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Australian Transport Safety Bureau

Grounding of *ABFC Roebuck Bay*

Henry Reef, Queensland | 30 September 2017



Investigation

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Addendum

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Safety summary

What happened

On 30 September 2017, shortly after midnight, the Australian Border Force cutter *Roebuck Bay* (ABFC *Roebuck Bay*) grounded on Henry Reef in the Great Barrier Reef, Queensland. The cutter was on a passage from Saibai Island in the Torres Strait Islands archipelago bound for Lizard Island, located about 71 NM south-east of Cape Melville. The cutter sustained substantial damage to the keel, stabiliser fins and propellers, with hull breaches in way of the storage void and tank compartment spaces. There were no reported injuries or oil pollution. The cutter was subsequently towed off the reef, stabilised and towed to Cairns, arriving on 5 October 2017.

What the ATSB found

The ATSB found that ABFC *Roebuck Bay*'s route plan was amended during the passage planning process resulting in the route being inadvertently plotted across Henry Reef, a potential navigational danger. The cutter's electronic chart display and information system (ECDIS) identified the reef as a danger to the planned route. However, the ship's deck officers did not identify the danger, either visually or using the ECDIS. It was also likely that the ECDIS look-ahead function did not encounter Henry Reef's chart symbol and therefore, did not generate an alarm before the grounding. The look-ahead was set-up based on Australian Border Force (ABF) work instructions, which also included other settings that likely reduced the ECDIS's effectiveness.

The effectiveness of the officers' visual check was likely influenced by a misinterpretation of chart symbology and possible obscuration of the reef's chart symbol and label. In addition, the officers' expected that the ECDIS would not save a route plotted across a chart danger, and had a misunderstanding of the ECDIS safety checking functions. The investigation found that the cutter's officers did not possess an adequate level of knowledge to operate the cutter's VisionMaster FT ECDIS as the primary means of navigation. The type-specific ECDIS familiarisation training, as undertaken by ABF deck officers, was not effective in preparing the cutter's officers for the operational use of the ECDIS. There was also no consistent provision of ECDIS annual continuation familiarisation training, as required by ABF procedures.

The ECDIS on board most ABF cutters, including ABFC *Roebuck Bay*, operated on a non-type-approved naval software version, although DNV GL (Det Norske Veritas - Germanischer Lloyd) certified them as using type-approved ECDIS as the primary means of navigation.

The cutters' ECDIS were also not up-dated to the latest International Hydrographic Organization (IHO) standards at the time of the grounding, specifically, the S-52 standard Presentation Library 4.0. Consequently, enhanced safety features of the new presentation library, which could have potentially alerted the officers to the danger posed by Henry Reef, were not available.

The ATSB also identified a risk associated with the hydrographic use of point feature objects to represent physical features of relatively significant spatial extent on an electronic navigational chart. The ATSB found that this could increase the risk of the hazard posed by such features being misinterpreted by mariners and potentially reduce the effectiveness of the ECDIS safety checking functions.

What's been done as a result

The ABF have advised the ATSB of several proposed and implemented measures aimed at improving fleet knowledge of ECDIS functions and features. There is an increased focus on passage planning, watchkeeping and use of ECDIS during the annual maritime operational compliance audits of vessels. These audits will now include training and information sessions and

watchkeeper assessments. The training package and requirements for ECDIS annual familiarisation training has been updated. Task books have also been implemented for each role to reduce the effects of incorrect information being communicated by trickle-down training. Specific training documentation for the navigation officer's role has also been improved.

The ABF is also engaged in ongoing work with the ECDIS manufacturer to improve ECDIS type-specific familiarisation training.

The ABF also advised that a review of navigation related procedures and work instructions was undertaken and completed. This resulted in several work instructions being updated and re-issued with the lessons learnt from the investigation incorporated into the instructions.

The ABF undertook a program of software and hardware upgrades to update all cutters to the IHO's S-52 Presentation Library 4.0. This was completed in September 2018.

The Australian Maritime Safety Authority have reminded all Recognised Organisations of the requirement that an ECDIS is only compliant when installed and operated in accordance with the type-approval issued. The authority have sought DNV GL's internal review of their vessel survey and certification processes and any corrective action taken. The Australian Maritime Safety Authority have also received confirmation that ABF vessel management plans captured the non-type-approved nature of ABF ECDIS units.

The Australian Hydrographic Office has identified about 2,200 point features on 243 Australian Electronic Navigational Charts potentially affected by the identified point feature safety issue. Commencing in December 2018, these point features were updated by encoding an obstruction area around the existing underwater, awash rock, obstruction or isolated danger symbols. In addition, the AHO has published an online supplement to the *Seafarers Handbook for Australian Waters* that will be fully incorporated as a new chapter into the new edition of the handbook (Edition 5), due for publication in 2019. The supplement addresses the dangerous effects of overscaled ECDIS displays near features such as isolated danger symbols. The supplement also aims to address a number of misconceptions amongst mariners regarding the accuracy of bathymetry within Electronic Navigational Charts and the impact that accuracy should have upon route planning and conduct. The content has also been offered to the IHO for publication as an IHO standard.

Safety message

The safe and effective use of ECDIS as the primary means of navigation depends on the mariner being thoroughly familiar with the operation, functionality, capabilities and limitations of the specific equipment in use on board their vessel. ECDIS type-specific familiarisation should be designed, delivered and undertaken so as to ensure the transfer of knowledge required to confidently operate the ECDIS as the manufacturer intended it to be operated. ECDIS, as a complex software based system, is subject to constant change and improvement. In order for mariners to always have the best possible advantage in conducting safe navigation, ECDIS needs to be maintained so as to be compatible with the latest applicable standards mandated by the appropriate organisations.

While the use of ECDIS and ENC's as an essential tool for navigation provides many safety benefits, navigation with ECDIS is fundamentally different from navigation with paper charts. The implementation of ECDIS and the replacement of paper charts has introduced certain risks to the conduct of marine navigation, as highlighted in this investigation. While the challenges faced by regulators, manufacturers, hydrographic offices and other concerned parties in resolving these risks is acknowledged, the ultimate goal must be to eliminate significant risks or at least reduce them to an acceptable level in terms of navigational safety.

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The occurrence

On 30 September 2017, at about 0025 Eastern Standard Time,¹ Australian Border Force cutter *Roebuck Bay* (ABFC *Roebuck Bay*) grounded on Henry Reef, a charted feature in the Great Barrier Reef, Queensland. The cutter was following a passage plan, with an amended route based on one that had been successfully used several times before. The amended route included a route leg plotted across Henry Reef.

Passage and grounding

Pre-departure activities

On 11 September 2017, the 38 m ABFC *Roebuck Bay* (Figure 1) was alongside in Cairns, Queensland, undergoing a routine crew change prior to commencing a 3-week patrol. Over the next 2 days, the crewmembers prepared the cutter for the patrol with several start-of-patrol and pre-departure checks being completed.

Figure 1: ABFC *Roebuck Bay*



Source: Australian Border Force

Start of patrol

On 13 September, ABFC *Roebuck Bay* departed Cairns to commence a patrol northward to the Torres Strait where it was to assume duties under the instructions of the Australian Maritime Border Operations Centre (AMBOC). The cutter was to remain in the strait until 29 September when it was to depart the area for Cairns for the conclusion of the patrol.

On 17 September, while underway, one of three electronic chart display and information system (ECDIS) and radar operation nodes² on the cutter's bridge malfunctioned and shut down while in use as a radar display. Attempts to re-boot the system failed and the cutter continued its patrol with two operational bridge displays, capable of being used interchangeably as an ECDIS or radar display.

¹ Eastern Standard Time (EST): Coordinated Universal Time (UTC) + 10 hours.

² In this case, a console and associated computer system used to operate ECDIS and/or radar.

On 25 September, at about 1549, *ABFC Roebuck Bay* dropped anchor off Saibai Island in the Torres Strait Islands archipelago. While at anchor, the cutter's officers and crew performed routine duties and maintained anchor watches.

Passage planning

On 26 September, the navigation officer began to work on the passage plan for the cutter's return voyage to Cairns. The passage plan, based on a previously used plan, initially consisted of a passage from Saibai Island directly to Cairns with some standing operational taskings en route. The passage plan and associated briefs were completed and then presented to the cutter's commanding officer (master)³ for approval.

The master reviewed the planned route on the ECDIS and made a few amendments. One of these amendments involved moving two planned course alteration positions (waypoints) in the vicinity of Wreck Bay in the Great Barrier Reef. One of the waypoints was moved about 0.2 NM south of its original position and designated waypoint 19 (W19) in the passage plan's waypoint list. The other waypoint, designated waypoint 20 (W20), was moved about 1 NM west of its original position and resulted in the cutter's route being inadvertently plotted across Henry Reef (Figure 2).

When the master tried to save the amended route, the 'Errors' tab in the route tab folder of the ECDIS's 'Edit Route' menu turned yellow indicating an error in the route. The master advised the navigation officer of his desired amendments to the route and of the error encountered. The navigation officer reviewed the route's waypoint list in the ECDIS's route editor table and found the error to be an incorrect turn radius for one of the waypoints. The turn radius was amended, which cleared the error; the error tab reverted to its normal grey colour and changed to 'No Error'. The master and navigation officer then reviewed the amended route visually and saved it.

Figure 2: Image from *ABFC Roebuck Bay*'s ECDIS showing the section of the overall route with the amended route legs

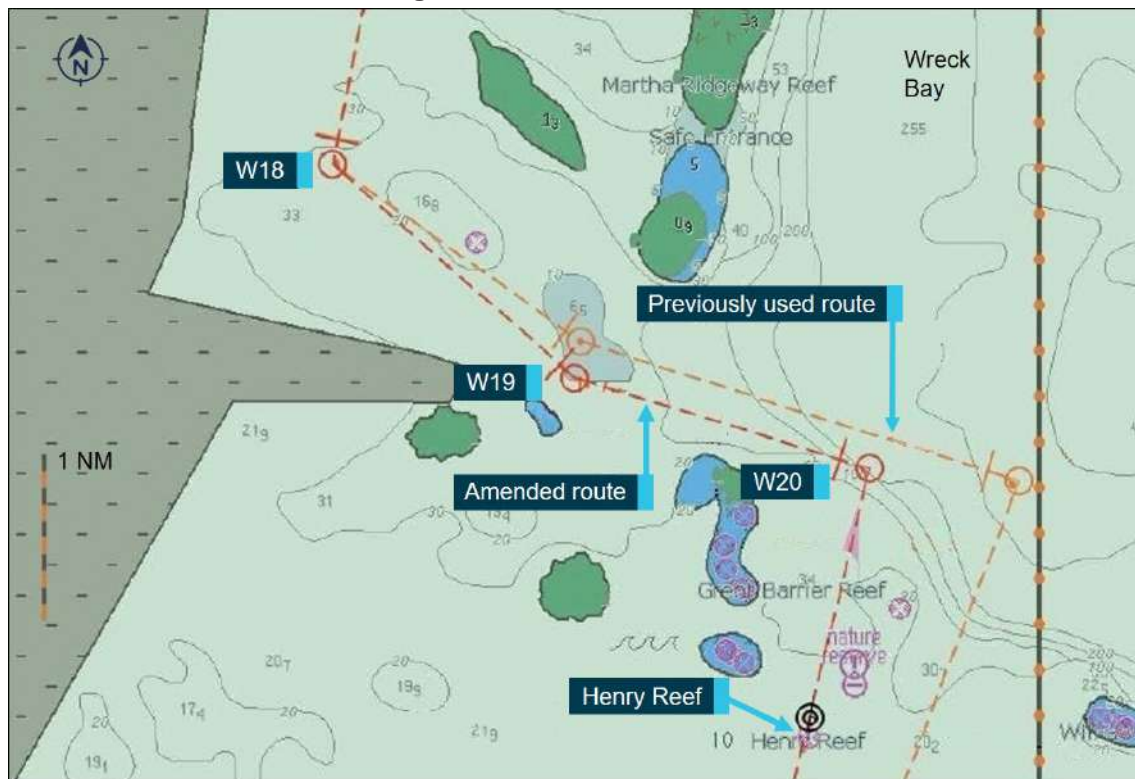


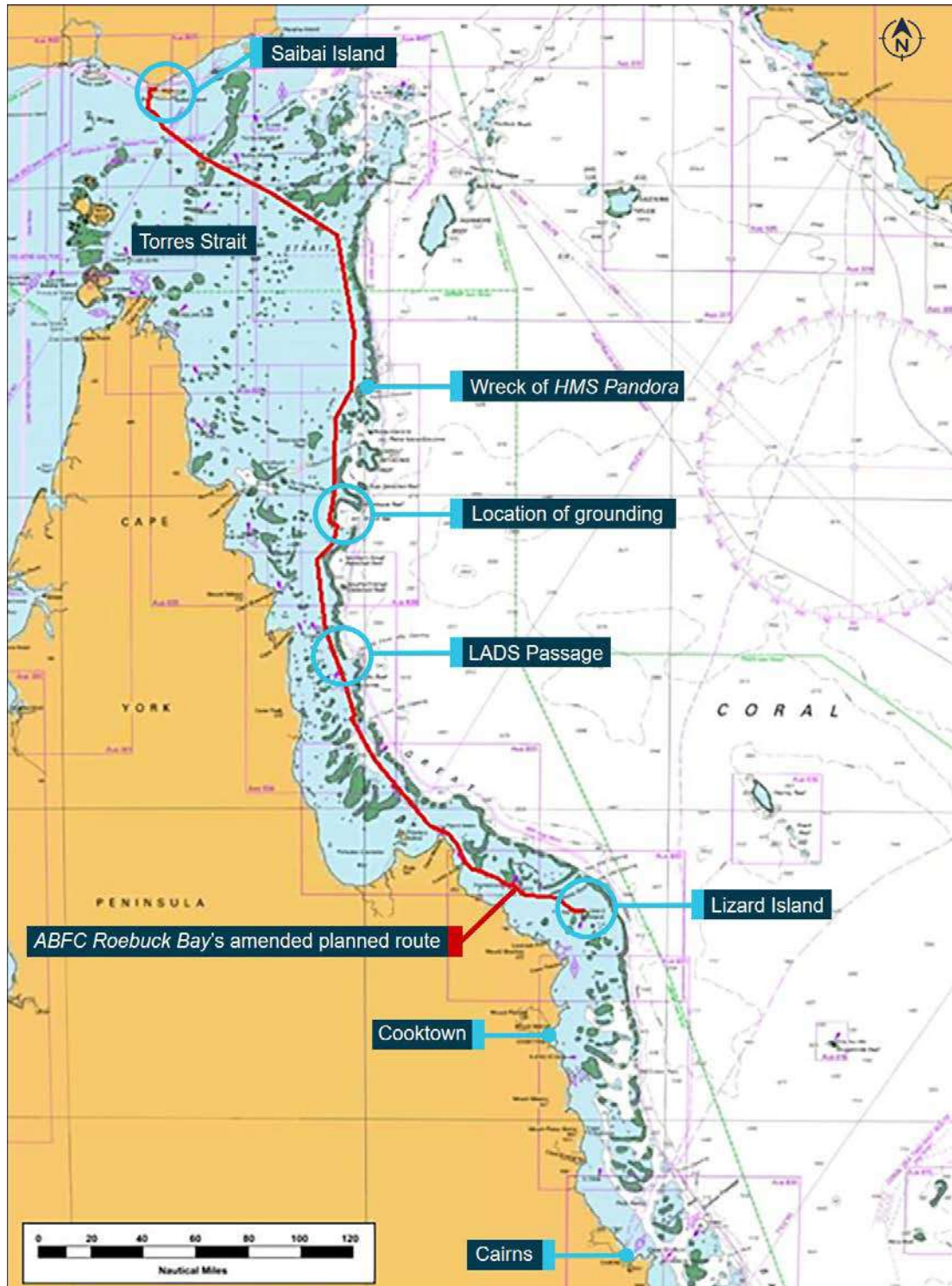
Image from *ABFC Roebuck Bay*'s ECDIS display, taken after the grounding, showing the previously used route (orange) and the amended route (red) based on the changed waypoints, W19 and W20.

Source: Australian Border Force, modified and annotated by the ATSB

³ Under Australian Border Force nomenclature, the master of an ABF vessel is known as the commanding officer.

The passage plan was subsequently split into two routes with a brief stop at Lizard Island, Queensland before continuing on to Cairns for the end of the patrol. The two routes were then saved on the cutter's ECDIS and named 'Saibai to Lizard via Outer Reef' (Figure 3) and 'Lizard to Cairns'. No further changes were made to the route plan.

Figure 3: Section of navigational chart Aus 4620 showing ABFC Roebuck Bay's planned route and key locations



Source: Australian Hydrographic Office, annotated by the ATSB

On 28 September, a passage plan briefing was conducted. The cutter's master, engineering officers and officers of the watch were briefed on the details and requirements of the proposed passage from Saibai Island to Lizard Island and then through to Cairns.

Departure from Saibai Island

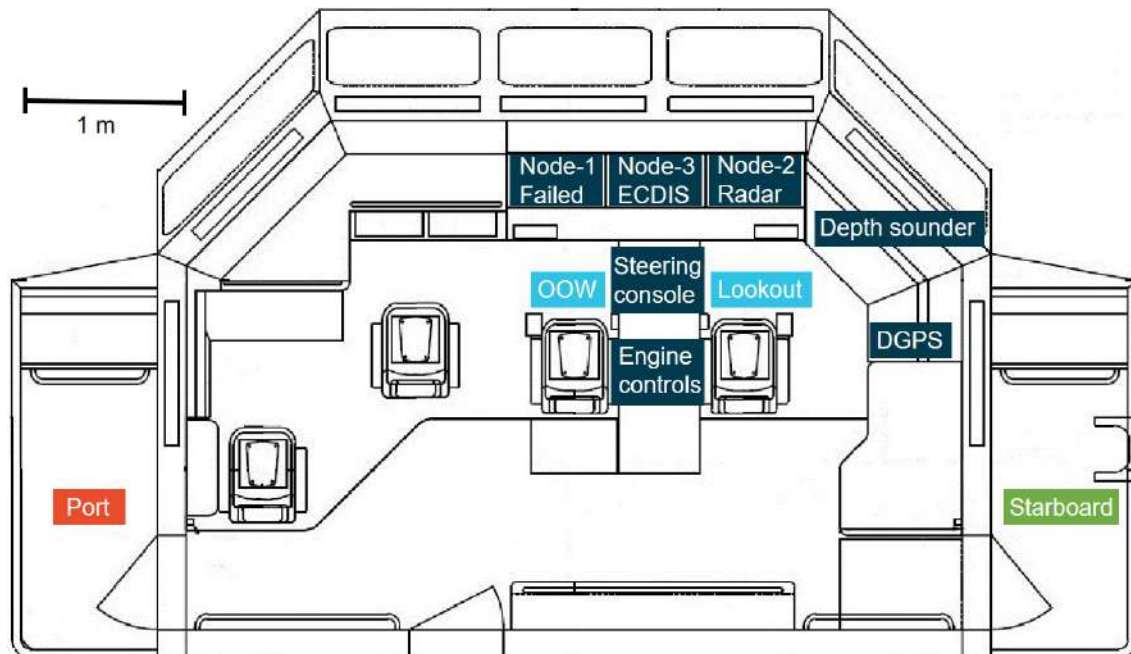
On 29 September, at about 0953, *ABFC Roebuck Bay* weighed anchor and departed Saibai Island. The cutter had a maximum draught⁴ of about 1.85 m with the propellers and skegs drawing a further 0.2 m. The route plan 'Saibai to Lizard via Outer Reef' was loaded for monitoring on the cutter's ECDIS. The cutter's bridge watchkeeping teams comprised an officer of the watch (OOW) and an assistant OOW performing the duties of a designated lookout.⁵ The bridge watchkeeping teams maintained a rotational 4-hour watch roster between 2000 and 0800 and a 3-hour watch roster between 0800 and 2000.

At about 2048, *ABFC Roebuck Bay* passed the location of a historic shipwreck, *HMS Pandora*, and finding nothing of concern, continued its passage south. The cutter's standing tasks during the passage also included surveillance for unauthorised incursions and activities in the Great Barrier Reef Marine Park.

At about 2345, the OOW and lookout for the next watch (between 0000 and 0400 on 30 September) arrived on the bridge and took over the watch shortly after. The OOW was also the cutter's navigation officer. The cutter was on autopilot on a heading of about 191° with a speed⁶ of about 16 knots.⁷ The night was partly cloudy with visibility recorded as 6 to 8 NM and the wind from the south-east at 20 knots with a 1 m sea and swell.

While on watch, the OOW was seated with the non-functioning display to his front and the ECDIS display his right. The lookout was seated in front of the radar display (Figure 4). The OOW used the ECDIS to review the cutter's expected passage over their coming watch and briefed the lookout accordingly. The OOW confirmed with the lookout that the depth sounder's shallow water alarm was set at 10 m. The lookout was also advised to switch periodically between the radar's 6 NM and 12 NM range scales on node-2.

Figure 4: Location of bridge team members at the time of grounding



Source: Australian Border Force, annotated by the ATSB

⁴ Draught is the vertical distance between the keel of the ship and the waterline at any position.

⁵ Under Australian Border Force nomenclature, a rating forming part of a navigational watch is known as an assistant officer of the watch.

⁶ All ship speeds referred to in this report are 'made good/over the ground'.

⁷ One knot, or one nautical mile per hour equals 1.852 kilometres per hour.

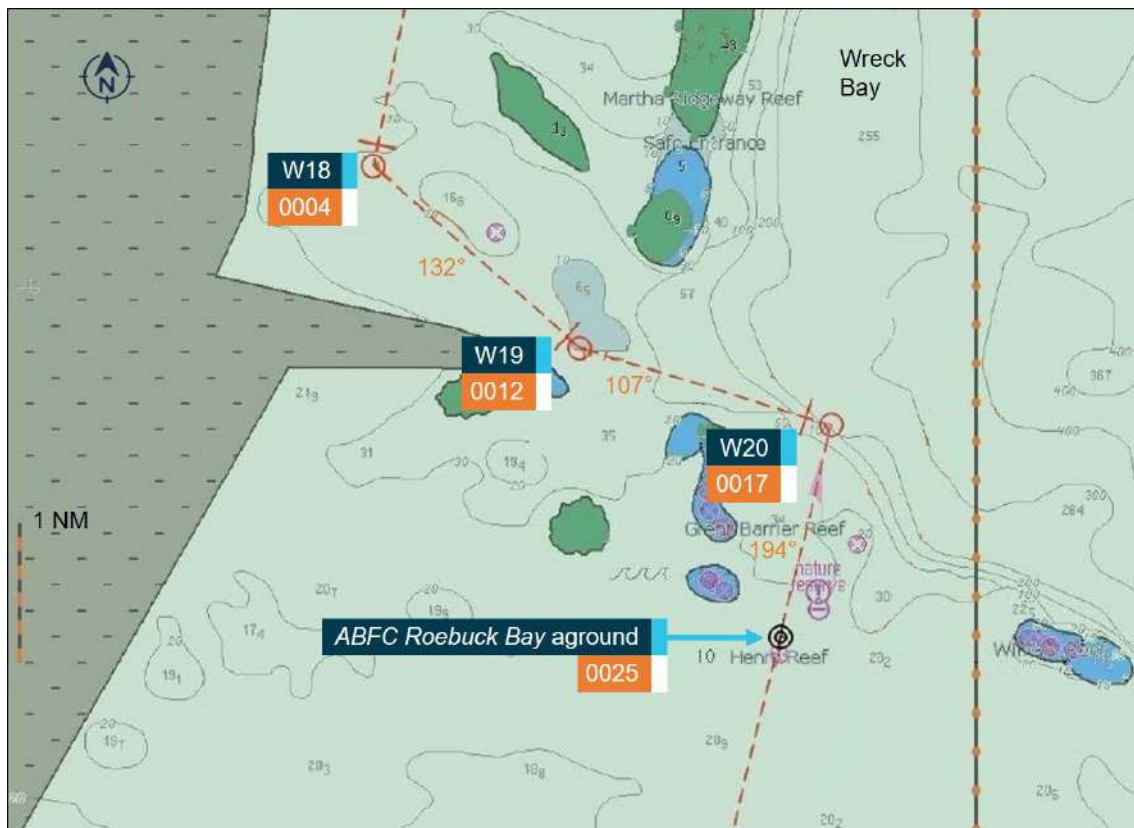
On 30 September, at about 0004, the OOW altered *ABFC Roebuck Bay*'s heading⁸ to 132° when at waypoint 18 (W18) (Figure 5). A few minutes later, at 0012, the heading was altered to 107° when at W19. Each course alteration was performed by the navigation officer using the autopilot and was logged in the bridge logbook by the lookout. The ECDIS also alerted the OOW that the cutter was approaching a waypoint by displaying a waypoint approach 'prompt'. These prompts were visual only as the ECDIS audible buzzer was silenced.

At about 0017, as *ABFC Roebuck Bay* approached W20 at a speed of about 16 knots, the OOW altered the cutter's heading to 194°.

The grounding

At about 0025, with the cutter about 15 m to east of the planned route, the bridge team felt a bump and a shuddering sensation through the cutter's hull. Almost immediately after, *ABFC Roebuck Bay* abruptly grounded on Henry Reef and came to a complete stop (Figure 5). The OOW and lookout were thrown out of their seats onto the display screens in front of them.

Figure 5: Grounding of *ABFC Roebuck Bay*

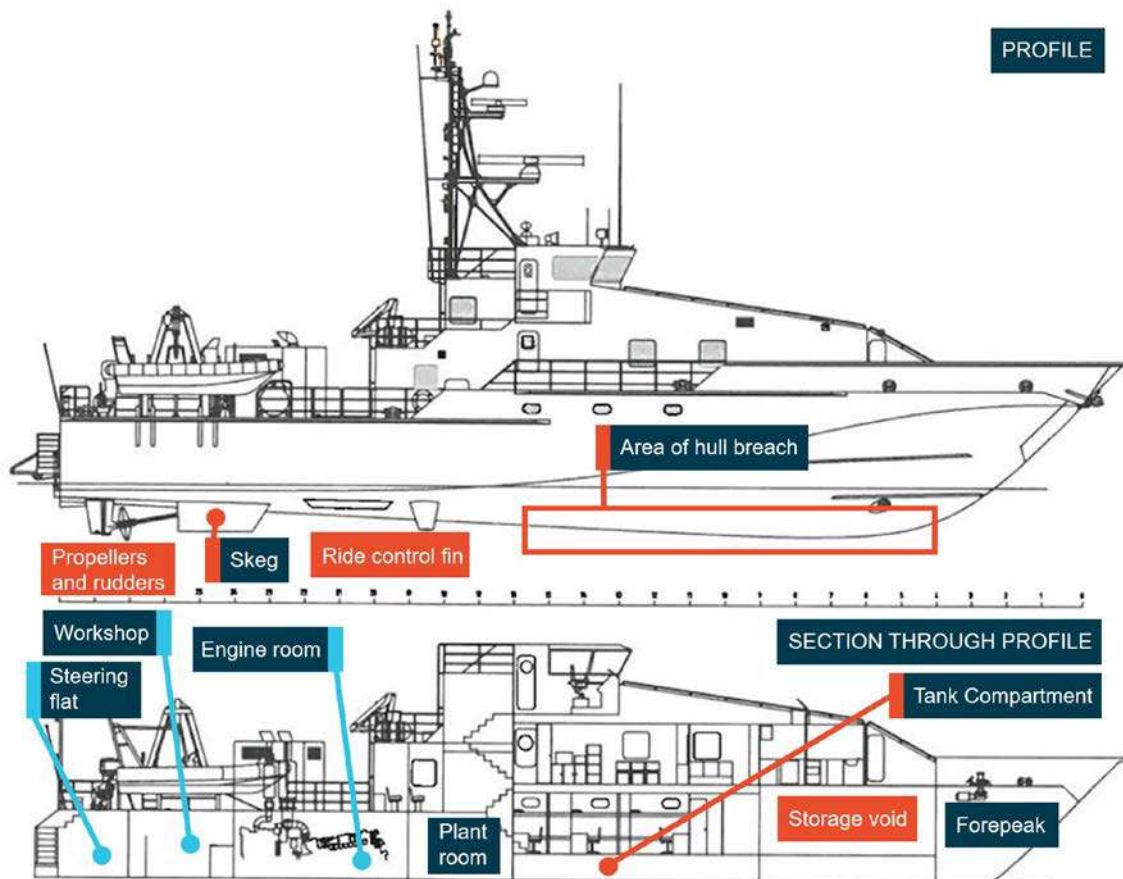


Source: Australian Border Force, modified and annotated by the ATSB

The master, who was in his cabin and was woken by the impact of the grounding, went to the bridge and activated the general emergency alarm. The cutter's crewmembers mustered and were all accounted for. They established that the cutter was aground on a reef and immediately began implementing damage control measures. Initial damage reports indicated that there was water ingress to the storage void space and the tank compartment immediately aft of it, while other spaces and compartments appeared to be intact (Figure 6).

⁸ All ship's headings in this report are in degrees by gyrocompass with negligible error.

Figure 6: Section of general arrangement plan showing affected spaces



Source: Australian Border Force, modified by the ATSB

Emergency response

By about 0032, bilge pumping was underway and shortly after, at about 0038, an urgency signal⁹ and message was broadcast on the very high frequency radio channel 16, with no response received. A few minutes later, an urgency signal and message was broadcast on channel 14, the designated channel for vessels to contact REEFVTS.¹⁰ No response was received to either call.

At about 0047, the master called AMBOC by satellite phone and advised them of the grounding. The master requested that AMBOC notify the Australian Maritime Safety Authority's (AMSA) Joint Rescue Coordination Centre and the designated person ashore at the Australian Border Force (ABF).

At about 0050, *ABFC Roebuck Bay* broadcast a distress¹¹ alert over the cutter's Inmarsat-C terminal and shortly after, the cutter's anchor was lowered. Contact was also established with Joint Rescue Coordination Centre via satellite telephone and a situation report provided. Meanwhile, inspections by the cutter's damage control party revealed hull breaches in the storage void space extending aft into the tank compartment. The damage control party also confirmed the integrity of the cutter's fuel tanks and that there was no pollution. At the time, the cutter's fuel tanks held about 18,000 litres of diesel.

⁹ The urgency signal consists of the words 'PAN PAN' and indicates that the station sending it has a very urgent message to transmit concerning the safety of a vessel, aircraft or person.

¹⁰ The Great Barrier Reef and Torres Strait Vessel Traffic Service, operated by Maritime Safety Queensland as a Vessel Traffic Service (VTS) authority approved by the Australian Maritime Safety Authority (AMSA).

¹¹ A distress alert or distress call indicates that a vessel or person is threatened by grave and imminent danger and requires immediate assistance.

At about 0115, the Joint Rescue Coordination Centre tasked AMSA's emergency towing vessel *Coral Knight* to respond to *ABFC Roebuck Bay*'s distress alert. *Coral Knight* departed Normanby Sound, Queensland for Henry Reef about 15 minutes later with an estimated time of arrival of 1800 later that day. The merchant ship *Toll Firefly* and an Australian defence vessel were also tasked to divert and render assistance to *ABFC Roebuck Bay*.

By about 0514, *Toll Firefly* was on scene and standing by, with communications established. A few minutes later, the cutter started to shift and change heading as a result of the sea conditions and the imminent high water at about 0700. As a precaution, about ½ a shackle (14 metres)¹² of anchor chain was walked out to allow the cutter to be kedged¹³ back onto the reef should it float into deeper water and start to sink.

At about 0605, shortly after first light, the cutter's two tenders¹⁴ were launched to conduct a cursory survey of the waters in the immediate vicinity of the grounding. The survey indicated that there was deep water with depths of between 20 to 30 m at a distance of about 20 m astern of the cutter.

At 1127, an ABF aircraft conducted several passes over Henry Reef to obtain aerial photographs of *ABFC Roebuck Bay* aground (Figure 7). The weather remained relatively fair with the wind from the south-east at about 14 knots and a 1 m sea and swell.

Figure 7: *ABFC Roebuck Bay* aground on Henry Reef



Source: Australian Border Force

By about 1306 that afternoon, the Australian Defence Vessel *Cape Inscription* (ADV *Cape Inscription*) had arrived on scene. A damage control team with equipment was transferred to the cutter and *Toll Firefly* was released to resume their passage.

¹² One shackle equals approximately 27.5 m of chain.

¹³ Kedge: To move a ship or boat along by means of a hawser or chain attached to an anchor.

¹⁴ Tender: A small boat usually carried by a larger vessel for service or support, in this case, used for rescue, interception and the deployment of boarding parties.

Re-floating of ABFC Roebuck Bay

At about 1730, *Coral Knight* arrived on location. A 250 m long fibre tow line was connected to a towing point on the cutter's stern and at about 1820, *ABFC Roebuck Bay* was towed stern first, off Henry Reef. The cutter's anchor was also walked out and eventually slipped at the bitter end.¹⁵ The anchor and chain were left on the reef with a marker buoy attached.

Coral Knight was manoeuvred alongside *ABFC Roebuck Bay* and made fast to it. *Coral Knight* used its anchor to arrest the drift of the two vessels while personnel and damage control equipment were transferred and consolidated between the two vessels. On board *ABFC Roebuck Bay*, the water level in the flooded storage void space appeared to be stable and the completely flooded tank compartment was sealed off. There were several other leaks in various spaces including the plant room and forepeak space, but these were controlled using the cutter's built-in bilge system or available portable pumps.

Passage to Cairns

At about 2200, with the weather deteriorating to south-westerly winds at 20 knots and 2 m seas, a decision was made to commence towing *ABFC Roebuck Bay* immediately. By 2254, *Coral Knight* had weighed anchor and at about 2307, *Coral Knight* commenced towing *ABFC Roebuck Bay* in the general direction of Cairns. Regular rounds were conducted to inspect and pump affected spaces on board the cutter and shortly after midnight, all non-essential personnel were transferred to *Coral Knight*. The tow proceeded at an average speed of about 3.5 to 4 knots (Figure 8) and by midnight on 1 October, the tow had passed through LADS passage (Figure 3). Regular situation reports were provided by *Coral Knight*'s master at about 3-hour intervals to all involved parties including AMBOC, AMSA and ABF.

Figure 8: *ABFC Roebuck Bay* under tow by *Coral Knight*



Source: Master, *Coral Knight*

On 2 October, *ABFC Roebuck Bay* suffered a reduction in bilge pumping capacity with the failure of three pumps. The speed of the tow was immediately reduced while arrangements were made to reinstate the redundancy of the cutter's pumping capability. At about 1400, a nearby vessel,

¹⁵ The inboard end of the anchor cable that is secured to a strong point normally with some form of quick-release arrangement to allow the cable to be safely slipped in the event of an emergency.

Bhagwan Dryden, provided a portable electric pump and at about 1520, an AMSA aircraft airdropped two petrol driven pumps along with several lengths of hose. With the pumps tested and operational, the tow resumed.

Meanwhile, arrangements were made ashore for a vessel to deliver several submersible pumps and other damage control equipment to *ABFC Roebuck Bay* off Cooktown, Queensland the next day. Salvage and emergency response specialists from Ardent Global Marine Services (Ardent) were also engaged and scheduled to board the cutter off Cooktown.

On 3 October, at about 1820, personnel and equipment transfers were conducted off Cooktown. Two additional ABF personnel and a salvage specialist were embarked on board *ABFC Roebuck Bay* while two ABF personnel were disembarked for transfer ashore.

By about 1915, after an assessment by the salvage specialist, *ABFC Roebuck Bay* and *Coral Knight's* masters agreed that it was safe to continue the tow to Cairns. AMBOC was advised and at about 2015, *Coral Knight's* master was formally directed by AMBOC to proceed to Cairns.

At about 0847 on 5 October, *ABFC Roebuck Bay* arrived at a marine yard in Cairns and was lifted out of the water and transferred onto blocks ashore.

Damage

Damage to ABFC Roebuck Bay

ABFC Roebuck Bay sustained substantial damage as a result of the grounding rendering the cutter unseaworthy. The storage void space and tank compartment (Figure 9) were both breached and flooded in way of the keel section with significant seawater damage to all electrical fittings in the two spaces.

Figure 9: Damage to ABFC Roebuck Bay's keel



Source: ATSB

Externally, the port and starboard ride control fins were found holed and bent. Similarly, the port and starboard skegs were found breached with a loss of watertight integrity and both stern tubes had sustained misalignments. The port and starboard propeller blades were also found to have

sustained extensive damage, especially to the blade tips, and both rudders showed minor deformation to the lower section of their trailing edges (Figure 10).¹⁶

Figure 10: Damage to ABFC Roebuck Bay's propellers, rudders and skegs



Source: ATSB

Damage to Henry Reef

In October 2017, officers from the Great Barrier Reef Marine Park Authority and Queensland Parks and Wildlife Service conducted a site assessment of Henry Reef. The assessment found that the maximum extent of physical reef damage occurred within an area of about 990 m² on the north-western aspect of Henry Reef.¹⁷ At the time of the assessment, ABFC Roebuck Bay's 184 kg anchor and about 150 m of anchor chain remained on the reef (Figure 11).

Figure 11: ABFC Roebuck Bay's anchor and chain on Henry Reef



Source: Australian Border Force, modified by the ATSB

The assessment report concluded with recommendations to remove the anchor, chain and any other metal and anti-foul paint still on-site and to stabilise coral debris on the reef. In November

¹⁶ The cutter has since been repaired and, after a period of sea trials, was returned to active service in September 2018.

¹⁷ Great Barrier Reef Marine Park Authority, 2017, Site assessment of damage report: Australian Border Force vessel Roebuck Bay – Henry Reef (12-053), GBRMPA, Townsville. Available at www.gbrmpa.gov.au

2017, *ABFC Roebuck Bay*'s anchor and chain was removed from Henry Reef. There was no reported oil pollution as a result of the grounding.

Context

Australian Border Force

The Australian Border Force (ABF) is an operationally independent agency under the Australian Government's Home Affairs portfolio and is responsible for the protection of Australia's border. The ABF was established on 1 July 2015, when the Australian Customs and Border Protection Service integrated with the Department of Immigration and Border Protection.

Australian Border Force (ABF) officers and assets form part of an enforcement body that patrol Australia's air and seaports, remote locations, mail and cargo centres and Australia's extended maritime jurisdiction. The ABF Marine Unit maintains an armed maritime capability around Australia's coastline and responds to reported or suspected border incidents and illegal activity.

The ABF manages a fleet of patrol boats and specialist vessels that operate within and beyond Australia's exclusive economic zone. The ABF marine fleet included eight Cape class patrol boats, two Bay class cutters, *ABFC Ocean Shield*, *ABFC Thaiyak* and about 51 other smaller vessels.

ABFC Roebuck Bay

ABFC Roebuck Bay was owned by the ABF and classed with DNV GL (Det Norske Veritas - Germanischer Lloyd). As an ABF vessel, *ABFC Roebuck Bay* was a regulated Australian vessel under the *Navigation Act 2012*.¹⁸

ABFC Roebuck Bay was the first of eight 38-m Bay class cutters that saw service with the ABF. The cutter was built and delivered by Austal Ships in 1999. From March 2013, eight new Cape class patrol boats began to replace the Bay class fleet, which were progressively stood down.

ABFC Roebuck Bay was removed from service in 2014. However, the cutter, along with another Bay class cutter, was brought back into service in 2015. Since then, the cutter has primarily been deployed in the Great Barrier Reef and Torres Strait.

Equipment

As a regulated Australian vessel, *ABFC Roebuck Bay* was subject to the requirements of the applicable Marine Orders¹⁹ issued by the Australian Maritime Safety Authority (AMSA). Therefore, *ABFC Roebuck Bay* was required to comply with the navigation equipment requirements of Marine Order 27.²⁰ The cutter's bridge navigation equipment included:

- two differential GPS receiver units²¹
- two radars with automatic radar plotting aid capability
- an automatic identification system transceiver
- depth sounder
- gyrocompass
- radio equipment

¹⁸ Section 15(2) of the *Navigation Act 2012 (Cth)*.

¹⁹ Marine orders are legal instruments made by AMSA pursuant to powers under Commonwealth legislation. They are also described as regulatory instruments or legislative regulations.

²⁰ Australian Maritime Safety Authority, 2016, Marine Order 27 – Safety of navigation and radio equipment 2016, AMSA, Canberra.

²¹ Differential global positioning systems are an enhanced form of GPS providing greater positioning accuracy than the standard GPS.

- a bridge navigation watch alarm system.²²

The cutter was not equipped with a voyage data recorder²³ nor was it required to be.

ABF procedures included checks of all navigation equipment prior to the cutter commencing the patrol. The navigation officer completed the electronic chart display and information system (ECDIS) start-up checklist, the navigation pre-departure checklist, and the bridge departure checklist while alongside in Cairns on 12 September 2017.

As part of the checks, an accuracy comparison was conducted for the two bridge differential GPS units, which were confirmed to be accurate to within 50 m. The cutter also carried two handheld GPS units and a GPS unit in each of the two tenders, which were also compared and found to be satisfactorily accurate.

Charts

As a regulated Australian vessel, *ABFC Roebuck Bay* was required to carry adequate and up-to-date official nautical charts for the intended voyage. At the time of the grounding, *ABFC Roebuck Bay*'s primary means of navigation, as recorded in the cutter's record of equipment attached to its certificate of survey, was an ECDIS (see *Electronic chart display and information system* for details). Therefore, on board *ABFC Roebuck Bay*, ECDIS was being used to meet the chart carriage requirements of the regulations. Consequently, the equipment was required to comply with SOLAS²⁴ regulations and International Maritime Organization (IMO) standards for ECDIS, as referenced in Marine Order 27.

ABFC Roebuck Bay was using official Electronic Navigational Charts (ENCs) issued by the Australian Hydrographic Office (AHO).²⁵ The cutter's ECDIS units were updated on 23 September 2017 to the latest Australian ENC updates available at the time (Week 38-2017).

Operating crew

The cutter had a crew of 11 Australian nationals. The cutter's complement of watchkeeping officers comprised the master, a deputy commanding officer, a navigation officer and a communications officer. Other crew included two engineering officers, four marine tactical officers and a cook.

The master held a valid Australian Master's (Master less than 500 gross tonnage) certificate of competency. He had about 27 years' experience at sea, initially with the Queensland water police and then, from about 2004, with the ABF and its predecessor. He had sailed as master primarily on Bay class cutters, since 2015, although he had acted in the role several times before. The master had completed a generic ECDIS training course in July 2014 and online type-specific ECDIS familiarisation training in December 2014 (see *ECDIS training requirements* for details).

The navigation officer held a valid Australian Master's (Master Class 4) certificate of competency and had about 21 years' experience at sea in various roles including fisheries investigations and compliance. He had been in the ABF for about 5 years and had sailed as an officer of the watch (OOW), primarily on Bay class cutters, since December 2015. During this time, he served in the roles of navigation officer, deputy commanding officer and communications officer on a rotating

²² A mandatory system, the bridge navigational watch alarm system automatically alerts the master or another qualified officer if the OOW becomes incapable of performing the OOW's duties for any reason such as falling asleep or becoming otherwise incapacitated.

²³ A voyage data recorder is designed to collect and store data from various shipboard systems in compliance with SOLAS requirements.

²⁴ International Maritime Organization, 2014, The International Convention for the Safety of Life at Sea (SOLAS) 1974 as amended, IMO, London.

²⁵ At the time of the grounding, the *Navigation Act 2012 (Cth)* referred to this agency as the Australian Hydrographic Service (AHS). In November 2017, an updated version of the Act referred to it as the Australian Hydrographic Office. This report uses the updated name.

basis. The navigation officer had completed generic ECDIS training in May 2016 and online type-specific ECDIS familiarisation training in June 2016.

Both of *ABFC Roebuck Bay*'s other watchkeeping officers also held appropriate certificates of competency and had completed generic and type-specific ECDIS familiarisation training.

Fatigue

The ATSB analysed the master's, navigation officer's and lookout's recorded hours of rest in the days leading up to, and at the time of the grounding.

The passage planning process including planning, amendment, checking and approval was conducted by the navigation officer and master while the cutter was at anchor over a period of several days. The ATSB analysed their recorded hours of rest in the days leading up to the grounding and found that they were compliant with the minimum hours of rest as required by ABF procedures and the relevant AMSA Marine Order. The ATSB analysis also indicated that fatigue levels during the time at anchor likely fluctuated depending on factors such as time of day for the task, time on task, workload and environmental factors. However, there was no evidence to indicate a high likelihood of either officer experiencing levels of fatigue known to have a demonstrated effect on performance during the stages of the passage planning process.

Recorded hours of rest for the navigation officer and lookout, after departing Saibai Island and up until the grounding also appeared to comply with the minimum hours of rest requirements. Analysis of the navigation officer's hours of rest indicated that there was a low likelihood that he was experiencing a level of fatigue known to have a demonstrated effect on performance at the time of the grounding.

Safety management system

ABFC Roebuck Bay operated under the ABF safety management system (SMS). The SMS was applicable to all ABF vessels and associated personnel. The primary aim of the SMS was stated to be:

...the promotion of the development and application of an organisational safety culture.

The SMS was structured to be compliant with the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code)²⁶ as well as AMSA's National Standard for Commercial Vessels. The ABF also held a document of compliance²⁷ issued by Lloyd's Register and most ABF vessels held safety management certificates,²⁸ on a voluntary basis. At the time of the grounding, *ABFC Roebuck Bay* did not hold a safety management certificate, nor was the cutter required to.

The SMS was divided into seven volumes. The first volume contained general policies, principles and documents called 'work instructions' applicable to all vessels and staff. These 'work instructions' were similar to standard operating procedures and provided instruction and guidance on the conduct of various vessel activities such as passage planning, use of ECDIS and the navigational standards expected of all ABF vessels. The other volumes contained forms and work instructions applicable to specific vessels or vessel classes.

ABF internal audits

ABF vessels were subject to annual internal audits by ABF auditors. They comprised a compliance audit of the vessel's documentation followed by an operational assessment. The

²⁶ International Maritime Organization, 2018, International Management Code for the Safe Operation of ships and for Pollution Prevention (ISM Code) as amended, IMO, London.

²⁷ A document of compliance (DOC) is issued to a company (or organisation), which complies with the requirements of the ISM Code.

²⁸ A safety management certificate (SMC) is issued to a ship to signify that the company and shipboard management operate in accordance with the approved SMS.

operational assessment was designed to assess the crew's competency, skill, knowledge and understanding of compliance with relevant ABF policies, legislation, standards and practices. Internal audits focussed primarily on the assessment of the vessel's operational readiness and emergency preparedness. There was little emphasis placed on specifically auditing vessel compliance with passage planning and navigational work instructions.

ABFC Roebuck Bay's master and navigation officer were last audited while serving together on board *ABFC Storm Bay* in November 2016. At the time of the assessment, the navigation officer was acting in the role of OOW and therefore, not performing the duties of the navigation officer. The report concluded that the crew showed a high level of competency with regard to the execution of procedures, policies and the use of equipment on board the cutter.

Vessel management plan

A vessel management plan is a provision of the *Navigation Act 2012 (Cth)* that allows for situations where an ABF vessel or person would not otherwise comply with certain provisions of the Act, such as those related to the safety of navigation. It requires that a plan be developed with specific requirements to be met by the vessel or person and for this plan to be reviewed and accepted by AMSA. At the time of the grounding, *ABFC Roebuck Bay* did not have a vessel management plan in place.

Australian Maritime Safety Authority

As a flag State, AMSA maintains the responsibilities and obligations imposed by international conventions for vessels flying the Australian flag. As such, AMSA is responsible for ensuring that Australian vessels comply with the relevant legislation.

AMSA delegates certain flag State administration functions to recognised organisations. These recognised organisations, known as classification societies, take on certain survey and certification functions on behalf of AMSA for vessels registered in Australia. These recognised organisations include classification societies such as DNV GL and Lloyd's Register.

ABFC Roebuck Bay, like many other ABF vessels, was classed with DNV GL. As a recognised organisation acting on behalf of AMSA, DNV GL surveyed and certified ABF vessels to ensure their compliance with the relevant legislation.

Electronic chart display and information system

An electronic chart display system is a general term for a configuration of electronic equipment, software, and nautical chart data that is capable of integrating position, speed and heading data to display the vessel's position and movement through the water, superimposed on an electronic chart.

There are two classes of electronic chart display systems - an electronic chart display and information system (ECDIS) and an electronic chart system (ECS). ECDIS can be used to meet SOLAS chart carriage requirements whereas an ECS can be used to assist navigation but does not meet the chart carriage requirements of SOLAS.

ECDIS and its use as the primary means of navigation at sea, is a relatively new development. ECDIS was first recognised as being able to meet the chart carriage requirements of the regulations in 2002. By July 2018, the fitting of ECDIS became mandatory for almost all passenger vessels and merchant ships.

An ECDIS, as defined in the IMO ECDIS performance standards,²⁹ means

²⁹ International Maritime Organization, 2006, Revised performance standards for electronic chart display and information systems (ECDIS), Resolution MSC.232 (82), IMO, London.

a navigation system which, with adequate back-up arrangements, can be accepted as complying with the up-to-date chart required by regulations V/19 and V/27 of the 1974 SOLAS convention, as amended, by displaying selected information from a system electronic navigational chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and if required display additional navigation-related information.

The primary function of ECDIS is to contribute to safe navigation. Under the IMO's performance standards, an ECDIS should offer the ability to execute all route planning, route monitoring and positioning as can be performed on paper charts and provide appropriate alarms or indications.

In general, where an ECDIS is being used to meet the chart carriage requirements of SOLAS, it must:³⁰

- be type-approved
- use up-to-date official electronic nautical charts
- be maintained so as to be compatible with the latest applicable International Hydrographic Organization (IHO) standards
- have adequate, independent back-up arrangements in place.

The type-approval process ensures that ECDIS equipment complies with the IMO ECDIS performance standards. Type-approval is conducted by testing an ECDIS against several test requirements developed by the International Electrotechnical Commission. These type-approval tests are normally conducted by recognised type-approval organisations or by marine classification societies and result in the issue of a type-approval certificate.

ECDIS software that is not updated to the latest version of the IHO standards may not meet the chart carriage requirements of the regulations. This is because an ECDIS that is not upgraded to read ENCs based on the latest version of the IHO standards may not be capable of displaying all the relevant digital information contained in the ENC. For example, the ECDIS may be unable to correctly display the latest chart features. In addition, symbols, alarms and indications may not be activated for features even though they have been included in the ENC.

ECDIS safety settings

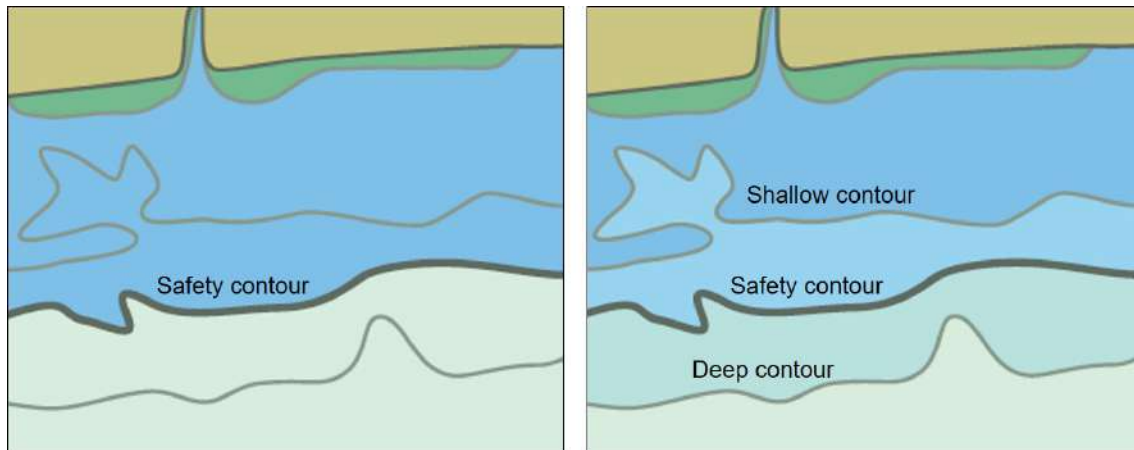
ECDIS safety settings such as the safety contour and safety depth allow the ECDIS display to be set up to reflect the vessel's specific circumstances and characteristics. It also allows the ECDIS's in-built safety functions to compare the safety settings with ENC's depth information and to generate an alarm or indication where the safety settings have been contravened. As such, ECDIS has the potential to increase situational awareness and safety, allowing the OOW more time to concentrate on a visual lookout.³¹

The safety contour value, set by the user, is based on factors such as the vessel's draft and required under-keel clearance. This is shown on the chart display as a bold black line, which marks the limit between navigable and non-navigable water for the vessel. Spot soundings shallower than the user-entered safety depth value appear in a bold black font. There is a distinctive change in colour between waters that are deeper and shallower than the safety contour. When used in the four colour scheme, additional settings for 'shallow' and 'deep' contour values become available (Figure 12). Based on these settings, the ECDIS then displays waters between these contours in different colour shades allowing for an enhanced chart display. Other important ECDIS safety features such as conditional symbolisation and the chart dangers look-ahead function also depend on appropriate safety depth settings to be effective.

³⁰ International Maritime Organization, 2017, ECDIS – Guidance for good practice, MSC.1/Circ.1503/Rev.1, IMO, London.

³¹ United Kingdom Hydrographic Office, 2016, Admiralty guide to the practical use of ENCs (NP 231), UKHO, Taunton.

Figure 12: ECDIS display in the two colour scheme (L) and four colour scheme (R)



Source: U.S. Chart No.1, National Oceanic and Atmospheric Administration and National Geospatial-Intelligence Agency, modified and annotated by the ATSB

ABFC Roebuck Bay's ECDIS was set-up to use the four colour scheme and the safety depth was set at 5 m. The safety depth also provided the safety contour setting on *ABFC Roebuck Bay's* ECDIS. The shallow contour was also set at 5 m and the deep contour was set at 10 m. Therefore, on *ABFC Roebuck Bay's* ECDIS display, all waters deeper than 10 m would appear white, all waters between 5 and 10 m would appear grey, and all waters shallower than 5 m would appear dark blue. Based on these settings, there would have been no areas shaded light blue. The use of the same 5 m setting for the safety contour and shallow contour values removed any advantages offered by the four colour display scheme by reducing the ECDIS display to a three colour scheme. The 5 m contour (or the next deepest contour if there was no 5 m contour) would have appeared as a bold, black line. All spot soundings less than 5 m would have appeared in black while those deeper and unlikely to affect the vessel would have appeared in grey.

ECDIS display modes

ECDIS users can control the level of chart detail and features displayed using three different display modes common to all ECDIS. The three display modes are:

- **'Base' display:** This is the minimum level of information required to be displayed on the ECDIS at all times. It is not intended to be sufficient for safe navigation.
- **'Standard' display:** This display mode includes all features defined by the 'Base' display plus additional features. This display is usually considered to be the minimum information that should be displayed at all times. It should be possible to return to this display mode by a single key stroke.
- **Other:** This display mode presents all available ENC information on the ECDIS display. This can result in the ECDIS display becoming very cluttered. Most ECDIS manufacturers allow the display to be customised to display information relevant to the mariner's needs. This can be done by adding feature categories to the 'Standard' display or by progressively removing feature categories from the 'Other/All' information mode.

ABFC Roebuck Bay's ECDIS was required to be set-up on the 'Other' display mode with all information selected. Feature categories could then be selected or de-selected depending on circumstances.

ECDIS alarms and indications

The IMO ECDIS performance standards require that an ECDIS generate alarms or indications in defined circumstances. An *alarm*, announced by audible means or, audible and visual means, the

existence of a condition requiring attention. An *indication* gave information about the condition of a system or equipment by means of a visual indicator only.³²

In the route planning stage, the standards required that the ECDIS provide an indication if a route was planned over the vessel's safety contour or closer than a defined distance from certain areas or objects such as isolated dangers.

In the route monitoring stage, the ECDIS was required to provide an alarm if the vessel was going to cross the safety contour in a given time and an indication if the vessel was going to pass closer than a specified distance from a rock, wreck or obstruction.

Presentation Library

The actual appearance of an object on an ECDIS display is governed by the IHO standard S-52³³ Presentation Library. The presentation library is a large electronic document containing the rules and information that define how an object or attribute is displayed on an ECDIS. It controls the graphical display of the ENC in ECDIS, including the symbols used to depict the features and colours.

Following investigations into operational anomalies in certain ECDIS, the IHO undertook a review of its ECDIS standards in 2012. The review found that certain requirements of the IHO ECDIS standards had been interpreted and implemented in different ways by various manufacturers. As a result of the investigations, a number of improvements were identified to reduce the risk of implementation irregularities and to improve standards. The review led to the development of three new editions of IHO ECDIS related standards—the IHO S-52 ECDIS Presentation Library – Edition 4.0 (PresLib 4.0), IHO S-63 Data Protection Scheme – Edition 1.2 and IHO S-64 test Data Sets for ECDIS – Edition 3.0.

The IHO issued PresLib 4.0 in September 2014. An eventual implementation date of 31 August 2017 was agreed upon to allow manufacturers time to develop software compliant with the new standard. The new standard was extensively updated to address display anomalies associated with the previous presentation library and improve ECDIS user experience. Among the principal benefits of the new presentation library was a reduction in alarms to address alarm fatigue³⁴ and the introduction of an alert model to harmonise ECDIS alarm and indication behaviour. A number of new symbols were also introduced including symbology to highlight objects that posed a navigational hazard to the vessel.

In order to meet the chart carriage requirements of SOLAS, ECDIS needed to be maintained so as to be compatible with the latest applicable IHO standards. Therefore, the IHO S-52 standard Presentation Library – Edition 3.4 (PresLib 3.4) was to be replaced by PresLib 4.0 by 31 August 2017. After this date, PresLib 3.4 was no longer valid. Essentially, this meant that vessels with ECDIS running the old presentation library after 31 August 2017 might be unable to correctly display the latest ENC features and symbols or activate appropriate alarms and indications.

At the time of the grounding, *ABFC Roebuck Bay*'s ECDIS was operating on PresLib 3.4, although PresLib 4.0 was in force.

ECDIS on board *ABFC Roebuck Bay*

In the ABF marine fleet, the first use of ECDIS to meet the chart carriage requirements was on the Cape class cutters, which began to enter service in 2013. Prior to this, paper charts were the

³² International Maritime Organization, 1995, Code on Alarms and Indicators, Resolution A.830 (19), IMO, London.

³³ International Hydrographic Organization, October 2014, Publication S-52, Specifications for Chart Content and Display Aspects of ECDIS, Edition 6.1(.1), IHO, Monaco.

³⁴ Alarm fatigue occurs when a person is exposed to a large number of frequent alarms and becomes desensitised to them. This can lead to longer response times or crucial alarms being missed altogether.

primary means of navigation. In addition, some cutters also carried an ECS as an aid to navigation.

In May 2017, *ABFC Roebuck Bay* was upgraded from using paper charts as the primary means of navigation (with an ECS as a navigation aid), to ECDIS. Like most other ABF cutters, it was equipped with a VisionMaster FT Naval ECDIS and radar system (VisionMaster FT) manufactured by Northrop Grumman Sperry Marine.

The VisionMaster FT system was installed and configured in a 'Total Watch' configuration. The system was operated as a multi-node system utilising four nodes and four associated multi-function displays (three on the bridge and one on a deck below). The 'Total Watch' configuration allowed for redundancy and meant that each node could be presented either as an ECDIS or as a radar display, as required.

As the vessel's owner, ABF had a responsibility to ensure that the installed equipment complied with the relevant ECDIS standards and regulations, including being type-approved, as referenced in Marine Order 27.

Survey and certification

Following initial installation of the ECDIS, DNV GL surveyed *ABFC Roebuck Bay* and the ECDIS was function tested during sea trials in June 2017. During the survey, a type-approval certificate for the ECDIS, issued by Lloyd's Register and listing software version 7.0.0, was presented to the surveyor. The survey statement recorded that a type-approved VisionMaster FT ECDIS operating on software version 7.0.0 had been installed on board, function tested and found satisfactory.

Consequently, on 16 June 2017, *ABFC Roebuck Bay* was certified by DNV GL as a vessel using a type-approved (commercial) ECDIS as its primary means of navigation.

ECDIS operating software

ATSB examination of *ABFC Roebuck Bay's* ECDIS equipment after the grounding found that the ECDIS was operating with a naval software version (Ver. MA 1.10.0.62) that was not type-approved. Evidence indicated that the VisionMaster FT system was installed on board *ABFC Roebuck Bay* pre-loaded with the non-type-approved naval software.

The manufacturer, Northrop Grumman Sperry Marine, advised that only commercial software versions were type-approved. The naval software was then developed by adding naval features to the type-approved commercial software. The naval software retained the same functionality as the commercial ECDIS software with regard to chart display, safety checking, route planning and route monitoring. However, although based on the type-approved commercial software, these naval software versions were not type-approved, with no type-approval certificates available. The manufacturer indicated that this was because certain features of the naval software versions would not pass the tests required for type-approval. The additional naval features were largely tactical or operational features unrelated to navigational safety.

With regard to the cutter's survey, the provision of correct information is understood to be a general obligation of classification. However, DNV GL advised that they were not informed that non-type-approved software, different to that listed on the type-approval certificate, was in use on the installed ECDIS. This discrepancy was also not identified during the survey on 16 June 2017.

Software updates

The naval software version in-use on board *ABFC Roebuck Bay* and the type-approved commercial software version it was based on (Ver. 8.0.0.2614) were first released by the manufacturer in March 2016. A new commercial software version (Ver. 9.0.0.390) was released by the manufacturer in May 2017. A key objective of this new software version was to introduce the new IHO S-52 standard and PresLib 4.0, which came into effect after 31 August 2017.

At the time of the grounding, the update to the naval software version introducing the new standard and PresLib 4.0 was not available from the manufacturer. Therefore, *ABFC Roebuck Bay*, and at least nine other ABF vessels, had not been updated and were still operating on PresLib 3.4. An updated naval software version (Ver. MA 2.0.0.60) was subsequently released in November 2017. This software and in some cases, necessary replacement hardware, became available to ABF vessels in May 2018.

AMSA required that ECDIS be maintained up-to-date and operate effectively in compliance with the latest applicable versions of the IHO standards. DNV GL recommended that vessel owners contact their ECDIS manufacturer to upgrade their ECDIS to ensure compliance with the new standards. Guidance from the manufacturer and other industry sources also emphasised the need for vessels to upgrade to the latest version of the IHO S-52 standard and PresLib 4.0 by 31 August 2017.

ABF ECDIS procedures

ABF work instructions³⁵ covering the use of ECDIS comprised operating procedures common to all classes of ABF vessels fitted with ECDIS. The instructions noted that ECDIS navigation was fundamentally different from navigation with paper charts and identified that the safe use of ECDIS required appropriately trained officers and bridge procedures.

The ABF ECDIS work instructions consisted of operating procedures for the use of ECDIS and seven annexes, named A to G, comprising equipment familiarisation diagrams and checklists for the set-up and use of ECDIS.

Annex A of the work instructions comprised an ‘ECDIS Start-up Checklist’ intended for use at the start of every patrol and after every system restart (Appendix A). However, there was no specific reference to the checklist in the body of the work instructions and no guidance as to whether the checklist needed to be retained for record keeping purposes.

Annex B consisted of an ‘ECDIS Management Card’, which could be filled out to provide the OOW with a summary of environmental information and ECDIS system settings. The work instructions did not mandate its use, stating only that it ‘may be used’. There was no evidence of its use on board *ABFC Roebuck Bay*.

Annex C comprised a document called ‘ECDIS Recommended Information Layers – Port/Coastal/Open Ocean’ (Appendix B). The checklist provided different ECDIS settings based on the nature of the waters in which the vessel was navigating and was divided into three categories—restricted waters, coastal waters and open ocean. There was no specific guidance or instructions on the use of this checklist in the work instructions, whether it applied to Bay class vessels, and no clear definition of what constituted the three categories of waters.

The master and navigation officer’s interpretation of the three categories was that they were to be set-up as three separate user-profiles. The appropriate user-profile and its associated settings could then be applied to the ECDIS depending on the waters in which the vessel was navigating. However, this understanding of the use and applicability of this checklist was not supported by the ECDIS work instructions, training, or operational experience. In any case, there were no equivalent user-profiles set-up on board *ABFC Roebuck Bay*.

Annexes D, E, F and G comprised bridge equipment familiarisation diagrams for the various vessel types in use with the ABF.

³⁵ Australian Border Force, 31 January 2017, Work Instruction NS 1007 – Use of ECDIS and RADAR on Australian Border Force Cutters V2.1, ABF, Canberra.

ECDIS configuration and settings

ECDIS start-up checklist

ABFC Roebuck Bay's ECDIS was reported to have been set up according to the 'ECDIS Start-up Checklist' in Annex A.

Key settings as provided under the Annex A—ECDIS Start-up Checklist were:

- node-3 un-silenced
- scale bar – set to 'Compilation scale' and 'Auto-scale'
- chart settings – 'Features' set to 'Other' and select 'All'
- overscale pattern – checked
- SCAMIN filtering – checked
- 'Text' – all boxes checked
- safety depth – 5 m
- shallow contour – 5 m
- deep contour – 10 m
- look-ahead span
 - look-ahead: time 3 minutes or distance 1 NM
 - proximity: added breadth 20 m
- alarm – 'Alarm on cautions' checked.

The settings in the 'ECDIS Start-up Checklist' most closely resembled the recommended settings for the 'restricted waters' category of the Annex C checklist, with a few key differences. The most significant difference between the two checklists concerned the lateral extent of the safety look-ahead function setting. The ECDIS start-up checklist prescribed the VisionMaster FT ECDIS's default look-ahead added breadth setting of 20 m while the 'restricted waters' category of the Annex C checklist recommended a setting of 0.1 NM (about 185 m) and was referred to as the 'Look Ahead (Anti-grounding cone – XTE)'.³⁶ While the Annex C checklist used a different term for the look-ahead added breadth setting, the fact that it pertained to the look-ahead function settings was clear. The effectiveness of the ECDIS look-ahead safety checking function could be significantly affected depending on the value of the setting.

Audible alert buzzer

At the time of the grounding, the audible alert buzzer on *ABFC Roebuck Bay's* ECDIS was permanently silenced. The buzzer was silenced on the master's orders to reduce alarm fatigue from ECDIS audible alerts and to prevent it distracting the officers during their watchkeeping duties. However, visual alerts would still be presented on the ECDIS. Other bridge equipment such as the depth sounder also contributed to the preponderance of audible alerts on the bridge. These alerts and possibly those from other equipment were likely replicated on the ECDIS thereby contributing to the number of audible alerts being generated and influencing the decision to silence the buzzer.

Compilation scale

The work instructions required that the primary ECDIS display node (node-3) should always remain in 'compilation scale' (See *Electronic Navigational Charts* below for details). Zooming and forward panning was only to occur on other display nodes. The ATSB could not establish the scale that was in use at the time of the grounding although the OOW reported that the ECDIS

³⁶ XTE – Cross track error, in this context, likely meaning the extent of the vessel's look-ahead safety region measured laterally on either side of the vessel's course over ground vector.

display was generally set to the compilation scale. However, this was sometimes increased to larger scales when navigating in relatively restricted waters such as those around Henry Reef.

The technical failure of node-1 meant that there were only two operational nodes on the bridge at the time of the grounding. Node-3 was being used by the OOW as the primary ECDIS display and node-2 was being used as a radar display. However, interview evidence and the ABF work instructions indicated that node-1 was normally used as a second radar display. Therefore, the unavailability of node-1 is unlikely to have influenced events on the night of the grounding.

Day-night mode

The preference as to whether the ECDIS display was used in the 'day' mode or 'night' mode was left to the OOW. At the time of the grounding, the ECDIS display was reported to have been in 'day' mode, but with the screen brilliance setting dimmed so as not to affect the watchkeepers' (OOW and lookout's) night vision.

ECDIS training requirements

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (The STCW Code)³⁷ covers the minimum training and competency requirements for officers who carry out navigational tasks. The need for these officers to have a thorough knowledge of, and ability to use nautical charts and by extension, ECDIS, is clearly covered in Part-A of Chapter II of the Code. AMSA's Marine Order 27 gives effect to these requirements. This means that masters and deck watchkeeping officers on vessels carrying ECDIS as the primary means of navigation must have completed an approved training course in its use. This requirement is usually met by the completion of an approved generic ECDIS training course.

The STCW Code also requires masters and officers to be familiar with the specific type of ECDIS fitted to their vessel. This requirement for equipment familiarisation is also recognised under the ISM Code and required by AMSA.

Generic ECDIS training

The objective of the generic ECDIS training course is to impart sufficient knowledge, skill and understanding of ECDIS navigation and ENCs to allow the mariner to undertake the duties of a navigational watchkeeping officer. AMSA-approved generic ECDIS training courses were based on, and conducted in accordance with the IMO Model Course 1.27.³⁸

The generic ECDIS training course is usually conducted in a classroom setting with an instructor, usually over a period of about 5 days (40 hours). The course comprised lectures, guided and independent practice on ECDIS simulators, and an evaluation. The IMO model course syllabus was divided into five main topics:

- elements of ECDIS
- watchkeeping with ECDIS
- ECDIS route planning and monitoring
- ECDIS targets, charts and system
- ECDIS responsibility and assessment.

The course syllabus then specified elements that were to be included within these five main topics. For example, the 'Elements of ECDIS' topic included an introduction to the purpose and value of ECDIS to navigation and the understanding of chart data, quality and accuracy. The

³⁷ International Maritime Organization, 2011, Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Code, IMO, London.

³⁸ International Maritime Organization, 2012, Model Course on the Operational Use of Electronic Chart Display and Information Systems (Model Course 1.27), IMO, London.

‘ECDIS route planning and monitoring’ topic covered the planning, checking and monitoring of routes on ECDIS. In particular, the syllabus covered the planning, checking and monitoring of routes for isolated dangers using ECDIS.

If the generic ECDIS training was conducted on the same make and model of ECDIS equipment installed on board, such training usually fulfilled the requirement for ECDIS type-specific familiarisation as well. However, where the shipboard ECDIS equipment was different, there was still a need for familiarisation specific to the type of ECDIS installed onboard.

Type-specific ECDIS familiarisation

At present, there are estimated to be more than 30 different makes and models of ECDIS available for use at sea. While most type-approved ECDIS can be expected to meet the minimum IMO performance standards, there can be significant variation in their design, operation, terminology and, most importantly, in the user interface used for reconciling route dangers to the user. It is a recognised fact that there are many different makes and models of navigation equipment, including ECDIS, each with differing displays, interfaces and controls. This variation poses a number of challenges for mariners. Apart from the need for familiarisation, the variation in equipment also has the potential to reduce efficiency, degrade situational awareness, hinder decision-making and jeopardise safety.³⁹ Efforts to address this issue are now advanced with agreement for a standardised mode common across all ECDIS models.⁴⁰

Training and instructional experiences are always approached from a position of prior knowledge or skill. Trainees usually have existing mental models, which provide a basis for gaining new knowledge. However, these existing mental models can also be an impediment. Research shows that prior knowledge will not necessarily be discarded once new knowledge is provided. Instead, a combination of both may be retained, especially if experience is unlikely to yield any inconsistencies.⁴¹ A mariner, either through training or during service at sea, can be exposed to multiple ECDIS models.

Operational knowledge of a particular ECDIS, if applied to a different system can have negative consequences. ECDIS type-specific familiarisation is intended to ensure that officers are familiar with the specific make and model of ECDIS in-use on board their vessel. This relies on an effective, structured type-specific familiarisation process.

AMSA guidance on type-specific ECDIS familiarisation stated that it should follow a structured plan and cover the following areas:

- familiarisation with available functions
- familiarisation with the menu structure
- display setup
- setting of safety values
- recognition of alarms and malfunction indicators, and action to be taken
- route planning

³⁹ Australia, Republic of Korea and other international organizations, 18 December 2015, IMO sub-committee on navigation, communications and search and rescue, NSCR 3/28/1, Agenda item 28, *Submission on development of guidance on the Standardized (or S) Mode of operation of navigation equipment*, IMO, London.

⁴⁰ To address this issue, a concept known as ‘Standardized (or S) Mode’ of operation of navigation equipment was submitted to the International Maritime Organization under its e-navigation program. The concept of S-Mode envisions future navigation systems having a standard mode for display, control and monitoring. When activated, the system would default to a standard display and present a standard user interface for key tasks. In January 2019, as a result of work led by Australia, guidelines have been finalised and approved at the IMO that will contribute significantly to standardising navigation systems in areas such as terminology, icons, operator actions and user settings.

⁴¹ Rouse, WB and Morris, NM (1985). *On looking into the black box: prospects and limits in the search for mental models* (85-2). Arlington: Office of Naval Research.

- route monitoring
- changing over to backup systems
- loading charts and licenses
- updating of software.

AMSA guidelines also stated that ‘trickle-down familiarisation’ (for example, one officer training another) was unacceptable as it was unstructured and led to incomplete knowledge of the system.

ECDIS training for ABF personnel

ABFC Roebuck Bay's master and navigation officer had intermittently served on cutters equipped with ECDIS since they were introduced into the ABF fleet in 2013. Although they had previously used electronic chart systems as a navigation aid, most of their seagoing experience was on vessels using paper charts as the primary means of navigation. Furthermore, almost all navigation training and studies undertaken in the course of gaining their seagoing deck officer qualifications were predominantly conducted on paper charts, as was also the case for most watchkeeping officers in general.

With the introduction of ECDIS into the ABF fleet, deck watchkeeping officers were required to complete generic ECDIS training and type-specific ECDIS familiarisation training. In addition, ABF procedures required officers to complete task books for their roles, and undergo initial and annual continuation familiarisation training.

Generic ECDIS training

ABFC Roebuck Bay's master completed generic ECDIS training utilising Endeavour Navigator ECDIS software. The navigation officer completed generic ECDIS training using a Kongsberg K-Bridge ECDIS. The Kongsberg K-Bridge ECDIS was also used in the delivery of the generic ECDIS training for both the other watchkeeping officers on board *ABFC Roebuck Bay*.

Therefore, all four watchkeeping officers on board *ABFC Roebuck Bay*, including the master and navigation officer, had completed AMSA approved generic ECDIS training courses that were largely aligned with the guidance in the IMO Model Course 1.27.

Type-specific ECDIS familiarisation training

To meet the requirement for ECDIS familiarisation, ABF deck officers underwent type-specific ECDIS familiarisation training. Type-specific ECDIS familiarisation training for the VisionMaster FT ECDIS was provided in the form of an online computer based training course delivered by Safebridge.⁴² The online course was approved by the manufacturer. The training was delivered using the manufacturer's commercial ECDIS software rather than the naval version installed on *ABFC Roebuck Bay*, but the key navigational functions were identical in both software versions. The training course comprised a structured tutorial with guided learning content and a test. It also allowed the user a period of 3 weeks to familiarise themselves, and gain experience with, the use and operation of the ECDIS software in a ‘free play’ mode.

The tutorial phase consisted of several guided modules and sub-modules covering the operational use of the VisionMaster FT ECDIS including ECDIS display, route planning, route monitoring, alarms and the use of the look-ahead safety checking function. The training clearly distinguished between the route validation, route dangers and look-ahead safety checking functions. The route planning and route monitoring modules both described the correct use of the dangers tab folder to evaluate a planned route for dangers. In short, the tutorial reflected the correct use of the ECDIS, as intended by the manufacturer.

The course was structured to allow flexibility and to take into account each user's existing level of familiarity with the equipment, allowing the user to skip or repeat steps in the tutorial as desired.

⁴² Safebridge is an online maritime training, assessment and certification provider headquartered in Hamburg, Germany.

This meant that, while the tutorial was designed to take 16 hours, it could be completed in less. The training, as undertaken by the master and navigation officer, did not require users to complete the tutorial or a percentage of the tutorial in order to progress to the test phase. The flexible nature of the course meant that the tutorial phase could be skipped entirely.

The test phase consisted of a number of interactive questions and required a minimum score of 70 per cent to pass. The test could be attempted twice in a 24-hour period with no limit on the total number of attempts.

Training records showed that the master did not undertake the guided tutorial phase of the training. He passed the test on his third attempt with a score of 71 per cent. The navigation officer completed 97 per cent of the guided tutorial and passed the test on his third attempt with a score of 71 per cent.

During interviews, the computer-based, online nature of the training was also raised as a possible factor that influenced the effectiveness of the training. The master completed the online familiarisation training on his personal computer and recalled his experience of the training as being very poor, convoluted and that although the test was completed successfully; little was gained from it. He also recalled that the system had been very slow with considerable lag between the user's actions and the outcome on the screen, possibly due to poor internet connectivity. The navigation officer also described poor connectivity as a key recollection of the online type-specific training course.

Other ABF officers also noted that the training software was not user-friendly and that poor internet connectivity and the resulting lag hampered the effectiveness of the online training. The use of personal computers to undertake the training while at home may also have influenced the usefulness of the training. The general view among the officers interviewed was that, while the course was completed and the test passed, the online type-specific training course was of little practical value in learning to use the ECDIS.

ABF training requirements

ABF procedures required that every officer performing the role of a watchkeeping officer complete a task book and receive an endorsement for the position from a master. The navigation officer had successfully completed his task book and been endorsed to serve in the role of the OOW in February 2016 while on board *ABFC Roebuck Bay*. At the time, the cutter was not equipped with ECDIS and the task book reflected this. The master had not completed a task book, as the ABF requirement for one did not exist at the time of him gaining command.

ABF officers received varying levels of mentoring and shipboard training from dedicated training teams or from other officers considered proficient. Officers were mentored during the completion of their task books and when acting in their role prior to endorsement. Training processes and teams were also put in place to train personnel during the transition from the older Bay class vessels to the Cape class vessels.

The master and navigation officer both transitioned from the Bay class vessels equipped primarily with paper charts (and ECS) to Cape class vessels equipped with ECDIS, before returning to Bay class vessels in 2015.

During service on the Cape class vessels, the navigation officer, in training to become an OOW at the time, was mentored and trained by senior navigators in the use of the VisionMaster FT ECDIS and in watchkeeping. When the navigation officer transferred back to *ABFC Roebuck Bay* in the role of acting OOW, he was once again mentored by senior watchkeepers for about 12 months before being confirmed in the role of OOW. These periods of mentoring and training involved the navigation officer learning the operation of the ECDIS through observation and guided use while on the job.

Similarly, during ATSB interviews, the master emphasised on-the-job training and instruction, from his peers and other ABF officers, as the source of his understanding for the operational use of the ECDIS.

ABF annual continuation familiarisation training

ABF procedures required that all members of bridge teams undertake initial and annual continuation familiarisation training on their vessel's specific type of ECDIS and radar. However, there was no evidence of such training being delivered to *ABFC Roebuck Bay*'s officers or to other ABF officers. ABF annual internal audits were reported as including an element of instruction and information delivery; however, this training delivery was not structured or consistent and was not documented.

ABF ECDIS work instructions also referred to a familiarisation checklist to assist with the provision of the annual ECDIS continuation familiarisation training. This checklist was found to contain incorrect guidance on the use of the ECDIS route dangers safety checking function. It described aspects of the ECDIS route validation mechanism, but used the term 'dangers' rather than 'errors'.

Electronic Navigational Charts

An electronic chart is essentially a display of geographical and navigational relevant information displayed on an electronic screen. There are two main types of electronic chart – raster charts and vector charts.

A raster navigational chart is essentially a passive, scanned image of an existing paper nautical chart. A vector chart is more sophisticated and, rather than comprising an image of a chart, it is a database containing the basic information of all the charted features in the chart. Often, both kinds of charts are produced by national hydrographic offices or other authorised government institutions, which then makes them 'official' charts. All other electronic nautical charts are, by definition, not official and are referred to as unofficial or private charts.

An ENC is an official, standardised, vector electronic chart conforming to IHO standards and issued for use with ECDIS. The chart information in an ENC is held as individual items (objects) in a database containing all the chart information necessary for safe navigation and possibly additional information to that contained in a paper chart. Most ECDIS convert the ENC dataset into the manufacturer's internal ECDIS format known as a system electronic navigational chart, which is used for the generation of the chart display and other navigational functions.

The IHO standards are used by hydrographic offices to produce charts and their content, including ENCs. These standards are generally known by their publication reference numbers, such as the S-57⁴³ standard, used for the production of ENCs for ECDIS, or the S-52 standard, containing the specifications for ENC display aspects within ECDIS.

The AHO is responsible for providing Australia's national charting service under SOLAS and the *Navigation Act 2012*. The AHO is part of the Department of Defence and, as the relevant hydrographic authority; charts (paper or electronic) that are produced by the AHO meet the requirements of marine navigation and are known as official charts. The ENC in-use on board *ABFC Roebuck Bay* when the cutter grounded was ENC AU413143.

Compilation scale of an ENC

The compilation scale of the ENC is the scale at which the ENC was designed to be displayed.⁴⁴ Hydrographic organisations compile ENC data for use at a certain scale for which the accuracy of

⁴³ International Hydrographic Organization, November 2000, Special Publication No. 57, IHO Transfer Standard for Digital Hydrographic Data, Edition 3.1, IHB, Monaco.

⁴⁴ International Hydrographic Organization, 2014, S-52 Specifications for chart content and display aspects of ECDIS, IHO, Monaco.

the compilation is appropriate. The compilation scale is defined based on several factors, but will always take into account the scale at which the original source information was captured. ENC's are normally assigned to one of the recommended standard IHO scales as described in the IHO publication S-65.⁴⁵ The compilation scale of an ENC is also related to the navigational purpose assigned to the chart.⁴⁶ The compilation scale of ENC AU413143 was 1:90,000.

Unlike paper charts, which have to be used at a fixed scale, ECDIS allows the user to zoom in and thereby change the scale at which the ENC data is displayed. However, over zooming can give the user the impression that the chart data is more accurate than it actually is. This could result in the chart being inappropriately used for a purpose for which it was not intended. Zooming in introduces the further risk that any positional errors that may exist in the ENC data may be magnified to the point where the data becomes unsafe to use. To safeguard against this, the IMO ECDIS performance standards require that ECDIS provide an indication to the user if the information is displayed at a larger scale than that of the ENC.⁴⁷ This indication is provided by a textual overscale warning. Additionally, if the display is compiled from ENC's at different compilation scales and part of the display is automatically grossly overscaled⁴⁸ by the ECDIS, it is filled with an overscale pattern consisting of a series of parallel vertical lines. The overscale pattern should not generally appear when the operator manually zooms in. However, this is not necessarily the case for all ECDIS types.

On the VisionMaster FT ECDIS, depending on the display option, a 'Primary Display Overscale' or 'Secondary Display Overscale' prompt appeared in the upper right-hand corner of the display when the chart was displayed at a scale larger than its compilation scale (Figure 13). With regard to the overscale pattern, the VisionMaster FT user manual stated that the pattern was generated by the ECDIS if the scale of the display was more than double the compilation scale of any chart in the display.

Figure 13: Image of a VisionMaster FT ECDIS display overscale prompt and pattern



Image shows the overscale display prompt and overscale pattern demonstrated on a different ENC of the same navigational purpose code and compilation scale as ENC AU413143.

Source: Northrop Grumman Sperry Marine, modified and annotated by the ATSB

⁴⁵ International Hydrographic Organization, 2017, Publication S-65, ENC's – Production, maintenance and distribution guidance, Edition 2.1.0, IHO, Monaco.

⁴⁶ ENC's are compiled for various navigational purposes. These are indicated by the ENC's navigational purpose code. On Australian ENC's, the first digit after the authorising nation code (AU) denotes the chart's navigational purpose. Therefore, on ENC AU413143, the navigational purpose code '4' denotes that it was intended as an 'Approach' chart.

⁴⁷ 6.1.1 of IMO Resolution MSC.232 (82) - Revised performance standards for electronic chart display and information systems (ECDIS)

⁴⁸ In this context, 'grossly overscale' means that the display scale is overscaled by more than twice the compilation scale.

During tests on chart AU413143, conducted by the ATSB and the manufacturer, it became apparent that, while the overscale text prompt appeared when the chart was viewed at scales larger than the compilation scale, the overscale pattern was not generated regardless of the scale at which the chart was viewed (Figure 14). However, the pattern did appear on other charts of the same compilation scale and navigational purpose as ENC AU413143 (see Figure 13).

Figure 14: Image of ENC AU413143 showing no overscale pattern



Image of a VisionMaster FT ECDIS display showing ENC AU413143 at a scale of 1:5,000 and displaying no overscale pattern.
Source: Northrop Grumman Sperry Marine, modified by the ATSB

Chart features

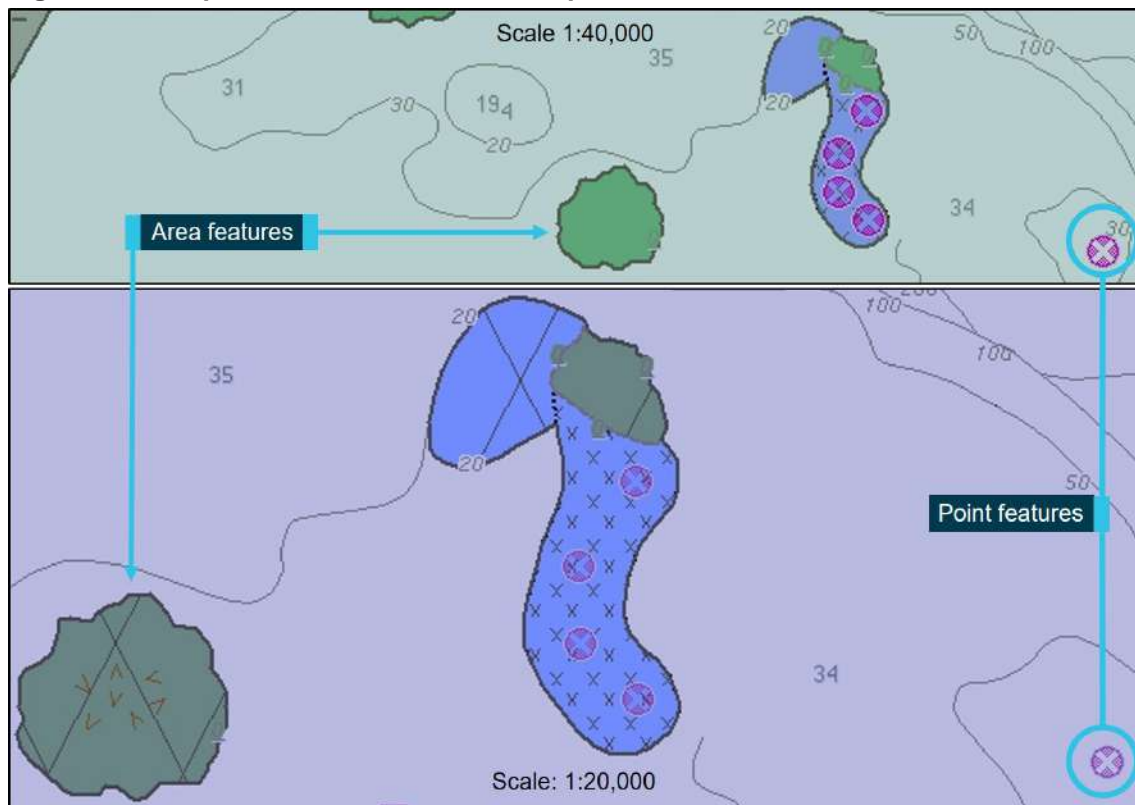
The ENC database encodes each real world, physical feature in the form of ‘feature objects’, with about 170 object classes defined in the S-57 standard, each denoted by a six letter code (for example, UWTRC is the code for an ‘Underwater/Awash Rock’). Each feature object then has a defined list of ‘attributes’ used to describe it. For example, the attribute ‘NATSUR’ is used to describe the ‘nature of surface’ of objects (such as rock or coral). The other information needed about a feature object is its geographical location and spatial form. Spatial forms are either:

- a point feature such as a buoy or light
- a linear feature such as a boundary or depth contour
- an area feature such as a marine reserve.

Some object classes, such as wrecks, rocks and other obstructions including reefs, can be defined as points, lines or areas depending on the compilation scale of the ENC and other factors.

Point features only indicate that a certain feature object exists in a given location. This means that, unlike area features, the only positional information available for a point feature is its geographical position (a point represented by latitude and longitude coordinates).

A key difference to note between area features and point features on an ECDIS display is that, area features change size in proportion to the scale at which the ENC is being viewed whereas the symbols representing point features remain the same size (Figure 15). Unlike area features, the size or shape of the point feature’s symbol does not necessarily represent the size or shape of the physical, real-world feature it is depicting.

Figure 15: Comparison of area features and point features at different scales

The images demonstrate a key difference between area features, which change size proportionate to the scale at which the ENC is being viewed, and point features, which remain the same size regardless of scale. The top picture is at scale of 1:40,000 and lower picture is at 1:20,000.

Source: Electrotech, modified by the ATSB


Conditional symbolisation

In certain cases, the display of a feature on the ECDIS is dependent upon automatic settings or settings designated by the user. This is called 'conditional symbolisation'. For example, the way in which point feature symbology for wrecks, rocks and obstructions can display depends on the user-defined safety depth and safety contour settings. When the feature is situated in water shallower than the safety contour value, it displays as the applicable ENC point feature symbol. However, when one of these features sits in deeper waters beyond the safety contour and is known to have a depth less than or equal to the user-defined safety depth value (or where the exact depth is unknown), the feature is displayed using a new symbol, unique to ENCs—the 'isolated danger symbol' (see Figure 19 in *Charting of Henry Reef* below).

The isolated danger symbol

The isolated danger symbol is applied to submerged rocks, wrecks and other obstructions when the feature is a hazard to navigation located in otherwise 'safe waters' (Figure 16). While the symbol usually represents a point feature, it sometimes appears in the centre of an area obstruction feature.

Figure 16: The isolated danger symbol

ENC Symbol	Explanation	Additional Information	SOI Ref
	Generic isolated danger symbol – with less depth than user-selected safety contour or where the depth is unknown	Wreck, rock or obstruction	K

Source: United Kingdom Hydrographic Office

Where the defined depth value for an isolated danger is of lesser depth than the surrounding water, the vessel's safety depth will drive the conditional symbology. Features with a defined depth less than the vessel's safety depth (and in navigable water) will be displayed as the magenta isolated danger symbol, whereas those deeper than the vessel's safety depth will be displayed as the applicable ENC point feature symbol.

Where a depth value is not defined or the chart producer has indicated that the feature is shallower than the surrounding water, the ECDIS will assume the value to be zero and display the magenta isolated danger symbol. All isolated danger symbols should therefore be treated with caution and the feature interrogated on the ECDIS to obtain more information and determine the danger posed by the feature.

Zone of confidence

ENC data is only as accurate as the original survey data from what it was derived and in most cases, this is the same as the data used to derive the equivalent paper chart. On paper charts, information to evaluate the relative accuracy of the chart data is provided by the means of a source data diagram. In ENCs, the primary means used to communicate this information is known as the 'category of zone of confidence in data' (CATZOC).

ENC data is divided into areas of differing quality based on criteria such as survey characteristics, position accuracy, depth accuracy and seafloor coverage. Of these criteria, the most important is seafloor coverage. Each area in an ENC is then assigned to one of six categories and allocated one of six CATZOC attribute values - A1, A2, B, C, D and U (Appendix C). On the ENC, these CATZOCs are graphically depicted by 'star' symbols. For example, a six star symbol (A1) denotes an area with high accuracy survey data and full seafloor coverage while a two star symbol (D) denotes an area with low accuracy survey data where large depth anomalies may be expected. CATZOC U (unassessed) is reserved for areas where the quality of bathymetric data has not been assessed.

CATZOC does not drive conditional symbology or any specific attribute within the automated route checking function in ECDIS. Rather, it is intended to allow the mariner to make an informed decision as to how far away they should plan to remain from certain potential hazards during the visual inspection phase of route planning, as well as prior to significant deviations from the planned route.

The waters in the vicinity of Wreck Bay through which *ABFC Roebuck Bay's* route was plotted, were categorised as CATZOC B meaning that, although unidentified hazards might exist, none were expected. ABF navigational standards generally considered waters of CATZOC A1, A2 and B to be acceptable for passage planning.

It is important to note that the CATZOC system only applies to bathymetry⁴⁹ such as depths, contours and submerged rocks and reefs. It does not apply to the accuracy of features such as the high water line, wharves, navigation aids and pipelines.

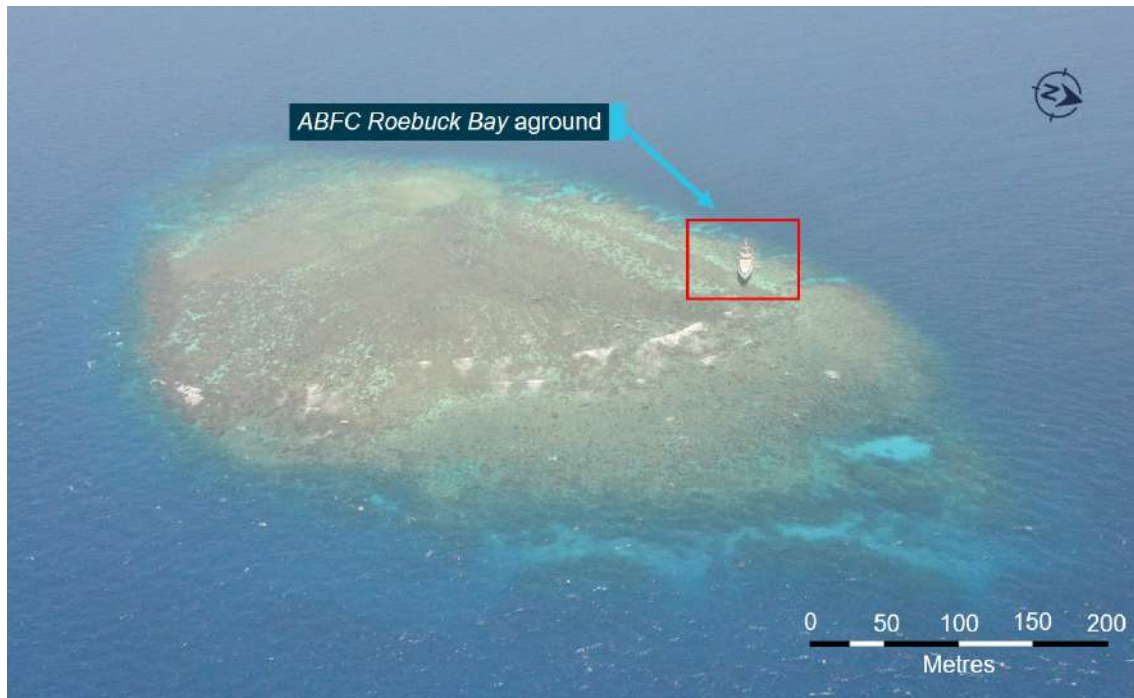
Henry Reef

Henry Reef (Figure 17) is located about 45 NM north-east of Lockhart River, Queensland on the south-western side of Wreck Bay in the outer Great Barrier Reef. The reef's diameter ranges between 400 to 600 m and rises sharply out of the surrounding waters of a depth between 20 to 30 m. In places, the reef has a shallow shelf at a depth of about 5 to 8 m with the reef gently sloping up to the reef crest on the eastern flank at or about the lowest astronomical tide.⁵⁰

⁴⁹ The measurement of depth of water in oceans, seas, or lakes.

⁵⁰ The lowest tide level, which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. On all new Australian charts, the lowest astronomical tide is used as chart datum.

Figure 17: Henry Reef



Source: Australian Border Force, modified by the ATSB

Charting of Henry Reef

Henry Reef was an identified geographical feature that was charted on official charts of the Great Barrier Reef. The original survey data, obtained in 1977, was compiled at a scale of 1:50,000 and then used to compile the paper chart Aus 836 at a scale of 1:150,000 (Figure 18).

Figure 18: Survey data (left) and section of paper chart Aus 836 (right)

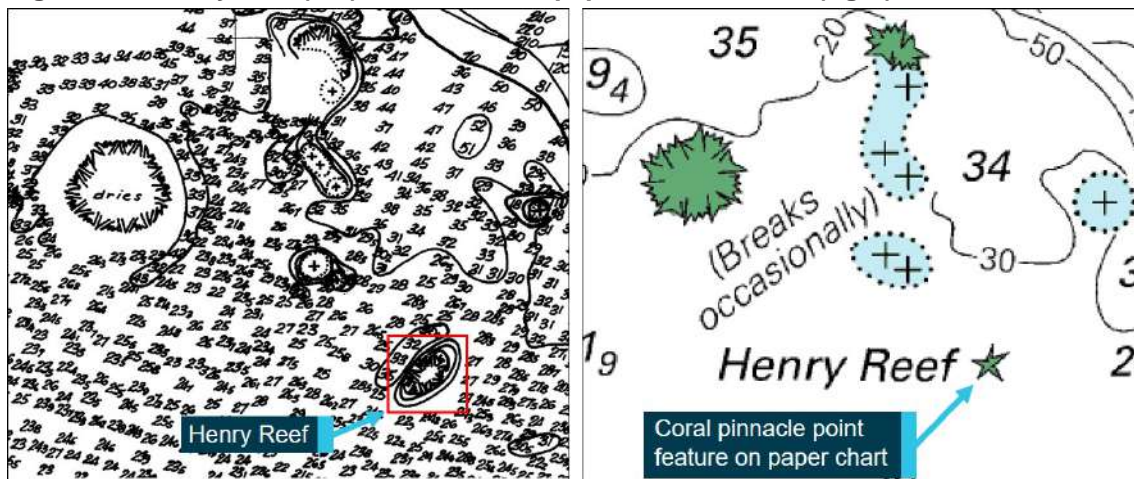


Image shows Henry Reef as surveyed (left) and Henry Reef represented by the 'coral pinnacle' symbol (right) on the paper navigational chart Aus 836.

Source: Australian Hydrographic Office, annotated by the ATSB

Based on the paper chart's compilation scale and other factors, reefs of a certain size were represented as area feature objects while smaller sized reefs were represented by point feature objects. The AHO assessed that Henry Reef could be adequately represented by a point feature object. The symbol used to represent the reef was the 'coral pinnacle' symbol—a green, 5-pointed star-shaped symbol (Figure 18). The coral pinnacle symbol was used to represent coral reef point feature objects on Australian paper charts. This symbol was unique to Australian charts and has not been adopted into the IHO list of chart symbols and abbreviations.

Compilation of ENC AU413143

Data for the production of an ENC can be obtained in two ways. First, a survey can be conducted of the area to be charted and this data can be used to compile an ENC. The second method uses data from an existing paper chart, which is digitally converted to create a vector chart. The method used depends upon a number of factors including the nature and density of shipping in the area, time and commercial pressures involved, and the available survey resources and technology.

The AHO used data captured directly from the paper chart Aus 836 (1:150,000) to compile the ENC cell AU413143, based on rules and guidance in the IHO standards. ENC AU413143 was compiled by the AHO at a scale of 1:90,000.

In the course of compiling the ENC, area and point features on the paper chart were transferred as area and point features respectively to the ENC. Therefore, some reefs appeared as green area features while others were charted as point feature objects. There was no re-assessment performed during the paper to electronic chart conversion process as to whether the form of feature objects continued to be suitable for the real world features they now represented on the ENC. However, there was also no expectation on the part of the AHO that mariners would routinely use ENCs at scales beyond the compilation scale.

The ENC was subsequently validated for distribution by the International Centre for ENCs, an independent organisation that provides validation services to national hydrographic offices to ensure ENC compliance with IHO standards.

Representation of Henry Reef on ENC AU413143

The IMO performance standards state that ECDIS should have at least the same reliability and presentation as the paper chart published by the government authorised hydrographic offices.⁵¹ However, this does not equate to a requirement for ECDIS symbology to be identical to paper chart symbology. As noted in IHO standard S-52:⁵²

The colours and symbols defined in this Specification are conceptually based on the familiar symbology of conventional paper charts. However, due to the special conditions of the ECDIS chart display as a computer generated image, the ECDIS presentation of ENC data does not match the appearance of a conventional paper chart closely. Instead, there are considerable differences in symbology in shape, colour and size, and in the placement of text in particular. The display of the ENC data and the conventional paper chart do not necessarily have to be identical in their appearance.

Henry Reef had been previously charted as a point feature object (coral pinnacle) on the paper chart. On ENC AU413143, the reef was charted using an equivalent ENC point feature object—an ‘underwater/awash rock’ (UWTROC). Additional information about Henry Reef was encoded as different attributes within the ENC and could be obtained by interrogating or querying the chart feature on the ECDIS (Appendix D).

As an ‘underwater/awash rock’, conditional symbology rules applied to the feature. Thus, when situated within the user-defined safety contour value, Henry Reef displayed as an asterisk-like symbol for an ‘underwater/awash rock’ (Figure 19 left). However, when situated in waters deeper than the safety contour, such as in otherwise ‘safe’ waters where one would expect to be navigating, Henry Reef’s symbol changed to an isolated danger symbol (Figure 19 right).

⁵¹ Paragraph 1.7 of IMO Resolution MSC.232 (82) - Revised performance standards for electronic chart display and information systems (ECDIS).

⁵² Paragraph c, Section 1.2 – Concept and limitations of ECDIS, Publication S-52, Specifications for Chart Content and Display Aspects of ECDIS, Edition 6.1(.1).

Figure 19: Henry Reef on ENC AU413143, displaying conditional symbology

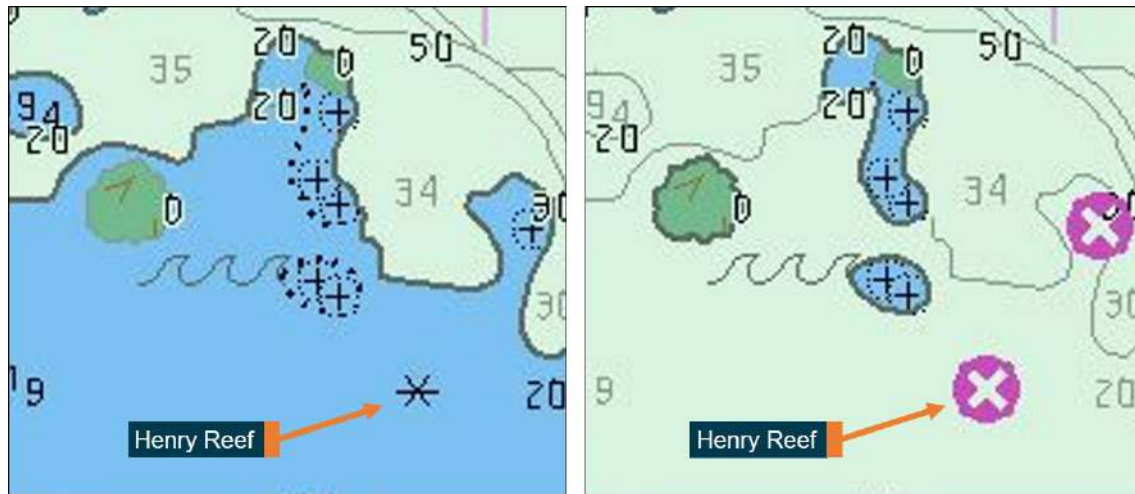
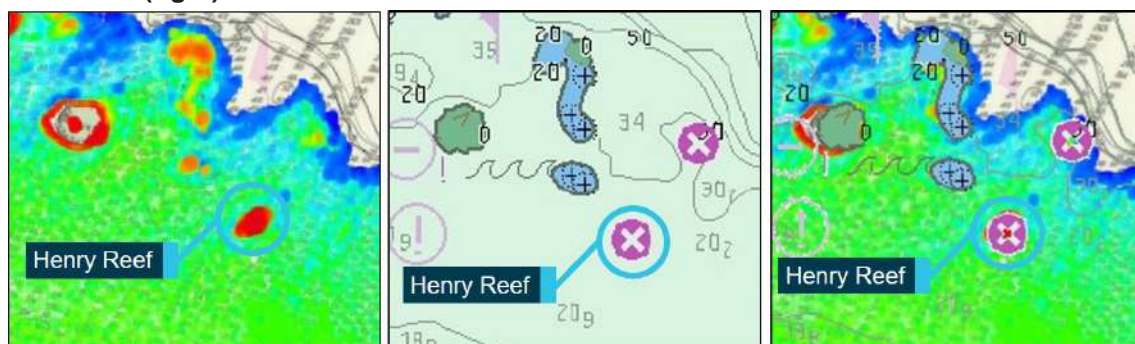


Image on left shows Henry Reef displayed as a 'rock awash' symbol when lying within the user-defined safety contour. The image on the right shows Henry Reef displaying as an 'isolated danger symbol' when lying outside the user-defined safety contour.
Source: Australian Hydrographic Office, annotated by the ATSB

The IHO presentation library applicable at the time of the grounding, PresLib 4.0, mandated that the user be given the option of displaying the isolated danger symbol even for features in waters shallower than the safety contour value. However, some ECDIS operating on previous versions of the presentation library, including the ECDIS on board *ABFC Roebuck Bay*, always displayed the isolated danger symbol for applicable features regardless of their location in relation to the safety contour. Therefore, on *ABFC Roebuck Bay*'s ECDIS, Henry Reef always displayed as an isolated danger symbol.

A cursory analysis of AHO survey data⁵³ obtained shortly after the grounding showed that, when superimposed on ENC AU413143 at compilation scale and, taking into account the position accuracy limits defined by the appropriate CATZOC, the isolated danger symbol appears adequately representative of the observed extent of Henry Reef (Figure 20). However, when viewed at scales progressively larger than the compilation scale, the symbol would progressively represent a smaller proportion of the reef on the ECDIS display.

Figure 20: AHO survey data (left), AU413143 (centre) and survey data overlaid on AU413143 (right)



Images show AHO survey data (left), section of ENC AU413143 (centre) and ENC AU413143 superimposed on survey data at compilation scale (right).

Source: Australian Hydrographic Office, modified, annotated and superimposed by the ATSB

As a point feature, Henry Reef was charted in position 12° 13.381'S 143° 49.126'E on the ENC. Visually, this meant that the symbol representing Henry Reef would always be centred on this position (Figure 21). However, with regard to the ECDIS route checking functions (see *Point features and ECDIS safety checking functions*), the use of a point feature meant that the only

⁵³ The survey data was collected in October 2017 by a laser airborne depth sounder; an aircraft based hydrographic surveying system used by the AHO.

information available for the system to detect Henry Reef was the charted position, regardless of the area covered by the symbol. On the ECDIS display, the symbol always maintains an absolute size of about 7 mm in diameter regardless of the scale at which the ENC is viewed.

Figure 21: Charted position of Henry Reef point feature object on ENC

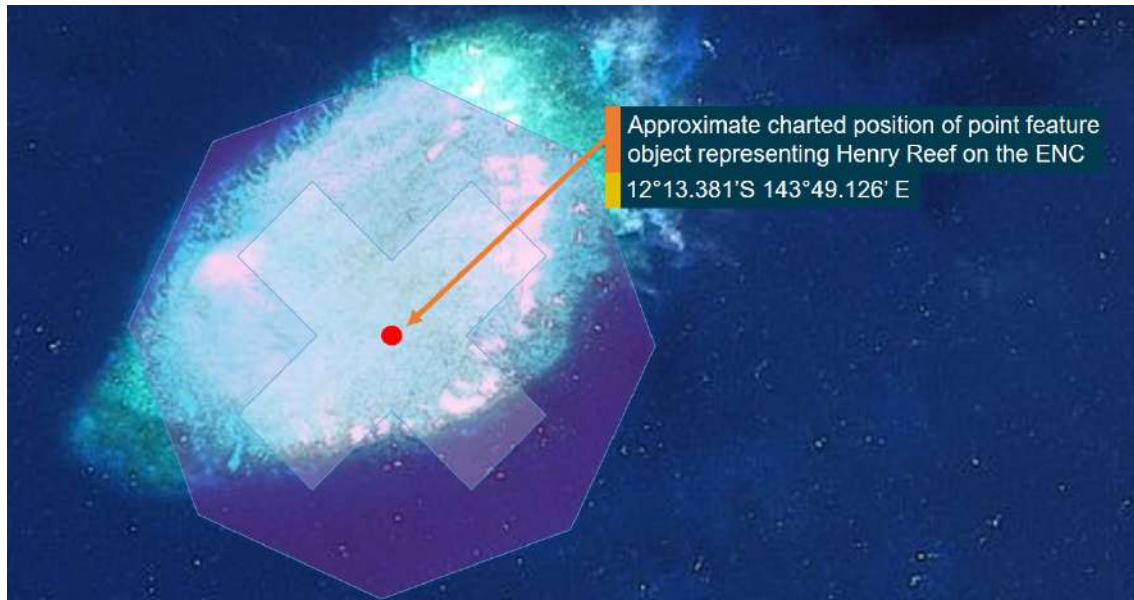


Image showing the charted 'point' position of Henry Reef as encoded in the ENC in relation to the actual reef. Note that the relative size of the isolated danger symbol to the reef is approximate only and that on the ECDIS display, the isolated danger symbol always displays at its standard size of about 7 mm regardless of scale.

Source: DigitalGlobe, Esri, modified and annotated by the ATSB

The Great Barrier Reef

In 1990, the IMO declared the Great Barrier Reef as the first ever particularly sensitive sea area⁵⁴ recognising the unique and pristine environment of the reef and the need to protect it from pollution.

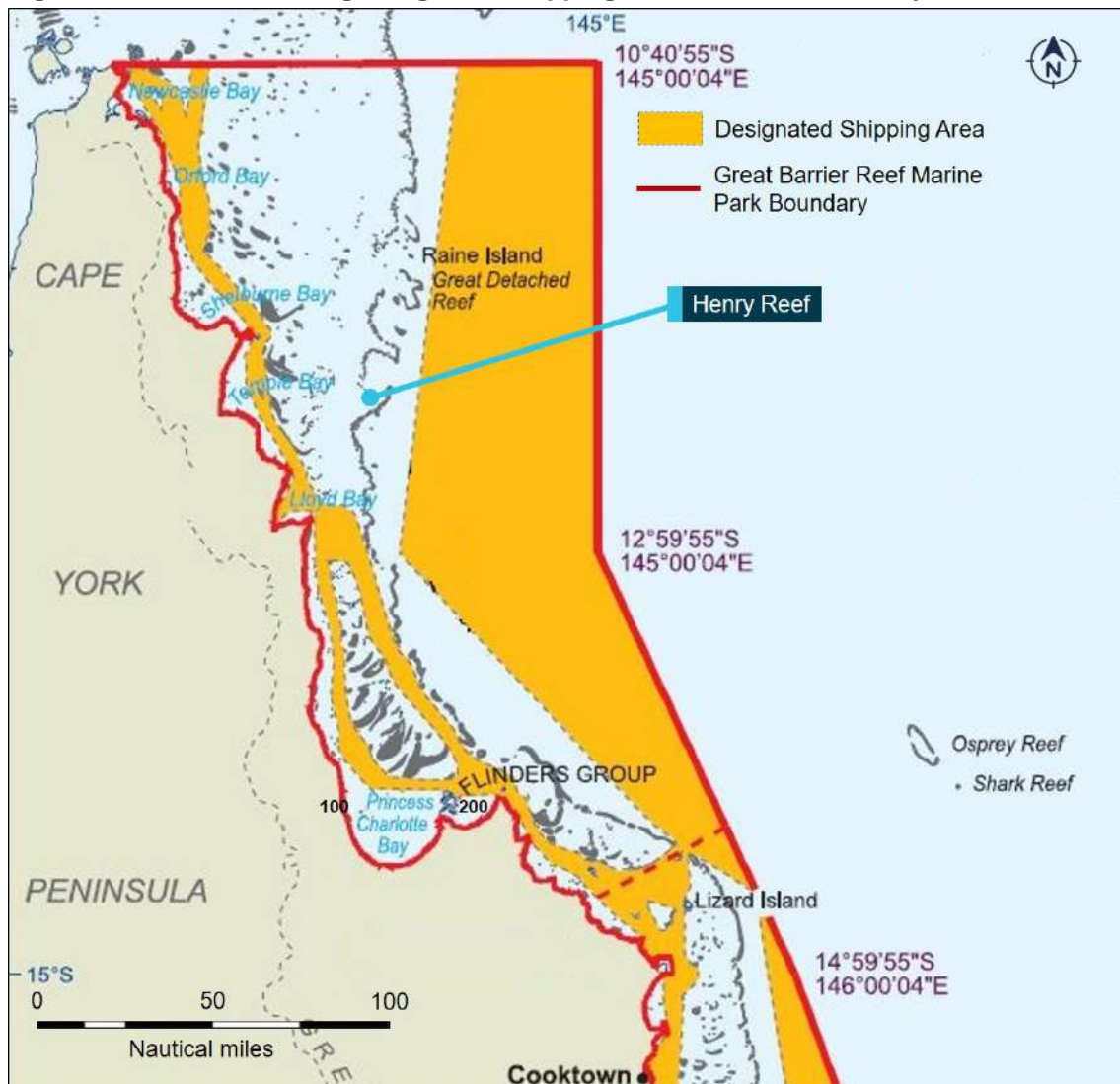
Navigation in the Great Barrier Reef can be particularly challenging. Navigational channels in the reef north of Cairns can be particularly narrow with relatively shallow water depths. In 1991, Australia introduced compulsory pilotage for certain vessels when transiting the Great Barrier Reef. To complement coastal pilotage and other navigational safety measures, a coastal vessel traffic service known as the Great Barrier Reef and Torres Strait Vessel Traffic Service (REEFVTS) was introduced in 2004. In addition, other measures to reduce the risk of a shipping incident in the Great Barrier Reef included a comprehensive network of aids to navigation and the implementation of ship routing and reporting measures.

The Great Barrier Reef Marine Park Authority (GBRMPA) was established by the *Great Barrier Reef Marine Park Act 1975* to provide for the long-term protection and conservation of the environment, biodiversity and heritage of the Great Barrier Reef region. GBRMPA achieves this objective by the management of the park and the various activities that occur within it, the formulation of policies, establishment of partnerships and the enforcement of regulations.

The Great Barrier Reef Marine Park is divided into areas that fall into one of seven zones with different activities allowed and/or prohibited in each zone. GBRMPA has also established a designated shipping area (Figure 22) and this, along with the general use zones, make up the area within which navigation through the Great Barrier Reef Marine Park is allowed.

⁵⁴ An area of the marine environment that needs special protection through action by the International Maritime Organization (IMO) because of its significance for recognised ecological, socio-economic or scientific attributes where such attributes may be vulnerable to damage by international shipping activities.

Figure 22: Chartlet showing designated shipping area in relation to Henry Reef



Source: Great Barrier Reef Marine Park Authority, modified and annotated by the ATSB

As partner agencies, GBRMPA worked closely with the ABF to achieve its objectives. As such, *ABFC Roebuck Bay* had several standing patrol tasks dedicated to the detection and deterrence of vessels operating illegally within the various zones of the marine park. The successful conduct of these tasks and others within *ABFC Roebuck Bay*'s remit required the cutter to operate in waters well outside the designated shipping area.

On the night of the grounding, *ABFC Roebuck Bay* was navigating in a remote area of the Great Barrier Reef, well outside the confines of the designated shipping area and recommended routes. *ABFC Roebuck Bay* was not required to carry a pilot when operating in the Great Barrier Reef. Further, very high frequency radio coverage in the area was poor and the cutter was not participating in, or required to participate in, REEFREP reporting.⁵⁵ Consequently, REEFVTS were not monitoring the cutter and there were no limits set up in the REEFVTS monitoring system in the vicinity of Henry Reef.⁵⁶

⁵⁵ The Great Barrier Reef and Torres Strait Ship Reporting System (REEFREP) requires that certain ships, such as ships over 50 m in length, tankers and gas carriers, report to REEFVTS when transiting the REEFVTS area.

⁵⁶ REEFVTS conducts near real-time monitoring of ships within most of its coverage. To monitor this traffic effectively, limits representing areas within which it is safe to navigate have been set up on the REEFVTS monitoring system. When a ship breaches this limit, indicating for example that it is in danger of grounding, an alarm is triggered allowing REEFVTS to initiate contact with ship and provide it with navigational assistance.

Passage planning

A passage plan is a comprehensive berth-to-berth navigation plan developed and used on board a vessel as a means of achieving a safe and efficient voyage. IMO guidelines state that the development and use of a passage plan is of essential importance for safety of life at sea, safety and efficiency of navigation and protection of the marine environment. A detailed passage plan is necessary to allow the bridge team to arrive at a shared understanding of what 'should' happen during the voyage and ensures appropriate margins of safety are maintained at all times. The vessel's master is required to develop a berth-to-berth plan for its safe and efficient passage.⁵⁷ Detailed plans are needed to ensure appropriate margins of safety are maintained at all times.

ABF passage planning procedures

The ABF SMS required that passage planning on board ABF vessels be conducted in accordance with AMSA requirements⁵⁸ and ABF work instructions.⁵⁹ The general concept of passage planning in the ABF work instructions reflected the guidance on voyage planning provided by IMO,⁶⁰ AMSA and The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers.⁶¹

ABF passage planning procedures placed a responsibility for passage planning upon the navigation officer, and upon the master for final approval of the plan. The procedures listed the minimum content to be included in the passage plan document. This included items such as planned track, courses and distances, wheel over positions, allowable off-track margins, under keel clearances, minimum expected depths and other information pertinent to the plan. While the plan for the passage from Saibai Island to Lizard Island included and documented most of this information, other information required by the procedures such as the minimum expected depths on each leg and expected under keel clearance was not. However, the requirement to record minimum depths and under keel clearances was stated to be the legacy of an older checklist applicable to paper charts and did not apply to ECDIS. It was reported that an equivalent safety outcome was achieved by the application of suitable safety depth and contour values, and compliance with ABF navigational standards.

The ABF passage planning work instructions used the term 'validating the route' to refer to the risk assessment of the route for possible dangers. This was inconsistent with the VisionMaster FT ECDIS route validation function, which only checked for errors not dangers (see *Route planning on the VisionMaster FT ECDIS*).

The work instructions also included a passage planning checklist, noting that it '...must be completed for every passage plan'. The checklist comprised a detailed list of checks covering the entire passage planning process. It included checks to ensure that relevant reference material such as the *Admiralty Sailing Directions* were consulted and that the route was checked, both visually and using the ECDIS route checking function. While it was reported that the checklist was used, its use was not documented nor was the completed checklist retained. However, other passage planning documents, such as the passage planning briefing card and departure briefing summary were retained.

⁵⁷ International Maritime Organisation (IMO), 1974, *The International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS 1974), Chapter V, regulation 34 Safe navigation and avoidance of dangerous situations*, IMO, London.

⁵⁸ Australian Maritime Safety Authority, 2016, Marine Order 27 - Safety of navigation and radio equipment, AMSA, Canberra.

⁵⁹ Australian Border Force, 14 September 2017, Work Instruction NS 1004 – Passage Planning V3.0, ABF, Canberra.

⁶⁰ International Maritime Organization, 2000, Resolution A.893 (21) - Guidelines for voyage planning, IMO, London.

⁶¹ International Maritime Organization, 2011, Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Code, IMO, London.

Phases of passage planning

In general, passage planning is divided into four stages and this was reflected in the ABF work instructions:

- appraisal
- planning
- execution
- monitoring.

Appraisal

The ABF work instructions described appraisal as the process where all pertinent information was gathered and the foundation of the plan was built including an examination of the risks of the intended voyage. Information that needed to be considered included the vessel's draught, operational taskings, availability of accurate and up-to-date charts of an appropriate scale, quality of chart data, information in sailing directions, and expected weather and tidal conditions. The work instructions included a list of reference materials that could be used to assist passage planning. The list comprised several publications including the *Bridge Procedures Guide*,⁶² *Admiralty Sailing Directions*,⁶³ *The Mariner's Handbook* and the *Australian Seafarer's Handbook*.

The sailing directions provided information for safe navigation that was not available on charts or in other hydrographic publications. The sailing directions provided advice for small vessels on routes leading south through Wreck Bay (Figure 23). While the directions cautioned that these routes were not normally used, there were often operational reasons for ABF cutters to navigate in waters that would generally be beyond the scope of regular merchant vessels. The directions also advised that these routes could not be considered proven safe by regular use.

The directions also warned mariners that waters to the west and north of Wreck Bay were incompletely surveyed⁶⁴ and that entrances on these sides should only be used in clear visibility and with extreme caution. However, the route leg leading into Wreck Bay and the amended sections of the cutter's route were plotted entirely in waters categorised as CATZOC B and were therefore considered suitable for navigation by ABF standards.

However, the pre-existing route, upon which the amended route was based, had been used successfully several times before and was therefore considered a proven route on board *ABFC Roebuck Bay*. As this route was plotted clear of Henry Reef, this would indicate that the appraisal for the pre-existing route likely did consider the presence of the reef and took into account the sailing directions.

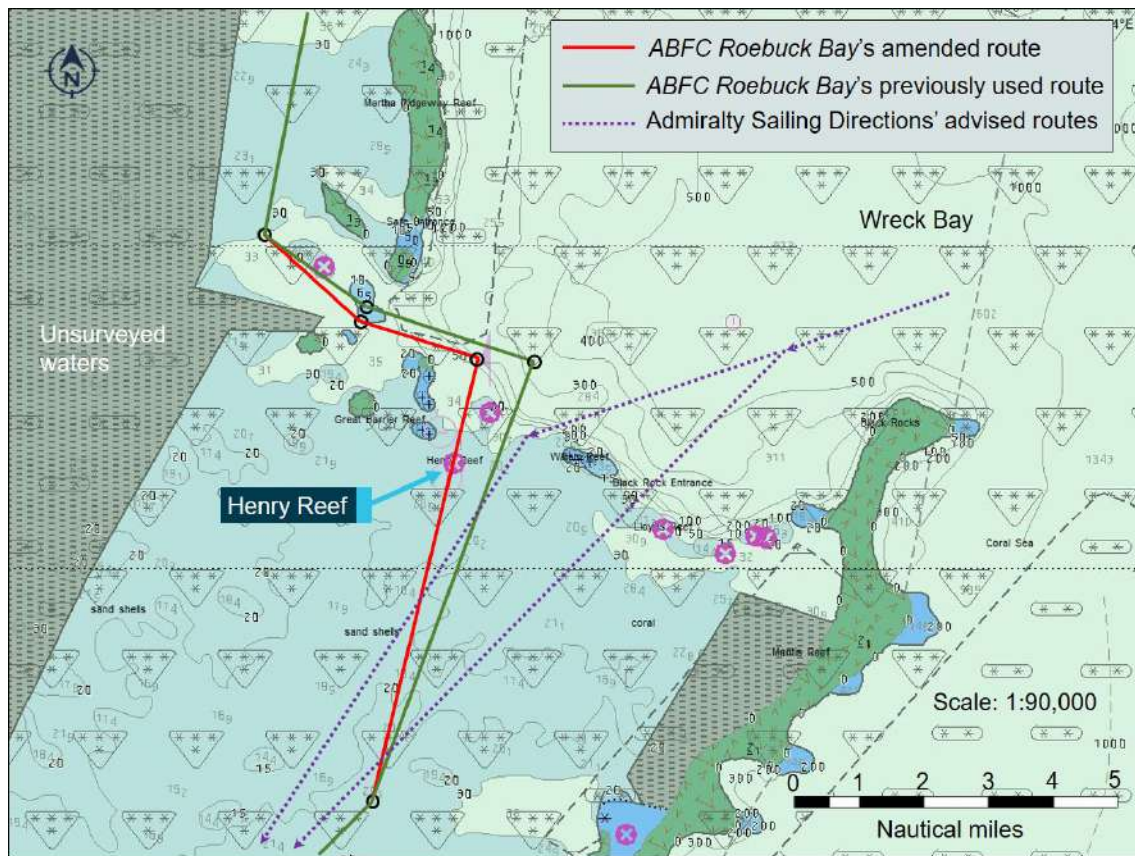
The master and navigation officer were using what they considered a safe, proven route in waters of an acceptable navigational standard. The potential risks of the subsequent amendments to the plan were to be managed by visual and ECDIS checks of the route in the planning and monitoring phases. Therefore, it was considered unlikely that further effort at the appraisal stage of the passage planning process would have influenced the outcome of the grounding.

⁶² International Chamber of Shipping, 2007, *Bridge Procedures Guide*, Fourth Edition, Marisec Publications, London.

⁶³ The *Admiralty Sailing Directions – Australia Pilot, Volume 3 (NP 15)* covered the waters of the Great Barrier Reef.

⁶⁴ The unsurveyed waters to the west and north of Wreck Bay have since largely been surveyed and charted as part of a long standing survey program aimed at supporting surveillance activities within the Great Barrier Reef.

Figure 23: Section of ENC AU413143 showing CATZOCs and ABFC Roebuck Bay's routes compared to advice in the Admiralty Sailing Directions



Source: Australian Hydrographic Office, annotated by the ATSB using information from the Australian Border Force and from Admiralty Sailing Directions (NP15)

Planning

The planning phase involves plotting the intended route of the passage on appropriate charts based on the information gathered in the appraisal stage. A key part of the planning stage involves checking every leg of the planned route prior to the commencing the passage.

The passage plan was based on a route that had been used safely a number of times before by the navigation officer and master. When presented with the plan for the passage to Cairns, the master decided to amend certain parts of the route for various reasons. One amendment involved shifting two planned course alteration positions (waypoints) in the vicinity of Wreck Bay—waypoint 19 (W19) and waypoint 20 (W20). W19 was moved south to skirt an area of relatively shallow water and W20 was moved to the west with crew comfort in mind. In the master's experience, the cutter usually experienced relatively rougher weather conditions on that particular leg of the route as it temporarily ventured seaward of the Great Barrier Reef. The waypoint amendment aimed to reduce the amount of time that the cutter would be exposed to these conditions. The shifting of W20 to the west resulted in the route leg from W20 to waypoint 21 (W21) being inadvertently plotted across Henry Reef. Further changes after this point, including the creation of two separate routes to include a brief stop at Lizard Island, did not affect the segment of the route in Wreck Bay.

Execution and monitoring

The execution and monitoring phases of the passage plan occur concurrently. The planned route, which has been checked and approved, is executed and the vessel's progress against the route is monitored. ABF work instructions for the monitoring phase of the passage plan required the OOW to consider whether the route being followed was safe and what the nearest danger to the route was. These instructions aligned with The International Convention on Standards of Training,

Certification and Watchkeeping for Seafarers (The STCW Code), which required the OOW to verify each leg of the route before following it.⁶⁵

On taking over the watch, the OOW reported visually reviewing the route that the cutter was expected to transit over the 4 hours of his watch. This check did not detect Henry Reef on the cutter's route.

The OOW briefed the lookout on the expected navigation during their watch and confirmed the status, settings and operation of other bridge equipment. Course alterations at waypoints were made by autopilot and prompted by the OOW's watchkeeping and ECDIS waypoint approach prompts. These prompts were visual only as the ECDIS audible buzzer was permanently silenced. Apart from the waypoint approach prompts, the watchkeepers could not recall any other ECDIS alerts in the time leading up to the grounding.

The depth sounder was set up to alarm if depths less than 10 m were encountered. However, the speed of the cutter and the steep nature of Henry Reef in relation to the surrounding waters meant it was unlikely to provide any useful warning of the grounding. The watchkeepers reported no significant radar return off the reef nor were there any audible or visual signs such as from breaking waves.

Route planning on the VisionMaster FT ECDIS

Route planning on the VisionMaster FT ECDIS was conducted using the 'Edit Route' function. This function's menu allowed waypoints to be inserted, deleted or amended. The menu also allowed the user to define other parameters for the route such as turn radius and cross track distance (XTD). Apart from representing the limit at which an off-track alarm is activated, the XTD value is also used to define the vessel's route safety region.⁶⁶ The default setting for the XTD on the VisionMaster FT ECDIS was 100 m either side of the planned route.

The IMO performance standards for ECDIS required that an indication be given if the mariner planned a route across the ship's defined safety contour or closer than a user-specified distance from a point object such as an isolated danger.⁶⁷ In the case of the VisionMaster FT ECDIS, this user-specified distance was defined by the route plan's XTD settings.

When a route was planned on the VisionMaster FT ECDIS, the system automatically performed two checks on the route—a route validation check and a route dangers safety check.

The route validation check examined the geometry of the route and if there were no errors, a tab displayed the words 'No Error'. If an error was detected (such as an incorrect turn radius),⁶⁸ the tab displayed the word 'Errors' with a yellow background (Figure 24). A route could be saved if it contained errors, but could not be loaded for monitoring until the errors had been rectified. The route validation process did not check the route for dangers

⁶⁵ International Maritime Organization, 2011, Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Code, IMO, London, Chapter VIII, Part 2-6 – Voyage planning, Verification and display of planned route.

⁶⁶ The route safety region comprises a zone of width equal to the XTD plus half the vessel's beam applied to both sides of the planned route.

⁶⁷ 11.3.4 and 11.3.5 of IMO Resolution MSC.232 (82) - Revised performance standards for electronic chart display and information systems (ECDIS)

⁶⁸ If a planned turn cannot be achieved based on the vessel's handling characteristics set up in the system, the ECDIS will detect this as an error.

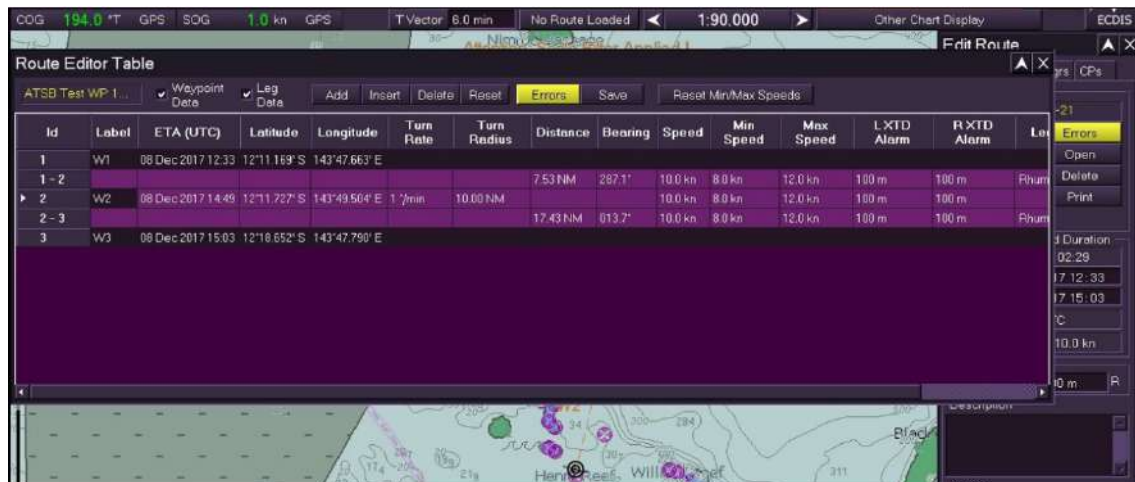
Figure 24: VisionMaster FT ECDIS route validation check displaying 'Errors'

Image shows a VisionMaster FT ECDIS displaying the 'Errors' highlighted in yellow due to an incorrect turn radius entered by ATSB investigators during testing.

Source: Electrotech and ATSB

The route dangers safety check searched the chart database for dangerous objects or areas that intersected the route safety region. The identified dangers and cautions were listed in a directory tree against each leg of the planned route under the dangers tab folder of the 'Edit Route' menu. To check a route for identified dangers or cautions, the user was required to manually check each leg of the route in the dangers tab folder of the 'Edit Route' menu (see *Detection of Henry Reef*). Identified route dangers were not graphically highlighted on the chart automatically. To highlight an identified danger on the chart, the user had to select the danger in the dangers tab folder by clicking on it. A route could be saved and loaded for monitoring even if it contained dangers or cautions.

Route monitoring on the VisionMaster FT ECDIS

Once a route has been planned, saved and validated for errors, it can be loaded for monitoring. The 'Monitor Route' window allowed the user to monitor the vessel's progress against all aspects of the planned route. The 'Monitor Route' window also contained a dangers tab folder that replicated the dangers and cautions identified in the 'Edit Route' menu's dangers tab folder. A 'Show Present Leg or Turn' button enabled the user to view dangers and cautions identified on the current route leg in the 'Monitor Route' window's dangers tab folder. The VisionMaster FT manual advised that the dangers tab folder of the 'Monitor Route' window should be checked whenever a new route was loaded and during the passage, when progressing to new legs.

Look-ahead safety checking function

The IMO performance standards for ECDIS require that an indication be given to the mariner if the ship, continuing on its present course and speed, over a specified distance or time set by the mariner, will pass closer than a user-specified distance from a danger such as a wreck, rock or obstruction.⁶⁹

The VisionMaster FT ECDIS provided a look-ahead safety checking function to meet this requirement. Based on the contents of the chart, this function generated alerts for shallow water or other dangers in an area around the vessel, based on settings defined by the user. The extent ahead of the vessel was defined in either time or distance while the lateral extent of the look-ahead was defined as a distance (Figure 25).

⁶⁹ 11.4.6 of IMO Resolution MSC.232 (82) - Revised performance standards for electronic chart display and information systems (ECDIS).

Figure 25: ECDIS look-ahead safety checking function

Image shows the key settings of the look-ahead safety checking function on a VisionMaster FT ECDIS. The rectangle represents the safety region 'box'.
Source: Safebridge

The ECDIS's default look-ahead setting was 15 minutes or 0.5 NM ahead of the vessel. A further setting, with a default value of 20 m, allowed a safety region breadth to be added to either side of the vessel's beam. Based on these settings, a rectangular safety region 'box' was defined around the vessel's course over ground. As these settings were increased or decreased, the safety region increased or decreased the area that the system checked. The software took a snapshot of where the look-ahead box was every 30 seconds, checked that chart area for dangers or areas of concern to the vessel, and generated appropriate alerts.

At the time of the grounding, *ABFC Roebuck Bay*'s look-ahead safety region was reported to have been set up to check an area of the chart 3-minutes ahead of the vessel with an added breadth of 20 m either side of the vessel's projected course over ground.

VisionMaster FT ECDIS alerts

Alerts on the VisionMaster FT ECDIS were classified into alarms, warnings and cautions. All three generated visual alerts in the ECDIS display's 'Alert Status Indicator' box. Alarms and warnings also generated audible alerts whereas a caution did not (by default). However, the VisionMaster FT ECDIS (operating on PresLib 3.4) gave the user the option for cautions to be treated and audibly presented as alarms.

Audible alerts for unacknowledged alarms and warnings consisted of three 'beeps' repeated at defined intervals. The specifications for the audible alerts differed to emphasise alarms over warnings. The length of the 'beeps' for alarms were longer and, intervals between sets of beeps shorter, than for warnings.

When the VisionMaster FT ECDIS look-ahead function detected a chart danger such as an underwater/awash rock, an alarm was raised. An audible alert sounded and a visual alert was raised on the ECDIS display. The 'Alert Status Indicator' box of the ECDIS display would have turned red with the word 'Chart Dangers' and the 'Chart Dangers' icon to the right of it would also have turned red. It is important to note that only the look-ahead function generated alarms for chart dangers. Dangers identified by the 'Edit Route' and 'Monitor Route' functions on the planned route required the user to engage with the respective dangers tab folders to be appraised of the identified dangers.

Detection of Henry Reef

The shifting of W20 resulted in an unsafe passage plan with a route leg plotted across Henry Reef. The detection of this potential navigational danger relied on the ECDIS and visual checks of the route required by ABF passage planning procedures and the general practice of passage planning.

Visual check of the route

The master and navigation officer reported visually checking the route after amending it. Both officers recalled seeing the words 'Henry Reef' but not the isolated danger symbol that represented the reef. They believed that the name applied to other reefs to the north-west of Henry Reef.

ABFC Roebuck Bay's master and navigation officer reported that they were not aware of the isolated danger symbol that represented Henry Reef until after the grounding, when they scrutinised the ECDIS display. However, when they subsequently checked the paper chart of the area (Aus 836), they reported an immediate awareness of the reef. They attributed this to the green, star-shaped, coral pinnacle symbol that represented the reef on the paper chart (see *Charting of Henry Reef*). This symbology and colour was familiar to them (probably due to their considerably longer use of paper charts in their careers) and was similar to the green symbology used for drying coral reef area features, both on paper charts and ENC's.

The officers' understanding of the isolated danger symbol was that it represented a rock, wreck or obstruction but not necessarily one that was dangerous to the navigation of their cutter. However, Henry Reef displayed as an isolated danger symbol to warn the mariner that a potential hazard to navigation existed in waters that were otherwise considered 'safe'. The conditional nature of the symbol may not have been apparent due to the VisionMaster FT ECDIS's property of always displaying the isolated danger symbol regardless of the safety contour value. This may have influenced the officers' understanding of the symbol's significance.

The symbol representing Henry Reef was situated in waters shaded white indicating depths greater than 10 m. The officers expected that isolated danger symbols representing features hazardous to navigation, would be surrounded by blue shading and/or contours on the ECDIS.⁷⁰ This likely reflected their knowledge of paper chart symbology, where rocks or wrecks considered hazardous to surface navigation were usually surrounded by blue shading when outside the safety contour. Nevertheless, the master and navigation officer agreed that sighting an isolated danger symbol on the planned route would certainly have triggered a chart query to assess the hazard posed by the feature. However, no such chart query of Henry Reef occurred. This indicated that neither officer sighted the isolated danger symbol during the visual check.

Clarity of symbols and labels

On a paper chart, symbology and text labels are positioned by the cartographer to allow for the best practical use of the chart based on its intended purpose. On ECDIS, the position of symbols and labels are determined by algorithms based on rules in the IHO standards. When only part of a large area feature (such as the Great Barrier Reef) is displayed on the ECDIS screen, the symbol and/or label defaults to the centre of the displayed area. At certain scales, when the ECDIS display was centred on Henry Reef, the reef's symbol and label could be obscured by the symbols and labels for the 'Great Barrier Reef' and 'nature reserve' features present on the ENC (Figure 26). This effect could be exacerbated by the fact that the symbol and text label for the nature reserve were the same magenta colour as the isolated danger symbol representing Henry Reef.

⁷⁰ Under IHO/AHO rules, there was no requirement for a contour to be encoded around Henry Reef given the compilation scale of the ENC and therefore, no blue shading. See section 5.3 – Soundings, Australian Use of the Object Catalogue, AHS.

Figure 26: Image of ENC AU413143 displaying text and symbol overlap



Image shows ENC AU413143 centred on Henry Reef, at a scale of 1:40,000 on a VisionMaster FT ECDIS, demonstrating text and symbol overlap. Note that all text is on display as required by the Annex A - ECDIS start-up checklist.
Source: Electrotech and ATSB

Point features and the visual check of the route

At compilation scale, the isolated danger symbol was reasonably comparable to the physical extent of Henry Reef (see Figure 20). A visual assessment of ABFC Roebuck Bay's planned route at compilation scale showed the route passing over Henry Reef (Figure 27, left). However, when viewed at progressively larger scales, the reef's isolated danger symbol appeared further away from the route. This could potentially give a false sense of sea room and safety.

While the ATSB could not determine the exact scale at which the visual check was performed, the navigation officer and master confirmed that the ENC was likely viewed at several scales including scales larger than the compilation scale (Figure 27, right). However, there was no evidence that the use of scales larger than the compilation scale influenced the visual check of the route.

Figure 27: ABFC Roebuck Bay's planned route on the ECDIS showing the relative position of the isolated danger symbol representing Henry Reef at different scales

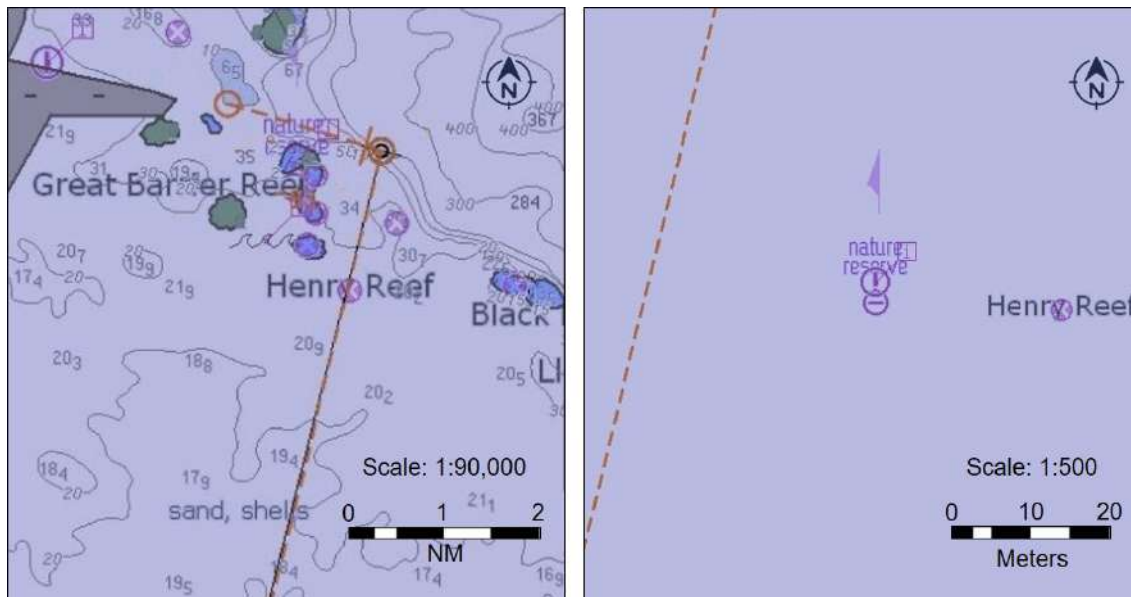


Image shows ABFC Roebuck Bay's amended route legs on the ECDIS at the compilation scale of 1:90,000 (left) and at the largest viewable scale, 1:500 (right).

Source: Electrotech and ATSB

ECDIS check of the route

When the master saved the amended route, the route validation process identified an error in the route. This was indicated by the highlighted 'Errors' tab. The master and the navigation officer incorrectly believed that this route validation process also checked the route plan for dangers. Their understanding was that an identified danger on the route would generate an 'Error', which would prompt them to check the dangers tab folder. However, 'errors' and 'dangers' were presented in completely different ways on the VisionMaster FT ECDIS.

When the identified error (an incorrect turn radius) was rectified, the 'Errors' tab changed to 'No error'. This led the officers to believe, incorrectly, that there were no chart dangers identified by the ECDIS on the planned route either. Therefore, the route was not checked in the dangers tab folder of the 'Edit Route' menu. The officers' understanding was further supported by their incorrect belief that the VisionMaster FT ECDIS would not allow a route to be saved if it was plotted across a chart danger. *ABFC Roebuck Bay's* other watchkeeping officers also appeared to share a similar understanding and expectation of the ECDIS's functions.

On *ABFC Roebuck Bay's* departure from Saibai Island, the passage plan for the route 'Saibai to Lizard via Outer Reef' was loaded for monitoring in the ECDIS. The route consisted of 42 waypoints and was planned with the VisionMaster FT's default XTD of 100 m. The ECDIS applied this setting to the vessel's beam⁷¹ and assigned a safety region of about 105 m on either side of the planned route. This meant that a route safety region, about 210 m in breadth, was checked by the ECDIS for route dangers and cautions. The charted position of the 'underwater/awash rock' point feature object that represented Henry Reef on the ENC lay about 55 m to the east of the planned route. Therefore, the isolated danger symbol fell well within the route safety region.

ATSB examination of *ABFC Roebuck Bay's* ECDIS after the cutter's arrival in Cairns confirmed that Henry Reef had been identified by the ECDIS and listed in the 'Monitor Route' menu's dangers tab folder (Figure 28). As discussed previously, the 'Monitor Route' dangers tab folder replicates the dangers identified in the 'Edit Route' dangers tab folder. Therefore, it was almost certain that Henry Reef was identified as a danger by the ECDIS in the 'Edit Route' dangers tab folder as well. This was confirmed during ATSB testing (see Figure 29).

Figure 28: Image of ABFC Roebuck Bay's ECDIS showing the 'Monitor Route' window

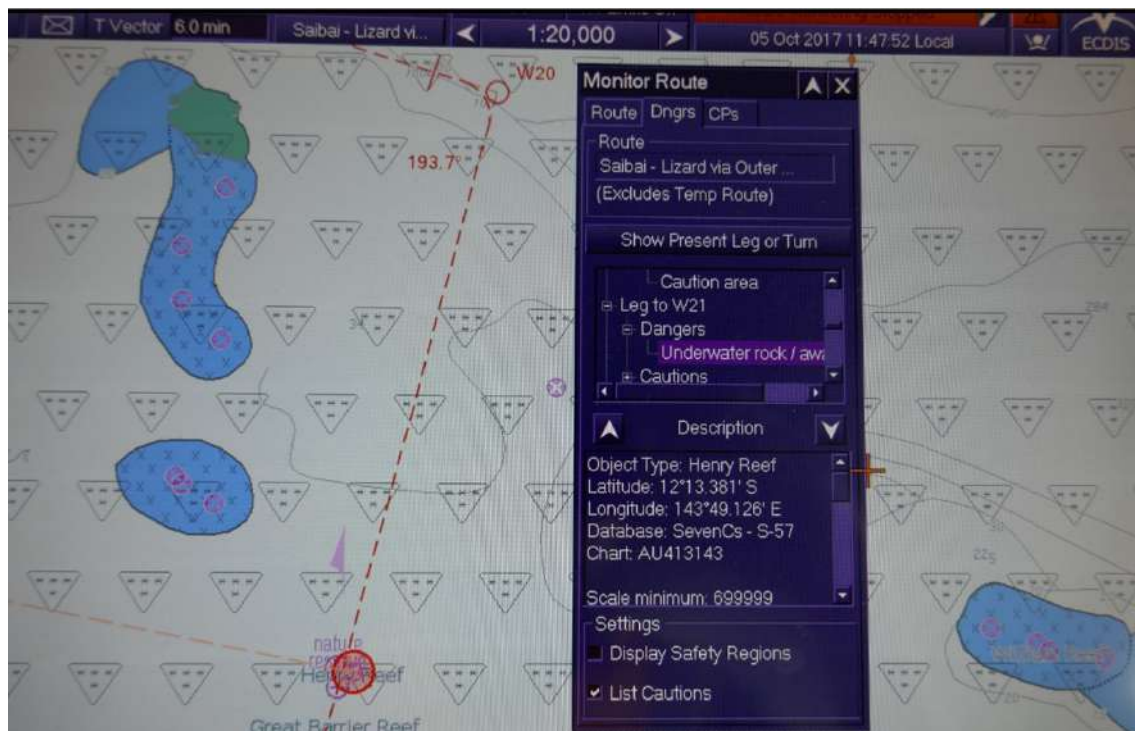


Image of *ABFC Roebuck Bay's* ECDIS showing an identified danger (Henry Reef) on the leg to W21 in the dangers tab folder of the 'Monitor Route' window. Selecting the danger highlights the reef graphically on the ECDIS display and provides available information on Henry Reef. Source: ATSB

ABFC Roebuck Bay's 'Saibai to Lizard via Outer Reef' ECDIS route plan contained about 151 cautions and nine dangers. Of the nine identified dangers, eight alerted the user to depth areas on the route where the range of depth values posed a potential hazard. The other identified danger

⁷¹ ABF ECDIS work instructions mandated a beam of 10.8 m to be set up for the cutter in the ECDIS.

was Henry Reef. ATSB tests, conducted on a VisionMaster FT ECDIS set-up based on ABF work instructions, found that the ECDIS detected Henry Reef as a route danger and listed it in the 'Edit Route' menu's dangers tab folder (Figure 29).

Figure 29: Danger identified on the amended route leg in the 'Edit Route' menu during testing

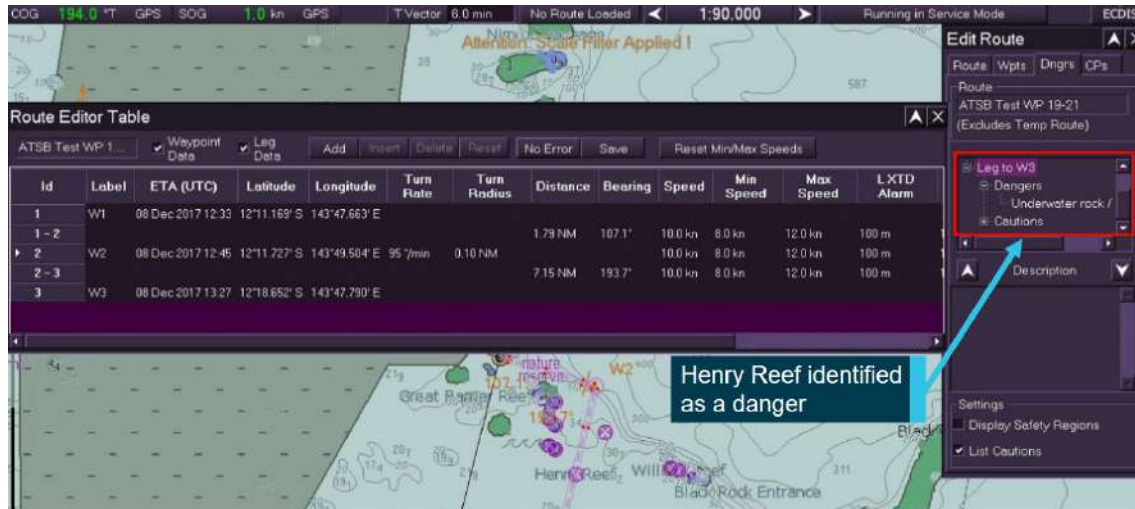


Image shows a danger (Henry Reef) identified by the ECDIS route dangers safety checking function on the amended route leg during ATSB testing. Note that the danger is not automatically highlighted on the chart and that the route validation function does not show any errors. Source: Electrotech and ATSB

Look-ahead safety checking function

Data logs were downloaded by the ATSB from *ABFC Roebuck Bay's* ECDIS after the grounding. The logs contained position, course and speed data. Alarm and alerts data from the night of the grounding had been overwritten and were not available for analysis.⁷² In the absence of a voyage data recorder, there was no other recorded data available to help establish if an ECDIS chart danger alarm was generated before the grounding.

The ECDIS manufacturer's analysis of the data logs concluded that, assuming the look-ahead function was active and no changes were made to the settings after the grounding, the data was consistent with a 20 m added breadth setting and a time-based look-ahead setting. This concurred with the interview and documentary evidence that look-ahead settings were as prescribed in the 'ECDIS Start-up Checklist'. Therefore, it was highly likely that *ABFC Roebuck Bay's* ECDIS look-ahead function safety region was set up with a time setting of 3-minutes and an added breadth of 20 m.

ATSB tests showed that the look-ahead function generated the appropriate alarms when it detected a chart danger. However, the tests also confirmed that it was possible, based on the settings applied, that the Henry Reef point feature fell outside the look-ahead safety region and that therefore, the look-ahead function did not encounter the isolated danger symbol representing the reef (Figure 30). The manufacturer's analysis also concluded that it was conceivable that the look-ahead function did not encounter the isolated danger symbol.

⁷² The manufacturer confirmed that alarm log data was not retained by the system for the same length of time as other logged data.

Figure 30: Image showing Henry Reef, undetected by the look-ahead function during testing

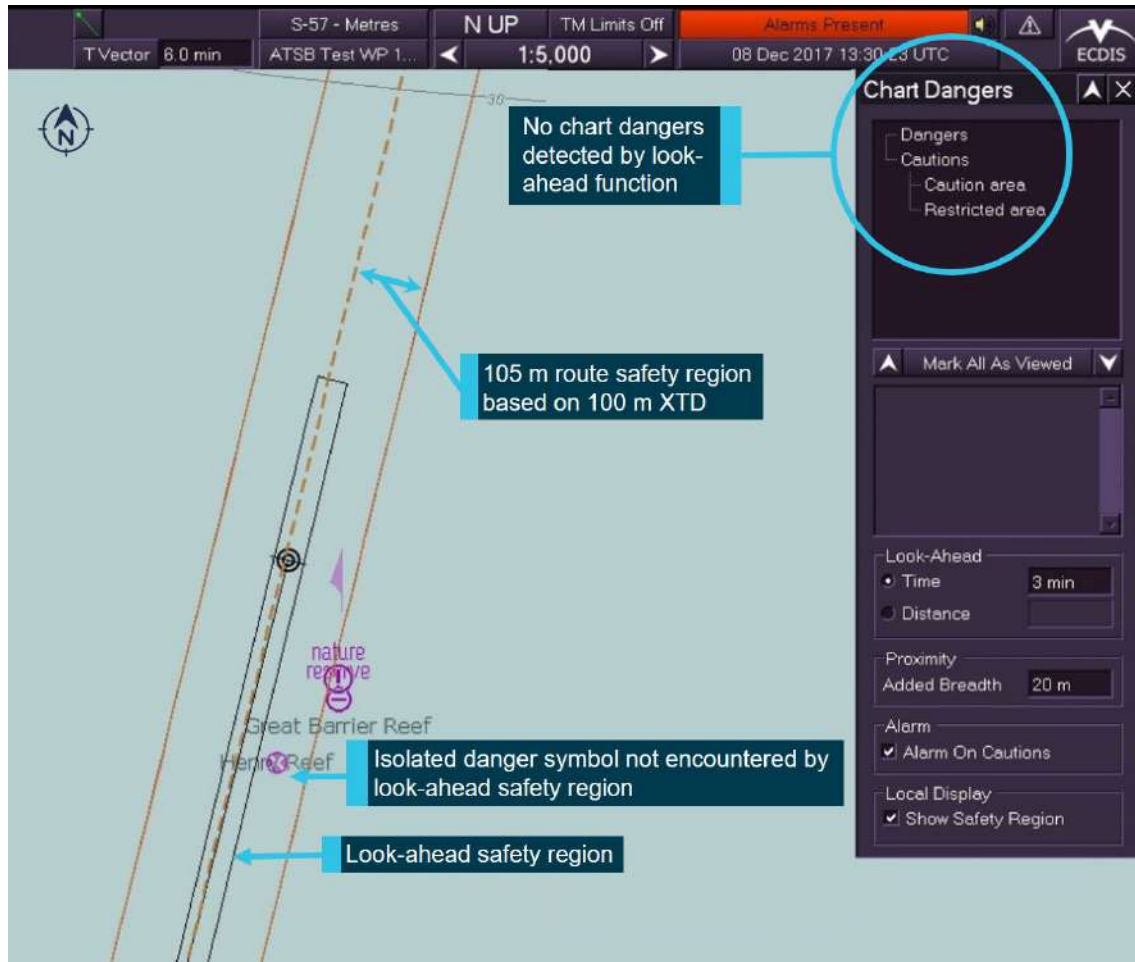


Image from ATSB testing showing Henry Reef going undetected by the ECDIS's look-ahead function when set up with a 20 m added breadth based on settings in the Annex A – ECDIS start-up checklist of the ABF work instructions.
Source: Electrotech and ATSB

ATSB tests using settings recommended in the 'restricted waters' category of the Annex C checklist in the ECDIS work instructions, namely the use of an added breadth of 0.1 NM (185 m), significantly increased the chances of the look-ahead function detecting the reef (Figure 31).

Figure 31: Image showing Henry Reef, detected by the look-ahead function during testing, based on the 'restricted waters' setting

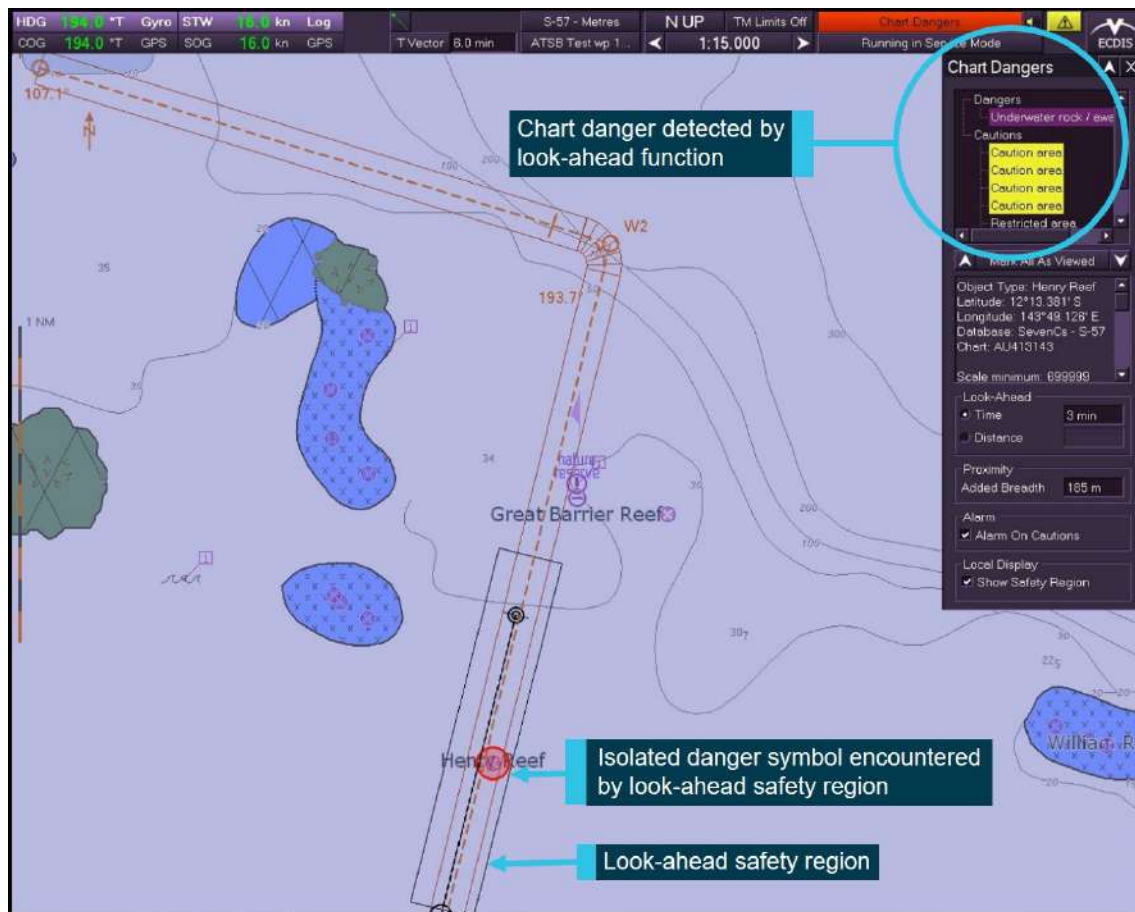


Image from ATSB testing showing Henry Reef being detected by the ECDIS's look-ahead function when set up with a 0.1 NM (185 m) added breadth based on settings in the Annex C – Restricted waters category checklist of the ABF work instructions. Selecting the danger highlights the reef graphically on the ECDIS display and provides available information on Henry Reef.

Source: Electrotech and ATSB

ATSB analysis also found the use of a 3-minute setting for the ECDIS's look-ahead function would have left limited time to take action in the event it did alert the OOW to the approaching reef. Calculations show that, given the 30-second interval of the look-ahead function, the cutter's speed of 16 knots and the actual extent of the reef in relation to its charted position (see *Charting of Henry Reef*); the OOW would potentially have had about 2 ½ minutes to take action before grounding.

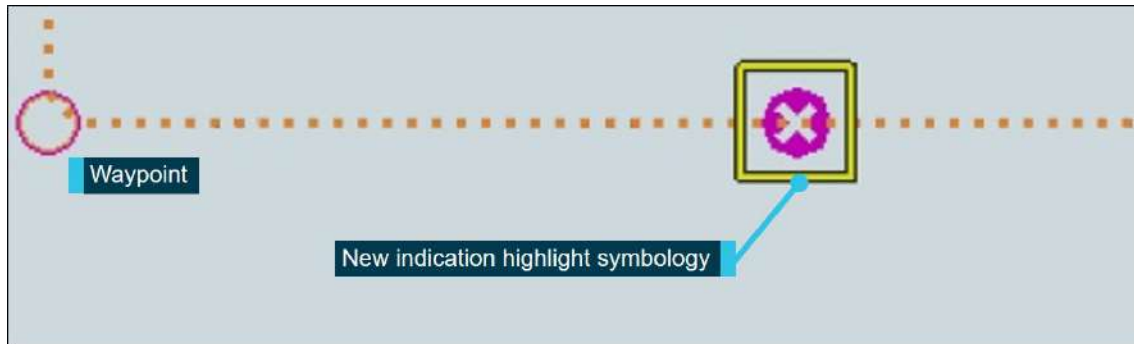
Presentation Library 4.0

The new presentation library (PresLib 4.0) introduced changes to the way in which dangers and hazards were defined and presented to the mariner on the ECDIS.

As discussed previously, the VisionMaster FT ECDIS required the user to manually check the dangers tab folder of the 'Edit Route' window to gain an awareness of dangers identified on the planned route. In order to view an identified danger on the ECDIS display, the user had to select it in the dangers tab folder.

PresLib 4.0 introduced new 'indication highlight' symbology for objects that posed a potential threat to the vessel. On ECDIS upgraded to PresLib 4.0, all navigational hazards identified on the route by the ECDIS route safety checking function could be automatically highlighted on the chart with the appropriate 'indication highlight' symbology (Figure 32). Identified hazards on the planned route could be highlighted during route planning and monitoring without the need for the user to manually select them in the danger tabs folder.

Figure 32: Route danger emphasised by new 'indication highlight' symbol in ECDIS updated to Presentation Library 4.0



Source: International Hydrographic Organization, annotated by the ATSB

In addition, one of the goals of PresLib 4.0 was to address the issue of alarm fatigue. This was achieved by the introduction of changes intended to reduce the number of alarms generated by the ECDIS look-ahead safety checking function. Under safety contour detection rules in the previous presentation library (PresLib 3.4), objects such as rocks, wrecks and obstructions (shallower than the safety contour) raised alarms by default. PresLib 4.0 introduced a new category for such objects which defined them as 'navigational hazards' and raised the appropriate indications rather than alarms, as required by the IMO performance standards.

On an updated VisionMaster FT ECDIS, alerts generated by the look-ahead function for navigational hazards such as Henry Reef were presented as a caution (by default) with a visual alert and the 'indication highlight' symbol rather than as an alarm. The VisionMaster FT gave the user the option of being able to present the cautions audibly, if required. In that case, the caution would be presented as a warning (with an audible alert that was less disruptive than that of an alarm).

PresLib 4.0 also gave the user the option of choosing whether the isolated danger symbol displayed for rocks, wrecks and obstructions in waters shallower than the safety contour whereas previously, it displayed them as such by default.

At the time of the grounding, ECDIS onboard *ABFC Roebuck Bay*, and most other ABF cutters operated with the superseded PresLib 3.4. An upgrade to the new PresLib 4.0 would have allowed *ABFC Roebuck Bay*'s bridge team access to enhanced safety features that could have aided the planning and monitoring phases of the passage plan. The visual check of the route leg from W20 to W21 would have shown Henry Reef, automatically highlighted as a navigational hazard by the new indication highlight symbol (Figure 33).

Figure 33: Images of ECDIS operating on PresLib 3.4 (left) and ECDIS updated to PresLib 4.0 showing indication highlight feature demonstrated on the amended route plan (right)

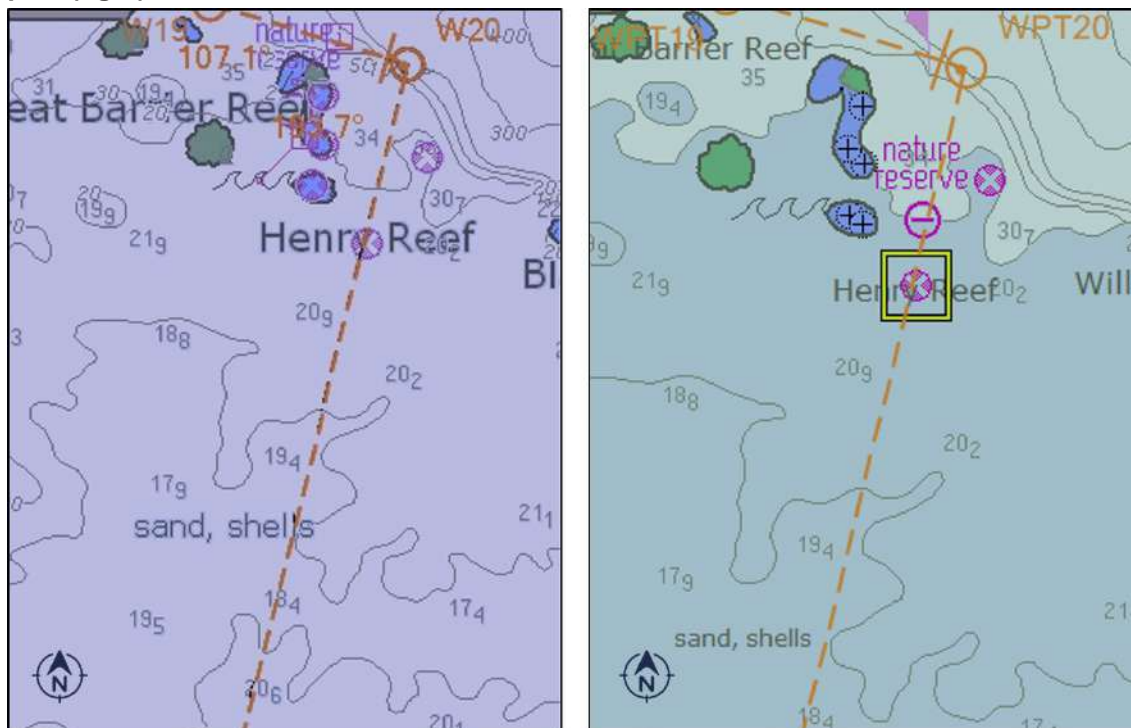


Image shows the amended route plan as it probably appeared on board ABFC Roebuck Bay (left) and as it might have appeared had the ECDIS been updated to PresLib 4.0 (right).

Source: Electrotech and Northrop Grumman Sperry Marine, modified by the ATSB

The reduction in audible alerts resulting from the implementation of PresLib 4.0 may have influenced the master to reconsider his decision to silence the audible alert buzzer. However, given the re-classification of Henry Reef as a navigational hazard in PresLib 4.0, this would have made little difference because the detection of the reef by the look-ahead function would have resulted in a caution with no accompanying audible alert. However, if it had been assessed appropriate to present cautions audibly (similar to the 'alarm on cautions' setting in the work instructions), under the new rules, the system would have generated a warning. The audible alert for a warning was less disruptive than that of an alarm. Therefore, the updated ECDIS could still have alerted the officers to the reef audibly while also reducing alarm fatigue when compared to the previous presentation library.

Point features and ECDIS safety checking functions

The use of the route checking function to check a route for dangers is a fundamental safety benefit of ECDIS. The ECDIS route check complements the visual check of the route. Where passage planning is conducted on ECDIS, the use of the route checking function is a key component of the passage planning process.

The ECDIS route safety checking function checked the route safety region against the chart database for dangers. With regard to point features, the ECDIS route safety region could only be checked against the position of the point feature regardless of the actual extent of the physical feature it represented. Essentially, the ECDIS would only identify the feature as a danger to the planned route if its charted position in the ENC fell within the route safety region.

In the case of *ABFC Roebuck Bay*, the charted position of the 'underwater/awash rock' point feature representing Henry reef lay about 55 m to the east of the planned route and fell within the route safety region (Figure 34). The ECDIS accordingly detected the reef as a danger to the planned route and identified it in the dangers tab folder for the relevant route leg.

Figure 34: ABFC Roebuck Bay's planned route and route safety region

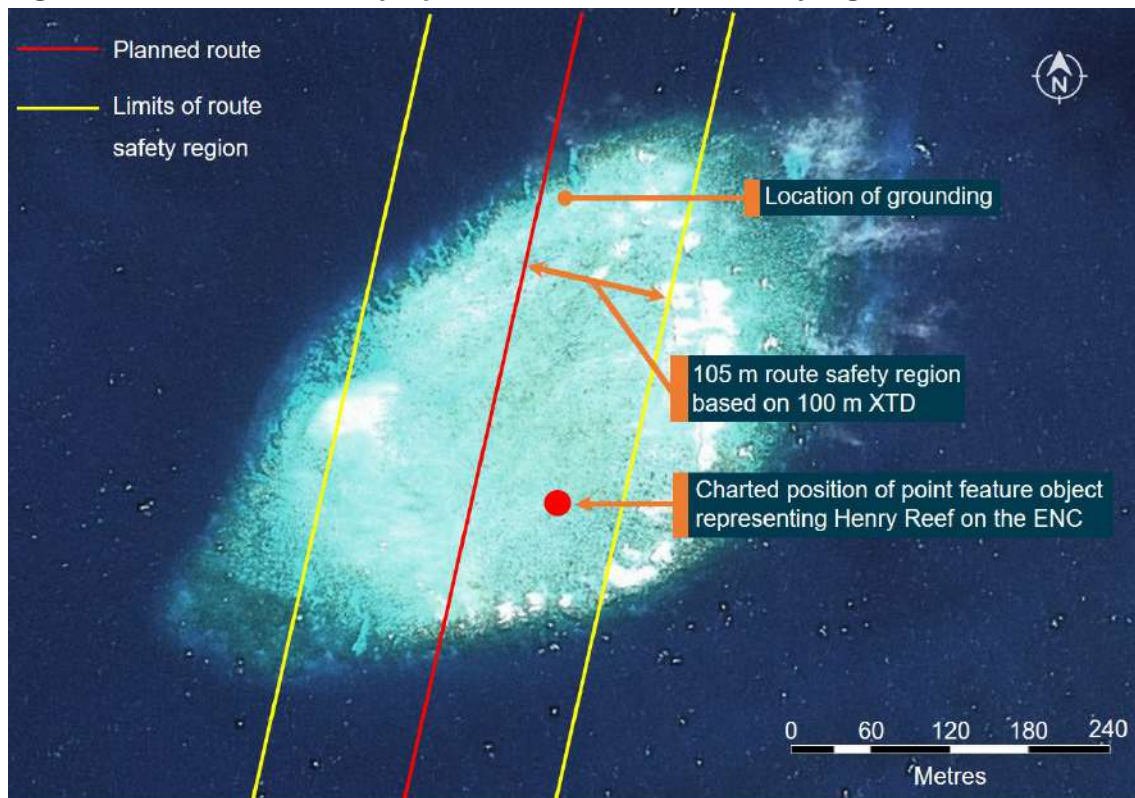


Figure showing ABFC Roebuck Bay's approximate planned route and the ECDIS route safety region based on a 100 m XTD in relation to the ENC's encoded position for Henry Reef. Note that the charted position of Henry Reef falls within the route safety region.
Source: DigitalGlobe, Esri, modified and annotated by the ATSB

However, when a point feature represents a physical feature of relatively significant size, it is possible for a part of the ECDIS route safety region to be obstructed by the feature despite its charted position falling outside the route safety region. If a hypothetical route were plotted about 55 m further to the west, the charted position of the point feature would now fall outside the ECDIS route safety region. In this case, the ECDIS would not have detected the reef as a danger to the planned route and it would not have been identified in the dangers tab folder. Nevertheless, the planned route and a significant proportion of the route safety region would remain across the reef (Figure 35). In this situation, *ABFC Roebuck Bay* would have potentially run aground with the ECDIS showing no identified dangers on the planned route. A similar scenario, and associated safety implications, would equally apply to the ECDIS look-ahead function and safety region.

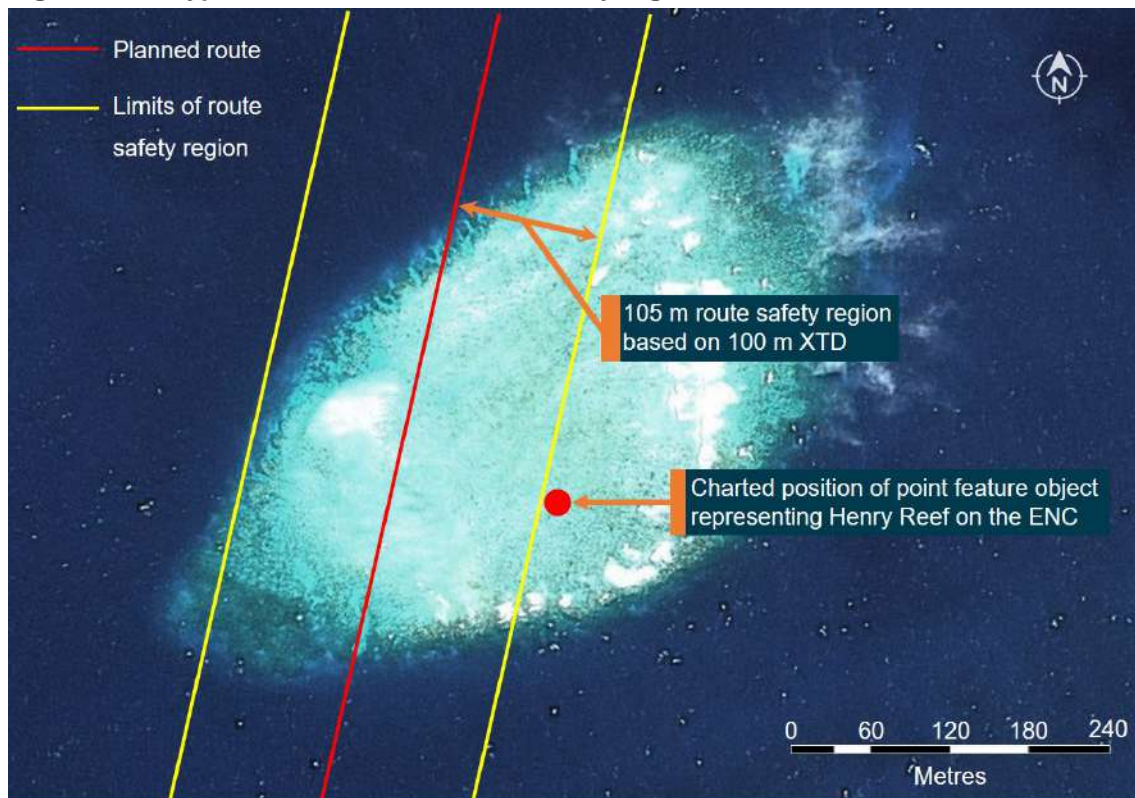
Figure 35: A hypothetical route and route safety region

Figure showing a hypothetical route laid about 55 m to the west of ABFC Roebuck Bay's planned route and the ECDIS route safety region based on a 100 m XTD. Note that the charted position of Henry Reef now falls just outside the route safety region. In this case, the route is still laid across Henry Reef but the ECDIS will not identify the reef as a danger on the route leg.

Source: DigitalGlobe, Esri, modified and annotated by the ATSB

Similar occurrences

Over the past two decades, flag administrations and agencies with a responsibility to investigate safety occurrences have investigated several groundings with certain common recurring themes.

Kea Trader

On 12 June 2017, the Malta registered container ship *Kea Trader* grounded on Durand Reef in the Pacific Ocean while on passage from Tahiti to New Caledonia. The ship's primary means of navigation was ECDIS using Japan Radio Company JAN 901-B ECDIS units. The ship's passage plan was amended during the passage with one waypoint shifted. This resulted in the amended route passing over the isolated danger symbol that represented Durand Reef (a point feature) on ENC GB204637 at a compilation scale of 1:700,000. The ship was then navigated into shallow waters where it grounded on the reef. The ship remained aground while salvage efforts ensued. On 4 December 2017, *Kea Trader* broke in two after being struck by heavy weather. At the time of writing, the ship remained stranded on Durand Reef.

Malta's Marine Safety Investigation Unit investigated the grounding and published [marine safety investigation report 14/2018](#). The investigation concluded that the revised route passed virtually over the isolated danger symbol representing Durand Reef and that the ECDIS route check function had not been enabled. It found that the second mate's observation of the symbol outside of the planned route's cross track limit of 0.5 NM due to an overscaled ECDIS display led to an incorrect assumption of safe water within the cross track limit. It also found that the detection vector (look-ahead function) settings were inadequate; the isolated danger symbol was not queried on the ECDIS, the audible alarm on the ECDIS had been switched off and that an ECDIS caution for the ship's passage into waters of CATZOC D were overlooked. The master and

navigation officer had completed generic ECDIS training and online type-specific familiarisation training.

Universal Durban

On 13 May 2017, the Malta registered bulk carrier *Universal Durban* grounded on a shoal south of the island of Pulau Serasan in the Indonesian archipelago while on passage from Australia to Malaysia. The ship's primary means of navigation was ECDIS using Furuno model FEA-2107 ECDIS units. The ship was subsequently refloated with minor damage and no pollution or injuries reported.

Malta's Marine Safety Investigation Unit investigated the grounding and published [marine safety investigation report 10/2018](#). The investigation concluded that a required ENC was inadvertently deleted while placing a chart order and that a small scale chart was being displayed on the ECDIS. The investigation found that the passage plan deviated from the designated Indonesian archipelagic sea-lanes and that there was no evidence of reference to *Admiralty Sailing Directions* during the appraisal stage of the passage planning. It also found that the OOW's visual check of the route was cursory and that the ECDIS route checking function did not trigger any navigational warnings. Significant positional and depth anomalies were also noticed on an ENC for the area. The master, second mate and third mate had all completed generic ECDIS training and type-specific familiarisation training.

Muros

On 3 December 2016, the Spain registered bulk carrier *Muros* grounded on Haisborough Sand off the East coast of England while on passage from the United Kingdom to France. The ship's primary means of navigation was ECDIS using MARiS ECDIS900 MK 10 ECDIS units. The ship's passage plan was amended by the second officer under the master's instructions about 3 hours before the grounding. This amendment resulted in the planned route passing across Haisborough Sands. The master did not check the amended passage plan and the ship followed the planned route and grounded. The ship was refloated 6 days later with damage to the rudder but no reported injuries or pollution.

The United Kingdom's Marine Accident Investigation Branch (MAIB) investigated the grounding and published [Report No. 22/2017](#). The investigation concluded that the visual check of the route was not performed on charts of an appropriate scale and that it failed to identify that the route passed over Haisborough Sand. It found that the ECDIS's route checking function identified the danger but that the function was not utilised to check the route. The investigation also found that the ECDIS audible alarm and guard zone (look-ahead function) had been disabled. All bridge watchkeeping officers had completed generic ECDIS training and online type-specific familiarisation training.

Nova Cura

On 20 April 2016, the Netherlands registered general cargo ship *Nova Cura* grounded on Lamnas Reef in the Mytilini Strait between Turkey and the Greek island of Lesbos. The ship was on a passage between the Turkish ports of Eregli and Izmir when it was required to divert to Aliaga. The ship's primary means of navigation was ECDIS. The ship's route was amended by the master to pass through the Mytilini Strait but no appraisal or further planning performed. The ship subsequently grounded on the reef although the ECDIS indicated a chart sounding of 112 m in that position. The vessel was eventually re-floated and towed to Piraeus, Greece where it was declared a total loss.

The Dutch Safety Board investigated the grounding and released a report titled, '[Digital navigation: old skills in new technology—Lessons from the grounding of the Nova Cura](#)'. The investigation found that Lamnas Reef was incorrectly marked on the Greek navigational charts. The report stated that the ENC of the area had been compiled using data from an existing paper chart and that the waters in which the ship grounded were designated CATZOC U (Unassessed).

The investigation also found that sector lights warning of the reef were marked differently on the paper charts and ECDIS. The report recommended that shipping companies amend their procedures to ensure CATZOCs were consulted during voyage planning and that all relevant voyage preparations be repeated when a route is amended. It also recommended that the IHO impose conditions on the age and reliability of data used to compile ENCs and that the IMO evaluate the inherent safety risks of ECDIS and make its practical use a factor in future development of the system.

Ovit

On 18 September 2013, the Malta registered chemical tanker *Ovit* grounded on the Varne Bank in the Dover Strait while on passage from the Netherlands to Italy. The ship's primary means of navigation was ECDIS using MARiS 900 ECDIS units. The passage plan passed directly over the Varne Bank in the English Channel. The ship refloated on a rising tide about 2 ½ hours after grounding with only minor paint damage.

The United Kingdom's MAIB investigated the grounding and published [Report No. 24/2014](#). The investigation concluded that the passage had been planned over the Varne Bank by an inexperienced, junior officer. The plan was not properly checked for navigational hazards using the ECDIS route checking function nor was it checked by the master. The investigation also found that the ECDIS audible alarm was inoperative and that several features of the MARiS 900 ECDIS were either difficult to use or appeared not to comply with international standards. All bridge watchkeeping officers had completed generic ECDIS training and type-specific familiarisation training but did not possess the level of knowledge required to operate the system effectively.

CFL Performer

On 12 May 2008, the Netherlands registered dry cargo ship *CFL Performer* grounded on Haisborough Sand off the East coast of England while on passage from Suriname to the United Kingdom. The ship's primary means of navigation was ECDIS using Furuno FEA-2107 ECDIS units. The ship's route was planned across Haisborough Sand, a shoal about 10 NM long and 1 NM wide, where the charted depth of water was considerably less than the vessel's draught. The ship grounded about 29 minutes after the OOW adjusted course to follow the ship's planned route. The ship was refloated shortly after with no reported injuries, damage or pollution.

The United Kingdom's MAIB investigated the grounding and published [Report No. 21/2008](#). The investigation concluded that the route plan was not adequately checked for navigational hazards in either the planning or monitoring stages of the passage plan process. The ECDIS's route check page was not used to check each leg of the route for navigational hazards. The investigation also found that none of the ship's bridge watchkeeping officers had been trained in the use of ECDIS and that the ECDIS's watch vector (look-ahead function) was not activated.

Design, functionality and use of ECDIS

In its investigation report into the grounding of the bulk carrier *Muros*, the United Kingdom's MAIB stated that there was increasing evidence to suggest that first generation ECDIS systems were designed primarily to comply with IMO performance standards, with insufficient attention being given to the needs of the user. It noted that, ECDIS systems were often not intuitive to use and lacked the functionality needed for accurate passage planning in confined waters. This has resulted in seafarers using ECDIS in ways which are at variance with the intended use of the system by manufacturers and/or regulators.

The effectiveness of complex technology like ECDIS depends, in large part, on the design of the technology's human-machine interface. Examples of problems encountered with regard to human-machine interaction include a lack of equipment standardisation and usability, insufficient operator

training and ignoring human factors aspects in the design of the technology.⁷³ Standards can be too general or only establish minimum requirements. Usability means that operators who use the equipment can do so quickly and easily to accomplish the required tasks. On the other hand, operator training and support is needed to make sure users are aware of the capabilities and limitations of their systems.

The design of the VisionMaster FT's route validation function, with its yellow 'Error' highlight indication, was demonstrated to be a practical and effective means of indicating the existence of errors in the route to a user. By contrast, there was no equivalent means of making the user aware of dangers on the route or of the introduction of a danger to a previously safe route. The dangers tab folder mechanism used for reconciling dangers identified on a route placed the responsibility solely on the user.

Similarly, while the ECDIS would not allow a route with errors to be loaded for monitoring, it would allow the loading and monitoring of a route with identified chart dangers. There was no system requirement for the dangers tab folder of a route to be checked before the route was released for execution and monitoring.

ECDIS safety study

As a result of several investigations into groundings, the United Kingdom MAIB, in collaboration with the Danish Maritime Accident Investigation Board, initiated a study designed to understand why operators were not using ECDIS as envisaged by the regulators and system manufacturers. The scope of the study included ECDIS development, implementation, training and lack of standardisation. The study aims to provide data that can be used to improve the design of future ECDIS systems. The findings of the study are expected in 2019, but preliminary observations⁷⁴ released have much in common with factors identified in this investigation. While ECDIS was found to contribute to safe navigation by saving time, reducing workload and allowing real-time positioning, concerns included:

- issues with alarms and disabling of alarms to avoid distraction
- duplication and relevance of alarms
- variations in the way information was grouped in different ECDIS models
- differing menu structures between systems
- variation in the quality of training
- diminished traditional skills/mental agility due to reliance on ECDIS and automatic radar plotting aids
- significant variation among certified officers in the understanding of key features such as safety contour and safety depth
- gaps in knowledge of chart symbology.

⁷³ Grech, MR, Horbery, TJ, and Koester T (2008). *Human factors in the maritime domain*. Boca Raton: Taylor and Francis.

⁷⁴ United Kingdom Marine Accident Investigation Branch (MAIB) and Danish Maritime Accident Investigation Board (DMAIB), 24 October 2018, IMO sub-committee on navigation, communications and search and rescue, NSCR 6/INF.5, Agenda item 22, Submission on safety study into use of ECDIS on board ships, IMO, London.

Safety analysis

Introduction

On 30 September 2017, shortly after midnight, Australian Border Force cutter *Roebuck Bay* (ABFC *Roebuck Bay*) grounded on Henry Reef, a charted feature in the Great Barrier Reef. The cutter sustained substantial damage but there were no reported injuries or oil pollution. ABFC *Roebuck Bay*'s officers held the appropriate qualifications for their positions and completed the mandatory ECDIS training required. Fatigue, workload, distraction and the loss of node-1 on the bridge were considered and discounted as factors that may have influenced the grounding.

As a vessel using an electronic chart display and information system (ECDIS) as the primary means of navigation, the functions, understanding and operation of the ECDIS were a central theme of this investigation. This analysis examines, among other factors, the passage planning process, the officers' understanding of the ECDIS and properties of the ECDIS and Electronic Navigational Charts (ENC).

Amended route plan

The passage plan for the voyage from Saibai Island to Lizard Island was based on a pre-existing route. This route passed through Wreck Bay and had been successfully executed as part of several previous passage plans. However, amendments made to the route, in particular, the shifting of a waypoint resulted in the amended route being inadvertently plotted across Henry Reef, which was a potential navigational danger. The detection of this potential navigational hazard (Henry Reef) relied on the checking of the route, which was an integral part of the passage planning process.

Detection of Henry Reef

Once a route has been prepared on the ECDIS, it has to be checked for dangers to ensure that it is safe. This is done by inspecting the entire route visually and by using the ECDIS route safety checking function. The ABF passage planning checklist included checks to remind officers that the ECDIS check and berth-to-berth visual check of the route was required.

Visual check of the route

According to Wickens and Flach (1988), a person's ability to gather information is critically influenced by that person's knowledge state or mental model of a task.⁷⁵ A mental model is the picture operators have in their heads of the way a system works.⁷⁶ During the visual check, the officers searched the route for dangers and obstructions based on their mental model of the expected hazards.

The officers' visual check focussed on looking for areas of green (indicating areas such as drying reefs) and areas of blue (indicating shallow water) on the amended route legs. The isolated danger symbol representing Henry Reef lay in waters shaded white indicating depths greater than 10 m.

The isolated danger symbol and its colour did not accord with ABFC *Roebuck Bay*'s master and navigation officer's mental model of coral reef symbology. They expected reefs to be represented by green areas or to be surrounded by blue shading, similar to paper chart symbology. This interpretation of chart symbology likely influenced the focus of their visual check of the route.

⁷⁵ Wickens, CD, and Flach, JM (1988). Information processing. In Werner EL and Nagel DC (Eds). Human factors in aviation (pp. 111-155). San Diego: Academic Press.

⁷⁶ Wise, JA, Hopkin, VD, and Garland, DJ (2010). Handbook of aviation human factors. Boca Raton: CRC Press.

The officers' search focus and interpretation of chart symbology implied that the chances of them visually detecting the reef on the ECDIS would have been greatly increased had it been represented by an area feature shaded green or been surrounded by blue shading. Nevertheless, Henry Reef was a charted feature, represented by an accepted, standard, international symbol—the isolated danger symbol. Therefore, had the isolated danger symbol represented an obstruction other than a reef, it was likely that the outcome on board *ABFC Roebuck Bay* would have been no different. Furthermore, the officers understood that the symbol represented a potential hazard to safe navigation and agreed that sighting the symbol on the route would have triggered further checks. However, the isolated danger symbol was not sighted and the officers remained unaware of the presence of Henry Reef on the route until after the grounding.

Another factor that may have influenced the effectiveness of the visual check was the way in which symbols and text labels were positioned on an ECDIS display based on rules in the International Hydrographic Organization (IHO) standards. The ATSB analysis showed that the symbol and label for Henry Reef could be obscured on the ECDIS display when viewed under certain circumstances and ECDIS settings.

The visual monitoring of the route, which is part of normal watchkeeping practice, also did not detect the reef. It was highly likely that the same factors that influenced the visual check of the route during the planning stage also influenced the OOW's visual monitoring of the route on the ECDIS.

ECDIS check of the route

ATSB tests and examination of *ABFC Roebuck Bay's* ECDIS established that the cutter's ECDIS detected and identified Henry Reef as a chart danger on the amended route plan. A check of the 'Edit Route' menu's dangers tab folder would have shown that Henry Reef had been identified as a chart danger on the amended route leg from waypoint 20 (W20) to waypoint 21 (W21). Selecting the listed danger would have highlighted the isolated danger symbol representing Henry Reef and displayed it graphically on the ECDIS display.

The correct use of the ECDIS route dangers safety checking function would have alerted the master and navigation officer to the presence of Henry Reef on the planned route. However, the ECDIS route dangers safety checking function was not used. An inadequate knowledge of the ECDIS safety functions (see *ECDIS knowledge* below, stemming from ineffective training (see *ECDIS type-specific training* below), supported by the incorrect belief that the ECDIS would not allow an unsafe route to be saved resulted in a route being plotted across Henry Reef and the potential danger going undetected.

The failure in the planning phase to detect that the route was plotted across Henry Reef meant that an unsafe passage had been approved for use. The next opportunity to detect the reef would be during the monitoring phase of the passage plan process.

The dangers tab folder of the VisionMaster FT ECDIS's 'Monitor Route' window replicated the information in the 'Edit Route' menu's dangers tab folder. A check of the dangers tab of the 'Monitor Route' window at any time during the passage and especially before altering course at W20 would have alerted the officer of the watch (OOW) to the presence of Henry Reef. However, the OOW's inadequate knowledge of the operation of the VisionMaster FT ECDIS and the use of its safety checking functions meant that the reef went undetected until the grounding.

This left the look-ahead function as the last barrier to preventing the grounding.

Look-ahead safety checking function

It was very likely that *ABFC Roebuck Bay's* ECDIS look-ahead safety checking function was set up according to the 'ECDIS Start-up Checklist', which prescribed a look-ahead setting of 3 minutes and an added breadth setting of 20 m.

Taking into account the 30-second interval of the look-ahead function, the charted position of the Henry Reef point feature and allowing for *ABFC Roebuck Bay*'s distance off the intended track, the 20 m added breadth setting could not guarantee the detection of Henry Reef. The manufacturer's analysis and interview evidence supported this conclusion. It was therefore considered likely that the look-ahead function, as set-up based on ABF work instructions, did not encounter the isolated danger symbol representing Henry Reef and therefore, did not generate a chart danger alarm before the impending grounding. However, had the look-ahead function's added breadth setting been wider, similar to the recommended setting for restricted waters in the Annex C checklist (0.1 NM or about 185 m), then it is very likely that Henry Reef would have been detected and a chart danger alarm generated.

The assessment that the look-ahead function likely did not detect the reef (and therefore, did not generate an alarm) is also consistent with watchkeeper recollections of the night and supported by the manufacturer's analysis of the ECDIS data logs.

In addition, the ATSB also established that, based on the cutter's speed, extent of the reef and charted position of the Henry Reef point feature, the 3-minute look-ahead setting would have offered limited time to take action in the event the system did alert the OOW to the reef.

The ECDIS audible alert buzzer

In the event the look-ahead function detected a chart danger, it would have generated an alarm with an audible and visual alert. However, the ECDIS audible alert buzzer on board *ABFC Roebuck Bay* had been permanently silenced thereby disabling audible alerts. This left the ECDIS's visual alert indicator as the only means of alerting the OOW.

ECDIS knowledge

ABFC Roebuck Bay's ECDIS identified a chart danger within the route plan's safety region; however, this information could not be acted upon because the user was not aware of it. This was because their understanding and operation of the ECDIS differed from the manufacturer's design and intended use of the system.

The cutter's master and navigation officer understood that the ECDIS had the ability to alert them to the presence of a chart danger on a planned route. However, their understanding of how the ECDIS fulfilled this function was incorrect. They believed that the route validation process' 'Error' function fulfilled this expectation. They expected that a danger identified on the route would generate a highlighted 'Error' message, which would prompt them to check the dangers tab folders. They also expected that the ECDIS would not allow them to save a route plotted across a chart danger, which likely provided a false sense of safety. *ABFC Roebuck Bay*'s officers did not have an adequate knowledge of the operation, capabilities and limitations of the VisionMaster FT ECDIS. Their expectations of the system's capabilities were inaccurate and they depended on it to prevent them from having an accident in situations where the system was not capable of doing so.

The VisionMaster FT ECDIS met the minimum required standards for ECDIS. However, in this case, its design and usability did not meet the expectations of its users. A design taking into account the human factors of how mariners actually use the system in practice, including the user's expectations can facilitate the interaction between the system and its users. This can significantly reduce the probability of erroneous actions thereby improving safety.⁷⁷ The users in turn, were not equipped with adequate knowledge of the system's capabilities and limitations, which would have allowed them to use the system as designed and intended by the manufacturer.

⁷⁷ Abeyisiriwardhane, Lützhöft, & Enshaei, 2014, *Human factors in ship design: Exploring the bottom rung*, cited in Olstedal, HA and Lutzhoft, M, 2018, *Managing Maritime Safety* (eds). Oxon: Routledge

ECDIS type-specific training

The VisionMaster FT ECDIS type-specific familiarisation training provided by Safebridge included a tutorial phase, which covered the relevant aspects of the system's route validation process and route safety checking functions. This training should have provided *ABFC Roebuck Bay's* officers with the correct understanding and working knowledge of the ECDIS. However, the training, as undertaken by ABF officers, did not require the tutorial phase of the training to be undertaken prior to progressing to the test phase.

Further, the use of personal computers to undertake the training, in some cases outside of work hours, using poor internet connections, also likely influenced the effectiveness of the training. Evidence from almost all the ABF officers interviewed was consistent and indicated that the online type-specific familiarisation training was poor and relatively ineffective. This meant that most officers, including *ABFC Roebuck Bay's* master and navigation officer, relied on training and instructions from their peers (trickle down training) for their practical understanding of the use and functions of the ECDIS.

Consequently, the type-specific training provided to ABF officers was ineffective in transferring the knowledge required to operate the VisionMaster FT ECDIS safely and effectively at sea.

ECDIS continuation familiarisation training

The ABF ECDIS work instructions required that all members of the bridge team undertake initial and annual continuation familiarisation training on their vessel's specific type of ECDIS and radar. However, there was no evidence of this training requirement being consistently implemented across the ABF fleet. Furthermore, the ECDIS route checking function was incorrectly described in the ECDIS continuation familiarisation training checklist. This appeared to indicate that the incorrect understanding of these functions likely extended beyond *ABFC Roebuck Bay*.

ECDIS start-up checklist

All ABF vessels were required to comply with ABF work instructions, which formed part of the organisation's safety management system. The ECDIS work instructions applied to all ABF vessels using ECDIS as the primary means of navigation and was therefore, applicable to *ABFC Roebuck Bay*. Annexes to the ECDIS work instructions contained two checklists relating to ECDIS settings—an 'ECDIS Start-up Checklist' (Annex A) and an 'ECDIS Recommended Information Layers' checklist (Annex C).

At the time of the grounding, the cutter was reported to have been set up according to the 'ECDIS Start-up Checklist'. There were no specific instructions or guidance in the work instructions as to the applicability, documentation or retention of this checklist for record-keeping purposes. The checklist was used by the navigation officer to assist with the set-up of the ECDIS at the commencement of the patrol and after a system restart. However, certain ECDIS settings in the checklist likely reduced the effectiveness of the ECDIS. For example:

- The use of the 5 m setting for both the safety depth (safety contour) and shallow contour values reduced the benefit of the ECDIS four colour display by reducing it to only three colours.
- The requirement for the 'Alarm on cautions' function would have increased the number of alarms generated by the ECDIS, and thereby increasing the likelihood of 'alarm fatigue' and the chance that the audible alert buzzer was silenced.
- The use of the default 20 m breadth setting in the look-ahead function (rather than a wider value) was likely to have influenced the effectiveness of the look-ahead function detecting Henry Reef (see *Detection of Henry Reef* above).

A separate checklist, in Annex C to the work instructions, comprised three lists of ECDIS settings categorised according to the navigational nature of the waters the cutter was operating in—

restricted waters, coastal waters and open ocean. The work instructions contained no guidance on the applicability or use of this checklist.

The lack of guidance on the use of checklists in the ABF work instructions meant that there was no consistent means of interpreting or applying the annexed checklists. While certain settings in the ECDIS start-up checklist may have reduced the effectiveness of the ECDIS for this passage, the look-ahead settings in the Annex-C restricted waters checklist may have allowed for a more effective look-ahead safety checking function. However, there was no clear guidance or instructions on the adaptation of the ECDIS settings to suit the changing navigational conditions, as described in Annex C of the work instructions.

ECDIS survey and certification

The ECDIS onboard *ABFC Roebuck Bay* was installed and operated with a non-type-approved naval ECDIS software. After installation, the cutter was surveyed and subsequently certified by DNV GL, on behalf of the Australian Maritime Safety Authority, as using a type-approved (commercial) ECDIS as its primary means of navigation. The type-approval certificate provided to DNV GL as part of the survey process was for a different software version to that installed on board. This meant there was a discrepancy between the ECDIS equipment installed on board and the ECDIS specifications based on which the cutter was certified. Further inquiries found that at least nine other ABF cutters were fitted with ECDIS operating on non-type-approved naval software, but were certified by DNV GL as using type-approved ECDIS to meet the chart carriage requirements of the regulations.

DNV GL were not made aware that non-type approved software was in use either during the survey or after. Nevertheless, the survey and certification process afforded an opportunity to identify that *ABFC Roebuck Bay*'s ECDIS did not meet the type-approval requirement of the regulations. Had this been identified, steps could have been taken to determine the potential risks associated with the use of a non-type-approved system. If it was determined that the naval ECDIS software was essential to the safe operation of ABF vessels, controls could have been put in place to ensure that the non-type-approved naval ECDIS maintained on-going safety compliance equivalent to the commercial variant. One such possible mechanism might have been the use of an ABF vessel management plan. This would have allowed appropriate risk mitigation measures to be devised, documented and acknowledged by AMSA. However, *ABFC Roebuck Bay* did not have a vessel management plan in place until November 2017 and other ABF vessel management plans did not include any reference to ECDIS.

ECDIS software

PresLib 4.0 was introduced by the IHO in order to address display anomalies associated with the previous presentation library and to improve ECDIS usability at sea. Among the benefits of PresLib 4.0 were the addition of a number of new symbols, safety features and functionality as well as the introduction of a new alert model to address the issue of alarm fatigue while maintaining safety at sea.

When the ECDIS manufacturer released the Presentation Library 4.0 (PresLib 4.0) software update for the type-approved commercial VisionMaster FT ECDIS in April 2017, there was no equivalent update for the naval version. Guidance from the manufacturer indicated that only vessels required to comply with SOLAS were affected by the required upgrade to PresLib 4.0. It advised that naval systems and other non-type-approved products were not affected. However, as a regulated Australian vessel, the ECDIS onboard *ABFC Roebuck Bay* and other ABF cutters needed to meet SOLAS requirements, as referenced in the relevant AMSA marine orders. Therefore, the ECDIS needed to be type-approved and maintained to be compliant with the latest applicable standards of the IHO in order to meet the chart carriage requirements of the regulations.

The consequence of *ABFC Roebuck Bay* operating on the non-type-approved naval version was that there was no update to PresLib 4.0 available by the compliance date of 31 August 2017. As a result, the cutter's officers did not have access to the enhanced safety features offered by PresLib 4.0, such as the new 'indication highlight' symbol that could have aided the planning and monitoring phases of the passage plan. The visual check of the route leg from W20 to W21 would have shown Henry Reef, automatically highlighted as a navigational hazard by the indication highlight symbol (see Figure 33) and would likely have alerted the officers to the presence of the reef.

ENCs and hydrography

Paper charts were compiled at fixed scales with symbols, text and other information, placed by the cartographer to provide the best possible presentation for the various purposes of the mariner.

Advances in technology facilitated the development of electronic charts and chart display systems. While raster charts retained the familiar characteristics of paper charts, vector charts offered significant new features and functionality. ECDIS offered users the ability to monitor the position and progress of their vessel in real time. However, it also introduced new risks inherent to ECDIS that did not exist with paper charts.

The nature of the ECDIS chart display as a computer-generated image meant there were fundamental differences between the presentation of ENC data and the paper chart, particularly in the shape, colour, size and behaviour of symbols and in the placement of text. The ability to personalise the chart display also introduced the risk of vital information being lost if the system was not configured correctly.

The requirement for official charts also placed pressures on hydrographic offices to produce ENCs for their areas of responsibility. As a result, many ENCs were produced by a direct conversion from existing paper charts. While the use of such charts on ECDIS with electronic position fixing systems gave the impression of highly accurate navigation, the content and accuracy of these new ENCs still reflected that of the original paper charts. Further, the ability to zoom in while text and symbols stayed the same size could result in a false sense of safety that did not reflect reality.

Many of these risks are recognised but current control measures only extend as far as making the mariner aware of them, through system warnings, training or the use of barriers. Warning operators of the intrinsic risks or issues with a system is the least effective control measure. While training aims to implement best practice among crewmembers, it does not completely eliminate the problem and barriers can be bypassed, removed or subject to failures.⁷⁸

The ATSB acknowledges the challenges faced by hydrographic offices, ECDIS manufacturers, regulators and training providers in the transition to navigation with ECDIS. However, the ultimate aim must be to eliminate significant risk or at least reduce them to an acceptable level in terms of navigational safety. The goal must be to provide mariners with ECDIS and charts that are capable of being used as humans would expect to use them.

ENC AU413143

The ENC in use at the time of the grounding, AU413143 was compiled from data captured directly from the pre-existing paper chart of the area, Aus 836. The ENC was compiled based on rules in the relevant IHO standards and rules and was independently validated. Henry Reef was an identified, surveyed feature, represented on the paper charts and ENCs of the area albeit by different symbols. The reef was represented as a point feature on both chart formats—using the 'coral pinnacle' symbol on the paper chart and by the 'underwater/awash rock' symbol or the isolated danger symbol, on the ENC.

⁷⁸ Oltedal, HA and Lutzhoft, M (2018). *Managing Maritime Safety* (eds). Oxon: Routeledge.

Point features and chart symbology

Henry Reef was represented by a point feature object on the ENC. This meant that an area on the earth's surface was represented by a single point in the ENC database with a visual symbol.

The ECDIS's ability to allow the ENC to be displayed at scales larger than the compilation scale is a function likely often used by mariners and provides additional advantages over passive paper charts. However, it also introduced an inherent risk that was not present in paper charts. At compilation scale, the visible size of the point feature's symbol is generally representative of the size of the physical feature it depicts. However, when the ENC is viewed at scales larger than the compilation scale, point features representing rocks, wrecks and obstructions appear progressively smaller in relation to the physical size of the features they represent. During route planning, this can give the impression that the obstruction is clear of the route or further away from it than is actually the case. There was no evidence to suggest that this was a factor in the grounding of *ABFC Roebuck Bay*. Nevertheless, navigation and route planning on ECDIS near point feature objects representing rocks, wrecks and obstructions requires particular caution, especially when the ENC is being viewed at scales larger than the compilation scale.

Electronically, the ECDIS route checking function treats a point feature as a single point with no consideration of the area covered by the symbol at compilation scale. This can reduce the effectiveness of the ECDIS route checking and look-ahead functions. It can result in situations where a vessel's planned route lies across an obstruction while the charted position of the point feature remains outside the route safety region and therefore, goes undetected by the ECDIS. In *ABFC Roebuck Bay*'s case, Henry Reef was within the ECDIS route safety region and was clearly identified by the ECDIS as a danger. Therefore, this factor did not influence the grounding. Nevertheless, the use of point feature objects to represent physical features on the earth's surface can adversely affect the ECDIS's ability to detect navigational hazards affecting the planned route and can increase the risk of the hazard posed by such features being misinterpreted by mariners.

While the above analysis focused on Henry Reef, the use of a point feature to represent any potential navigational hazard of significant size in any ENC increases the risk of grounding when mariners use those ENCs. As may be inferred from the investigation into the grounding of *Kea Trader* in the Pacific Ocean, the use of point features to represent reefs or rocks of significant area can be shown to be linked to a significant grounding elsewhere.

ECDIS overscale indications

The VisionMaster FT ECDIS user manual indicated that a display overscale prompt and pattern was displayed on the ECDIS whenever any chart on the display was viewed at more than twice its compilation scale. However, during ATSB testing, the prompt appeared but there was no overscale pattern displayed on ENC AU413143 regardless of the scale at which it was viewed.

There was no evidence to suggest that the absence of the overscale pattern influenced the passage planning or route monitoring on board *ABFC Roebuck Bay*. However, the absence of the pattern could potentially be misleading to users of the VisionMaster FT ECDIS who were guided by the manual and accustomed to the overscale pattern as a safety precaution.

Emergency preparedness and response

Accounts of *ABFC Roebuck Bay*'s grounding and of the immediate events that followed were indicative of a calm, well-drilled response to the emergency. Damage control measures implemented were effective in stabilising the vessel, controlling water ingress and preventing further damage to the cutter. The master, officers and crew demonstrated high standards of seamanship in their emergency preparedness and response to the grounding.

The subsequent response, re-floating and safe recovery of the cutter to Cairns involved the coordinated actions of several different organisations, vessels and aircraft. The tasking of

assisting vessels, including *Coral Knight*, was timely and effective in the successful recovery of *ABFC Roebuck Bay*.

Findings

From the evidence available, the following findings are made with respect to the grounding of *ABFC Roebuck Bay* on Henry Reef, Queensland on 30 September 2017. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance.

A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Contributing factors

- The amended route plan for the passage from Saibai Island to Lizard Island was inadvertently plotted across Henry Reef, which was a potential navigational danger.
- The deck officers did not visually identify Henry Reef as a navigational danger on the ECDIS display during the passage planning and monitoring processes. The effectiveness of the visual check was likely influenced by a misinterpretation of chart symbology and possible obscuration of the reef's chart symbol and label. In addition, although the ECDIS detected Henry Reef as a navigational danger, this system function was also not correctly utilised. This was in part due to an expectation that the ECDIS would not save a route plotted across a chart danger and because of a misunderstanding of the ECDIS safety checking functions.
- It was likely that the ECDIS look-ahead function, as set-up based on ABF work instructions, did not encounter the isolated danger symbol representing Henry Reef and therefore, did not generate a chart danger alarm before the impending grounding. Furthermore, the ECDIS audible alert buzzer was permanently muted leaving the ECDIS's visual alert indicator as the only means of alerting the officer of the watch.
- The deck officers on board *ABFC Roebuck Bay* did not have an adequate level of knowledge to operate the VisionMaster FT ECDIS as the cutter's primary means of navigation.
- **Although the online VisionMaster FT ECDIS type-specific familiarisation training included the relevant content, the training as undertaken by Australian Border Force deck officers was not effective in preparing *ABFC Roebuck Bay*'s officers for the operational use of the ECDIS. [Safety issue]**
- The ABF ECDIS start-up checklist included settings that likely reduced the ECDIS's effectiveness and contained no guidance on the adjustment of these settings to suit the changing navigational environment. These settings included:
 - a 20 m look-ahead added breadth setting
 - same depth value for safety contour and shallow contour settings
 - the requirement that cautions be presented as alarms.
- **Most Australian Border Force cutters, including *ABFC Roebuck Bay*, were installed with ECDIS operating on non-type-approved naval software. Subsequently, DNV GL, acting on behalf of the Australian Maritime Safety Authority, incorrectly certified these vessels as using type-approved ECDIS to meet the chart carriage requirements of the regulations. This removed an opportunity to put in place controls to ensure ongoing safety compliance. [Safety issue]**
- **ECDIS on board most Australian Border Force cutters, including *ABFC Roebuck Bay*, operated with a non-type-approved naval software version that was not updated to the latest applicable standards of the International Hydrographic Organization. The ECDIS therefore did not comply with the minimum requirements of an ECDIS being used to meet the chart carriage requirements of the regulations. As a result, the enhanced**

safety features of the new presentation library, which would have potentially alerted the officers to the danger posed by the reef, were not available. [Safety issue]

Other factors that increased risk

- ABF officers were not consistently provided with annual ECDIS continuation familiarisation training required by ABF procedures. Training resources referenced in the procedures contained incorrect guidance for the use of the VisionMaster FT ECDIS's route checking functions.
- **The hydrographic use of point feature objects to represent physical features of relatively significant spatial extent on an Electronic Navigational Chart can increase the risk of the hazard posed by such features being misinterpreted by mariners and potentially reduce the effectiveness of the ECDIS safety checking functions. [Safety issue]**
- The ECDIS did not display a chart overscale pattern when Electronic Navigational Chart AU413143 was viewed at scales larger than twice the compilation scale, as stated in the ECDIS manual. However, the ECDIS did display a text prompt when the chart was viewed at scales larger than its compilation scale.

Other findings

- The Electronic Navigational Chart AU413143 was compiled by the Australian Hydrographic Office to International Hydrographic Organization standards and was based on data captured directly from the paper navigational chart Aus 836. Henry Reef was a charted geographical feature represented as a point feature object on both the paper and Electronic Navigational Charts of the area.
- The master, officers and crew of *ABFC Roebuck Bay* demonstrated high standards of seamanship in their emergency preparedness and response to the grounding. Subsequent response efforts involving the Australian Maritime Safety Authority, *Coral Knight* and other assisting vessels and aircraft were timely and effective in the safe recovery of the cutter.

Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the [aviation, marine, rail - as applicable] industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

The initial public version of these safety issues and actions are provided separately on the ATSB website to facilitate monitoring by interested parties. Where relevant the safety issues and actions will be updated on the ATSB website as information comes to hand.

ECDIS familiarisation

Safety issue number:	MO-2017-009-SI-01
Safety issue owner:	Australian Border Force
Operation affected:	Marine: Shipboard operations
Who it affects:	Australian Border Force deck officers

Safety issue description:

Although the online VisionMaster FT ECDIS type-specific familiarisation training included the relevant content, the training as undertaken by Australian Border Force deck officers was not effective in preparing *ABFC Roebuck Bay's* officers for the operational use of the ECDIS.

Status of the safety issue

Issue status:	Safety action pending
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Proactive safety action

Action taken by:	Australian Border Force
Action number:	MO-2017-009-NSA-004
Action date:	14 June 2019
Action type:	Proactive safety action
Action status:	Monitor

Safety action taken: The Australian Border Force (ABF) have advised the ATSB of the following safety action taken in relation to ECDIS training:

- the Maritime Operational Compliance team will be undertaking training and information sessions with all deck watchkeepers during compliance audits and operational assessments
- compliance audits will include assessments of watchkeeper knowledge of ECDIS and radar operations/functions

- training documentation updated, including ECDIS information and annual familiarisation requirements
- annual ECDIS and radar training package and checklists drafted, implemented and to be undertaken by all deck watchkeepers
- information to increase knowledge and awareness of isolated danger symbols, their presentation and interaction with ECDIS has been incorporated into training packages
- the process of 'class specific' endorsement has been strengthened with the implementation of task books for each role to reduce trickle down training
- training documentation specific to the role of navigation officer has been updated
- ongoing ABF efforts to implement a program for senior watchkeepers to visit the Australian Hydrographic Office (AHO)
- ongoing work with the ECDIS manufacturer and service provider to improve the ECDIS type-specific familiarisation training.

ATSB comment: The ATSB acknowledges the safety action taken by the ABF to improve ECDIS knowledge within the fleet. The ATSB will monitor ABF progress on ongoing safety action related to the ECDIS type-specific familiarisation training and, once completed, will re-assess the safety issue.

Vessel survey and certification

Safety issue number:	MO-2017-009-SI-02
Safety issue owner:	Australian Maritime Safety Authority
Operation affected:	Marine: Shore-based operations
Who it affects:	Australian flagged vessels

Safety issue description:

Most Australian Border Force cutters, including *ABFC Roebuck Bay*, were installed with ECDIS operating on non-type-approved naval software. Subsequently, DNV GL, acting on behalf of the Australian Maritime Safety Authority, incorrectly certified these vessels as using type-approved ECDIS to meet the chart carriage requirements of the regulations. This removed an opportunity to put in place controls to ensure ongoing safety compliance.

Status of the safety issue

Issue status:	Adequately addressed
Justification:	Customs vessel management plans now capture the fact that most ABF cutters are installed with ECDIS operating on non-type-approved naval software. In future, this will allow steps to be taken to ensure that the ABF ECDIS equipment maintains safety compliance equivalent to the type-approved commercial systems or, will at least allow for an appreciation of any risks related to delays in maintaining up to date safety compliance.

The Australian Maritime Safety Authority's (AMSA) notification to other Recognised Organisations will serve to highlight the importance of ensuring that ECDIS equipment is only used as the primary means of navigation when it meets the requirements of the regulations.

Proactive safety action

Action taken by:	Australian Maritime Safety Authority
Action number:	MO-2017-009-NSA-007
Action date:	4 June 2019
Action type:	Proactive safety action
Action status:	Closed

Safety action taken: The Australian Maritime Safety Authority advised the ATSB of the following safety action taken to address the vessel survey and certification safety issue:

- AMSA confirmed that the ABF and DNV GL coordinated and carried out the required hardware and software upgrades to ensure the cutters were updated to the latest applicable standards of the International Hydrographic Organization (IHO)
- at AMSA's request, DNV GL commenced an internal review of their processes. The results of the review will be provided to AMSA for consideration when it is completed
- AMSA received confirmation that the ABF safety management system, under the Customs vessel management plan, captured the safety issue in order to prevent recurrence
- AMSA notified all Recognised Organisations, reminding them of their responsibility to ensure that the requirement that an ECDIS is only compliant when installed and operated in accordance with the type approval issued, is met.

ECDIS software

Safety issue number:	MO-2017-009-SI-03
Safety issue owner:	Australian Border Force
Operation affected:	Marine: Shipboard operations
Who it affects:	Operators of Australian Border Force cutters

Safety issue description

ECDIS on board most Australian Border Force cutters, including *ABFC Roebuck Bay*, operated with a non-type-approved naval software version that was not updated to the latest applicable standards of the International Hydrographic Organization. The ECDIS therefore did not comply with the minimum requirements of an ECDIS being used to meet the chart carriage requirements of the regulations. As a result, the enhanced safety features of the new presentation library, which would have potentially alerted the officers to the danger posed by the reef, were not available.

Status of the safety issue

Issue status:	Adequately addressed
Justification:	The upgrade of ECDIS on board ABF cutters serves to bring the vessels into alignment with the latest applicable standards of the International Hydrographic Organization (IHO). The update to PresLib 4.0 ensures that ABF watchkeepers now have the benefit of the improved user experience, new symbols, enhanced safety features and reduction in audible alerts that was the intended purpose of the new presentation library.

Proactive safety action

Action taken by:	Australian Border Force
Action number:	MO-2017-009-NSA-005
Action date:	27 September 2018
Action type:	Proactive safety action
Action status:	Closed

Safety action taken: The ABF advised the ATSB of safety action, undertaken to update the ECDIS on board all ABF cutters to the S-52 Presentation Library 4.0. The ECDIS manufacturer, Northrop Grumman Sperry Marine, provided a software update for the VisionMaster FT Naval Total Watch system in May 2018. The ABF commenced a program of hardware upgrades along with software installation in June 2018. By September 2018, all ABF cutters operating with ECDIS were updated to the latest applicable standards of the IHO.

Hydrographic use of point features

Safety issue number:	MO-2017-009-SI-04
Safety issue owner:	Australian Hydrographic Office
Operation affected:	Marine: Shore-based operations
Who it affects:	Vessels using Australian Electronic Navigational Charts

Safety issue description

The hydrographic use of point feature objects to represent physical features of relatively significant spatial extent on an Electronic Navigational Chart can increase the risk of the hazard posed by such features being misinterpreted by mariners and potentially reduce the effectiveness of the ECDIS safety checking functions.

Status of the safety issue

Issue status:	Adequately addressed
Justification:	Australian Hydrographic Office (AHO) work to remediate the existing Australian ENC portfolio by encoding circular obstruction area features at the same location as applicable point features significantly reduces the risk identified by this safety issue. While the new area feature does not specifically reflect the shape and extent of Henry Reef, it nevertheless reduces the risk of the reef not being detected, both visually and when using the ECDIS. The challenges involved in charting all possible area features to the standard desired by users with specialised needs are significant. However, close engagement between such users and hydrographic service providers can help prioritise waters where better hydrographic detail may be required.
	The information published by the AHO will serve to improve the general awareness among mariners of the potential risks of using over-scaled ECDIS displays near point features representing rocks, wrecks and obstructions. It will also aid to improve users' understanding of chart accuracy. The submission of this publication to the IHO for consideration as an IHO standard provides an opportunity to raise awareness of this safety issue on an international level.

Proactive safety action

Action taken by:	Australian Hydrographic Office
Action number:	MO-2017-009-NSA-006
Action date:	21 March 2019
Action type:	Proactive safety action
Action status:	Closed

Safety action taken: The Australian Hydrographic Office (AHO) has undertaken work to remediate the existing ENC portfolio by setting up a dedicated project team to encode obstruction area features at the same location as underwater rock and obstruction point features. An initial search revealed approximately 2,200 such features affecting about 243 ENCs. The project commenced in December 2018 and involved creating an obstruction area the same size as the isolated danger symbol, while also retaining the latter. This means that within the ECDIS, the symbol behaves electronically in the same way as it looks visually. The project was completed in March 2019 and the issue was raised with the IHO.

In addition, the AHO has advised the ATSB that they have published a supplement to the Seafarers Handbook for Australian Waters (AHP 20) to address a number of misconceptions amongst mariners regarding the accuracy of bathymetry within Electronic Navigational Charts (ENCs) and the impact that accuracy should have upon route planning and conduct. The supplement also addresses the dangerous effects of over-scaled ECDIS displays near features such as isolated danger symbols (Appendix F). The content of this supplement will be fully incorporated as a new chapter into the new edition of the handbook (Edition 5), due for publication in 2019. The content has also been offered to the IHO for publication as an IHO standard.

Additional safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Australian Border Force

The ABF have conducted a review of work instructions related to the use of ECDIS and radar, bridge watchkeeping and passage planning. The ECDIS work instructions have been updated to reflect the findings of the ATSB investigation into the grounding of *ABFC Roebuck Bay* and address the conflicting information in the annexes. The look-ahead added breadth setting has been increased to a setting of 200 m on either side of the ship. The updated work instructions were published in March 2019.

The ABF also advised that a navigation and ECDIS specific section has been included in the annual internal audit package.

Northrop Grumman Sperry Marine

In order to provide mariners more time to react to information, Northrop Grumman Sperry Marine has increased the frequency of the look-ahead danger checking function from every 30 seconds to every 15 seconds. This change was made in version 11 of the VisionMaster FT ECDIS (released in December 2018).

The ECDIS manufacturer advised the ATSB that a more recent software version showed the overscale pattern being generated on ENC AU413143 when viewed at scales larger than twice the compilation scale, as described in the ECDIS user manual.

General details

Occurrence details

Date and time:	30 September 2017 – 0025 EST	
Occurrence category:	Accident	
Primary occurrence type:	Grounding	
Location:	Henry Reef, 45 NM north-east of Lockhart River, Queensland	
	Latitude: 37° 13.25' S	Longitude: 143° 49.13' E

Ship details

Name:	<i>ABFC Roebuck Bay</i>
IMO number:	9193094
Call sign:	VNZJ
Flag:	Australia
Classification society:	DNV GL
Ship type:	Patrol vessel
Builder:	Austal Ships
Year built:	1999
Owner(s):	Australian Border Force
Manager:	Border Force Capability Division, Australian Border Force
Gross tonnage:	240
Displacement:	134 t
Draught:	1.85 m
Length overall:	38.2 m
Measured length:	34.95 m
Moulded breadth:	7.2 m
Moulded depth:	4.5 m
Main engine(s):	Twin MTU 16V 2000 M70
Total power:	2100 kW
Speed:	24 knots
Damage:	Hull breach resulting in flooding of two compartments and damage to stabiliser fins, skegs, propellers and rudders.

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- ABFC Roebuck Bay's deck officers
- Australian Border Force (ABF)
- Australian Maritime Safety Authority (AMSA)
- Northrop Grumman Sperry Marine (NGSM)
- Australian Hydrographic Office (AHO)
- Electrotech (ECDIS sales and service providers)
- DNV GL
- Great Barrier Reef Marine Park Authority (GBRMPA)
- REEF VTS
- Maritime Safety Queensland (MSQ).

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Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003 (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the Australian Border Force, *ABFC Roebuck Bay's* master, deck officers and lookout, Australian Maritime Safety Authority, Northrop Grumman Sperry Marine, Electrotech, REEF VTS, Maritime Safety Queensland, the Australian Hydrographic Office, DNV GL Det Norske Veritas - Germanischer Lloyd, the Great Barrier Reef Marine Park Authority, and *Coral Knight's* master.

Submissions were received from Australian Border Force, *ABFC Roebuck Bay's* master and navigation officer, Australian Maritime Safety Authority, Northrop Grumman Sperry Marine, the Australian Hydrographic Office, and DNV GL. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Appendices

Appendix A – Annex A – ECDIS Start-up Checklist

Extract from the Australian Border Force Work Instruction NS-1007 Use of ECDIS and RADAR on Australian Border Force cutters.

Annex A of WI NS 1007 - ECDIS Start-up Checklist

COMMENCEMENT OF PATROL / AFTER SYSTEM RESTART	
TOP MENU BAR	Completed
SENSOR INPUT are Green (HDG / COG / SOG / STW)	
STABILISATION MODE – select Sensor input for display: WATER - Ships Log [HDG / STW] or GROUND - GPS [COG / SOG]	
TARGET DISPLAY – set Target /AIS display information required	
AIS DISPLAY – Check all boxes	
CHARTS – Set to SevenC's S57 chart database	
ROUTE – No route loaded	
DISPLAY MONITOR ORIENTATION – Select Course or North Up	
TRUE MOTION INDICATOR – set TM Limits	
SCALE BAR – set scale to "Compilation Scale" & "Auto-scale"	
ALARMS – Investigate any current alarms, & action	
CAUTIONS / WARNINGS – Investigate Prompts	
AUDIO ALARM – set NODE 3 to "Un-Silenced", set NODE's 1, 3, & 4 to "Silenced"	
CHART DANGERS – when a Route is monitored, investigate dangers	
MOB ALARM – Test & Clear	
BOTTOM MENU BAR	Completed
POSITION SENSORS - GPS / DGPS are green	
SHIP's POSITION FUNCTION – Test	
CURSOR POSITION FUNCTION – Test	
DATE & TIME – Confirm correct	
DISPLAY BASE FUNCTION – Test	
RANGE RINGS FUNCTION- Test	
ERBL 1 & 2 FUNCTIONS – Test	
BRIGHTNESS FUNCTION – Test	
SHIP's DISPLAYED POSITION - Test "CENTRE" & "MAX" Functions	

CURSOR MENU	Completed
SHIP's DISPLAYED POSITION - Test Off Centre Function	
PAN – Test	
CURSOR MENU	Completed
SHIP's DISPLAYED POSITION - Test Off Centre Function	
PAN – Test	
MAIN MENU – NAV TOOLS	Completed
LINES OF POSITION – Test (Plot a Position Fix)	
OWNSHIP HISTORY – Check GPS Sensor	
DISPLAY SETTINGS – Set Own ship to Beam 10.8 metres Own Ship Vector Tick Marks 6 minutes	

MAIN MENU – CHARTS	Completed
CHARTS UPDATES SUMMARY – confirm last update is current	
CHART SETTINGS – “FEATURES” set to “OTHER” & select “ALL”	
CHART SETTINGS – “SYMBOLLOGY” check / uncheck following boxes	
a. “Overscale Pattern” – checked	
b. “Scamin Filtering” – checked	
c. “Simplified Symbols” – unchecked	
d. “Two Shades” – unchecked	
CHART SETTINGS – “S-57” – check / uncheck following boxes	
a. “Scamin Filter Warning” – checked	
b. “Text” – all text boxes checked	
CHART PROJECTIONS – Mercator	
CHART DEPTHS & HEIGHTS – set to meet Nav Standards / CO Orders	
a. “Safety Depth” - 5 metres	
b. “Safety Height” – 35 metres	
c. “Shallow Contour” – 5 metres	
d. “Deep Contour” – 10 metres	
CHART DATABASE – “SEVEN C's S-57”	
CHART DANGERS – Set Look Ahead Span to	
a. “Look Ahead” – Time 3 minutes or Distance 1 nm	
b. “Proximity” – Added Breadth 20 metres	
c. “Alarm” – Alarm on Cautions check box	

ROUTES - ROUTE DISPLAY SETTINGS	Completed
DISPLAY MONITORED ROUTE – check box	
SHOW CRITICAL POINTS / LABELS – check box	
SHOW LEG BEARINGS – check box	
SHOW WAY POINT LABELS – check box	

AUTO-PILOT - TRACK CONTROL	Completed
LIMIT FROM BASE = 20 degrees	
TRACK SENSIBILITY = TIGHT	
SET & DRIFT = UNCHECKED	

Appendix B – Annex C – ECDIS Recommended Information Layers – Port/Coastal/Open Ocean

Extract from the Australian Border Force Work Instruction NS-1007 Use of ECDIS and RADAR on Australian Border Force cutters.

Annex C of WI NS 1007 - ECDIS Recommended Information Layers – Port / Coastal / Open Ocean

Restricted Waters	Coastal Waters	Open Ocean	Chart Settings	Default Values
			Display Mode (Base / Standard / Other)	
On	On	On	Coastline	On
On	On	On	Own Ship safety Contour	On
On	On	On	Isolated underwater dangers depths < safety contour	On
On	On	On	Buoys, beacons, aids to navigation	On
On	On	On	Chart scale boundaries	On
On	On	On	Scale, range, and north arrow	On
On	On	On	Units of depth and height	On
On	On	On	Drying lines	On
On	On	On	Boundaries of fairways, channels, etc	On
On	On	On	Visual and radar conspicuous features	On
On	On	On	Prohibited and restricted areas	On
On	On	On	Indications of cautionary notes	On
On	On	On	Ship routing systems and ferry routes	On
On	On	On	Archipelagic sea lanes	On
Off	Off	Off	Data quality pattern (ZOC)	Off
On	On	On	Deep soundings (spot soundings under safety depth)	Off
On	On	On	Depth contour labels	Off
On	On	Off	Ignore time dependencies (display all S-57 time dated chart objects)	Off
On	On	On	Information tags (i boxed symbol)	Off
On	On	On	Light Distinction (non standard light symbology)	Off
On	On	On	Light features	Off
On	On	Off	Light sector areas	Off
On	On	On	Official boundary (between official & unofficial data)	On
On	On	Off	Overscale pattern (display at 2 * compilation scale)	On
On	On	On	Safety contour labels	Off
On	On	On	Scamin Filter warning	On

Restricted Waters	Coastal Waters	Open Ocean	Chart Settings	Default Values
On	On	On	Scamin filtering (suppress chart symbols at certain ENC scales)	On
On	On	Off	Shallow pattern (when waters < safety contour)	Off
On	On	Off	Shallow soundings (spot soundings < safety depth)	Off
On	On	Off	Shallow water dangers (Danger symbols < safety contour)	Off
Off	Off	Off	Simplified symbols	Off
On	On	On	Symbol filtering (suppress over lapping chart common symbols)	Off
On	On	On	Text (Important for navigation)	Off
On	On	On	Text (Other text e.g. object names)	Off
On	On	On	Text (Outline around text)	On
On	On	On	Text scale factor (scale text size)	2.0
4	2	2	Two shade depths (Two or Four water depth shades)	Off
S-57	S-57	S-57	Chart Database	
On	On	On	Chart Auto-scale	Off
On	On	On	Chart Projection (Mercator)	
			Chart Depths / Heights	
5m	8m	8m	Safety depth (Draft + Squat + Safety UKC - Height of Tide)	30m
35m	35m	35m	Safety height (sea surface to height of object)	30m
5m	8m	8m	Shallow contour (Spot depths < safety depth lighter shaded)	2m
10m	10m	10m	Deep contour	30m
3 mins	12 mins	15 mins	Look Ahead (Anti-grounding cone - Time [mins]or Distance [nms])	Off
0.1 nm	0.1 nm	0.2 nm	Look Ahead (Anti-grounding cone - XTE [Nms])	Off

Appendix C – Categories of zone of confidence in data table (CATZOC)

1	2	3	4	5	6
ZOC	Position Accuracy	Depth Accuracy	Seafloor Coverage	Typical Survey Characteristics	Symbol
A1	± 5 m	$= 0.50 + 1\%d$ Depth (m) Accuracy (m) 10 ± 0.6 30 ± 0.8 100 ± 1.5 1000 ± 10.5	Full area search undertaken. All significant seafloor features detected and depths measured.	Controlled, systematic survey, high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system	
A2	± 20 m	$= 1.00 + 2\%d$ Depth (m) Accuracy (m) 10 ± 1.2 30 ± 1.6 100 ± 3.0 1000 ± 21.0	Full area search undertaken. All significant seafloor features detected and depths measured.	Controlled, systematic survey achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder and a sonar or mechanical sweep system	
B	± 50 m	$= 1.00 + 2\%d$ Depth (m) Accuracy (m) 10 ± 1.2 30 ± 1.6 100 ± 3.0 1000 ± 21.0	Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist	Controlled, systematic survey achieving similar depth but lesser position accuracies than ZOC A2, using a modern survey echosounder but no sonar or mechanical sweep system	
C	± 500 m	$= 2.00 + 5\%d$ Depth (m) Accuracy (m) 10 ± 2.5 30 ± 3.5 100 ± 7.0 1000 ± 52.0	Full area search not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage	
D	Worse than ZOC C	Worse than ZOC C	Full area search not achieved, large depth anomalies may be expected.	Poor quality data or data that cannot be quality assessed due to lack of information	
U	Unassessed – The quality of the bathymetric data has yet to be assessed				

Appendix D - Henry Reef ENC information

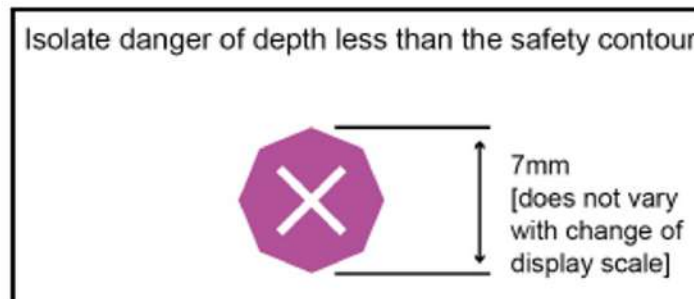
A chart query of the isolated danger symbol representing Henry Reef on *ABFC Roebuck Bay's* ECDIS provided the following information:

- underwater rock/awash rock
- object type: Henry Reef
- latitude: 12° 13.381' S
- longitude: 143° 49.126' E
- database: SevenCs – S-57
- chart: AU413143
- scale minimum: 699999
- value of sounding: 0
- natural surface: coral
- exposition of sounding: shoaler than range of depth of the surrounding depth area
- object name: Henry Reef
- water level effect: covers and uncovers
- quality of sounding measurement: depth unknown.

Appendix E – Extract from supplement to the Seafarer's Handbook for Australian Waters (AHP20)

13.8 Dangerous effects of over-scale ECDIS display near 'Isolated dangers'

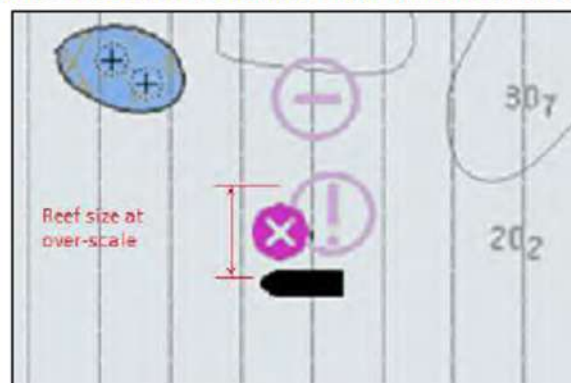
1. Use of over-scale display of an ENC may be dangerous in certain circumstances. There is a mistaken belief that zooming in allows for greater accuracy – however, this is not the case. In reality, zooming in beyond the intended maximum display scale may be misleading and dangerous, particularly for 'isolated dangers of depth less than the safety depth'.
2. Every ENC is compiled at an intended maximum scale. At this scale the maximum level of detail is revealed, while zooming out will progressively reduce the level of detail. None of this affects the accuracy of the chart. Zooming in may reveal a new, larger scale ENC, but this too has limits, and a point will be reached where there is no point zooming in further.
3. At the intended maximum compilation scale, details which are too small to chart, but which still present a hazard to navigation, are typically replaced by a symbol larger than the charted size of the feature (such as a very small reef). Zooming in to over-scale destroys the relationship between the size of the (now larger) hazard and the size of the symbol.



4. When the ENC is displayed correctly, the danger to a ship close to an isolated danger is clear.



5. However, when displayed at over-scale, a ship the same unsafe distance from the isolated danger incorrectly appears to be safe because the isolated danger symbol is still the same size.



6. This is not more accurate, and is definitely not safe.
7. Remember, the positioning accuracy of the isolated danger may be worse than 500 metres. Routes should be planned to clear these dangers by at least as far as the ZOC category immediately around the danger dictates.

Glossary

ABF	Australian Border Force
AHO	Australian Hydrographic Office
AMBOC	Australian Maritime Border Operations Center
AMSA	Australian Maritime Safety Authority
CATZOC	Category of zone of confidence in data
DNV GL	Det Norske Veritas Germanischer Lloyd
ECDIS	Electronic chart display and information system
ECS	Electronic chart system
ENC	Electronic navigational chart
EST	Eastern Standard Time
GBRMPA	Great Barrier Reef Marine Park Authority
GPS	Global positioning system
IHO	International Hydrographic Organization
IMO	International Maritime Organization
ISM	International Management Code for the Safe Operation of ships and for Pollution Prevention
MAIB	Marine Accident Investigation Branch
NGSM	Northrop Grumman Sperry Marine
OOW	Officer of the watch
REEFVTS	The Great Barrier Reef and Torres Strait Vessel Traffic Service
REEFREP	The Great Barrier Reef and Torres Strait Ship Reporting System
SOLAS	The International Convention for the Safety of Life at Sea (SOLAS) 1974 as amended
STCW	Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Code
UWTROC	Underwater/awash rock
XTD	Cross track distance

Australian Transport Safety Bureau

The ATSB is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Terminology used in this report

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing factor: a factor that, had it not occurred or existed at the time of an occurrence, then either:

- (a) the occurrence would probably not have occurred; or
- (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or
- (c) another contributing factor would probably not have occurred or existed.

Other factors that increased risk: a safety factor identified during an occurrence investigation, which did not meet the definition of contributing factor but was still considered to be important to communicate in an investigation report in the interest of improved transport safety.

Other findings: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report Rail Occurrence Investigation

Grounding of *ABFC Roebuck Bay*
Henry Reef, Queensland, on 30 September 2017

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