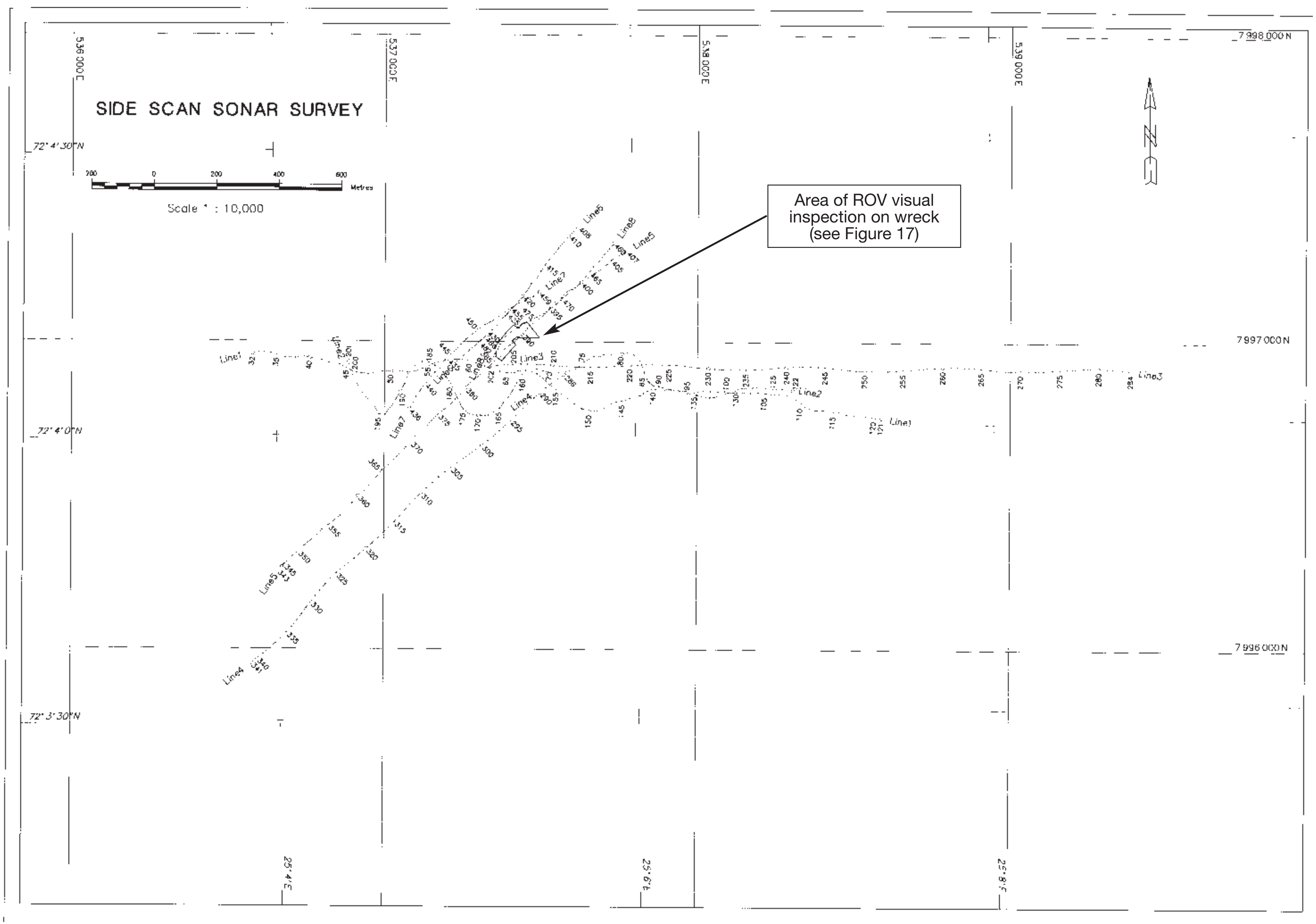


Figure 16: **Sidescan sonar images of the seabed around the wreck**

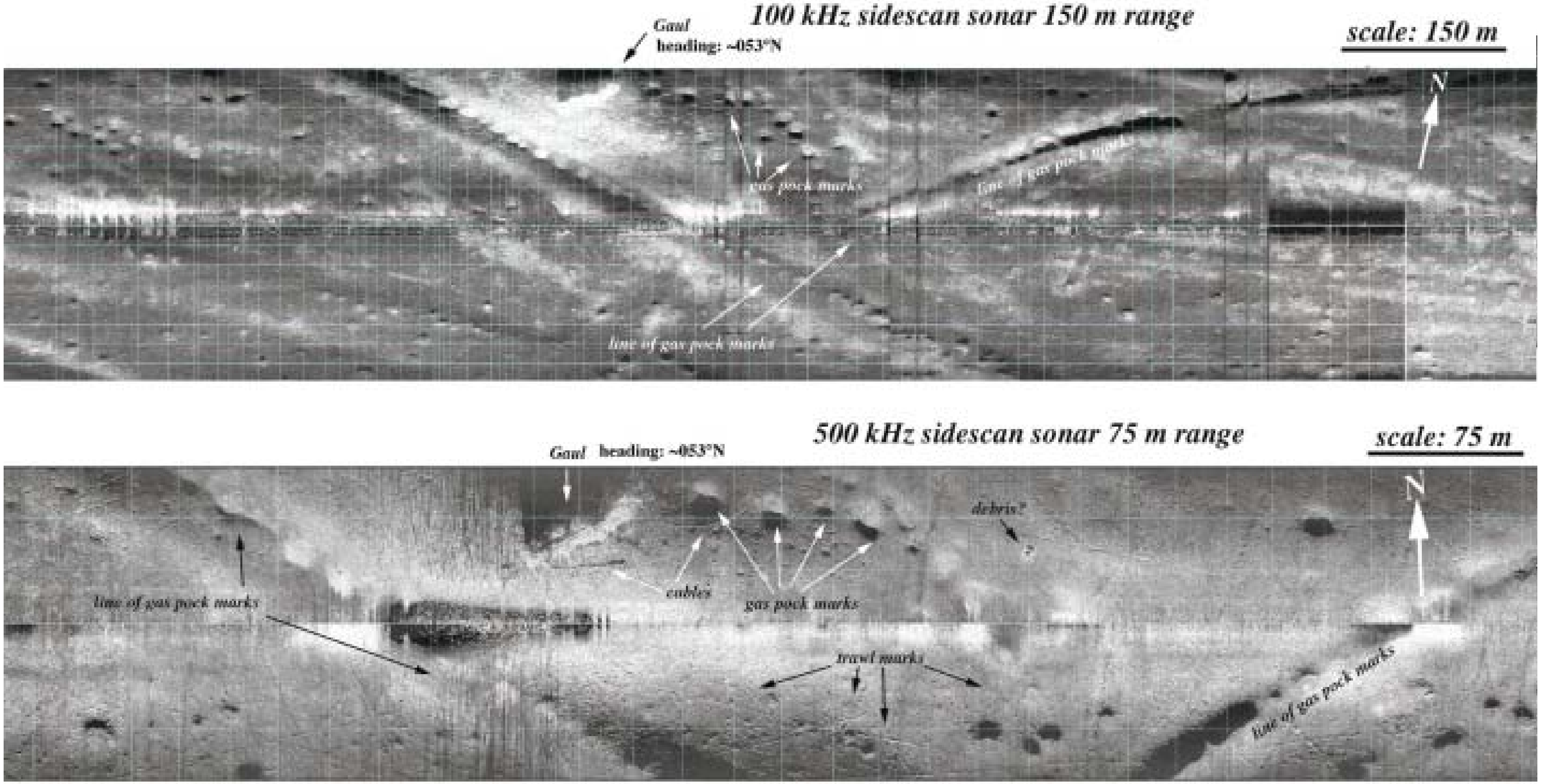


Figure 17: **Area of ROV visual inspection**

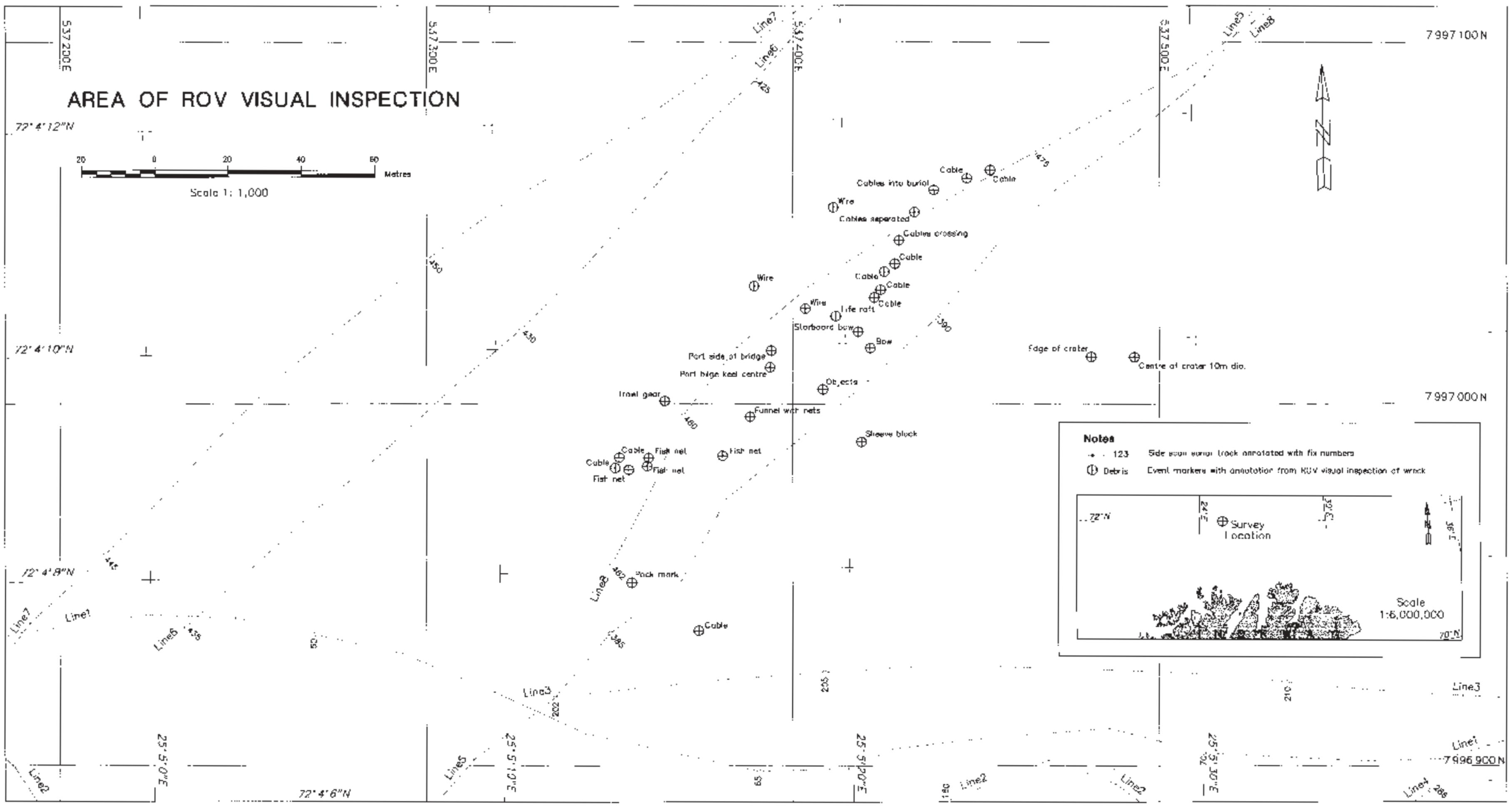
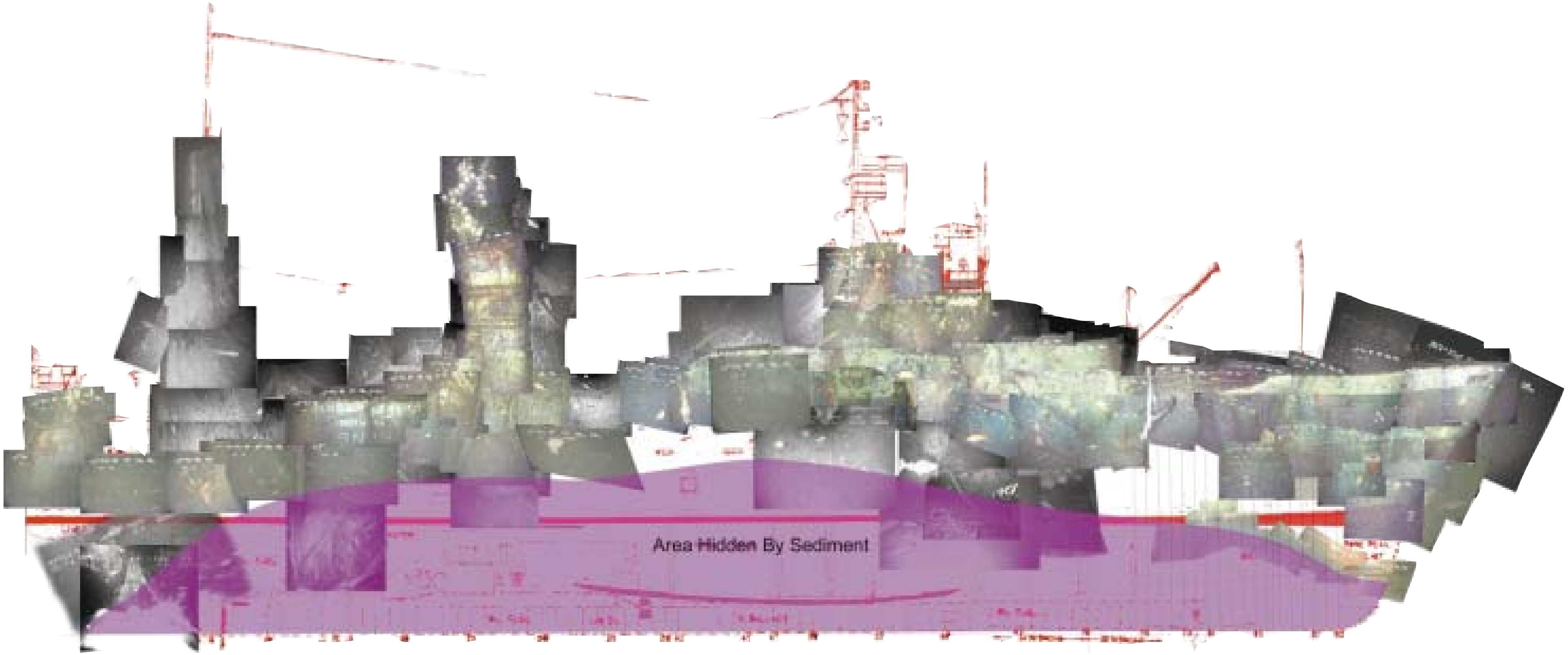
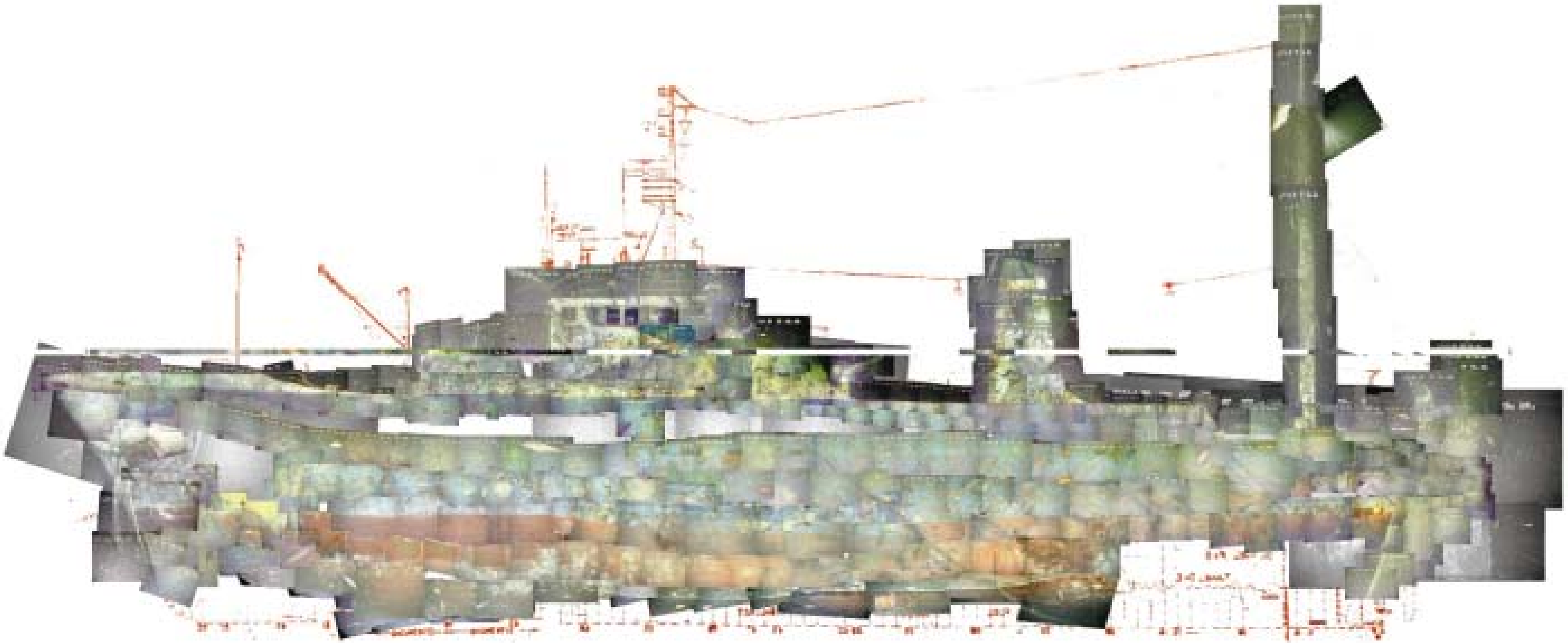


Figure 18: **Photo mosaic of starboard side**



The photographic mosaic is incomplete in those areas where there was not sufficient detail or the correct perspective provided by the video survey.

Figure 19: **Photo mosaic of port side**



The photographic mosaic is incomplete in those areas where there was not sufficient detail or the correct perspective provided by the video survey.

Figure 20: **"Beaufort" liferaft container on seabed**

Figure 21: **Damage to outboard face of port funnel**

Figure 22: **Photo mosaic of transom**

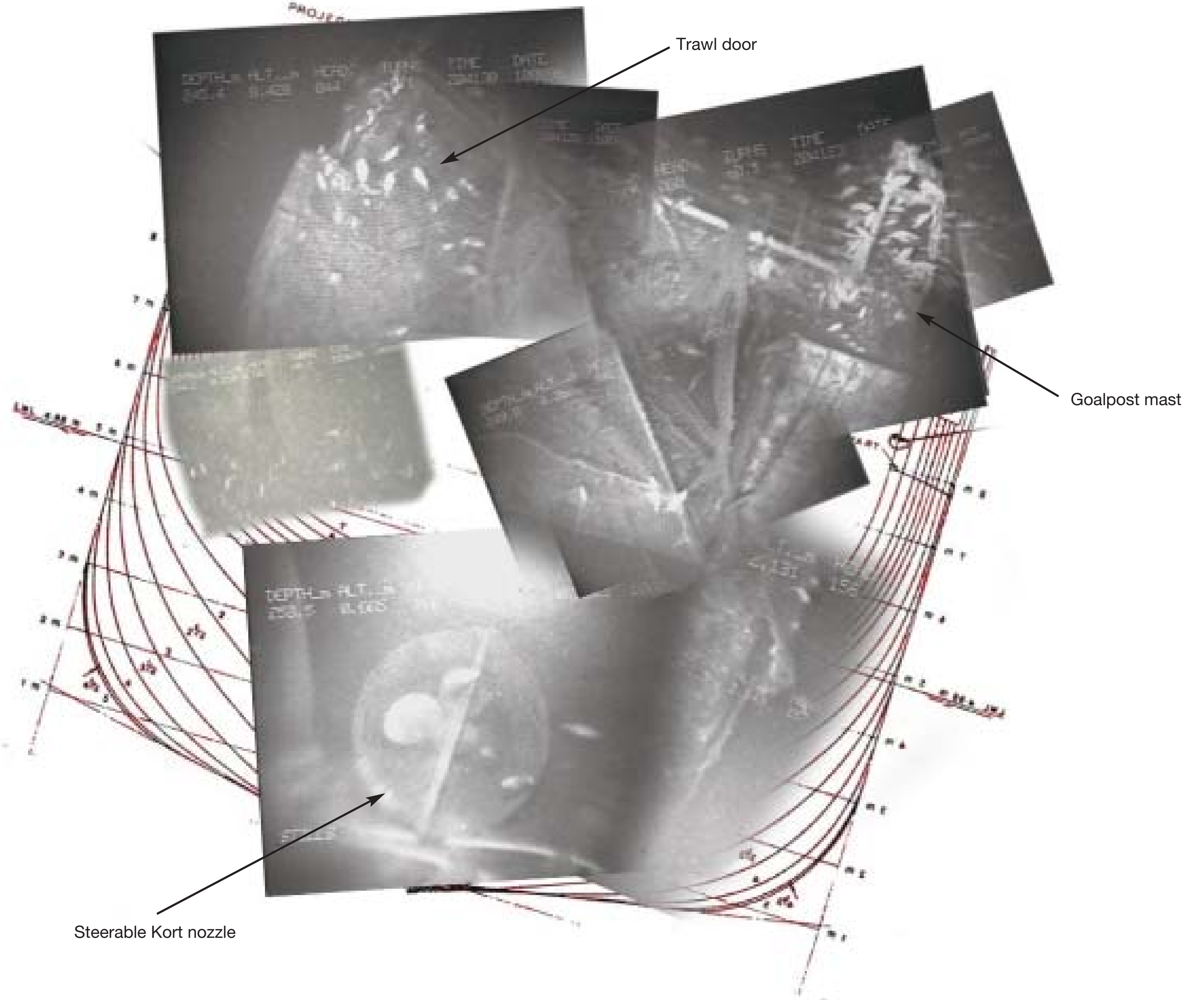
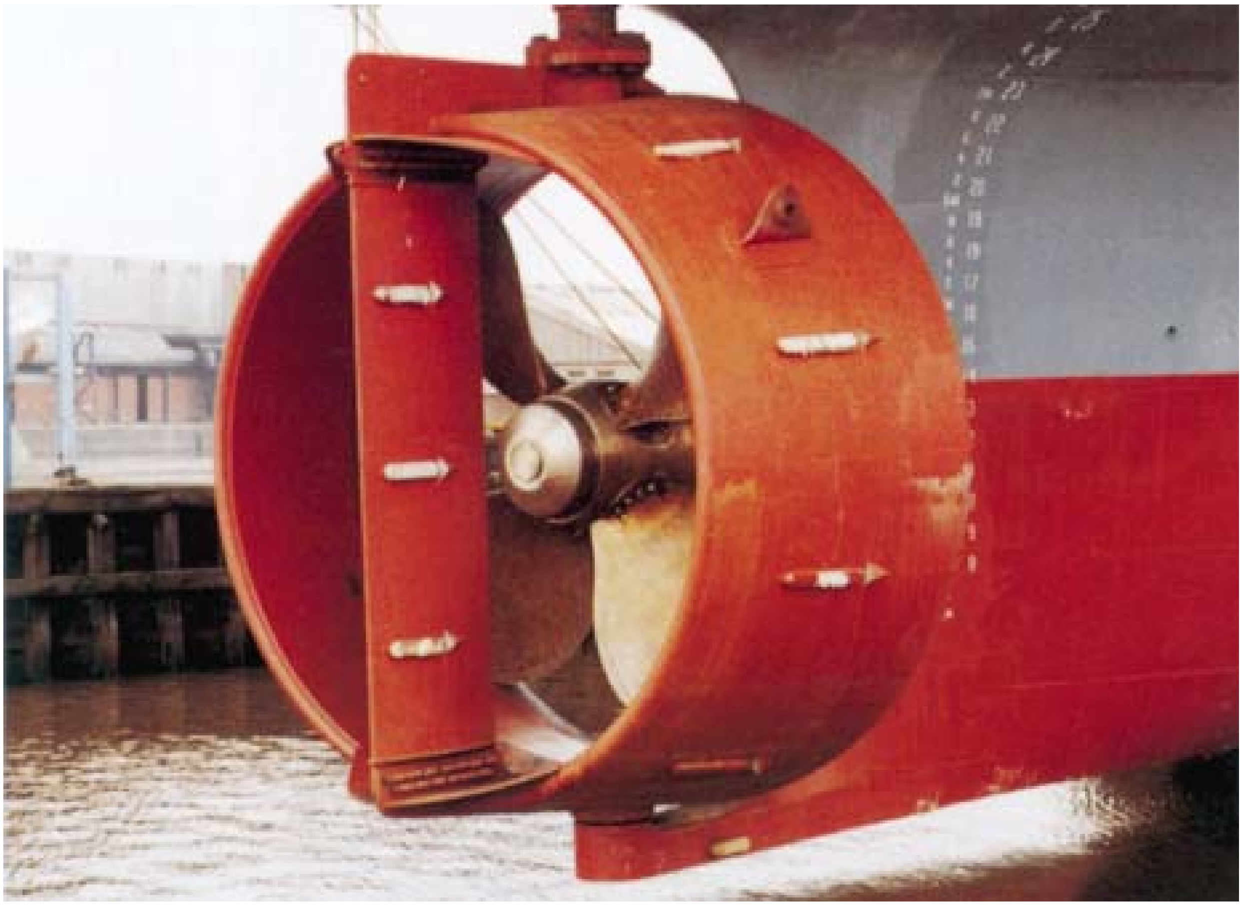


Figure 23: **A typical steerable Kort nozzle**



Photograph courtesy of Kort Propulsion

Figure 24: **Gaul's Kort nozzle viewed from astern**

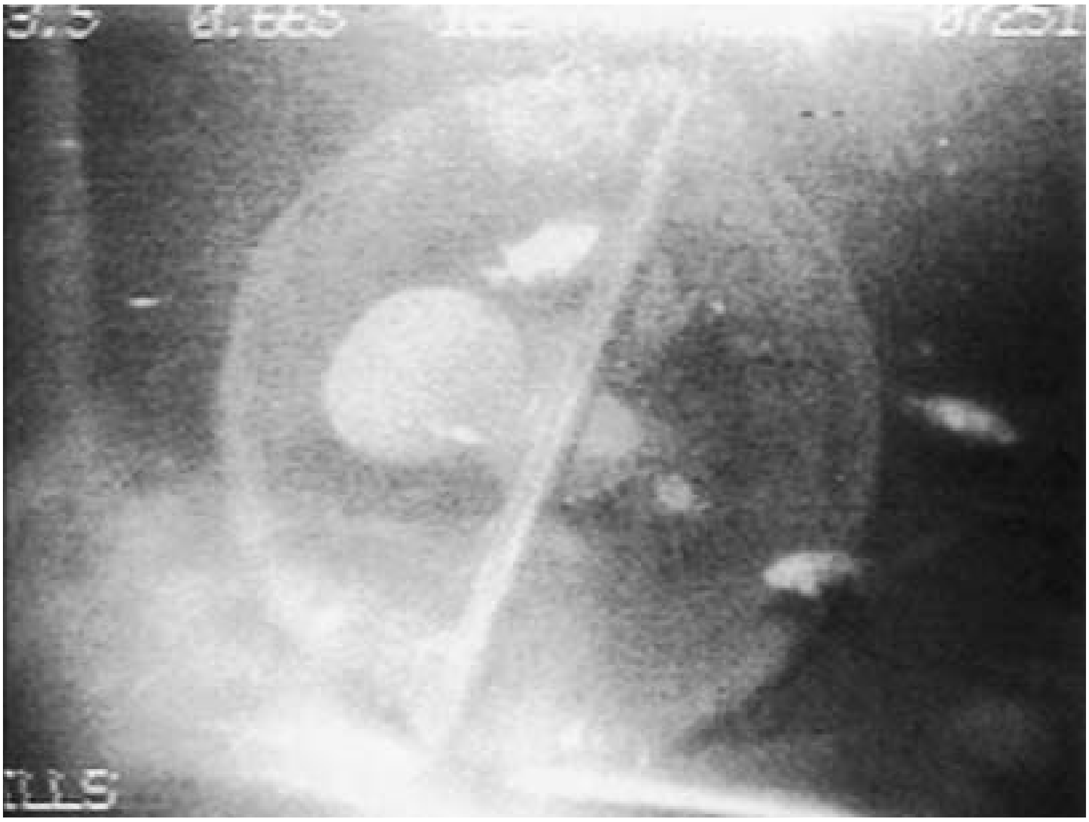


Figure 25: **Photo mosaic of forecastle deck (forward)**

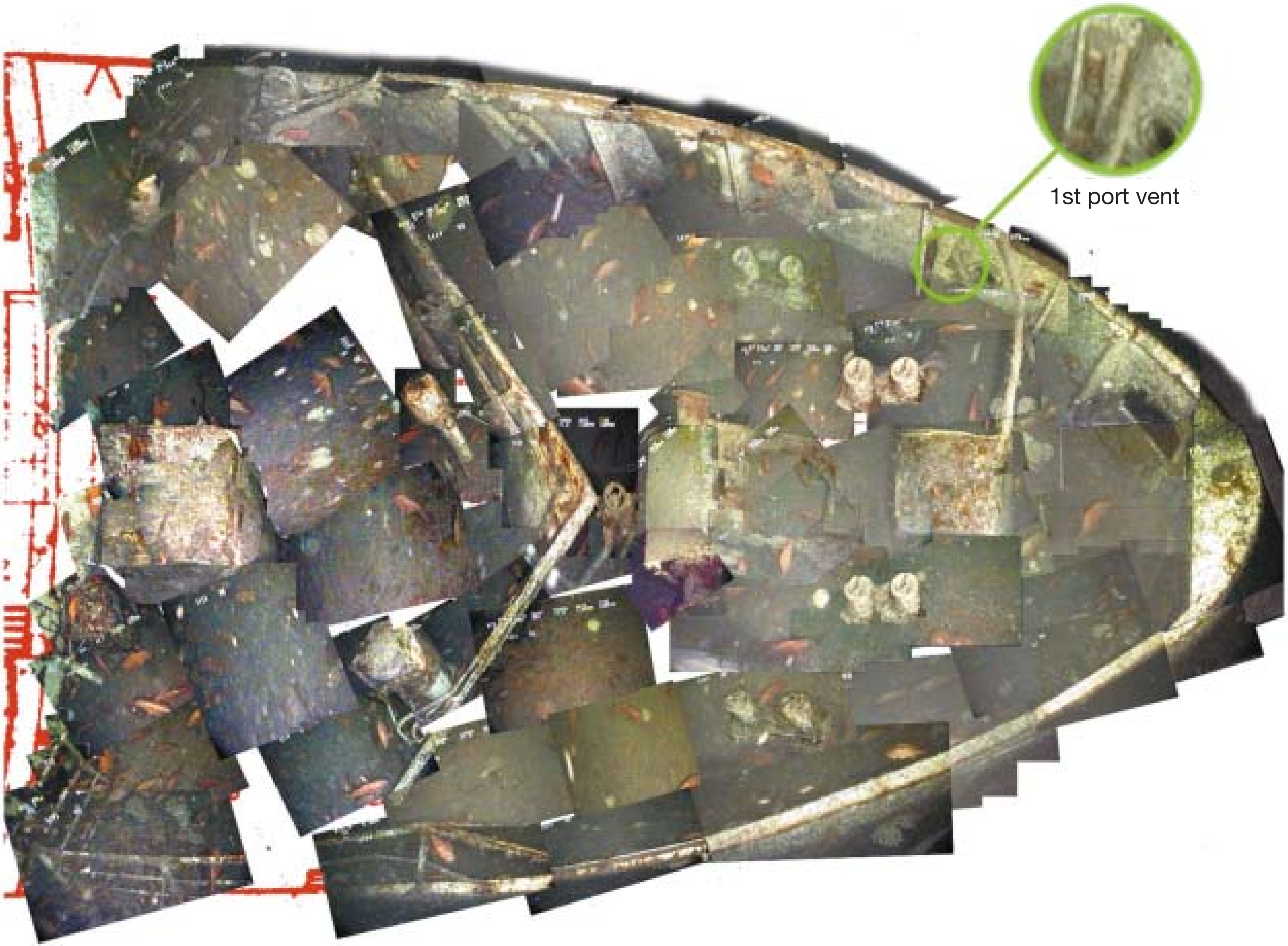


Figure 26: **Photo mosaic of deckhouse front**

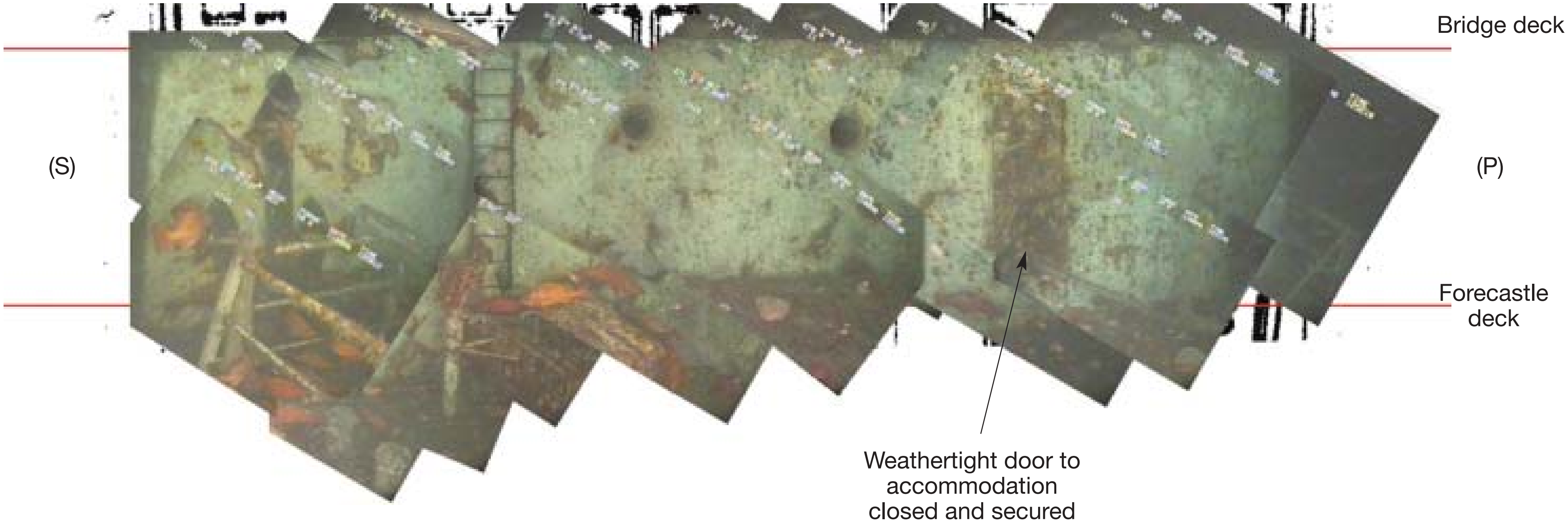


Figure 27: **Photo mosaic of bridge front**

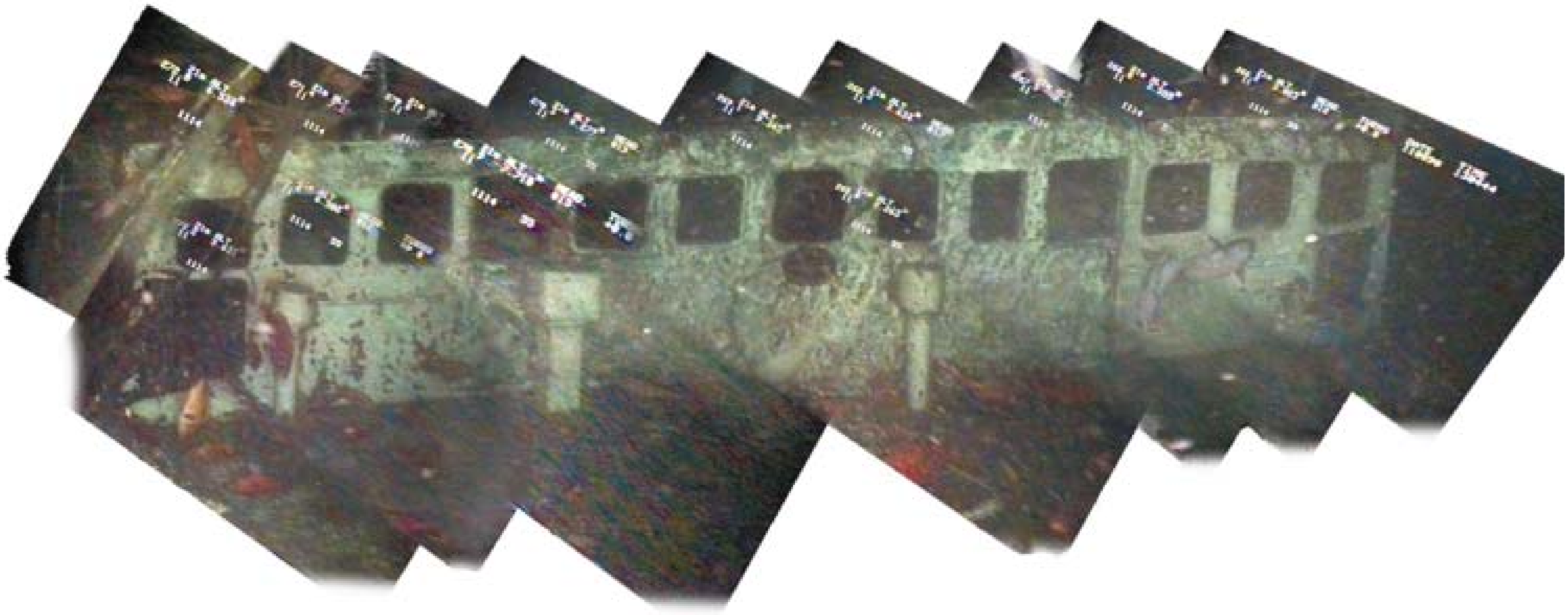


Figure 28: **Control console (front, looking to port)**

Figure 29: **Control console (starboard forward corner)**

Note: See Figure 4 for photograph of control console

Figure 30: **Steering position at bridge front**

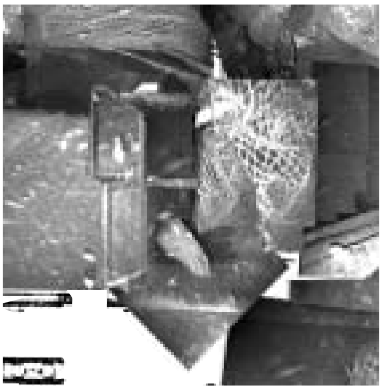
Figure 31: **Radar set below bridge windows**

Note: (1) Hood is missing
(2) Cathode Ray Tube has imploded
(3) See Figure 2 for position and, appearance of original radar

Figure 32: **Open access hatch on aft face of port funnel**

Figure 33: **Looking aft onto the open fish loading hatches**

Note: 1) The dark border to the hatch covers is the rubber seal which ensures that they are weathertight when closed.
2) The hatches are undamaged.



Looking down onto open fish loading hatches

Figure 34: **View down outboard edge of port fish loading hatch**

Note: 1) Locking pin should have been visible in this view, it is missing.
2) Securing clip is in closed position, but is undamaged.

Figure 35: **View onto port bobbin rail showing port stern ramp gate fully open and in its recess**

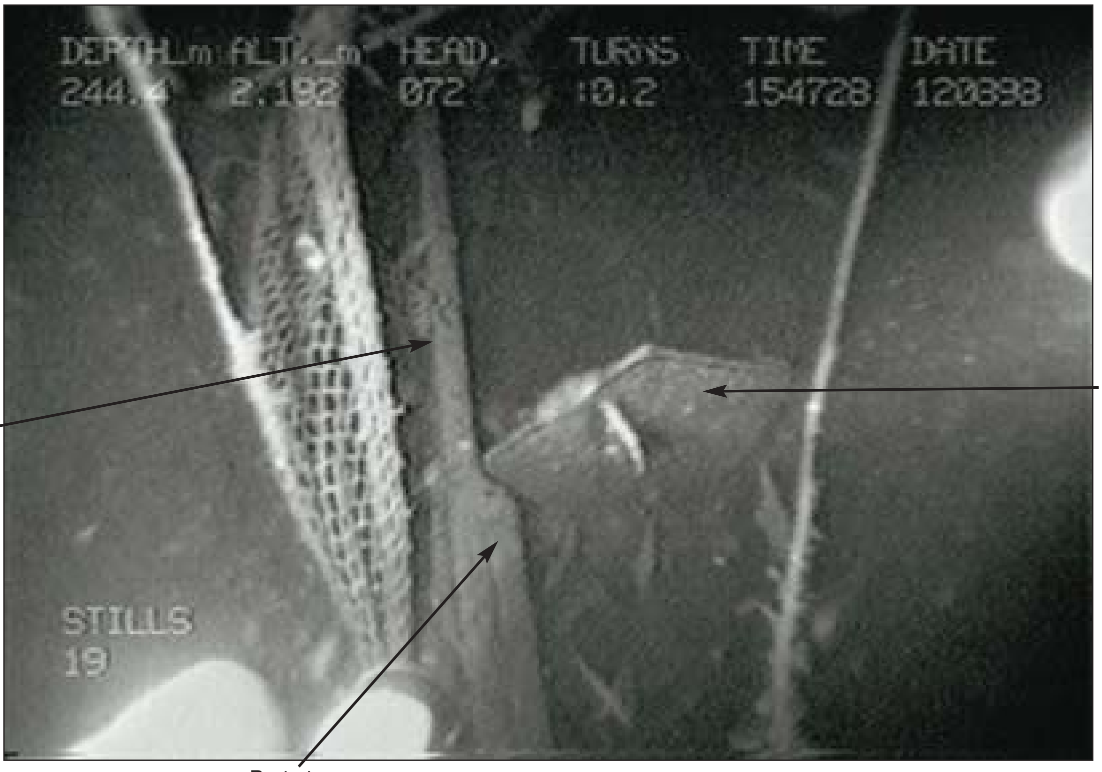


Figure 36: **Photo mosaic of port side trawl deck**

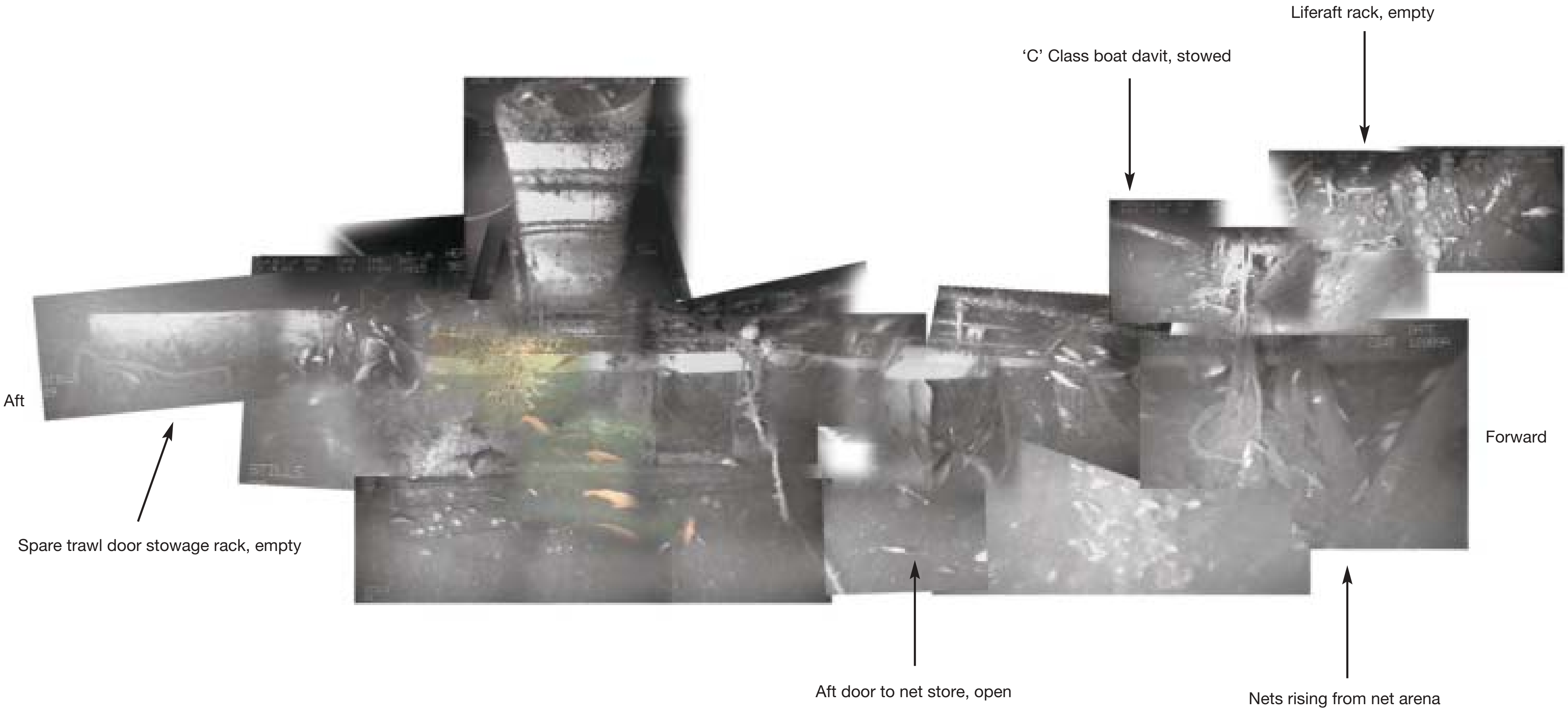


Figure 37: **Photo mosaic of starboard side trawl deck**

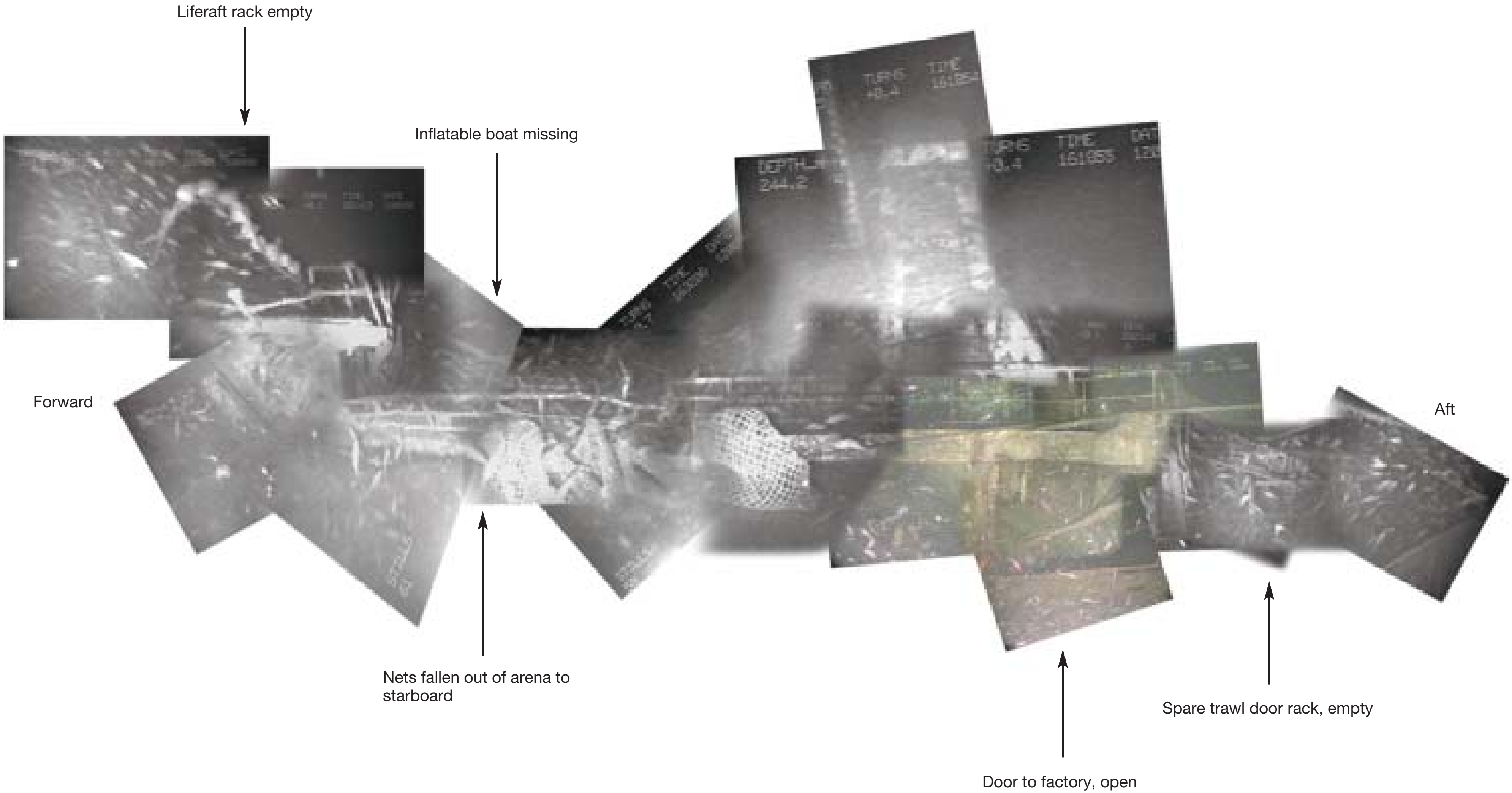
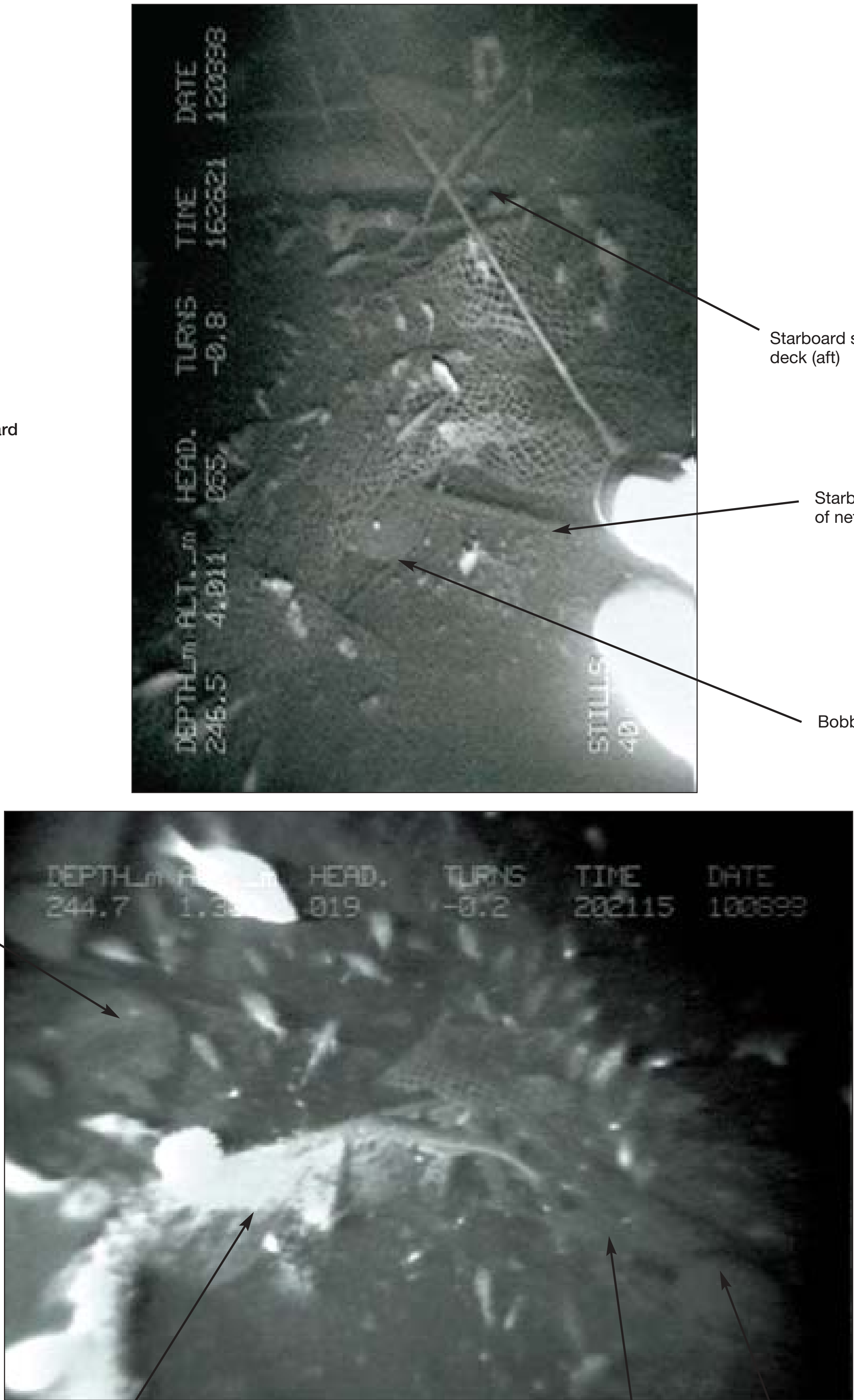


Figure 38: **Bobbins lying inside net arena**



Note: 1) Bobbins (1) and (2) are connected.
2) The danleno bobbin is a spare attached to the port bobbin rail.

Figure 39: **Photo mosaic of ‘A’ frame mast**

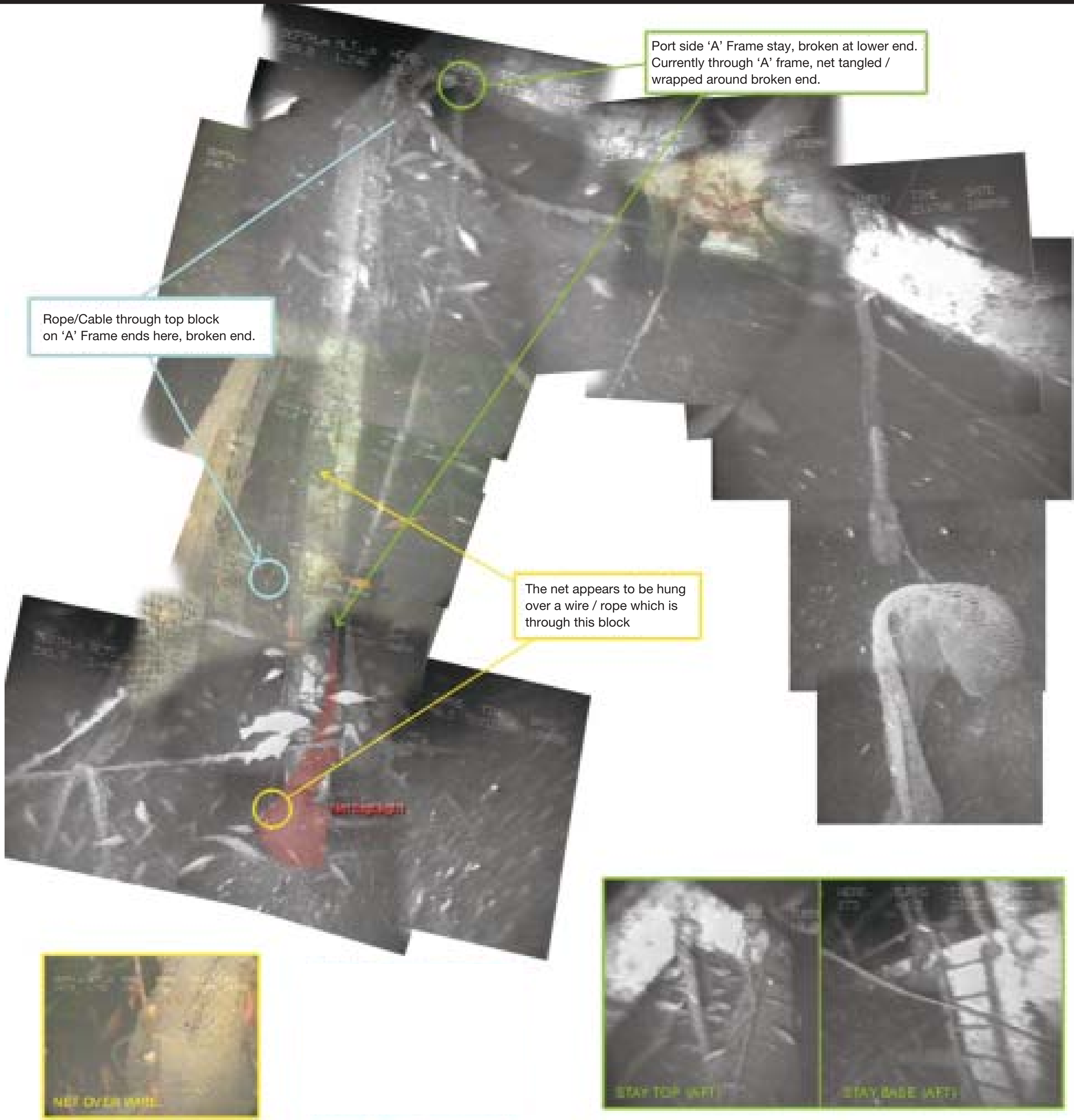
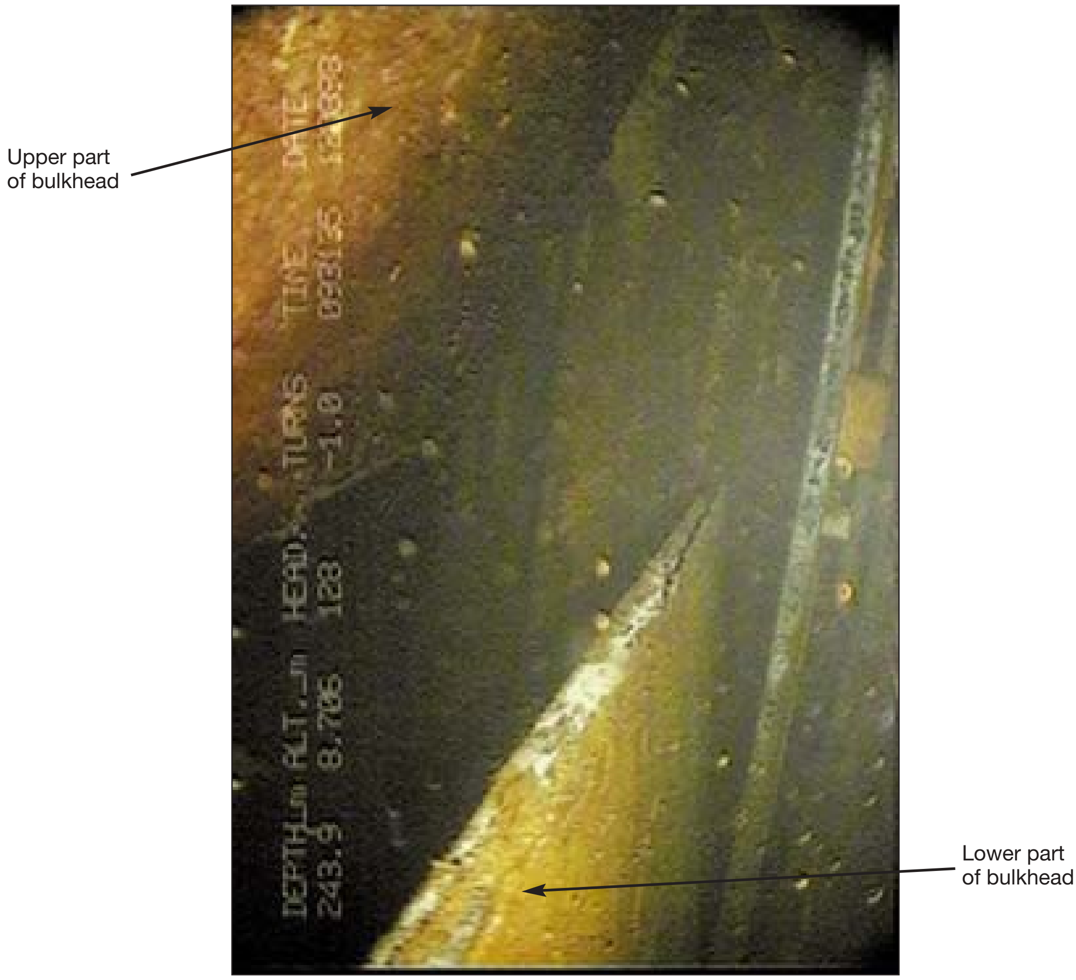


Figure 40: **Partition bulkhead burst forward**



Note: 1) This bulkhead was the forward bulkhead of the No. 2 four crew man cabin.

Figure 41: **Desk drawers in mate's cabin**

Note: 1) Desk is facing to port, drawers have fallen out to starboard.

Figure 42: **Seabed cables in vicinity of wreck**

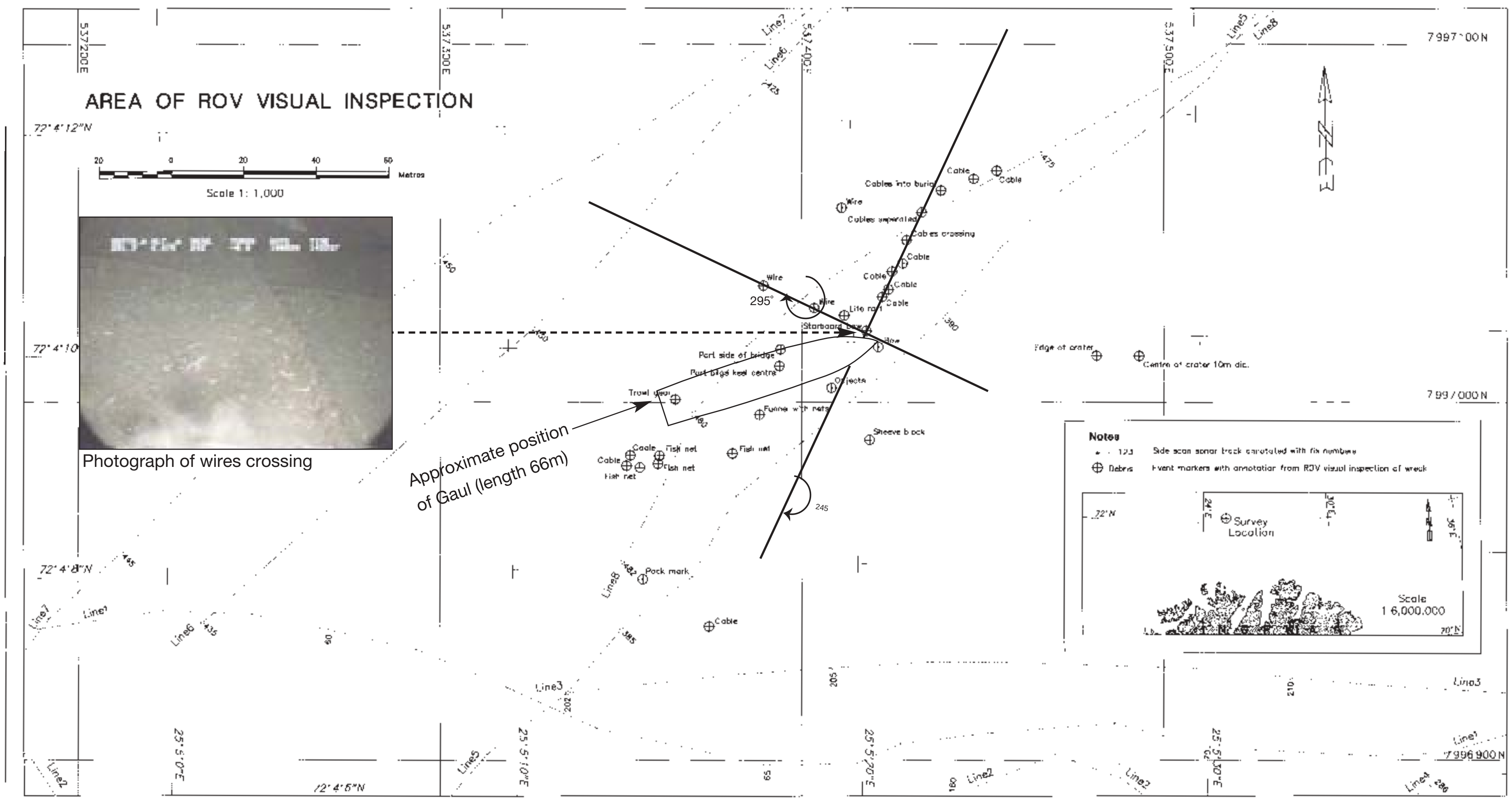


Figure 43: **Bow damage – view from ahead**

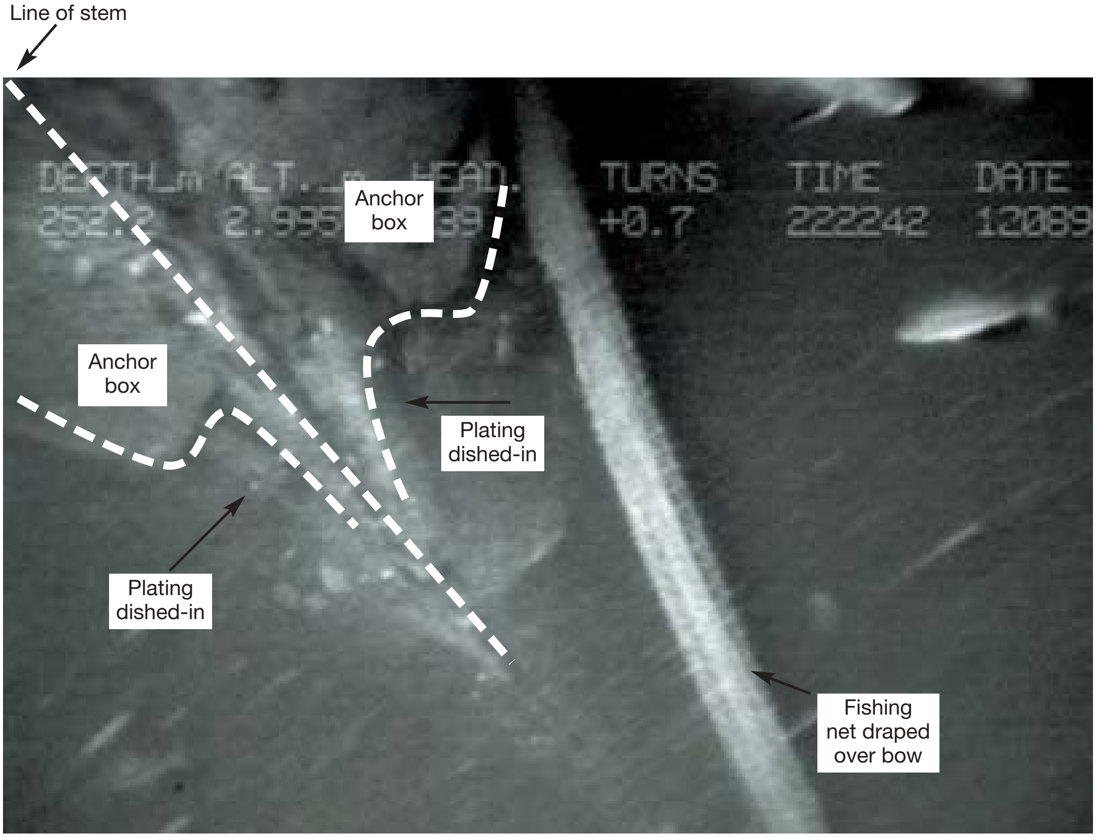


Figure 44: **Section through net arena looking forward**

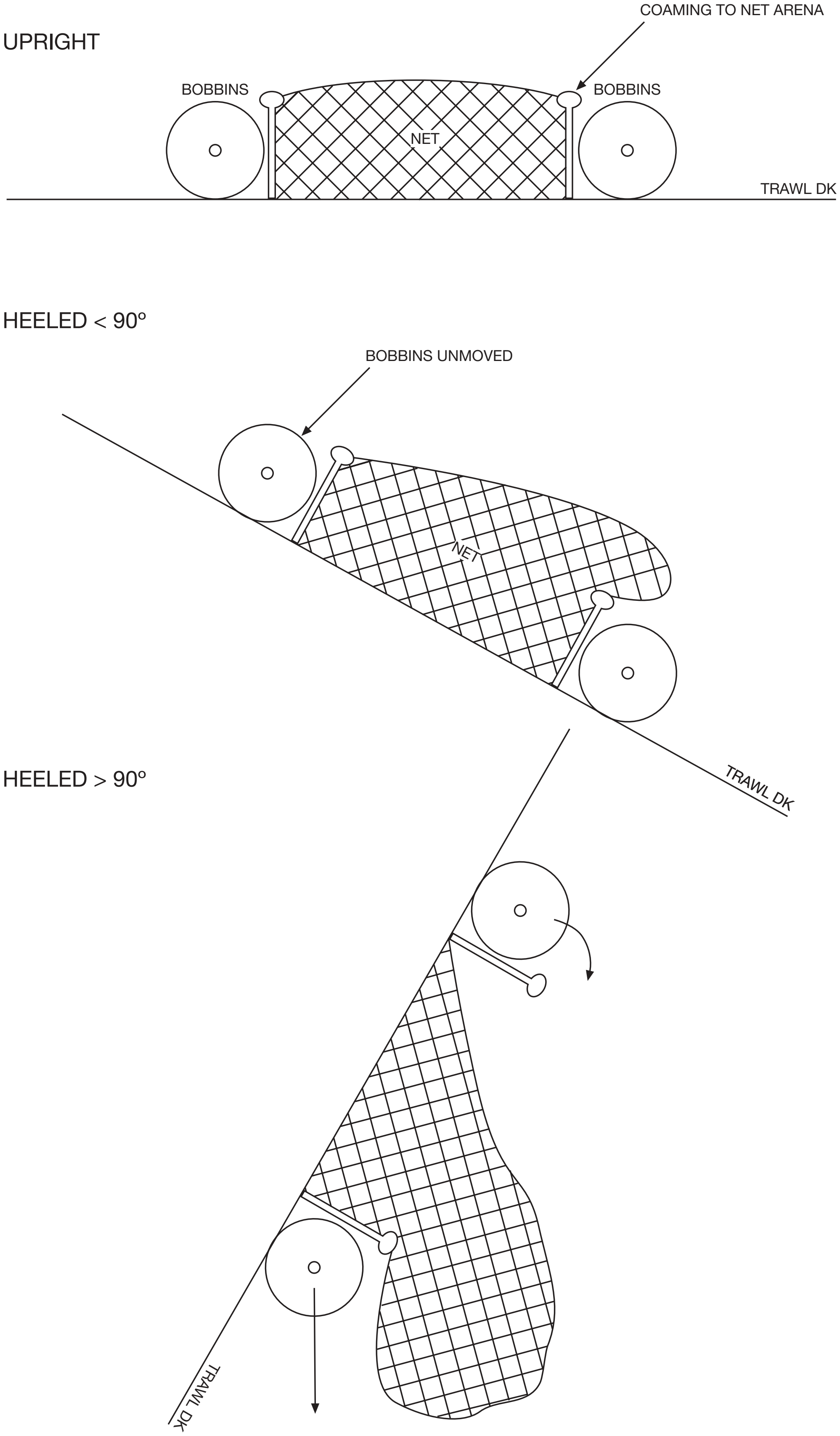
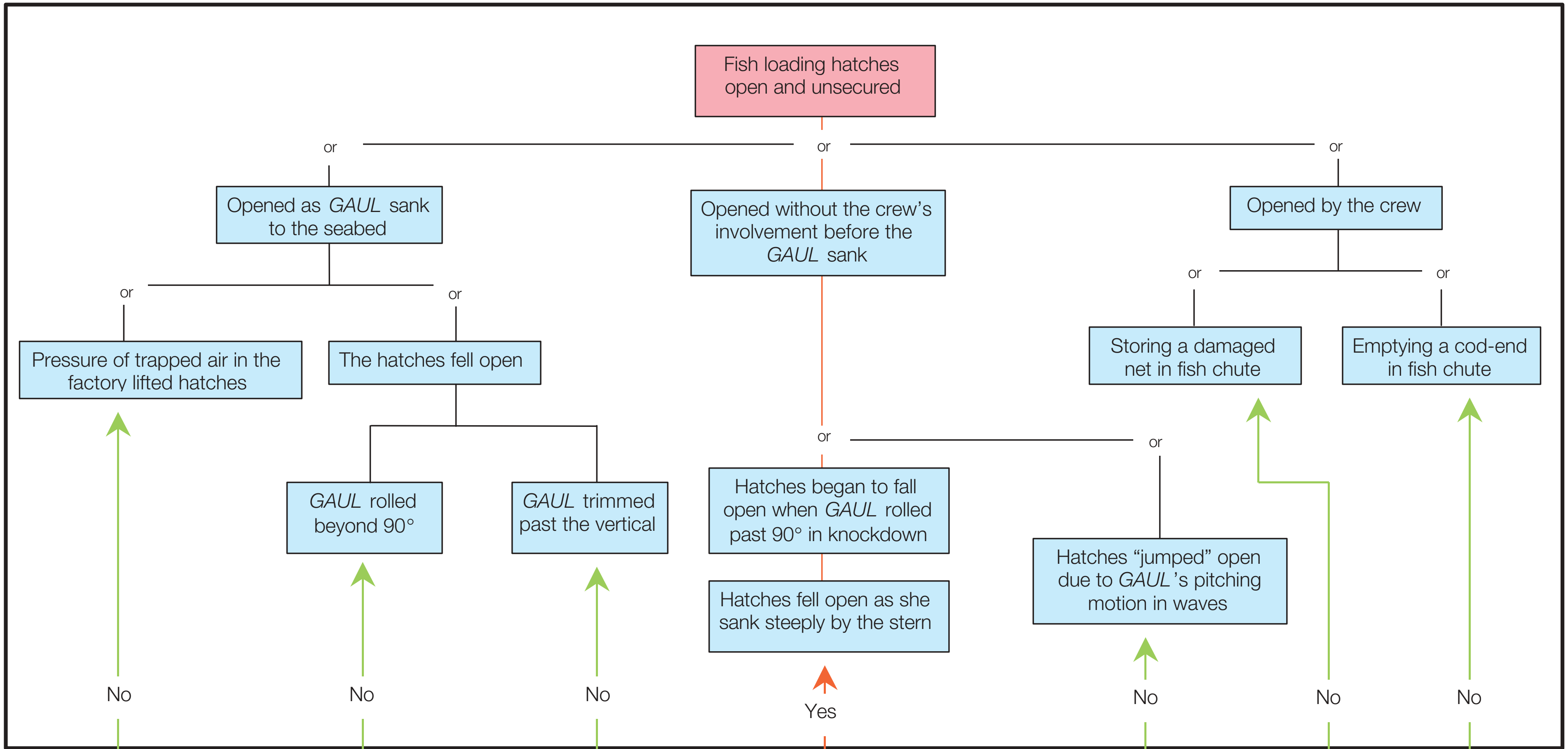


Figure 45: **Gaul – Factors tree for the open fish loading hatches**



COMMENT	COMMENT	COMMENT	COMMENT	COMMENT	COMMENT	COMMENT
(1) Calculations showed that there would be insufficient pressure. (2) If *GAUL* sank by the stern and factory flooded completely, there would be no trapped air.	(1) Research has shown that sinking vessels return closer to the upright and do not roll over.	(1) Positions of floor mats in bridge indicate this did not occur.	(1) Consistent with evidence and results of model experiments.	(1) There is no evidence that this had ever occurred on *GAUL* (2) It could only occur with GAUL dodging head to sea in which case it would not have led to dangerous flooding.	The fish chute was found to be empty.	(1) All the evidence indicates that *GAUL* was not fishing.

Figure 46: **Gaul – accident factors tree**