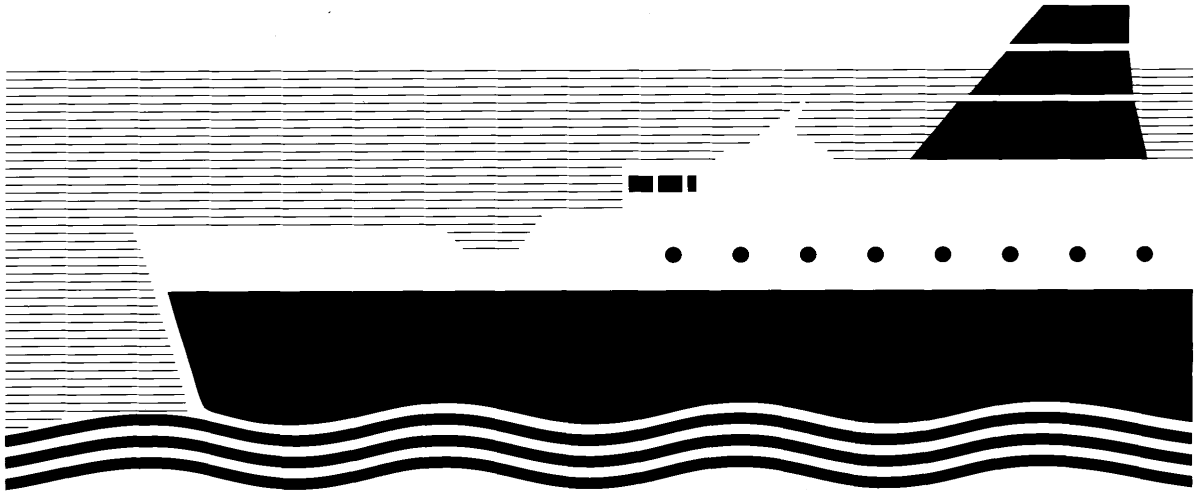

M A R I N E   O C C U R R E N C E   R E P O R T

04-208 jet boat *CYS*, propulsion failure and capsize, Waimakariri River 13 May 2004

TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

Report 04-208

jet boat *CYS*

propulsion failure and capsize

Waimakariri River

13 May 2004

Abstract

On 13 May 2004, a party of 18 passengers hired 2 jet boats to take them for a trip on Waimakariri River, north of Christchurch. At the conclusion of the trip, at about 1700, while the driver of *CYS* was manoeuvring back onto the boat's trailer, the reverse duct jammed in the down, or astern, position. The driver tried to rectify the problem, but the boat was caught in the swift flowing current and was swept towards a motorway bridge, less than 100 m downstream. The driver tried to manoeuvre the boat, but he was unsuccessful and it collided with one of the bridge supporting piers.

On impact, the downstream side of the boat rode up against the pier causing the back of the upstream side to become submerged, allowing water to enter the hull. The boat quickly filled with water, tipping the occupants out and capsizing.

The driver and most of the passengers were thrown clear of the boat and managed to make it to shore a short distance below the bridge. However, one passenger was missing. The second boat was sent to check the upturned hull, which was being swept down the river. As the other boat neared the upturned hull, the missing passenger swam free and was picked up.

There were no injuries, but the jet boat *CYS* suffered significant damage to its engine and electronics.

Safety issues identified included:

- modification and design of the reverse latch assembly and the detent in the brake rod
- adequacy of driver training and the risk management of the jet boat operation

Safety recommendations were made to the owner of Jet Stream Tours Limited.

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Abbreviations

cumecs	cubic metres per second
ECan	Environment Canterbury
SOP	Safe Operational Plan

Glossary

authorised person	Maritime Safety Authority appointed person to inspect and audit jet boat operations
cumecs	a measurement of water current flow in a river
detent	a notch in a rod into which sprung clips fit to restrict movement of the rod and give an indication of its position
eddy	area of calm in a fast flowing river usually near the banks or downstream of an obstruction
Hamilton turn	a 360° spin, particular to jet boats
high-side	where a vessel is swept onto the upstream side of an obstruction in a river, the downstream side of the vessel rises up causing the upstream side to submerge and allow the ingress of water. Usually results in a capsize or the craft becoming wrapped or stuck on the obstruction
pier	an upright support for the deck of a bridge
Safe Operational Plan	manual containing guidelines for the operation of a jet boat as required by Maritime Rules Part 80.

Data Summary

Vessel Particulars:

Name:	*CYS* (referred to as the *white boat*)
Type:	jet boat
SOP Authorised Person:	Tony Turner
Limits:	Lower Waimakariri River
Length:	5.2 m
Built:	Cobra Marine in 2002
Engine:	Chevrolet HO350
Propulsion:	Hamilton HJ 212 jet unit
Service speed:	about 70 km/h
Owner/operator:	Jet Stream Tours NZ Ltd
Date and time:	13 May 2004 at about 1700[1]
Location:	Waimakariri River
Persons on board:	crew: 1 passengers: 8
Injuries:	crew: nil passengers: nil
Damage:	engine seized and minor damage to the upper hull. Water damage to the electronics and furnishings from the boat being submerged
Investigator-in-charge:	Capt Doug Monks

[1] All times in this report are New Zealand Standard Time (UTC +12 hours) and are expressed in the 24-hour mode.

The *CYS* (*white*) jet boat

1 Factual Information

1.1 Narrative

1.1.1 About a week before the accident a company holding a conference in Christchurch organised a jet boat trip as part of its team-building programme. Initially the trip was organised for 24 persons, so the owner of Jet Stream Tours NZ Ltd arranged for his 2 boats, driven by himself and one of his contracted drivers, and another boat owned and driven by another of his contracted drivers to be available at 1600 on Thursday 13 May 2004.

1.1.2 On the day of the trip the number of passengers decreased to 21 and the start of the trip was delayed until 1630. So the owner informed the drivers and cancelled the third boat, but decided that the contracted drivers would drive his 2 boats.

1.1.3 At about 1600, the 2 drivers picked up the boats from their storage area close to the river and towed them to the launching ramp on the north shore of the Waimakariri River, to the west or upstream of the motorway bridge (see Figure 1). The drivers completed pre-trip checks with the boats on their trailers reversed into the river, before parking the boats on their trailers at the top of the ramp to await the passengers. The Cobra 6200C (the *black boat*) was to the extreme downstream side of the launching ramp and *CYS* (the *white boat*) to the extreme upstream side, leaving the centre of the ramp clear.

1.1.4 At about 1640 the passengers, whose number had fallen to 18, arrived at the launching ramp and were kitted out in spray jackets and lifejackets. Woollen hats and gloves were also offered to those who wanted more protection against the elements. The passengers were divided between the 2 boats; 10 in the larger *black boat* and 8 in the *white boat*. They climbed into the boats, which were still on their trailers at the top of the launching ramp.

1.1.5 Once the passengers were seated in the boats, the trailers were reversed into the water ready for launching. The drivers released the wires securing the boats to the trailers and then gave the passengers a safety briefing before starting the engines.

1.1.6 The drivers used their jet units with the reverse duct down to pull themselves off the trailers. The *black boat* was the first to launch followed by the *white boat*. The boats then proceeded upstream with the *black boat* as the lead boat. On the trip upstream each boat performed a Hamilton turn, which involves a boat being spun through 360°.

1.1.7 The weather and river conditions were less than favourable, so the lead driver decided to shorten the trip and turn around near the confluence of the Eyre River about 5 nm upstream from the launching ramp.

1.1.8 The return trip was uneventful, although the boats touched the bottom a couple of times but not hard enough to impede their progress. Because the trip had been shortened, when they arrived back at the launching ramp the drivers carried on downstream under the motorway bridge before turning back upstream. Each boat did one more Hamilton turn. The *white boat* waited off the ramp until the *black boat* was secure on its trailer. When the *white boat* driver approached his trailer, he found that his boat was not correctly aligned and so he put the boat into reverse to reposition it, but when he tried to move the reverse duct control lever forward he found that it was jammed and the boat was stuck in reverse.

1.1.9 The driver of the *white boat* called out and told the other driver that the boat was stuck in reverse, and at the same time he was jiggling the lever and pumping the throttle to try and clear the jam. The *white boat* driver was unable to clear the problem and very quickly the boat was caught in the swift current passing close to the launching ramp. He tried to maintain the boat's position by steering the boat in reverse into the flow but was unable to overcome the swiftness of the current.

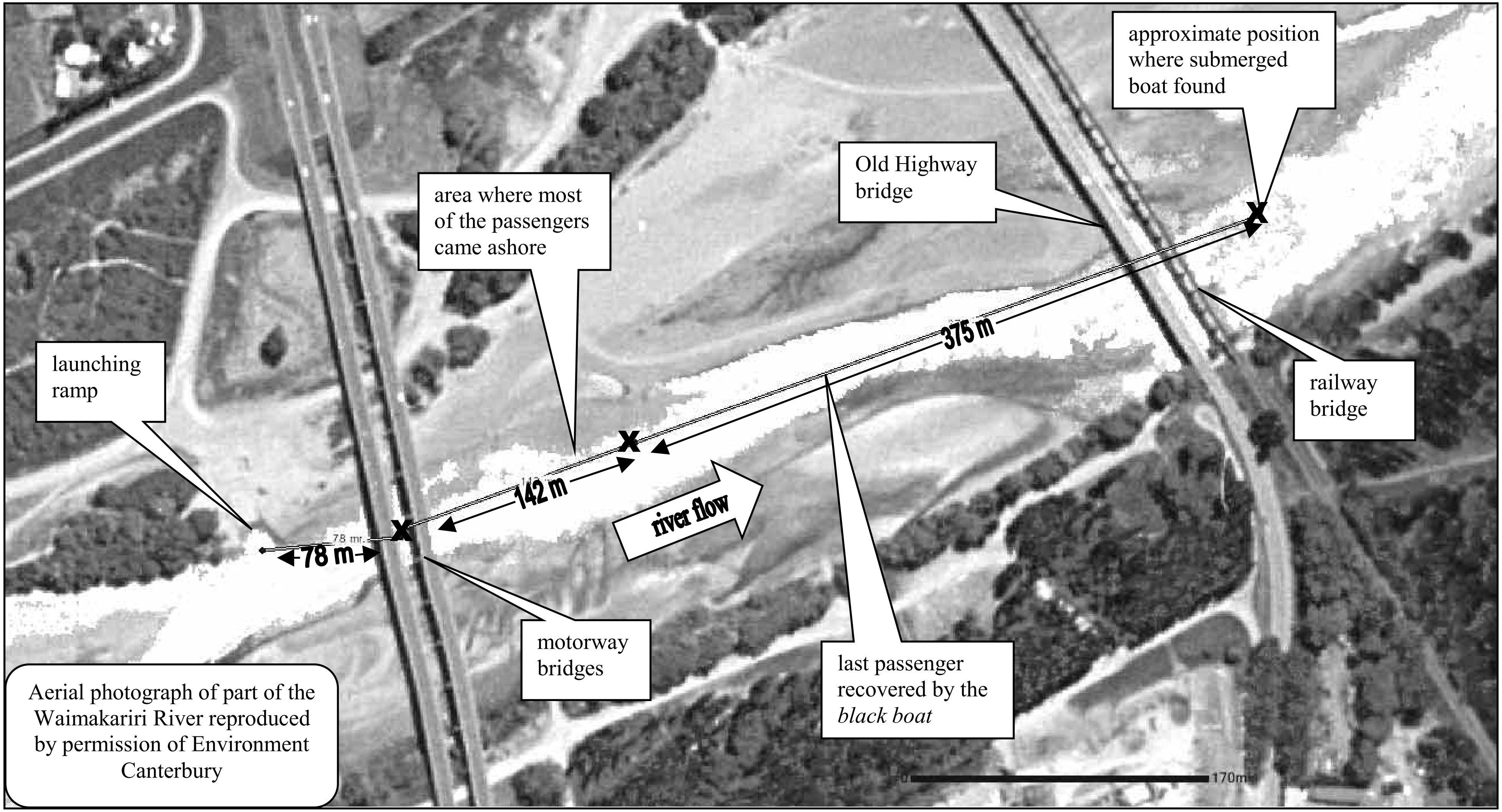

Figure 1
Aerial photograph showing part of the Waimakariri River

1.1.10 The boat was swept towards the motorway bridge (see Figures 1 and 2). The driver initially thought that the boat would pass between the 2nd and 3rd sets of piers, but the current pushed the boat towards the downstream of the 2 piers in the 3rd set. Before they made contact the driver warned the passengers and expressed a hope that they would just bump into the pier and then be pushed clear. However, the boat initially made contact on its starboard side just behind the front row of seats, and the strength of the current was such that the starboard side rode up the pier causing the after port corner to be submerged allowing water to enter the boat. As it filled with water, the boat started to flip and the driver and passengers were thrown into the water.

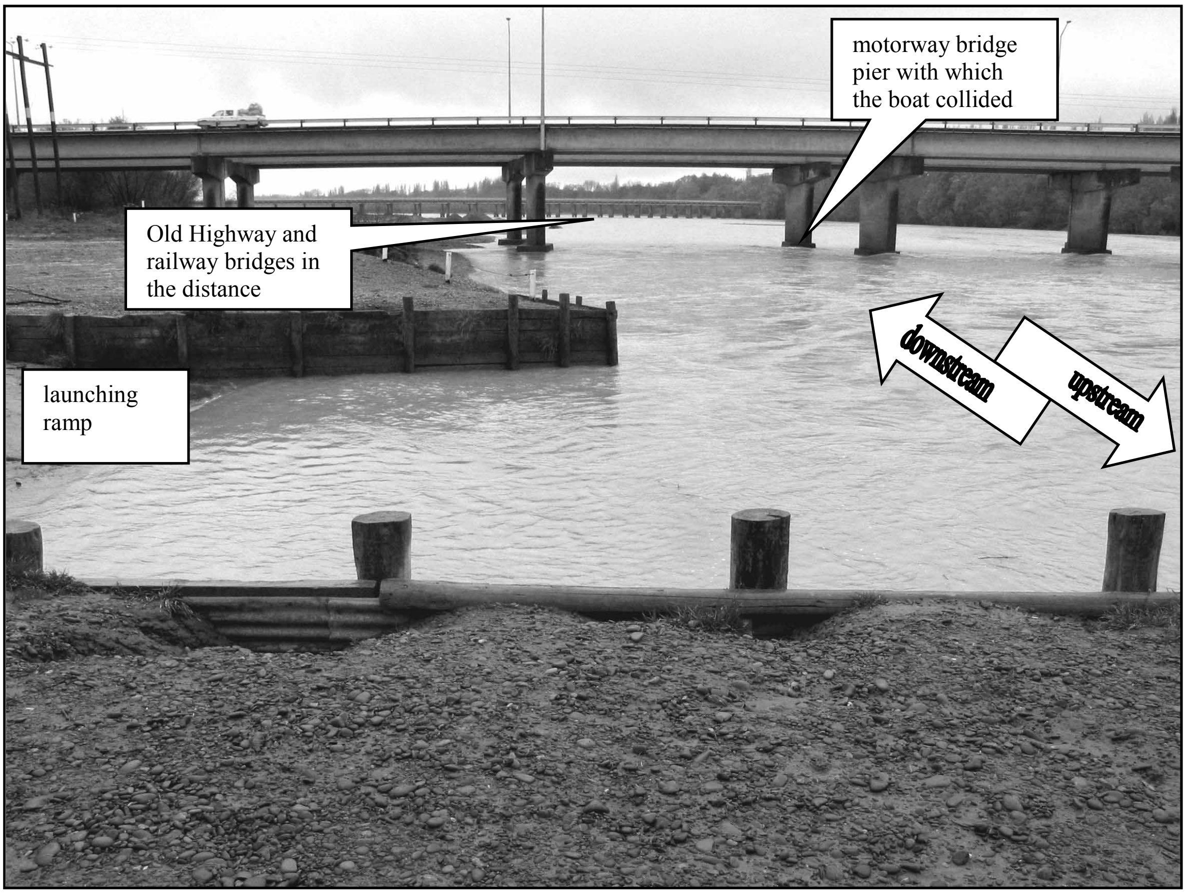

Figure 2
Motorway bridges from the launching ramp

1.1.11 As soon as the driver of the *black boat* was told that the *white boat* was stuck in reverse, he ordered all his passengers, except for 2 men, out of the boat and then re-launched it. By the time the *black boat* was clear of the launching ramp and the driver could see the bridge, the *white boat* had flipped and there were people in the water. The driver of the *black boat* used his cell phone to call the owner, telling him the situation and asking him to raise the alarm. A member of the public who saw the accident also called the emergency services.

1.1.12 Passengers from the *white boat* were swept downstream and were able to swim to the shore, where they were met by the passengers from the *black boat* who had run down the riverbank. The driver of the *white boat* was further out and had floated past the point where most of the passengers came ashore. However, the *black boat* assisted him to the shore.

1.1.13 Once ashore, the passengers checked that they were all there and discovered one person missing. The passengers called out to the driver of the *black boat* telling him that one person was unaccounted for. The *black boat* driver immediately headed his boat towards the upturned hull of the *white boat*, which was still being swept downstream. As the *black boat* approached the upturned hull, the missing person swam free and was picked up.

1.1.14 The *black boat* returned to the launching ramp and the rescued person was taken ashore, given a towel and sat in a car with its heater on. The police arrived shortly after and took the passengers' details before allowing them to return to their hotel.

1.1.15 The following morning, the sunken *white boat* was found, upside down, downstream of the railway bridge (see Figure 3). It was recovered using the *black boat* and a front-end loader.

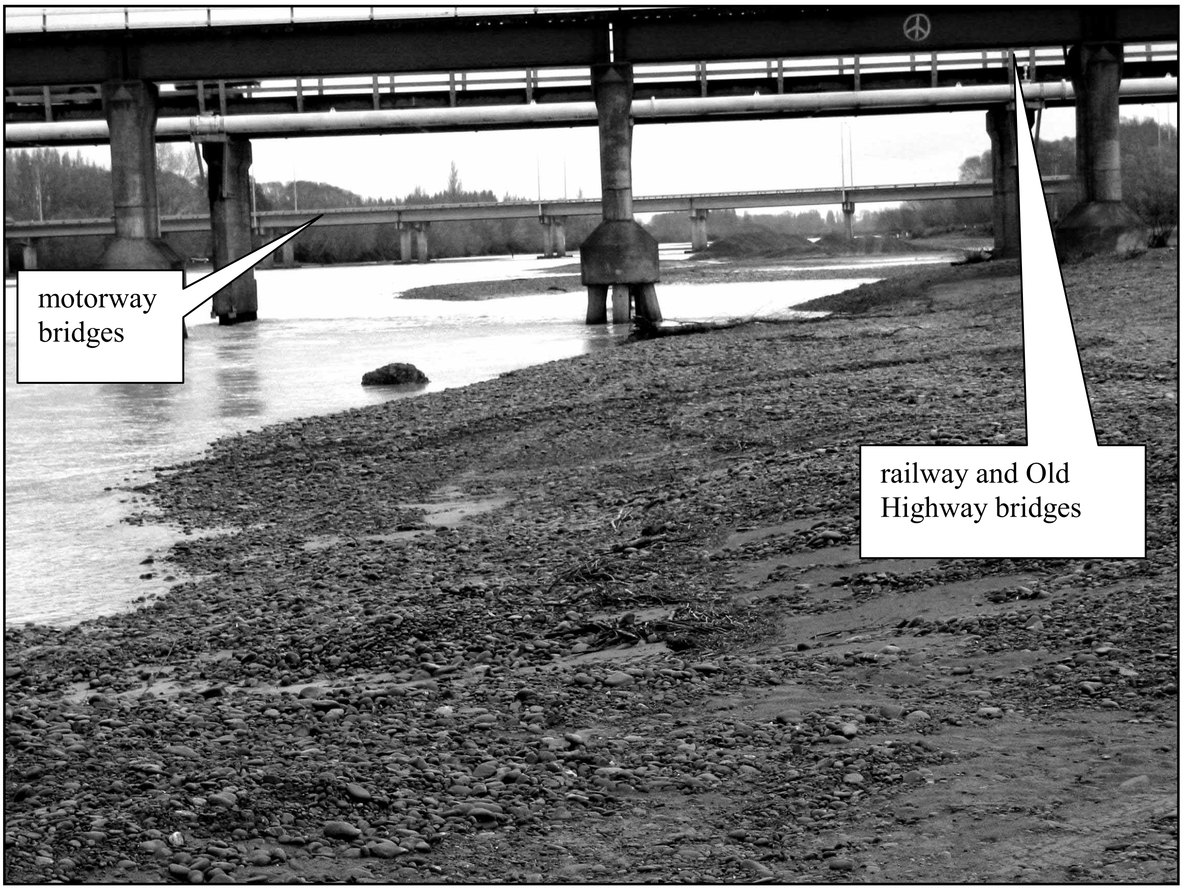

Figure 3
Looking upstream from the position where the *white boat* was recovered

1.2 Vessel information

1.2.1 The *white boat* was built in 2002 by Hamilton Jet and fitted out by Cobra Marine of Christchurch. The boat had an aluminium hull and a glass reinforced plastic deck. It was 5.2 m in length and had a Chevrolet HO 350 cubic inch engine. The jet unit was a Hamilton HJ 212. It was able to carry 10 adult passengers.

1.2.2 The *black boat* was about a year older, and was built entirely of aluminium. It was 6.2 m in length, and was powered by a Chevrolet 400 cubic inch engine with a Hamilton HJ 212 jet propulsion unit. It was able to carry 14 adult passengers.

1.2.3 The owner of Jet Stream Tours NZ Limited had purchased the business in 1999. In February 2003 he had purchased a competitor's business and the present 2 boats were part of that transaction. Because the 2 boats were nearly new and larger than his existing boats, the owner decided to sell his original boats and use the newer ones.

1.3 Personnel information

1.3.1 The driver of the *white boat* had operated jet boats since 1982. He initially operated his own private jet boat and then in 1986 started driving commercial boats in the Waimakariri Gorge. He drove commercially full time for 6 years and then continued part time. He had driven for the owner for 3 years as a part time contractor. He also owned a commercial jet boat which, when required, was used to supplement the 2 Jet Stream Tours boats.

1.3.2 The driver of the *black boat* had operated jet boats since 1977. From 1985 he had operated commercial boats on the Lower Waimakariri River as a relief contract driver. He had worked for the owner since 1999.

1.3.3 The owner had been driving jet boats since 1981. He had bought an established jet boat operation in 1999 and had driven commercially since that time.

1.4 Climatic and river information

1.4.1 The weather at the time of the accident was overcast with light drizzle.

1.4.2 At the time of the accident there was a substantial flow on the Waimakariri River, which had increased through the day.

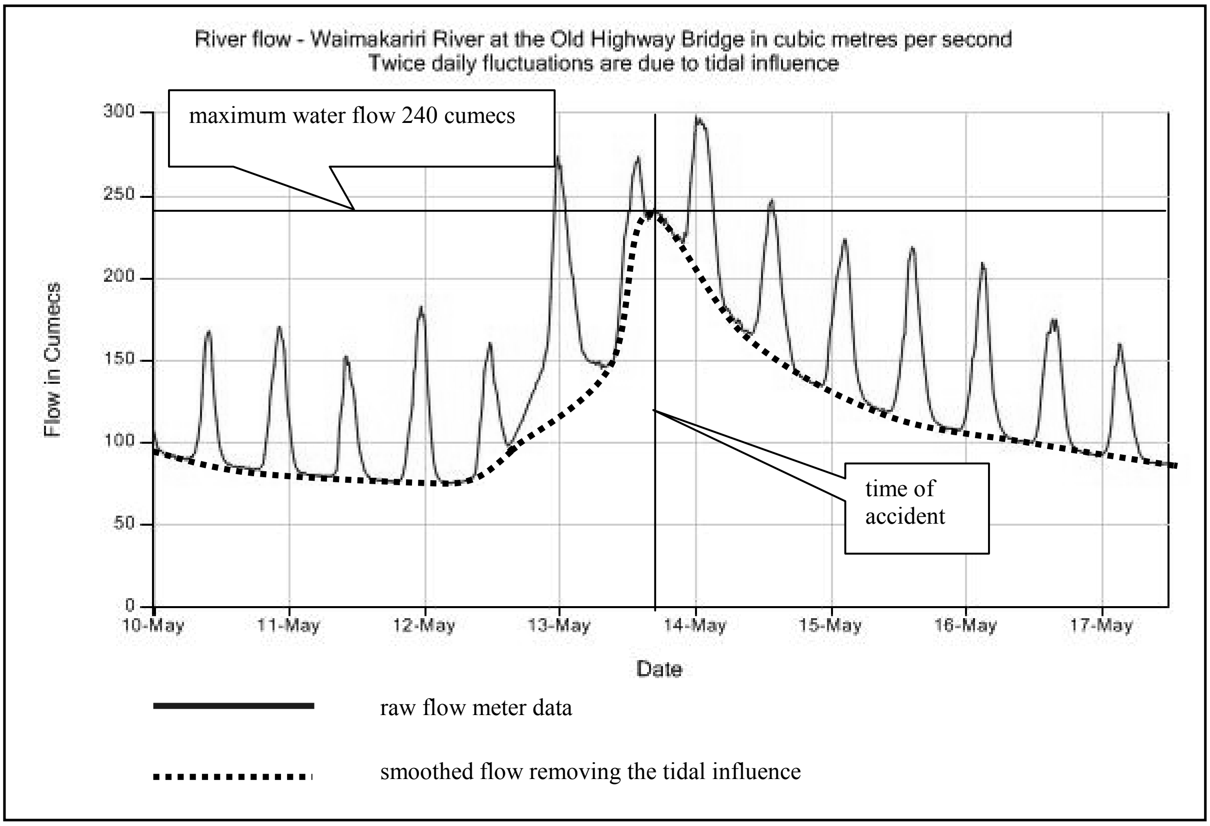

Figure 4
River flows at the Old Highway Bridge for the previous week as shown on the Environment Caterbury website on 17 May 2004

1.4.3 Environment Canterbury (Ecan) measured the flow of the Waimakariri River and other rivers in its jurisdiction. Every 15 minutes, an automatic water level recorder measured and recorded the water level. Once a month, or more often in flood situations, ECan staff "gauged" the river, which involved measuring the width, depth and velocity of the river. The velocity was measured by suspending current meters at a minimum of 20 locations across the river. Using the velocity, the distance between the current meters and the depth, the discharge flow of the river was calculated. The "gauging" was used to establish the relationship between water level and river flow, called a rating curve. This allowed a simple calculation to provide water flow from the more easily measured water level. The continued reliability of the rating curve depended on a number of factors, the most significant being the shape of the channel. A water level recorder was sited at the Old Highway Bridge, about 500 m downstream of the launching ramp. The rating calculation was applied to the recorded levels and the resultant water flows were posted on the ECan website both in tabular and graph form (see Figure 4).

1.4.4 The Old Highway Bridge was close enough to the sea for the river to be subject to tidal fluctuations and the readings from the water level recorder showed twice-daily maximum fluctuations around the time of high water. When the water level data was subjected to the rating calculation it incorrectly showed the water flow increasing around the time of high water. The water flow graph on the website did carry a warning that there were twice daily fluctuations due to tidal influence (see Figure 4). On 13 May 2004, the information on the website showed tidal peaks at midnight and midday, high water was at 2345 on 12 May and 1206 on 13 May 2004. The peak flow of about 270 cumecs occurred at about midday. When the tidal peaks were smoothed, the resultant peak flow was about 240 cumecs in the afternoon.

1.4.5 The information displayed on the ECan website was not real time but delayed by up to 6 hours.

1.4.6 The site at the Old Highway bridge was gauged and rated on 20 May 2004 and the data gathered since 6 May 2004 was retrospectively adjusted to include the new rating. A new graph was produced for the period of 6 May 2004 to 15 May 2004 (see Figure 5). The adjusted flows showed that on 13 May 2004 the flow was above 300 cumecs between 1115 and 2145, peaking to 324.6 cumecs at 1315. At 1700 the flow was 320.8 cumecs (see Figure 5)

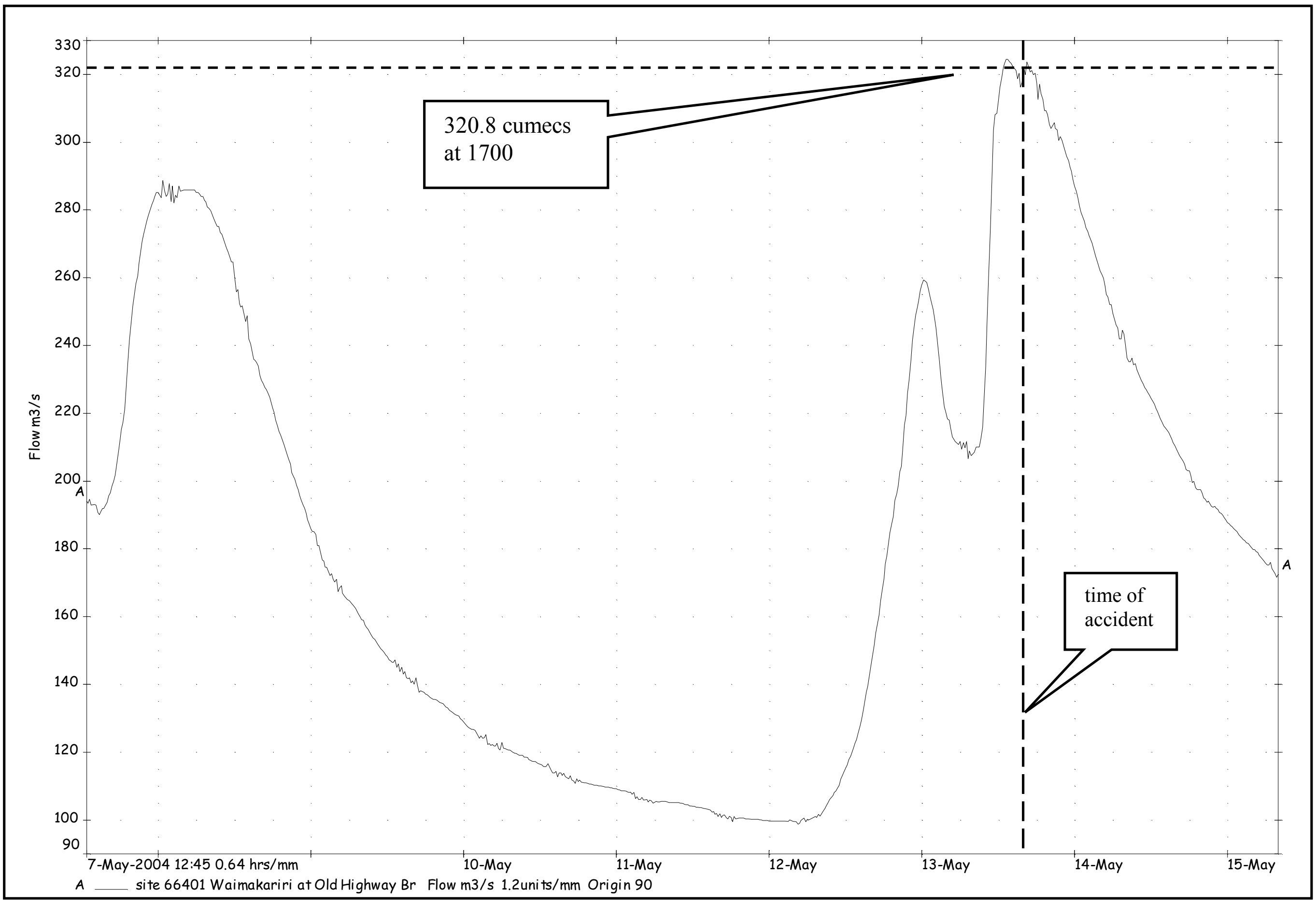

Figure 5
Smoothed and re-rated river flows at the Old Highway Bridge

1.4.7 The day after the accident, when the river flow had subsided to about 220 cumecs, the river current speed was estimated by timing how long it took for sticks thrown into the river at the launching ramp to reach the motorway bridge. The current speed was estimated to be about 6 knots using a distance of 78 m and an average time of 25 seconds.

1.4.8 The drivers and passengers noted that there was a great deal of floating debris in the eddy at the launching ramp.

1.4.9 The owner said the riverbed adjacent to the launching ramp had been eroded by the effect of the propeller and jet wash of boats using the ramp. Loose stones settled in the eroded area but were dislodged when jet boats used reverse thrust when manoeuvring off of or onto their trailers.

1.4.10 The bridge piers were of rectangular cross section and had similarly shaped, but larger, bases that rose to just above the surface of the water. The river flow caused a pillow of water to form on the upstream side of the piers.

1.4.11 The owner had completed a trip on the Waimakariri River on the morning of the accident. He had found the river swift but well below the point where a trip would need to be cancelled. He had consulted the ECan website to check the river conditions before that trip and again around lunchtime. On the last of those occasions a flow of between 150 and 190 cumecs would have been shown, depending on the delay in the data being posted on the website.

1.4.12 The owner indicated that besides the flow meter information from the website, the drivers also used a visual aid to determine that the river was at navigable levels. They checked the river height against the horizontal boards on the downstream side of the launching ramp. When the level was below the bottom of the second board from the top, the river was suitable for operations. The river height had been below this level throughout the day of the accident and the driver of the *white boat* remembered that it was about 4 or 5 boards below the top when they launched the boats.

1.5 Injuries to passengers and damage to the boat

1.5.1 The passengers and driver all escaped unharmed. Although wet and cold, they were recovered sufficiently quickly to prevent the onset of hypothermia.

1.5.2 The passenger who was caught under the upturned hull was in an air pocket and decided to evaluate his position before he tried to swim free. As the boat progressed down the river it started to settle lower in the water and so the passenger decided that he should swim out. As he emerged, the *black boat* was only metres away and picked him up immediately. The upturned hull continued on down the river and soon disappeared from view.

1.5.3 The sunken boat was recovered from the river on the morning after the accident. The hull was largely undamaged, but there was silt throughout the boat and some slight damage to the fairing on the stern. The reverse duct was in the fully down position and reverse duct control lever could be moved easily. There were no marks on the jet unit casing or inside the reverse duct to indicate where it had jammed. When the engine space was examined, it was found that the brake rod of the reverse duct assembly (see Figure 8) was fractured in way of a detent. When the control lever was moved, the fracture in the brake rod allowed movement of the control cable but did not operate the reverse duct. On the starboard side of the boat's hull, just behind amidships, there was a dent and scratch marks.

1.5.4 When the boat capsized, the engine was still running and so water had been drawn into the cylinders, damaging the engine sufficiently that it required rebuilding. The ignition, fuel and electrical systems also suffered water damage and had to be refurbished. The reverse duct control assembly was replaced before the boat returned to service.

1.6 Legislation

1.6.1 Maritime Rules Part 80 Appendix 1 paragraph 8.4 required that jet boats have a Safe Operational Plan covering the operation of the boat.

1.6.2 The Maritime Rule stated that the safe operational plan must include at least the following -

(i) a record of initial inspection of each boat and the report of the authorised person of initial inspection and any subsequent inspection;

(ii) a planned maintenance schedule for each boat and motor with a record of the work undertaken;

(iii) a record of the safety equipment required by Appendix 1 for each boat, its maintenance, testing and inspection;

(iv) personal records of each driver employed, including a copy of their medical certificate and first aid certificate and their experience and employment record;

(v) training procedures and training record for each driver employed; information on the area of operation and river conditions which limit operations; pre-operational and operational checks of the boat and its equipment;

(viii) a requirement that if the grade of fuel is changed the engine(s) must be re-tuned and the performance of the boat checked under its normal operating conditions before passengers are carried;

(ix) operational management procedures, including contact with shore and other boats and commercial operators on the river as necessary;

(x) details of

(aa) accident recording and reporting procedures complying with sections 30 and 31 the Act; and

(bb) accident investigation procedures; and

(xi) details of how the owner intends to inform and commit employees to meet their health and safety responsibilities under Part II of the Act and this Code; and

(xii) a requirement for the number of passengers carried on each trip to be recorded and be available at the base and on the boat.

1.6.3 Jet Stream Tours operated under a Safe Operational Plan (SOP), which was last audited and approved on 6 March 2004 by a Maritime Safety Authority (MSA) Authorised Person. The SOP covered the requirements of Maritime Rules Part 80.

1.6.4 Section 4 of the SOP dealt with the condition of the river necessary for a trip to proceed, it stated:

Jet boat rides will not be undertaken in conditions that compromise safety.

Factors assessed include visibility, high winds, floating debris, and river flow

(a) Maximum Flow: If the river exceeds 300 cumecs as taken from the Ecan river flow site situated at the Old Waimakariri River bridge the trip will be cancelled.

(b) In the case of a static or falling river 350 cumecs is allowable.

(c) Floods; Trips will be cancelled in the event of flood warnings which are available from Environment Canterbury.

(d) Minimum Flow. Trips will be cancelled if the flow falls below 27 cumecs at site as per (a).

(These conditions are provisional as of 08/01/2002 and may be altered in conjunction with the Authorised Person after a period of time as specified by him.)

The owner said that the limitations on the river flow levels were due to the likelihood of logs and other debris being swept down the river.

1.6.5 Maritime Rules Part 80 Appendix 1.7 enumerated the requirements for drivers of commercial jet boats. Drivers had to be at least 18 years of age, hold a medical certificate and a first aid certificate. They were required to have not less than 50 hours' experience including an acceptable (to the authorised person) time on the river on which the driver is going to operate. There was no requirement for a driver to hold a licence or a maritime certificate of competency.

1.6.6 At the time of the accident the Maritime Safety Authority was in the process of dividing Part 80 into 2 parts; Part 80A covering jet boats and Part 80B covering white water rafting. Part 80A completed public consultation on 30 January 2004 and was expected to come into force in early 2005. One of the main sections of Part 80A dealt with driver qualifications and proposed that new drivers hold a provisional licence while undertaking post-provisional training, which would lead up to them gaining a full licence. There was provision in Part 80A that established drivers would be eligible for a full licence without any further training.

1.7 Description of the engine and jet unit of the *white boat*

1.7.1 The *white boat's* engine ran on a mixture of 80% 96 octane unleaded petrol and 20% 100 octane leaded petrol.

1.7.2 The jet unit was a Hamilton HJ 212, which was commonly used in small commercial or private jet boats. The jet unit was a single stage water pump, which was connected to the engine by a drive shaft. The jet unit drew water through an intake grill under the hull and expelled it under high pressure through a steerable nozzle. A split deflector reverse duct was provided to give astern propulsion (see Figure 7).

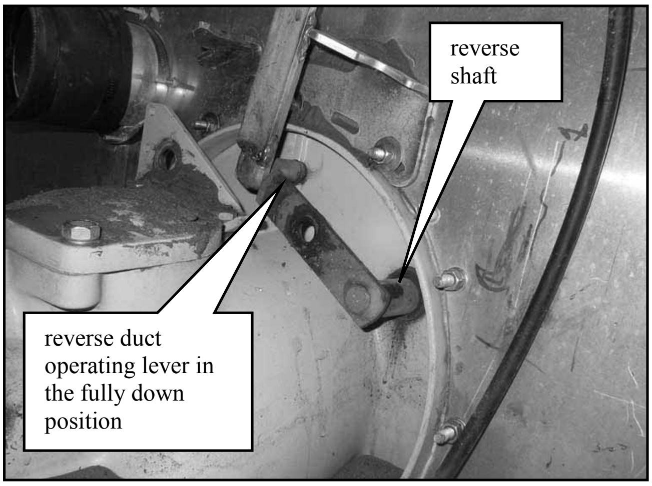

Figure 6
Reverse duct lever with the latch assembly removed

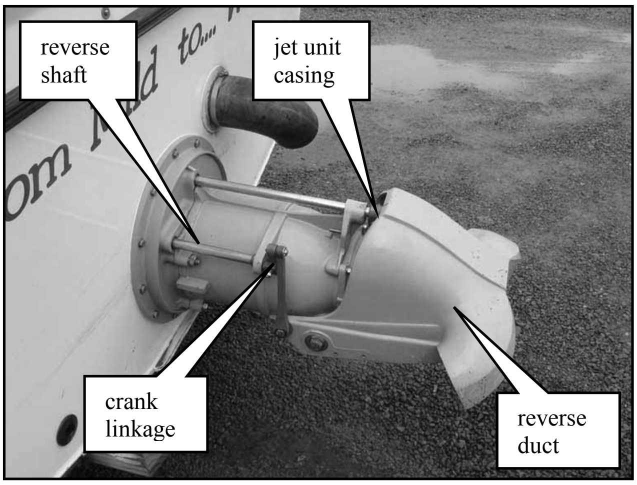

Figure 7
The reverse duct showing the reverse shaft and crank linkage

1.7.3 Speed and reverse thrust were achieved through a combination of throttle setting and a cable operated split deflector reverse duct. When the reverse duct was fully open the water efflux was rearwards, thrusting the boat forward. As the duct was lowered, an increasing amount of the water jet was deflected downward and forward, progressively changing the resultant thrust from forward to reverse. The engine throttle, also cable operated, was independent of the reverse duct.

1.7.4 When a driver moved the reverse duct control lever, the cable pulled a latch assembly along a 12 mm diameter brake rod. The latch assembly was connected to the reverse duct through a series of shafts and operating levers and thus raised or lowered the duct.

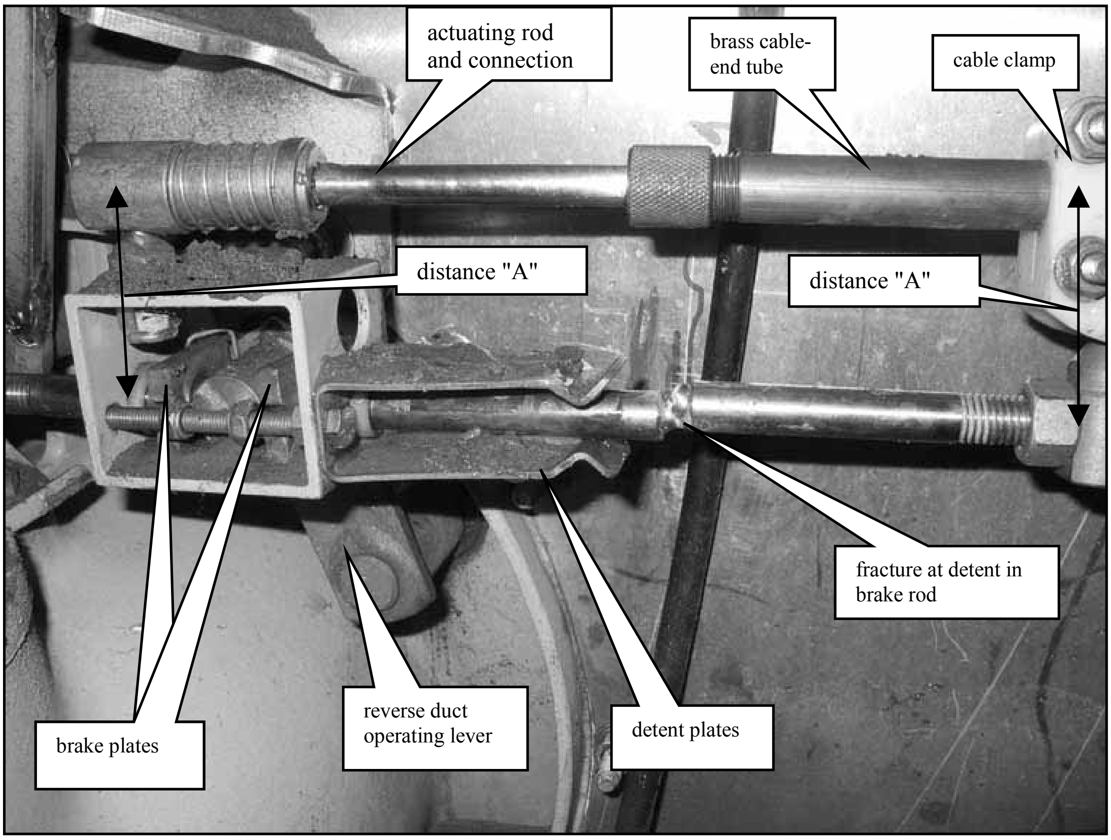

Figure 8
Reverse latch assembly as found after the accident

1.7.5 Within the latch assembly were 2 brake plates, tensioned by springs and set at an oblique angle to the brake rod, which kept the reverse duct in the position set by the driver. Without the latch, the weight of the duct would cause it to drop into the reverse position. The amount of friction exerted by the brake plates could be adjusted using the adjusting rod and nuts (see Figures 9 and 11).

1.7.6 The reverse latch assembly was designed for use with a Morse 64C cable and a Morse B71 control lever. However, commercial operators considered that the system, and in particular the control lever, was not sufficiently robust for the rigors of their work and chose to replace it with a heavier duty control lever, which required the use of a heavier cable. When the *white boat* was commissioned, the reverse duct was fitted with a heavy-duty Morse D0002 control lever and heavy-duty D0499 control cable that had a 3/8-inch (9.5 mm) diameter actuating rod at the reverse latch end.

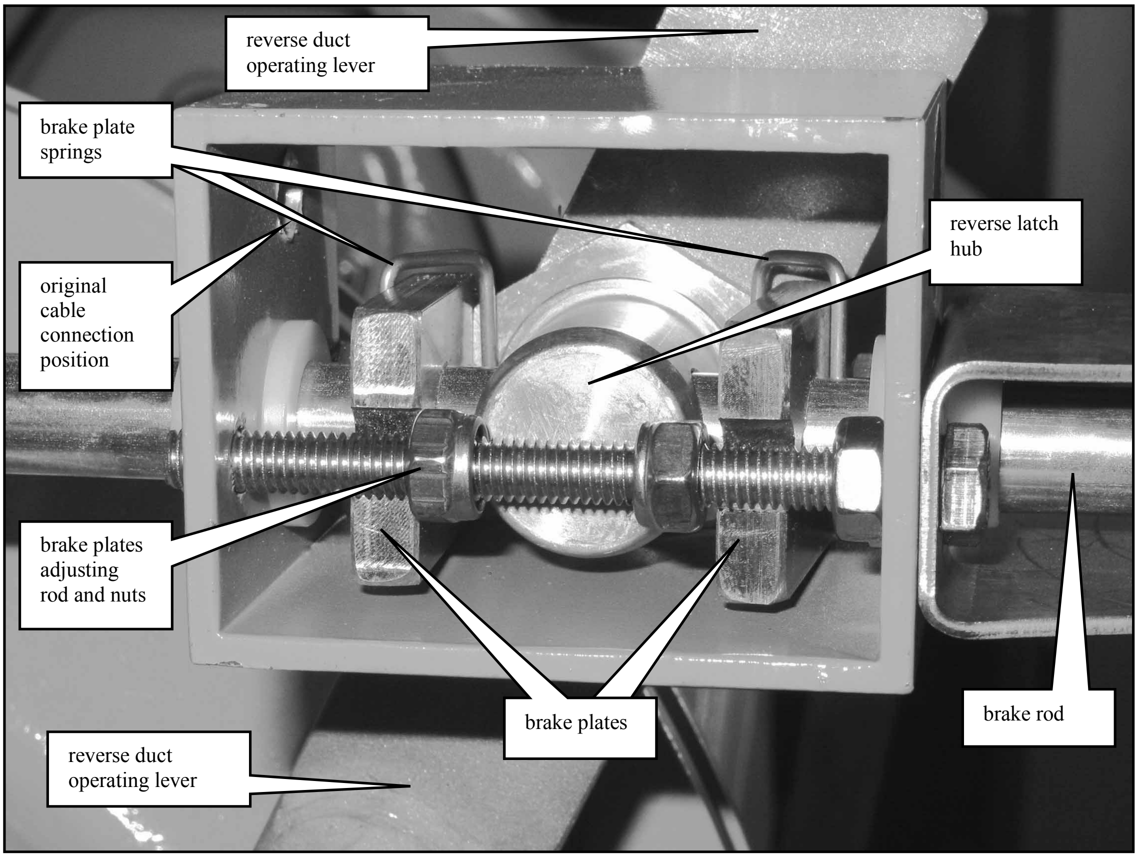

Figure 9
A new reverse latch, in elevation

1.7.7 The smaller Morse 64C cable was designed to be fitted directly to the latch assembly through pre-drilled holes (see Figure 9) and the brass cable end tube was connected to the brake rod by a clamp with a ball and socket type joint. The larger D0499 cable was too big to be fitted in this way, instead, a connection, also with a ball and socket type joint (see Figure 8), was mounted onto the top of the reverse latch assembly and connected to the cable end rod. A larger clamp, with a ball and socket type joint was used to connect the brass cable end tube to the brake rod. The new clamp and connection increased the distance between the axis of the brake rod and the axis of the cable from 18 mm in the original design to about 50 mm (distance "A" in Figure 8).

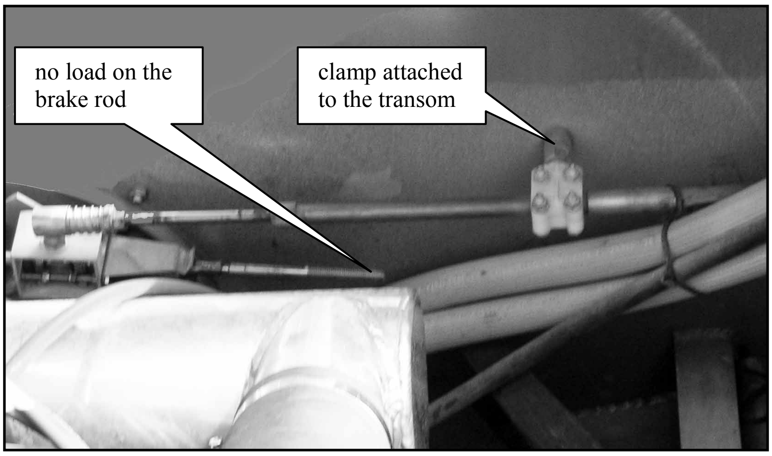

Figure 10
Reverse latch assembly as fitted to the *black boat*

1.7.8 CWF Hamilton and Co Ltd commented that a number of tour boats had been set up with the larger cable and control lever but the clamp at the end of the brass cable end tube was attached to the transom of the boat rather than the brake rod. In this way no load was applied to the brake rod and bending at the detent would not occur. The reverse latch assembly on the *black boat* was of this type.

1.7.9 The ball and socket joints on the clamp and cable end rod connection were necessary to allow for the vertical movement of the latch assembly caused by the radial movement of the reverse duct operating lever (see Figures 6 and 9).

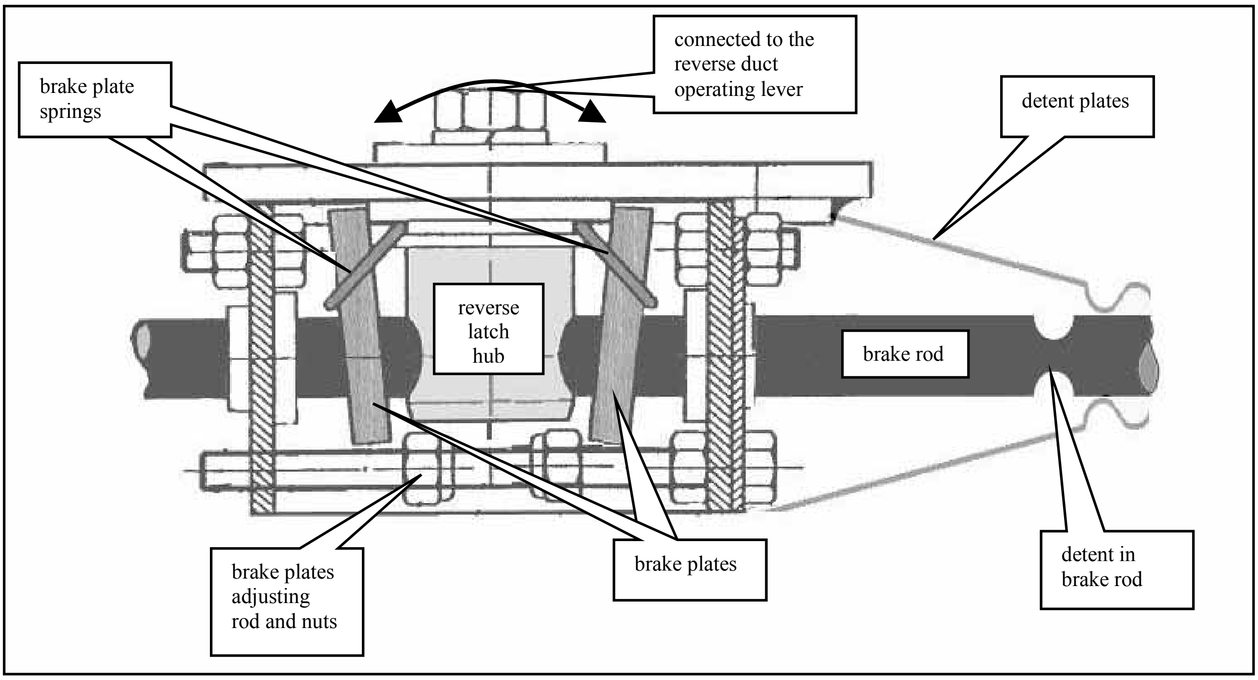

Figure 11
Plan view of reverse latch assembly

1.7.10 The 12 mm diameter brake rod had a 2 mm detent machined into it, reducing its diameter to 8mm. The detent gave the driver a reference point for the neutral position of the reverse duct. The detent did however reduce the cross sectional area by over 50%; (12 mm diameter rod has a cross sectional area of 113.1 mm^2 and 8 mm rod has an area of 50.3 mm^2).

1.7.11 When the reverse duct was fully down, the reverse latch assembly was at the far end of its travel with the maximum length of brake rod exposed. In this configuration, the detent was subject to the maximum amount of bending moment, which increased as the brake rod deflected under the moment (see Figure 12). Note that the comparative length of the two arrows shows how the bending moment lever arm increases with rod deflection.

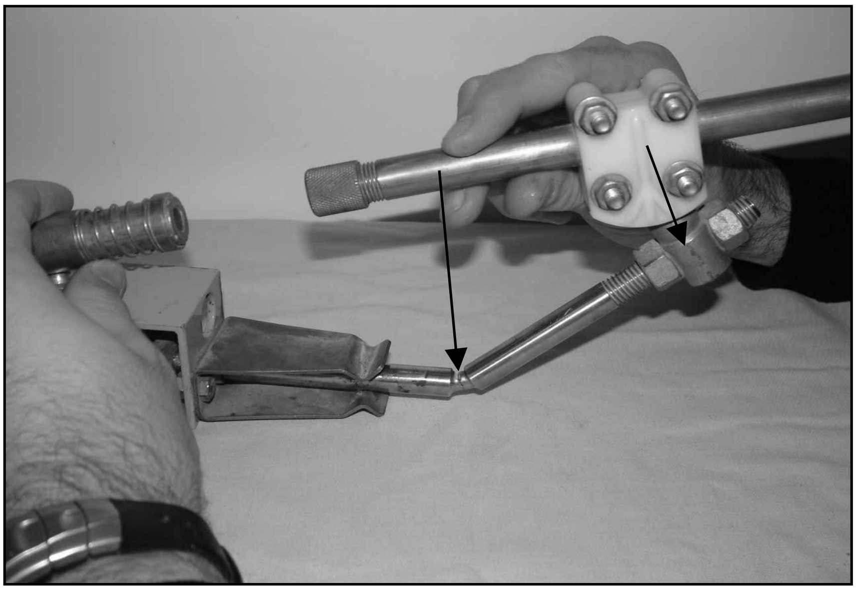

Figure 12
Reconstruction of the brake rod and cable connector at failure

1.7.12 Should the reverse duct become obstructed and jam while in the fully down position, a driver attempting to free this by actuating the lever to lift it would apply tension to the actuating cable, which would in turn apply a bending moment to the brake rod. When the actuating cable was under tension it created an inward and upward bending moment at the end of the brake rod. This bending moment would act on the weakest part, which in this case was the detent (see Figure 13). The driver indicated that shortly before the boat hit the bridge pier he pushed so hard on the reverse duct control lever that he thought that he had broken the control lever or the cable. However, during inspection the control lever and the cable were found intact.

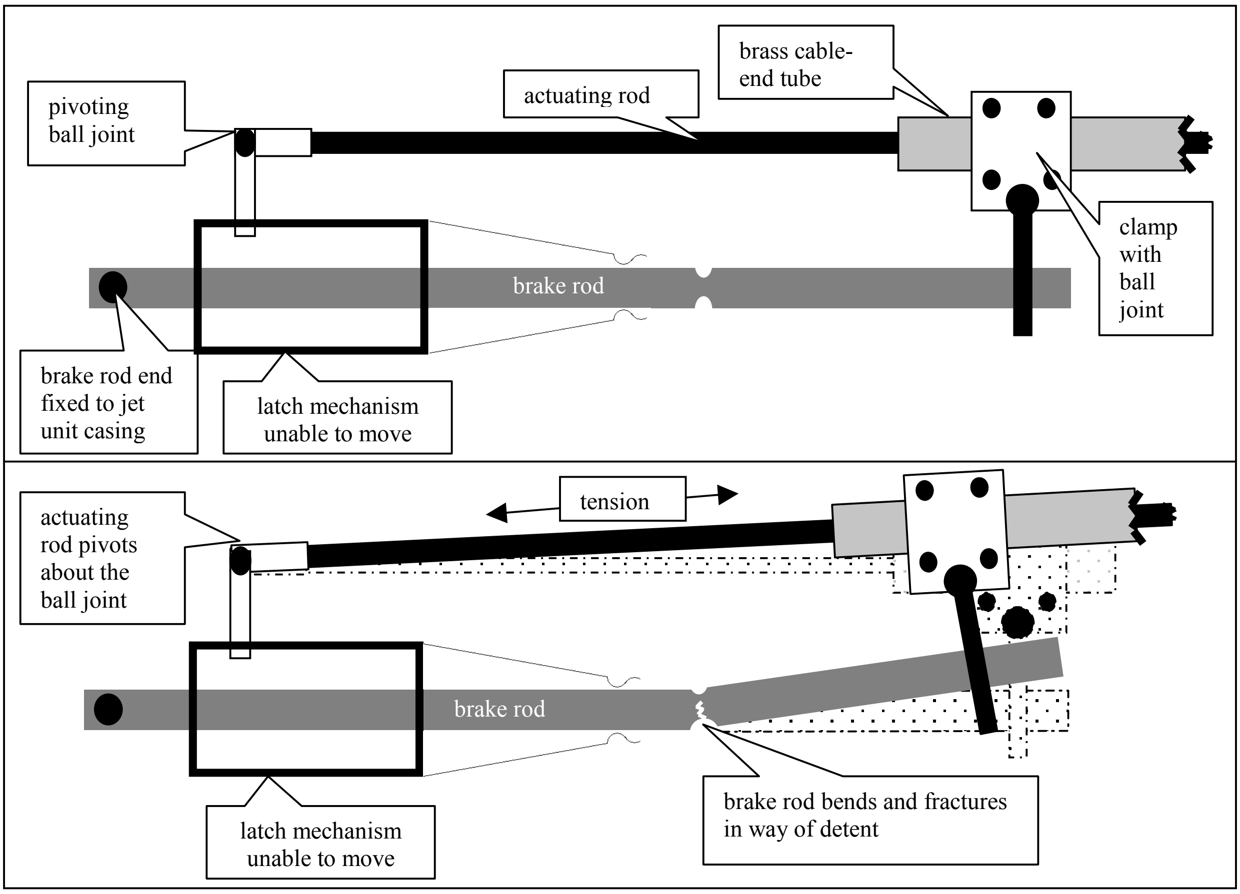

Figure 13
Effect of tension on the reverse duct operating cable should the reverse latch be unable to move

1.7.13 A mechanical engineer was engaged to assess the failed brake rod and latch assembly. A summary of his findings follows:

> The tip of the [brake] rod bent at an angle of approximately 45 degrees to the rod centreline before failing.
>
> Shear lips occur at the fracture surface of a round bar that fails in pure tension and form the classical "cup and cone" fracture of a round bar subject to excessive uniaxial tensile stress. The fact that a shear lip exists for only part of the circumference is consistent with a variable stress gradient across the rod fracture plane as the stress changes from tensile to compressive, which occurs in simple bending.
>
> Clearly the reduction in area at the detent weakened the rod significantly at that point, not only because of the reduction in cross sectional area but also because of the stress concentration that such a change in geometry imparted to the rod. Stress raisers are a common initiator of cracks and fatigue failures. However there is no evidence of fatigue at the fracture surface. Nearly the entire fracture surface is fibrous in appearance, without any evidence of beach or conchoidal marks. These marks would be expected with a fatigue failure.
>
> The absence of fatigue indicates that throughout its working life, the weakest point of the rod (the detent) was sufficiently strong enough to perform its necessary functions without weakening further. This also suggests that the rod failed during a single event and possibly as a result of an operational abnormality.
>
> Clearly for the rod to fail in bending, a bending moment had to be applied to the fracture plane. Applying a force via the cable and nylon connector would impart a bending moment to the fracture plane with a lever arm equal to the distance between the cable and the fracture plane. This is the most likely source of bending moment that failed the rod.
>
> It is important to note that because the cable connector is free to pivot on the grey box [the latch assembly], the lever arm increases as the rod deflects. The lever arm at failure would have been significantly greater than it would normally be during standard operation.
>
> The existence of a stress raiser (the detent) in an important control linkage is not best design practice but there is no evidence that it weakened the rod over its normal working life, prior to the failure. If however it is possible for an abnormal operational event of the type that facilitated the failure to recur in the future, then some review of the linkage design should be undertaken.

1.7.14 A survey of other commercial users of the Hamilton HJ 212 jet unit was taken to determine whether jams in the latch assembly of the reverse duct system were common. There had been instances where the brake plates had become worn and allowed the weight of the reverse duct to drop into the fully down position and also some instances where the latch assembly became stiff due to the adjustment of the brake plates or contamination of the brake plate/brake rod interface, but no-one canvassed had experienced a total jam. To avoid the relatively high maintenance that the latch assembly required, at least 2 commercial operators had chosen to change to either a rod system or a hydraulic system to operate the reverse duct.

1.7.15 During the survey, 3 instances of total reverse duct jams, not caused by the latch assembly, were reported; one was due to the duct hitting a log and being sufficiently displaced for it to jam on the jet unit casing. The other 2 jams were caused by debris between the reverse duct and the jet unit casing.

2 Analysis

2.1 When the boat became stuck in reverse, the driver could not move the reverse duct control lever, indicating that the system was jammed. Every effort of the driver to free the jam by jiggling the controls failed. However, almost immediately before the boat collided with the bridge pier the driver did exert sufficient pressure to move the lever, but the boat remained in reverse. The driver thought that he had stripped the control lever assembly, this was not the case as it was intact when inspected later. It is probable that the movement he felt was the bending and breaking of the brake rod at the detent, its weakest point.

2.2 The modification to the latch assembly to enable the heavier D0499 cable to be used was common for the commercial usage of the Hamilton HJ 212 jet unit. However, it did increase the distance between the axes of the cable and the brake rod thus increasing the bending moment on the brake rod. The brake rod fracture occurred at the detent, which had a significantly smaller section modulus than the main rod. This, together with the stress concentration of the detent shape, meant that the detent was significantly weaker than the main rod and predisposed it to failure in preference to other points along the rod. Modification to enable the use of the heavier D0499 cable was possible without using the brake rod as an anchor for the clamp attached to the brass cable end tube. Instead, the clamp could have been secured to the boat's hull and no load would have been borne by the brake rod.

2.3 If the failure had not occurred at the detent on the brake rod, it may have been possible for the driver to exert sufficient force for another part of the reverse duct control system to fail, possibly the control lever or the cable.

2.4 The mechanical engineer's observations indicated that the fracture of the brake rod was due to bending, and was a single event rather than as a result of fatigue failure throughout its working life. The detent was an obvious weak point, not only because of the reduction in cross sectional area but also because of the stress concentration at the change in geometry. However, the fracture surfaces of the brake rod showed no evidence of fatigue and the brake rod was sufficiently strong to perform its function until an unusual operational event occurred.

2.5 The movement of the cable and the fracture of the brake rod indicate that the jam occurred at or aft of the reverse latch assembly. When the reverse latch assembly was removed from the boat it was contaminated by mud and sand but could still be slid along the brake rod. After the latch mechanism was removed the reverse duct and its control linkages moved freely without any sign of jamming. It is therefore probable that the reverse latch assembly was restrained by the reverse duct being jammed in the fully down position.

2.6 The river was high and there was much debris in the water. It is probable that when the driver was repositioning the *white boat* at the launching ramp, debris became caught between the jet unit casing and the reverse duct jamming the reverse duct in the fully down position.

2.7 The breakage of the brake rod was almost certainly as a consequence of the jammed reverse duct rather than the cause of the jam.

2.8 On the boat's recovery there were no marks on the reverse duct to indicate that any debris had caused it to jam. Neither was there any damage to the reverse duct and it moved freely once the latch mechanism was removed. It was possible that while the boat was submerged and upside down any foreign object that may have jammed the reverse duct would have been washed away. So while it is likely that debris did cause the reverse duct to become jammed, there was no conclusive evidence.

2.9 The weather and river conditions at the time of the accident were not good, the drizzle making the passengers cold and wet and the swift running and murky river making the river difficult for the driver to "read". Added to that, the amount of daylight left was limited, so the lead driver's decision to shorten the trip was appropriate.

2.10 When the owner checked the ECan website at 1238, the river flow was well below the SOP recommended maximum of 300 cumecs. However, when the flow meter was rated on 20 May 2004, the retrospectively revised flow peaked at 324 cumecs. This reading was above the usual maximum flow for operations stated in the SOP but was below 350 cumecs, which was allowed on a static or falling river.

2.11 The river flow information from the ECan website had a time delay, but generally gave a reasonable indication of the trend of the river. The recalibration of flow meters was necessary to ensure that the data collected was reliable.

2.12 The drivers did check the height of the river against the boards of the sides of the launching ramp and confirmed that the river was within their operating limits

2.13 The speed of the river was swift and once the boat had become stuck in reverse, the driver had little time to think and plan a strategy to control the boat and prevent it colliding with the bridge. The boat was drawn away from the launching area before a bow line could be thrown ashore, and even with propulsive power, albeit astern, the boat very quickly reached the motorway bridge. It is probable that the driver had sufficient manoeuvrability to maintain some control of the boat and prevent it hitting the pier. However, in the heat of the moment, the driver while trying to free whatever was causing the jam in the reverse system, manoeuvre the boat and care for the passengers was unable to prevent the boat being swept towards the bridge pier.

2.14 Jet boats were designed to operate in shallow braided rivers common in New Zealand, where it was not uncommon for the boats to touch the shingle bottom. Such contact rarely caused significant damage other than scratches to the hull and possible blockages of the inlet for the jet unit. In the raised position the reverse duct would be unlikely to touch the bottom so would be unlikely to sustain damage through such contact.

2.15 Had the boat not collided with the bridge pier, it is probable that the *black boat* would have been able to reach it and take it under tow, before it reached the Old Highway and Rail bridges, without any harm coming to the occupants.

2.16 The pillow of water that formed on the upstream side of the bridge pier caused the starboard side of the boat to rise on contact. The part of the base of the pier extending upstream from the pier itself may have also helped lift the starboard side of the boat. The dents and scratches on the starboard side were quite light but were sufficient to show where the boat collided with the pier.

2.17 The pillow of water that forms on the upstream side of a fixed object, such as a rock or a bridge pier, has been found to be the principal contributing factor in a number of accidents involving white-water rafts and canoes that have resulted in fatalities, where those craft have high sided, wrapped or capsized. Usually jet boats have sufficient power to avoid being high-sided but without proper control the white boat became trapped on the pillow, high-sided and capsized.

2.18 The passenger who was unable to swim free of the boat before it capsized, maintained his composure and was able to evaluate his options before deciding to swim out from under the boat.

2.19 Had this been a single boat trip, the rescue, particularly of the entrapped passenger, would have been delayed and the consequences may have been more serious.

2.20 The operator had an appropriate SOP and the driver was suitably experienced. At the time of the accident Maritime Rules Part 80 did not require a jet boat driver to hold a specific licence. However, the amended Maritime Rules Part 80A, which was going through public consultation at the time of the accident, proposed specific training and licensing for jet boat drivers. The "grandfather" provisions in the proposed rule would have meant that the driver of the *white boat* would have been eligible, subject to a fit and proper person requirement, to be issued with a full licence without any further training or examination.

3 Findings

Findings are listed in order of development and not in order of priority.

3.1 The reverse duct system probably jammed due to debris becoming wedged between the reverse duct and the jet unit casing. The reverse thrust during the astern manoeuvre to reposition the boat could have caused stones and debris to be sprayed up and around the jet unit.

3.2 A less likely possibility was that the latch assembly jammed. This cannot be totally discounted, but when the latch assembly was removed from the boat it could be moved by hand. In addition, the position of the brake plate adjusting nuts suggested that the latch was more likely to be too slack rather than stiff enough to jam the whole system.

3.3 Once the jet unit became stuck in reverse the driver had a very short time in which to formulate a strategy to maintain control of the boat. He was unable to maintain control against the swiftly flowing river and the boat was swept onto the water pillow on the upstream side of the bridge pier where it capsized.

3.4 The fracture of the brake rod was caused by a bending moment induced by the cable and probably occurred when the driver exerted extreme pressure on the reverse duct control lever, shortly before the boat struck the bridge pier.

3.5 The design of the modified reverse latch assembly was deficient because it created a large bending moment on the brake rod.

3.6 The detent in the brake rod created a weak point, where failure was likely to occur.

3.7 The driver was properly trained, qualified and experienced to operate a commercial jet boat on the lower Waimakariri River.

3.8 The contemporaneous information about the river conditions available at the time indicated that it was safe for the trip to go ahead. The information was bolstered by the owner's experience on the river that morning and the driver's visual check on the height of the river.

4 Safety Actions

4.1 Prior to the accident, in response to the problems experienced by the commercial operators with the lighter Morse B71 control lever, CWF Hamilton and Co Limited had designed a more robust control lever, part number JM 1289. The new control lever was designed for use with the Morse 64C cable, thus avoiding the need to modify the cable to latch mechanism connection.

4.2 As part of the repairs, the operator fitted the new JM 1289 control lever and Morse 64C cable. He also fitted a brake rod that had been manufactured without the detent.

5 Safety Recommendations

Safety recommendations are listed in order of development and not in order of priority.

5.1 On 16 November 2004 the Commission recommended to the owner of Jet Stream Tours Limited that he:

5.1.1 Undertake a hazard identification audit of his operation, with special regard to the particular risks associated with operating from a launching ramp close to a bridge, where strong river currents may be experienced. (077/04)

5.1.2 Instigate regular training of his drivers, paying particular attention to unexpected events so that they can react automatically. (078/04)

5.2 On 3 December 2004 the owner of Jet Stream Tours Limited replied:

077/04 I have recently completed a risk identification and evaluation of our operation (23 Nov 04). This audit covered aspects such as severity, frequency and a final risk rating. This is still in draft form until discussed with the companies drivers for their feedback.

With regard to the Bridge Piles, (Hazard ID #006) we are in contact with Ecan to see if we can remove 1 steel fence post and replace the guard cable with a removable chain so we can put our passenger jetty in closer to the ramp area.

Also we have been in contact with Ready Mix Concrete who will (once the guard chain is removable) begin putting in a shingle wall on the downstream side of the ramp area out into the main flow. This will create a deep eddy on the upstream side and make a good holding pool and boat parking area in the ramp entrance for the general public. Currently the area can get silted up on the downstream side.

078/04 We will be having a training day on 5th December (subject to river and weather conditions). Special attention will be given to the Hazard Identification implementation of controls considered in the Hazard Audit. From this training day we will be able to assess what is possible and practical.

Approved on 22 November 2004 for publication

Hon W P Jeffries
Chief Commissioner

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