Report on investigations 99-212 and 99-213

jet boats *Shotover 14* and *Shotover 15*

separate collisions with canyon wall

Shotover River, near Queenstown

21 October and 12 November 1999

Abstract

On Thursday 21 October 1999 at about 1810, jet boat *Shotover 14* entered the first canyon on the Upper Shotover River with the driver and 9 passengers on board, travelling at about 65 km/h. While travelling close to the left side of the canyon a component in the steering system caught on a bracket, preventing the driver from steering to the right. The driver overcame the jammed steering by applying considerable force through the steering wheel, but too late to prevent the jet boat glancing off the canyon wall into a rock face. Eight passengers and the driver received minor injuries and one passenger received moderate injuries in the impact. The boat was extensively damaged.

On Friday 12 November 1999 at about 1415, jet boat *Shotover 15* entered the second canyon on the Upper Shotover River with the driver and 12 passengers on board, travelling at about 65 km/h. While the boat was travelling close to the right canyon wall the steering locked and the boat struck the canyon wall. The passenger in the right rear seat struck his head on a rock overhang and was fatally injured. The other passengers and driver received minor injuries.

Safety issues identified included:

- standards of maintenance
- standards for design of jet boat components
- small safety margins designed into the trip
- driver training
- the effectiveness of Rule Part 80 in ensuring safety in the jet boat industry
- management style and its effect on safety.

Drawing on lessons learned from these 2 accidents and others investigated in the past, several safety recommendations were made to the director of Maritime Safety, the operator and a manufacturer of water jet units, to address the safety issues.

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

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Transport Accident Investigation Commission
P O Box 10-323, Wellington, New Zealand
Phone +64 4 473 3112 Fax +64 4 499 1510
E-mail: reports@taic.org.nz Web site: www.taic.org.nz

***Shotover 14* after the 21 October accident**

***Shotover 15* after the 12 November accident**

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List of Abbreviations

HJL	Huka Jet Limited
ISO	International Standards Organisation
km/h	kilometres per hour
LPG	liquid petroleum gas
m	metre(s)
mm	millimetre(s)
MSA	Maritime Safety Authority
Nm	Newton-metres
QLDC	Queenstown Lakes District Council
SJL	Shotover Jet Limited (The parent company.)
SJQ	Shotover Jet Queenstown
TAIC	Transport Accident Investigation Commission
UTC	universal time co-ordinated

Glossary

chine	point where the hull bottom joins the hull sides
braided river	river where the main flow divides into several secondary channels within the river banks

Data Summary

Investigation:	99-212	99-213
Boat particulars:		
Name:	*Shotover 14*	*Shotover 15*
Type:	Shotover Mark III high water jet boat	Shotover Mark III high water jet boat
Limits:	Upper Shotover River	Upper Shotover River
Allowable occupants:	13 persons	13 persons
Length:	5.3 m	5.3 m
Construction:	aluminium monohull	aluminium monohull
Propulsion:	one Chevrolet 502 petrol engine driving an HJ-212 single stage Hamilton water jet unit	one Chevrolet 496 petrol engine driving an HJ-212 single stage Hamilton water jet unit
Normal operating speed:	65 to 70 km/h	65 to 70 km/h
Owner:	Shotover Jet Limited	Shotover Jet Limited
Operator:	Shotover Jet Queenstown	Shotover Jet Queenstown
Driver experience:	831 hours on Upper Shotover River	873 hours on Upper Shotover River
Location:	Upper Shotover River, first canyon	Upper Shotover River, second canyon
Date and time:	Thursday 21 October 1999 at about 1810[1]	Friday 12 November 1999 at about 1415
Persons on board:	crew: 1 passengers: 9	crew: 1 passengers: 12
Injuries:	crew: 1 (minor) passengers: 1 (moderate) 8 (minor)	crew: 1 (minor) passengers: 1 (fatal) 11 (minor)
Nature of damage:	major to hull	major to hull
Investigator-in-charge:	Captain Billy Lyons	Captain Tim Burfoot

[1] All times in this report are New Zealand Daylight Time (UTC + 13 hours) and are expressed in the 24-hour mode.

1. Factual Information

1.1 History of the trip (*Shotover 14* on 21 October 1999)

1.1.1 The driver of *Shotover 14* commenced work at about 0745 on Thursday 21 October having just returned from a 10-day break. Another driver launched the boat and made the morning boat check before taking it for a short run down Upper Shotover River to warm the engine. It was raining too hard for commercial operations, so he trailered the boat again.

1.1.2 Later that day the rain cleared so the driver launched *Shotover 14* and made a short trip down river to warm the engine. At about 1800 nine passengers boarded *Shotover 14* at the jetty having been fitted out with life jackets and spray jackets. The river was running high but within company guidelines for safe operation.

1.1.3 The driver briefed the passengers about the trip, which included:

- remain seated
- sit upright
- hold on to the hand rails tightly
- brace their feet against the foot rails
- keep all limbs inside the boat
- prepare for a spin[2] when he gave the signal.

1.1.4 *Shotover 14* departed the jetty shortly after 1800 and headed up river for about 200 m and performed a tight turn on the plane, headed back down river past the jetty and entered the first canyon, converging with the rock wall on the left at about 65 km/h.

1.1.5 The driver intended to pass about one metre off the rock wall but when he tried to steer to the right the steering wheel would not turn in that direction. The driver made 2 attempts to steer right and then applied considerable force to the steering wheel, which caused it to come free. The boat turned sharply to the right, causing the back left corner to glance off a rock outcrop and sending the boat into a sharp left-hand sliding turn toward the next rock outcrop (see Figure 1). The engine stopped during the accident sequence.

1.1.6 The forward right side of *Shotover 14* struck the outcrop heavily, causing extensive damage to the hull and topsides. The initial impact on the back left corner left a significant dent near the chine about half a metre long. The force of the impact dislodged the motor from its mounting, causing the exhaust couplings to part and water began entering the boat through the exhaust outlets.

[2] A spectacular manoeuvre unique to jet boats where the boat is turned at relatively high speed almost within its own length. A spin is often used when a rapid stop or change in direction is required in narrow sections of the river but is often used by commercial jet boat drivers to enhance the thrill of a trip.

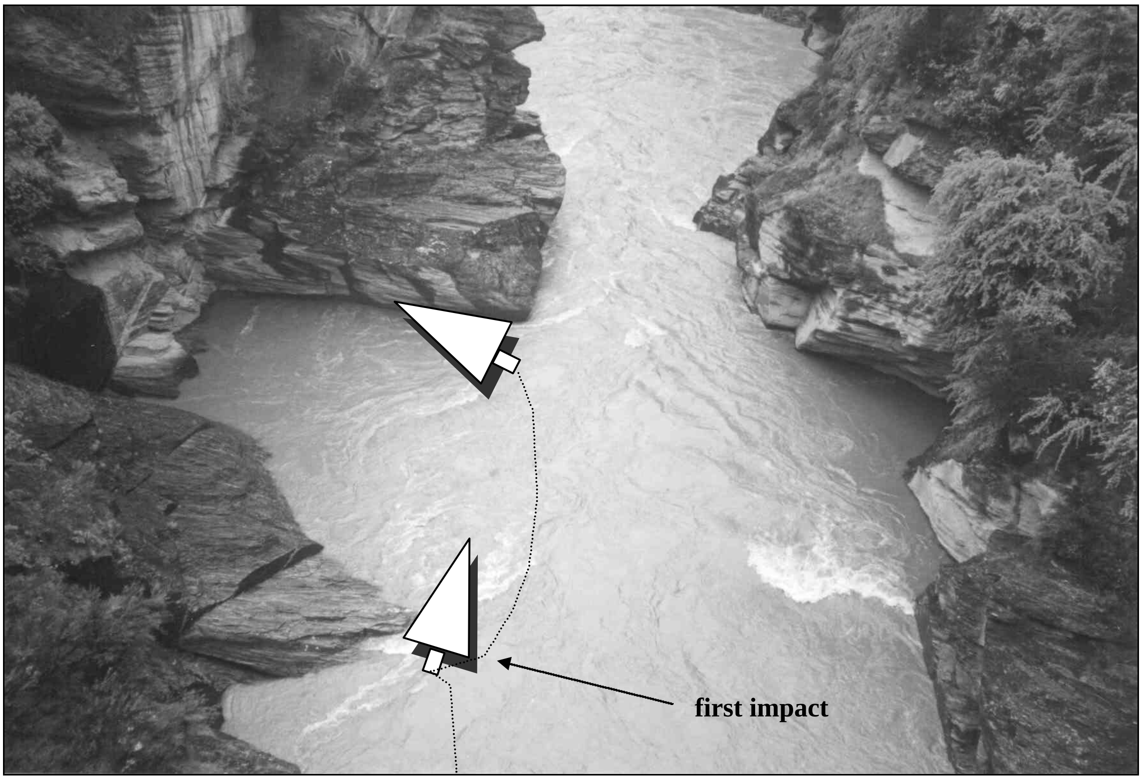

Figure 1
Accident site in the first canyon
and the approximate path of *Shotover 14*

1.1.7 The driver made a code 2[3] call on the radio and then stuffed towels in the exhaust outlets to stem the water ingress. *Shotover 14* drifted down river until another boat nearby arrived and managed to manoeuvre *Shotover 14* into a recess in the canyon wall and hold it there. A third boat soon arrived and the passengers were transferred and taken back to the Shotover Jet base, where they received medical attention.

1.1.8 One passenger received fractures to her wrist and 2 ribs. The driver and other 8 passengers received minor cuts and bruising.

1.1.9 Steering of *Shotover 14* was achieved using the steering wheel to turn a sprocket and chain located behind the dashboard. The chain was joined by shackles to cables that ran through a pulley system and were attached to the steering tiller mounted on the jet unit steering shaft at the transom. An inspection of the steering system revealed that a shackle connecting the chain to the steering cable had caught on an aluminium bracket supporting the dashboard. There were many marks on the bracket, indicating the shackle had been catching on the bracket for some time.

1.1.10 Heavy fresh marks were evident on the edge of the bracket where the shackle would have been passing across the bracket with each movement of the steering wheel. The shackle was found with its pin end partially forced through the thimble at the cable end, consistent with some considerable force having been applied to the shackle through the steering system when the other side of the shackle was being restrained (see Figure 2).

[3] Shotover code for a serious accident without major injury

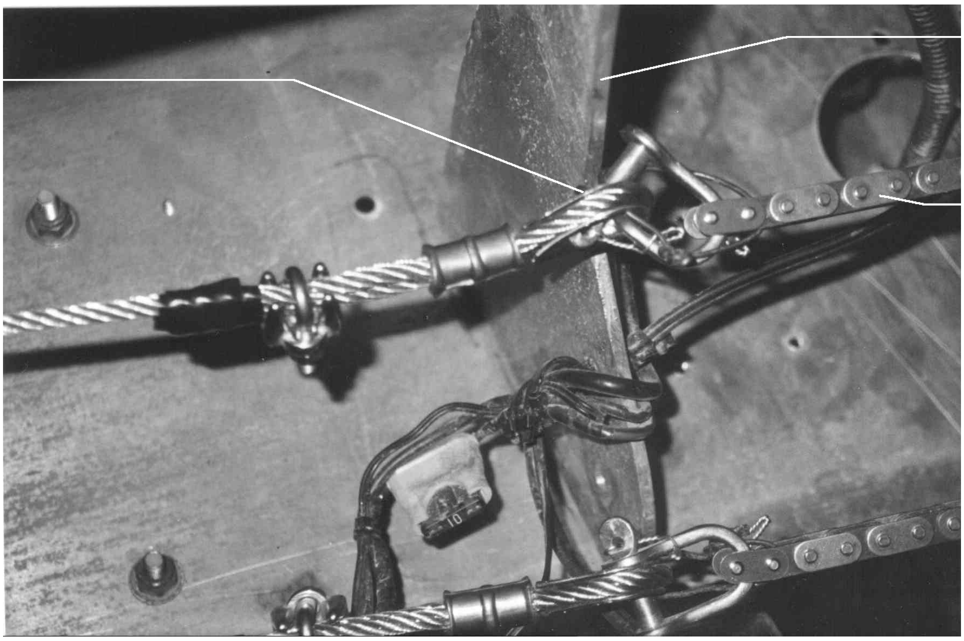

Figure 2
The steering arrangement behind the dashboard, as found

1.2 History of the trip (*Shotover 15* on 12 November)

1.2.1 On Friday 12 November 1999, the driver of the jet boat *Shotover 15* reported for work at about 1100. He was the same driver of *Shotover 14* when it was involved in the accident 3 weeks earlier. The driver of *Shotover 15* was rostered to do 8 trips that day, each of about 30 minutes duration. By prior arrangement another driver took his first 2 trips, he took the third and fourth driving jet boat *Shotover 18*, had a one-hour break and then took *Shotover 15* on the accident trip scheduled to depart at 1400. Other drivers had used *Shotover 15* for most of the day.

1.2.2 On arrival at the Shotover Jet base, the 12 passengers assigned to *Shotover 15* were fitted with life jackets and spray jackets. They were then marshalled down at the jetty where they boarded *Shotover 15*. The driver gave them a safety briefing similar to that given to the passengers of *Shotover 14* three weeks earlier.

1.2.3 *Shotover 15* departed from the jetty at about 1400 in moderately high river conditions. The route took the boat about 200 m up river where the driver made a high-speed turn on the plane and went down river past the jetty and into the first canyon. The driver followed normal company practice by intentionally passing close to 5 rocky features in the first canyon and then performed a spin in deep water near Big Beach.

1.2.4 After checking with the passengers that they were comfortable with the format of the trip, the driver continued past Big Beach and entered the second canyon passing to the right of Tombstone Rock.

1.2.5 The driver kept to the left side of the second canyon for about 500 m before crossing to the right side to remain in smoother water. He set the boat up to pass about half a metre off a rock known locally as Mary’s Rock and turned into the canyon wall briefly to flick the stern of the boat out to avoid striking the rock. This manoeuvre left the boat on a heading converging with the next rock outcrop. The driver went to turn left to regain the centre of the river but found the steering “locked solid”, preventing him from turning in that direction.

1.2.6 The driver later stated that he thought the same thing had happened to the steering as had happened 3 weeks earlier in *Shotover 14*. He pumped the accelerator "a couple of times" and applied considerable left force to the steering wheel in an attempt to steer the boat away from the canyon wall. The steering did not respond and the right shoulder of *Shotover 15* struck the canyon wall a glancing blow near the gunwale. The boat then ricocheted off the canyon wall back into the centre of the river.

1.2.7 Just above the point of impact on the canyon wall was a rock overhang. The passenger seated in the back right seat struck his head on this rock overhang and was fatally injured. The driver and other passengers received minor injuries.

1.2.8 The driver immediately made a Code 2 radio call and then turned to check the passengers. The passengers appeared to him to be relatively calm. Nobody realised at that stage that the passenger in the right rear seat had been fatally injured. The engine was still operating and the boat had turned around in the river current pointing toward a beach up river, so the driver applied throttle and drove the boat onto the beach. He could not recall if he was using the steering wheel to achieve this, nor could he recall if the steering was still jammed solid.

1.2.9 The driver did not hear any response to his Code 2 call because the radio speaker had dislodged in the impact, but his call was heard and several boats turned up to assist and transport the surviving passengers back to the base from where they were taken to hospital for medical attention.

1.3 Driver information

1.3.1 The driver was employed by Shotover Jet Limited for its Queenstown operation in October 1998 and started his training as a jet boat driver on 16 November 1998. He had no previous boating experience.

1.3.2 Over a period of 33 days the driver amassed 120 hours of training under the supervision of the Shotover Queenstown training driver. The training included route familiarisation and boat handling, building up to completing whole trips using sandbags to simulate a fully laden boat.

1.3.3 Initially the driver was taught to maintain a driving line that took the boat about half a metre off the various designated features on the sides of the river, such as rocks and trees. As his confidence and ability improved he was urged to drive the boat closer to the features to fulfil the company's objective of providing the "world's most exciting jet boat ride" based on a "perceived risk". The perceived risk was created by choosing a driving line that resulted in the momentum of the boat drifting away from the feature that was being worked[4].

1.3.4 Part of the driver's training was how to deal with a steering lock-up caused by a jet unit ingesting debris. The Hamilton HJ-212 jet unit was manufactured with a fine tolerance between the steering nozzle and its casing. Fine debris passing through a jet unit could build up and lodge between the steering nozzle and its casing, restricting the movement of the nozzle. Drivers detected this as a stiffening of the wheel movement and were taught to shake the wheel from side to side with power on to dislodge the debris. If this was not done, the build-up could cause a full nozzle jam. If the nozzle casing was worn or deformed, the gap between it and the nozzle was bigger, allowing larger debris to lodge. The ingestion of larger debris could cause a more sudden jam.

1.3.5 The risk of the jet unit ingesting debris increased when operating in shallow water where the water intake was close to the river bed, or in high river conditions when more debris was held in suspension in the water.

[4] The term used in the jet boat fraternity for passing close to or "buzzing" rocks and other features.

1.3.6 The driver said that in his 873 hours' driving on Shotover River he had never experienced a steering lock-up at planing speed in deep water due to debris ingestion, but he had experienced a steering lock-up during his training where the steering cables on a new installation caught up on a vertical frame on the transom. Most experienced drivers spoken to said they had experienced a steering lock-up due to debris ingestion at planing speed at some stage of their career.

1.3.7 When river conditions were high, drivers were urged to be more conservative with their driving line as the turbulent water made it more difficult to drive an accurate line. The Mark III boats were used when river conditions were higher. Part of the driver training was made in these boats because they handled differently from the other boats.

1.3.8 After completing 120 hours on Shotover River the driver made a successful check trip with the Queenstown Lakes District Council (QLDC) harbourmaster in December 1998. He was then licensed by both the company and the QLDC to operate jet boats on Shotover River.

1.3.9 The QLDC by-laws required drivers to have a minimum of 25 hours' driver training and pass the test with the harbourmaster to obtain a QLDC jet boat driver's licence. Rule Part 80 covering marine craft used for adventure tourism required 50 minimum driving hours, but did not require drivers to pass a test or to be issued with a licence.

1.3.10 The driver made his first commercial trip the same day he became licensed under QLDC by-laws, after which he started on the normal driver roster. The company kept him under observation for a probationary 25 hours' driving.

1.3.11 The roster was based around 5 days' work then 2 days off. The working hours varied depending on the shift and passenger numbers. Trips were scheduled to leave every half hour on the hour and half hour. If customer numbers demanded, boats would leave on the quarter and three quarter hour also. Drivers rostered on one of the primary shifts could drive up to 22 trips or 11 hours' driving in one day, with a total duty time of 15 hours. Back-up drivers relieved the main drivers for meal and rest periods, and were available to relieve at other times if required.

1.3.12 The driver of *Shotover 14* and *Shotover 15* started his commercial driving career in the busy season just before Christmas and New Year. In the 16-day period from 21 December to 5 January he drove a total of 150 trips for 75 hours' driving time. Allowing for 3 days off during that period that amounted to 11.5 trips per day, with him driving 20 trips on his busiest day.

1.3.13 The driver had been driving jet boats for about one year and had completed 1662 trips at the time of the first accident and 1746 trips at the time of the second accident.

1.4 Boat information

1.4.1 Both *Shotover14* and *Shotover 15* were Mark III boats, almost identical in design. They were built with a deeper vee hull form than the other boats, to handle high water conditions better with a greater degree of comfort for the passengers. The deeper vee made them more directionally stable and less prone to side slip in a turn. Drivers had to alter their driving lines and style when operating these boats.

1.4.2 Both boats were fitted with Chevrolet V-8 engines driving Hamilton HJ-212 water jet units. They both had the same passenger-carrying capacity and both had a top speed of about 70 km/h.

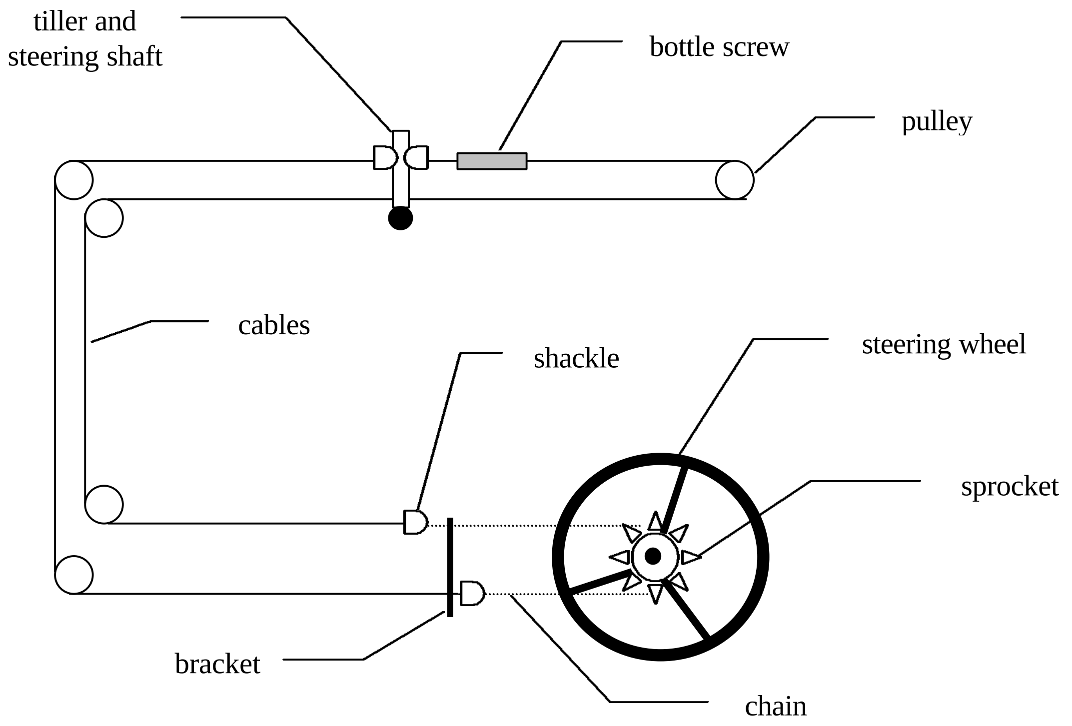

Figure 3
Schematic diagram of steering system

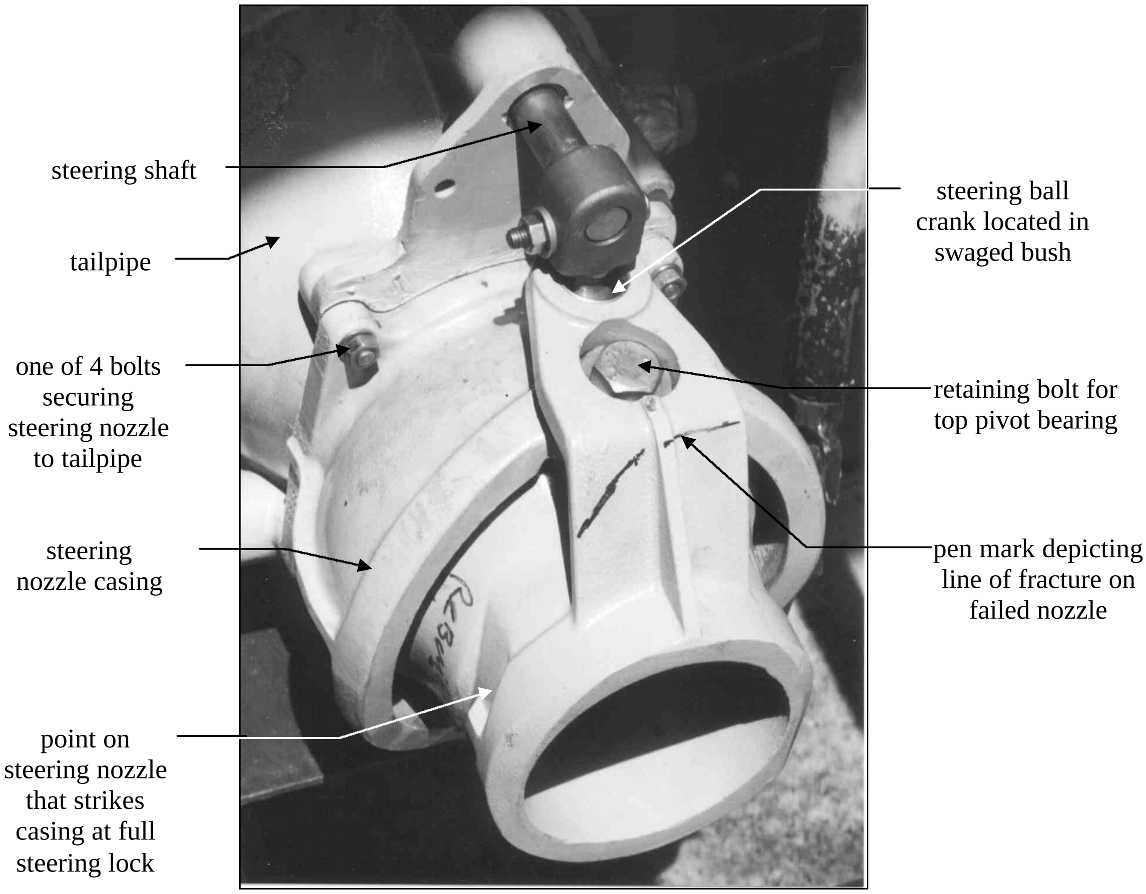

Figure 4
Hamilton HJ-212 steering nozzle with reverse bucket removed

1.4.3 Steering was achieved by the water efflux from the jet unit being deflected left or right by a steering nozzle at the back of the jet unit tailpipe. The steering nozzle could rotate laterally about 2 bearings to achieve this. The nozzle had a steering arm on top. The nozzle and steering arm were made from a single aluminium casting.

1.4.4 A steering ball crank rotating about a steering shaft achieved lateral movement of the nozzle. The crank fitted into a swaged bush near the end of the steering arm. The rotational action of the steering shaft was transformed to lateral movement of the steering arm through this arrangement.

1.4.5 The other end of the steering shaft was fitted with a tiller inside the transom of the boat. Left or right movement of this tiller was controlled by the steering wheel through a chain and sprocket arrangement behind the dashboard that pulled on a set of steering cables running through pulleys and connected to the tiller (see Figures 3 and 4).

1.5 Shotover Jet Limited

1.5.1 In 1970 Shotover Jet Queenstown Limited was one of the first commercial jet boat operators formed in the Queenstown area. Since that time it had carried some 1.75 million passengers.

1.5.2 Over the years the company set up a number of subsidiaries: Huka Jet in 1990, Shotover Jet Fiji Limited in 1994 and Goldfields Jet Limited in 1999. The company acquired Dart River Jet Safaris as a going concern in 1996 and part of Helijet Limited in 1994. The Helijet operation became a wholly owned subsidiary in 1998, and the business was subsequently sold to another operator in 1999.

1.5.3 At the time of the accidents Shotover Jet Limited operated 26 jet boats in its 5 subsidiaries and employed 33 drivers.

1.5.4 Shotover Jet Queenstown Limited marketed its operation as “The world’s most exciting jet boat trip”. Advertising brochures included statements such as “big reds of the Shotover fleet slicing through the waterway at incredible speeds, skimming the natural walls with only millimetres to spare”. The natural scenery, the speed of the boats and the spins they executed provided a good level of excitement. The narrowness of the canyons meant that the boats had to pass reasonably close to canyon walls in places, but drivers intentionally skimming the walls achieved the real thrill aspect of the trip. The driver training reflected the intention of the company to achieve the intent of these more recent marketing phrases, although the style of driving had been essentially the same for the previous 30 years.

1.5.5 Drivers were told that they need only drive as close to features as they felt comfortable with, but during their induction to the company they were told that the principal purpose of the company was to make a profit and they were left under no illusion that to attract customers the trip had to be exciting and that this could only be achieved by passing close to the canyon walls. One driver spoken to said that some drivers felt pressured on occasions to drive in high river level conditions in which they were not comfortable, although any pressure came indirectly and was in part due to peer pressure.

1.6 Scene examination

1.6.1 A Shotover Jet mechanic, Police officers, the QLDC harbourmaster and a Maritime Safety Authority (MSA) officer were involved in recovering *Shotover 15* back to the base. A decision was made that it would be safer to drive the boat back at planing speed rather than tow it in displacement mode and risk it sinking.

1.6.2 The mechanic tried the steering wheel and found it operated freely in both directions. He inspected the steering cable system and found that it was continuous down to the steering tiller on the transom, but the hull had been pushed in where the forward steering pulleys were attached, causing the cables to slacken. The jet unit steering nozzle was found to have fractured through the steering arm, rendering the unit unserviceable. The broken steering nozzle was not noticed at first because the unit was under water with the boat in displacement mode.

1.6.3 Another steering nozzle was brought down from the base and exchanged for the damaged unit. The slack in the steering cables was taken up by adjusting the bottle screw and the boat subsequently driven back to base, trailered and secured for later inspection.

1.6.4 The point on the rock overhang where the deceased struck his head was easily distinguishable. The distance from there to the water line was measured and compared with the measurement from the water line to his head when seated upright. Allowing for a draught of 30 cm with the boat on the plane, the deceased should have passed under the rock with about 44 cm clearance.

1.6.5 Several runs were made down past the accident site the following day with another Shotover Jet driver. The same speed, approach and distance off Mary's Rock used on normal commercial trips were followed on each run. On each pass, the bow of the boat was pointing directly at the point of impact at the position where the driver of *Shotover 15* said his steering would not turn to the left.

1.6.6 The boat took an average of 1.2 seconds to travel from Mary's Rock to adjacent to the point of impact at normal operating speed.

1.7 Examination of *Shotover 15*

1.7.1 The first impact point was in line with the front passenger seat on the starboard side just below the windscreen. The hull was severely pushed in from there back to the second row of seating. The hull was ruptured for about one metre just above the water line. The hull next to where the deceased was sitting was virtually undamaged.

1.7.2 The hull of *Shotover 15* had numerous scrapes and gouges consistent with contact with rocks, gravel and possibly its trailer. Most of these marks were aged. There was one relatively new scrape near the rear left underside of the hull. It was not possible to establish if this occurred at the time of the accident or some time shortly before or even during the subsequent recovery. The scrape was on the opposite side to the main damage.

1.7.3 A protective bar had been fitted around the transom to protect the jet unit. This bar had numerous dents and scrapes, but none appeared recent. Both of the exhaust mufflers mounted on the outside transom had at some time suffered blows to their underside despite the protective bar. The trim tabs located under the jet unit were heavily scarred, but again no new marks were evident. The hull had the general appearance of one that had been worked hard, but appeared basically sound.

1.7.4 The complete steering system was dismantled and inspected. There was some incorrect use of bulldog grips to secure thimbles in the cable ends and some undersized shackles in the system but nothing of note inside the boat appeared to have been capable of causing the reported steering lock-up.

1.7.5 The reverse bucket was removed from the jet unit to inspect the operation of the steering nozzle arrangement as fitted. The spare steering nozzle used to recover the boat was still fitted. The web under the steering arm on the replacement unit was cracked as shown in Figure 5.

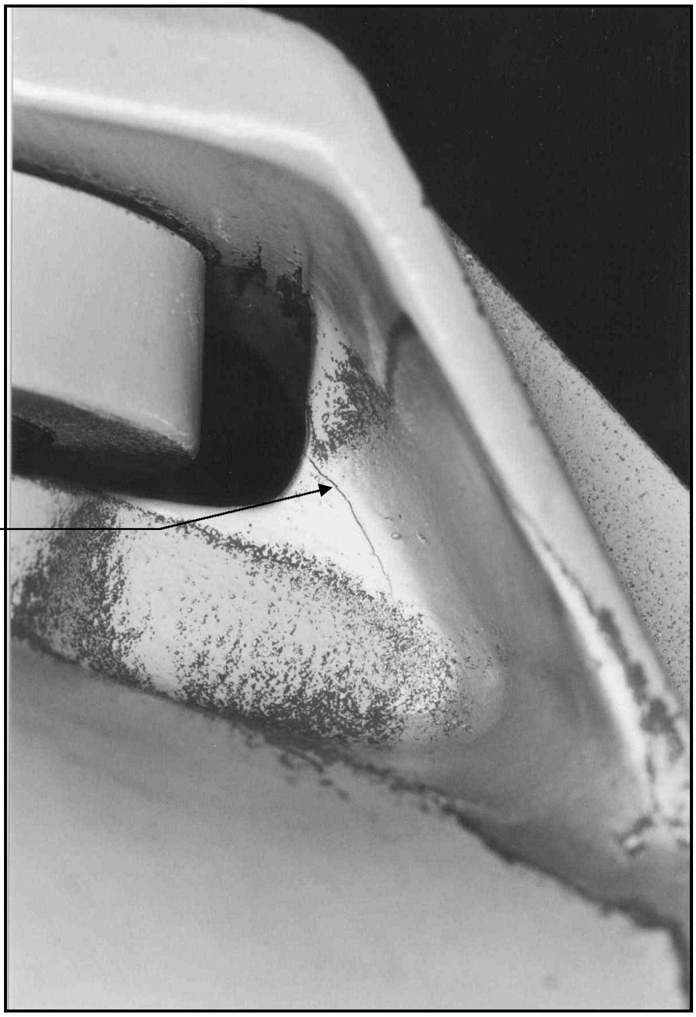

Figure 5
Crack in web of replacement nozzle for *Shotover 15*
Crack shown was typical of other cracks found in other steering nozzles

1.7.6 When what was considered a normal working load was applied to the steering wheel with the nozzle at full lock, the steering ball crank visibly lifted and then twisted the steering arm, which opened the crack in its web. The twisting appeared to occur when the stem of the steering ball crank came into contact with the top of the swaged bush in which it was sitting.

1.7.7 The steering nozzles on all HJ-212 units in the Shotover fleet were removed and crack tested. Seven of 8 nozzles tested were found cracked in the same web. Two of those tested had cracks near the change in section of the steering arm, indicating that fatigue failure of the steering arm had begun.

1.7.8 The following items were sent for independent metallurgy analysis:

- the broken steering nozzle fitted to *Shotover 15* at the time of the accident
- the steering nozzle fitted to *Shotover 15* following the accident to facilitate recovery
- the steering crank fitted to *Shotover 15* at the time of the accident
- the steering crank fitted to *Shotover 15* following the accident
- a steering nozzle obtained from the Shotover Jet workshops
- a control sample steering nozzle unit obtained from the manufacturer CWF Hamilton & Co. Limited (Hamilton Jet).

1.8 Examination of failed steering nozzle and other components

1.8.1 The fracture surface on the steering arm started near the change in section of the steering arm and ran at 2 distinctly different angles: from the right side looking forward, at an angle of about 5 degrees to the line of the change in section and then at an angle of about 45 degrees to that same line (see Figure 6).

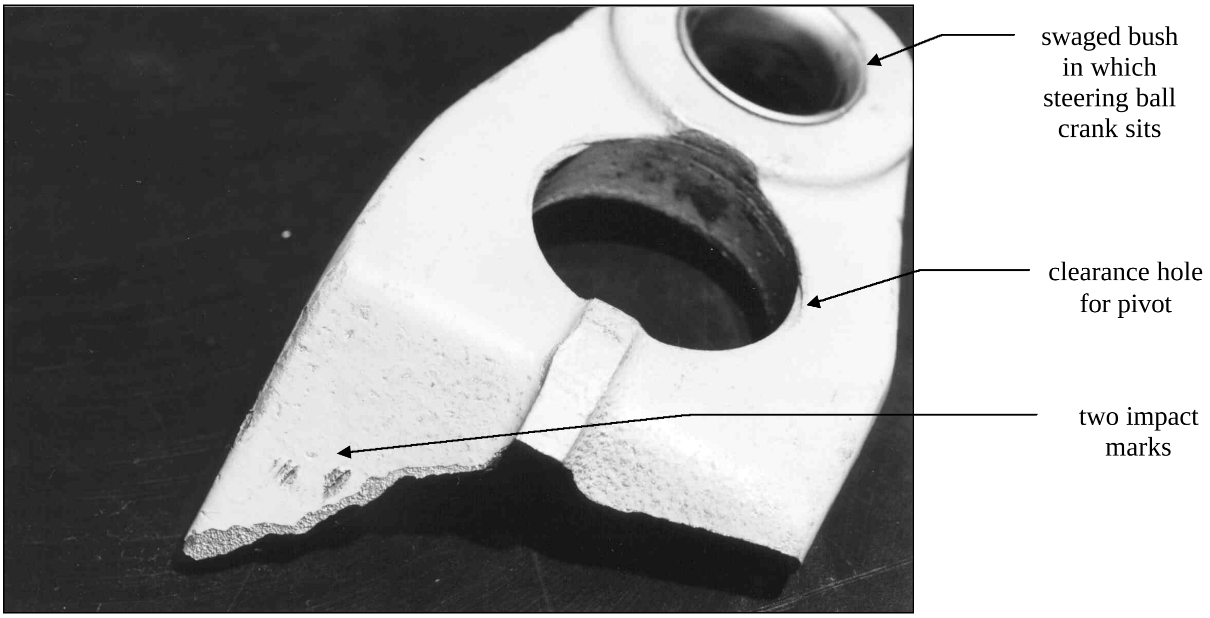

Figure 6
Fractured steering arm
The 2 impact marks labelled were consistent with the thread pitch on the bolts securing the steering nozzle to the jet unit tailpipe

1.8.2 The fracture on the right side of the steering arm was typical of a multi-origined fatigue crack that had started under the steering arm. Fatigue cracks had also started on the left side of the casting. A series of fine cracks was present in the paint under the steering arm on both sides (see Figure 7).

1.8.3 When the fracture surfaces were placed together this revealed that the arm had been bent upwards. Similar deformation was noted on the other 2 used steering nozzles. Figure 8 shows the comparison between a new and used steering nozzle.

1.8.4 A 10.5 mm long crack was present in the web supporting the steering arm similar to that shown in Figure 5. One side of this crack was removed from the casting by sectioning. Examination of the fracture surface revealed that it was typical of fatigue that had started at both top corners of the web. The crack then ran 45 degrees to the surface on both sides. In cross section a vee shaped fracture was then produced which was consistent with the web being cyclically twisted.

1.8.5 The nozzle had been damaged by a series of impacts near its rear face, which had deformed the circumference of the casting. That is, the nozzle exit was no longer round. The diameter ranged from 107.5 mm to 112 mm.

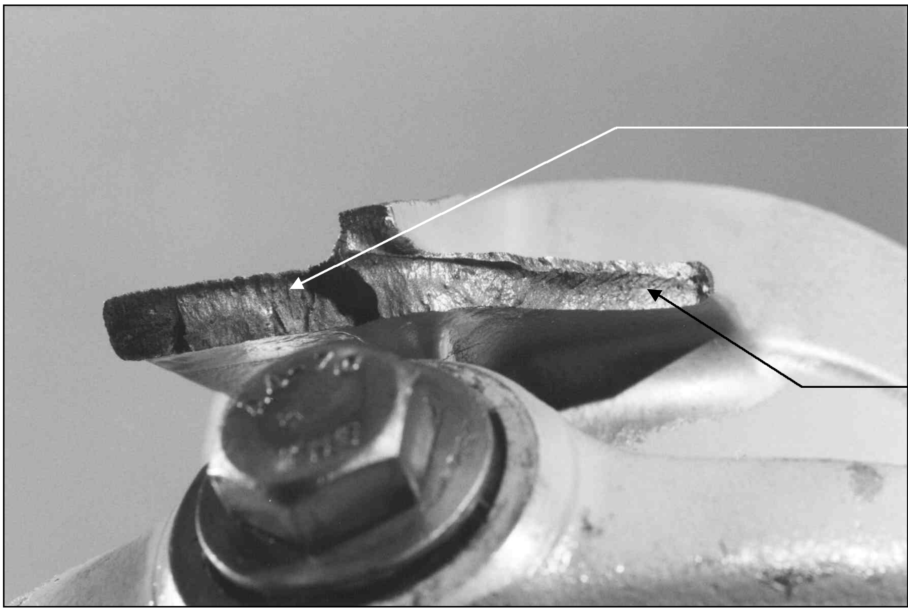

Figure 7
The fracture surface

1.8.6 Impact marks were present on the outside of the nozzle where it had been striking the sides of its casing when it reached the limit of its travel.

1.8.7 The swaged bush in the hole of the steering arm where the steering ball crank sat was heavily worn on opposing faces near its base. This wear was relatively even on both sides. The bush was also marked on opposing faces where the stem of the steering ball crank had been contacting before full steering lock had been achieved.

1.8.8 The steering ball crank was heavily worn. It had been reconditioned at some time and the metal used had worn through to the original metal and spalled. Wear marks were present on both sides of the steering ball crank stem. These marks were consistent with the wear marks on the inside edges of the swaged bush. These marks together with the heavy wear at the base of the swaged bush indicated that the steering ball crank and bush had become locked near the end of its travel on a regular basis (see Figure 9).

1.8.9 The clearance hole in the steering arm where the top pivot bearing sat contained a significant impact damage mark where the bolt washer had been forced into the side of the hole. The washer found in the hole was deformed. A series of marks was present in the paint inside the clearance hole where the washer had rubbed on the inside when the bolt had previously been removed (see Figure 10). This indicated that the steering arm had been bent before the bolt was last removed. Maintenance records showed that the nozzle bearings had been last changed on 23 November 1999, 3 weeks before the accident. Since that date the unit had been disassembled on 3 other occasions: once to replace a broken stud securing the jet unit, once to sharpen the impeller and once to fit a rebuilt impeller.

1.8.10 Two impact marks were present on the top left side of the broken steering arm. The marks were possibly a result of impact with a screw. The pitch of the thread on the end of the studs securing the steering nozzle assembly to the jet unit tailpipe was similar to the indent spacing of these 2 impact marks (see Figure 5).

Figure 8
Comparison between a new (top) and used steering nozzle
Note how steering arm on the used nozzle is bent away from the nozzle

1.8.11 Sealed ball bearings had been used in the steering nozzle swivel in place of the standard bushes fitted by the manufacturer. The bearings were not seized when the unit was dismantled from the boat but they contained grit and did not rotate freely. When the broken nozzle unit arrived at the metallurgist some 3 weeks later the ball bearings on one side were seized. The bearings were held in place by locking nuts. The locking nuts were eroded by high-velocity water from the jet unit. The high-velocity water would have been present at one side of each bearing in the steering nozzle.

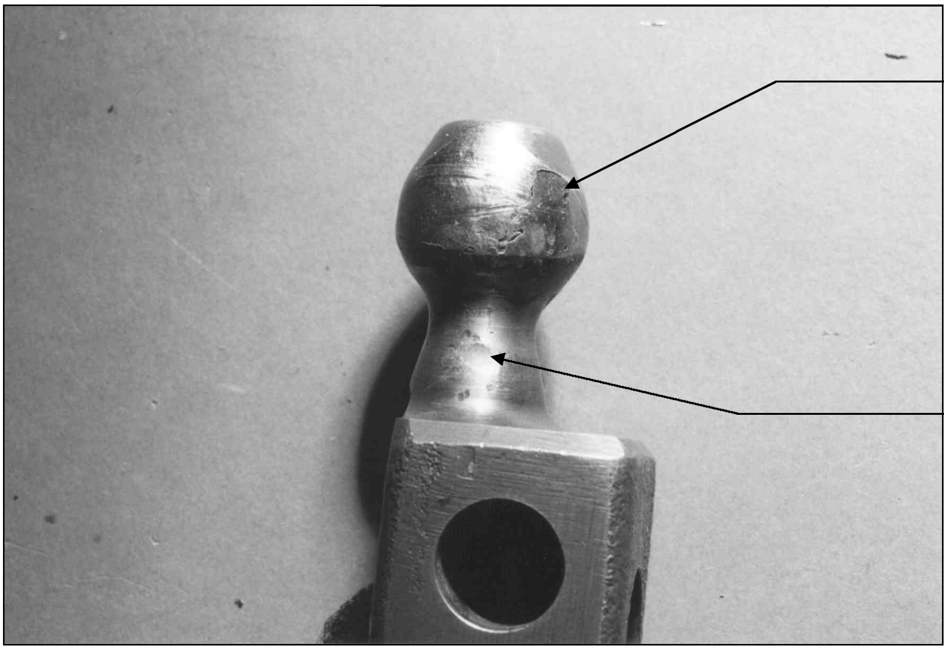

Figure 9
Steering ball crank from *Shotover 15*

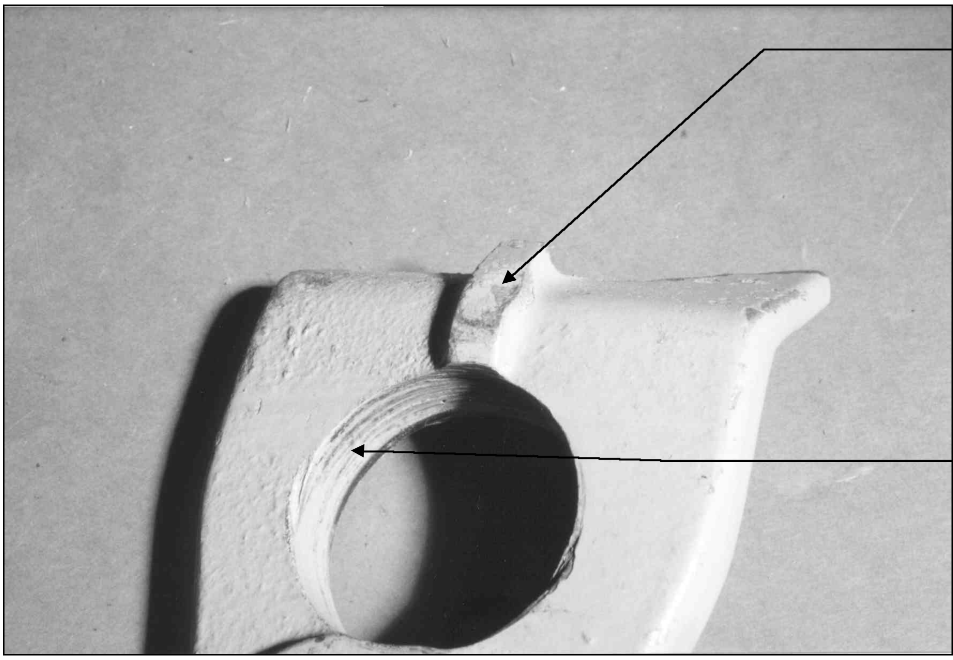

Figure 10
Failed steering arm showing markings inside the bearing clearance hole

1.8.12 The seized ball bearing was cut with a fibre abrasive wheel. Examination of the inside of the bearing revealed that a clip seal consisting of a steel plate covered with a soft polymeric material was present on both sides of the bearing. The inside of the bearing was covered with red rust and the balls and races were covered with small corrosion pits. There was no evidence of grease in the bearing.

1.8.13 Shotover River was known to contain a relatively high level of suspended mica, which can be abrasive. The inside of the damaged steering nozzle and its casing were severely eroded by the high-velocity river water. The outer circumference of the steering nozzle that provided the tolerance fit within its casing was severely eroded by high-velocity water and larger debris. This indicated that debris had frequently passed between the nozzle and its casing. This would have increased the likelihood of a steering nozzle jam, but it was not possible to determine how recently this had occurred.

1.8.14 An area of damage consistent with a blow from a hammer or similar tool was present on the rib on top of the steering arm.

1.9 History of failed nozzles

1.9.1 The failure of the steering nozzle on *Shotover 15* was not the first known case. In about March 1998 several HJ-212 steering nozzles were returned to Hamilton Jet with cracks in the web under the steering arm. One of these nozzles returned from Huka Jet Limited of Taupo had fractured in almost an identical fashion to the one from *Shotover 15*. The final failure was reported to have occurred during maintenance, and not in service. Huka Jet was a subsidiary of Shotover Jet Limited.

1.9.2 The fractured nozzle had been sent to Hamilton Jet for assessment. There it was noted on placing the broken components together that the arm had been bent down and there were several impact marks on top of the steering arm.

1.9.3 Hamilton Jet made the following observations in an internal report:

- the crack in the web was in no way related to the fracture across the steering arm
- the cracking of the web did not present any immediate danger of the arm failing
- the web could be eliminated altogether with little effect on the strength of the steering arm
- there were impact marks on the side of the steering nozzle where it had been impacting on its casing at full deflection
- although the balanced design of the steering nozzle meant normal operating stresses on the arm were quite low, the system could be overloaded at full lock when the nozzle hit the casing dependent on loads applied at the steering wheel
- there was nothing unusual in the appearance of the break (an independent material analysis report was being prepared)
- there were a number of impact marks on top of the steering arm

1.9.4 The report concluded that it was Hamilton Jet’s intention to change the design of the steering nozzle by thickening the arm and webs sufficiently to prevent any possibility of cracking. The new strengthened nozzles were available by October 1998.

1.9.5 The report also recommended that limiting stops should be fitted either side of the steering tiller on the transom to limit the travel of the tiller so that at full lock the steering nozzle stopped clear of its casing by about 1 mm.

1.9.6 In about April 1998, another commercial jet boat operator in Central Otago had noticed a reduction of steering performance in one direction on one of its boats. On inspection the owner found that the steering nozzle arm was bent up and twisted, resulting in reduced nozzle deflection in one direction. He noted that the web under the steering arm was cracked. His second jet boat fitted with the same jet unit of similar operating hours was not afflicted with the same problem. Each of his boats was driven by their designated driver only. He ordered a replacement nozzle and sent the damaged one to Hamilton Jet.

1.9.7 The material analysis report on the fractured Huka Jet steering nozzle commissioned by Hamilton Jet was received on 9 June 1998. The report concluded that the alloy used in the nozzle casting was on specification. One side of the fracture was generally lacking crystallinity. A number of fatigue cracks had initiated under the steering arm near the change in section, which had propagated up through that section. After that side of the steering arm had failed, the other side failed in overload. The report commented that loads higher than the fatigue strength of the alloy caused the fracture.

1.9.8 Hamilton Jet initially assumed that the high loads mentioned in its internal report were caused by blows to the top of the steering arm, but the report referred to the small fatigue cracks originating under the steering arm indicating they were caused by upward loads. Hamilton Jet then realised that fatigue cracks had started due to operational loads, but as it had already decided to strengthen the steering arm to address the cracking webs, it took no further action.

1.9.9 Meanwhile in May 1998, Shotover Jet Queenstown Limited discovered the webs on 3 of its HJ-212 steering nozzles were cracked. Shotover Jet Queenstown Limited returned these cracked steering nozzles to Hamilton Jet. Hamilton Jet passed both the metallurgy report on the broken Huka Jet steering nozzle and Hamilton Jet's internal report to Shotover Jet Limited and informed it about its intention to strengthen the nozzles, and recommended that it fit limiting stops to the steering tiller.

1.9.10 A number of letters were exchanged between the 3 jet boat operators and Hamilton Jet, discussing whether the cracked webs were a design fault or whether they were due to driver technique. When the new strengthened nozzles became available in October 1998, 3 were sent to Shotover Queenstown to replace the 3 cracked nozzles.

1.9.11 Later in October 1998 another 3 cracked nozzles were discovered by Shotover Jet Limited; one in its Dart River Jet subsidiary and 2 more at its Queenstown operation. Three more of the new strengthened nozzles were ordered to replace these.

1.9.12 No other correspondence was recorded between Hamilton Jet and Shotover Jet Limited until the fatal accident occurred on 12 November 1999.

1.9.13 Shotover Jet Limited did not fit the steering stops to its boats as recommended by Hamilton Jet.

1.10 Stress analysis of HJ-212 steering arms

1.10.1 After the accident involving *Shotover15*, Shotover Jet Limited commissioned a stress analysis of the steering arms. The loads for the analysis were derived analytically from a given torque of 180 Nm, which was measured at the steering shaft while a driver applied estimated maximum steering forces to the steering wheel.

1.10.2 The analysis indicated that the steering arm should have suffered total failure at the first application of such a load, with linear stresses between 5 and 8 times the typical yield stress of the arm. If the analysis was accurate, there would have been more reported failures of the steering arms than there had been. The analysis did show that the point of highest stress in the steering arms was on the web at the point where most of the cracking was observed, and the second highest point of stress was at the change of section under the steering arm where fatigue cracks were noted in both the Huka Jet fracture and the *Shotover 15* fracture.

1.11 Maintenance, inspection and audit

1.11.1 Maintenance of the Shotover Jet Limited boats was documented in the standard operational procedures manual. The system allowed for both planned and unplanned maintenance. Unplanned maintenance was raised by drivers or mechanics from the daily inspections of the jet boats. Planned maintenance was based on engine running hours.

1.11.2 Planned maintenance took the form of 7 types of service plans labelled A to G. Each type of service was planned for a certain number of engine hours. For example a C service involved changing the engine oil filter and spark plugs, which was planned for every 200 hours. An F schedule involved replacing the engine cylinder heads and the overhauling of the jet unit and steering system, which was planned for every 1500 hours. Checking the hull for cracking was included in the G service but for reasons unknown the G service did not feature on the service schedule. It could not be determined from the schedule when to check the hull for cracks.

1.11.3 The documented procedures for daily boat inspections required drivers to complete an inspection of the boat before it was launched, and then to complete warm-up checks while the boat was in the water still attached to its trailer. A check sheet was to be completed and signed by the driver. Any repair or maintenance items were to be noted on the check sheet, which went to the workshop at the end of each day to be transferred on to a whiteboard displaying work pending for each boat.

1.11.4 A number of months before these accidents the system was changed. A permanent check list was mounted under the engine cover. The checks were to be made by the driver and a mechanic together at the end of each day. This was done to improve the quality of the checks and to allow any urgent repairs to be made overnight rather than in the morning under time pressure to have the boat operational in time for the first commercial trip. The procedures manual had not been amended to accommodate this change.

1.11.5 One driver spoken to stated that in practice, some drivers did not always take part in the checks at the end of the day. They were sometimes engaged in other end-of-day activities such as putting away equipment. This was observed to be the case with one driver during the investigation.

1.11.6 The planned maintenance and checking procedures covered essentially the mechanical operation of the boat. Neither included a check of the safety equipment each boat was required to carry.

1.11.7 Of particular relevance to the *Shotover 15* accident, the daily check of the steering nozzle did not include removing the reverse bucket to check the steering ball crank or steering arm, in spite of the known problem of cracking in this area.

1.11.8 Shotover Jet Limited boats operated a high number of hours and were driven in a reasonably aggressive manner in a harsh environment. Wear on components occurred at a high rate and any design issues often showed in its boats first.

1.11.9 It was not unusual for mechanics to make modifications to the jet units to suit the company operation and to extend the maintenance periods. Such modifications were not always subject to a formal design change procedure. An informal arrangement existed between Shotover Jet Limited and Hamilton Jet whereby Shotover would tell Hamilton Jet of any problems encountered with components and what it had done to solve them. Hamilton Jet would occasionally make design changes to some components for Shotover but these were not put through the Hamilton Jet company quality assurance system for design.

1.11.10 Some modifications were not consistent throughout the fleet, particularly within the various subsidiary jet boat companies acquired in latter years.

1.11.11 In December 1997 the QLDC harbourmaster made an annual check of the Shotover Jet Queenstown jet boats. He found that 2 of the boats had substandard hulls and noted these as requiring repair. A further note was made that a guard on the back of the driver seat was to be fitted.

1.11.12 In July 1998 the QLDC harbourmaster conducted a driver check in one of the same boats and noted the following:

- the general hull condition was still substandard having numerous dents and cracks
- the bilge had significant quantities of oil residue which appeared to have been caused by a bad oil leak on the engine
- the guard had not been fitted to the back of the driver seat

1.11.13 In August 1999, an external audit of the Shotover Jet Queenstown operation commissioned by the QLDC identified a number of procedural issues relevant to maintenance and design, which still existed at the time of the 2 accidents. In summary they were:

- boat design concepts followed an evolutionary approach developed within the technical division with no established procedure for design changes
- the machinery and jet unit installation details had been developed in conjunction with the boats and were all subject to continuous improvement without the established procedure for design change
- the maintenance manual did not contain information relating to specific mechanical items or procedures, technical data or standards of workmanship required. Such matters appeared to be covered within the corporate knowledge of the staff.

1.11.14 On 26 November 1999, the director of Maritime Safety placed an interim operating restriction on all Shotover Jet Limited boats operating on Shotover River, preventing them from intentionally passing closer than one metre from rocks, rock faces and identified underwater obstructions. The restriction was imposed pending the outcome of MSA investigations into the 2 accidents.

1.11.15 The MSA consulted with some of the Queenstown jet boat industry and enlisted the advice of 2 jet boat consultants to analyse the effect and consequences of the new restriction. A point of view put forward by industry was that it was better jet boats be close to the canyon wall so if in the event of an engine or steering malfunction, any collision would be a glancing blow rather than a loss of control in the centre river which could result in a head-on impact.

1.11.16 Shotover Jet Limited stated in a letter to the MSA that it had a "grave concern" that in its view the one-metre rule added an "unnecessary element of danger to the trip" as a result of its drivers needing to concentrate on staying about one metre from the banks rather than driving as they had been instructed in the past, "the optimum line providing a safe but thrilling trip". This concept is discussed in the analysis of this report.

1.11.17 After considering the points of view and advice, the MSA considered that to retain the restriction was not appropriate for the Shotover Jet operation at that time, and withdrew the restriction.

1.11.18 In January 2000, the QLDC harbourmaster conducted an audit of all the jet boats in one of the Shotover Jet Limited subsidiaries operating in the Queenstown area. The findings of that audit are summarised below:

- the engines and jet units on all boats could not be faulted
- the hull of one boat was dented and cracked to such an extent that immediate withdrawal from service was recommended
- the hulls of 6 other boats required urgent hull bottom repair or renewal as they would probably sink if left in the water without the bilge pumps on
- the interiors and seat frames were not user friendly and could result in serious injury to occupants in the event of a beaching
- one jet boat hull was of an unsuitable design for the type of operation
- the fixed fire extinguishing systems did not have appropriate nozzles fitted and required certification by an appropriate agency.

1.11.19 The harbourmaster requested the company provide a programme of proposed action to address the maintenance issues.

1.11.20 The managing director of Shotover Jet Limited responded to the report essentially “taking issue with most of the comments” and employed an independent consultant to conduct a review of the boats, but the managing director did provide a repair and replacement programme as requested.

1.11.21 In February 2000 the independent consultant’s report was prepared. The report generally concurred with the harbourmaster’s report and identified the following additional issues:

- maintenance problems were exacerbated by the difference in design and the wide variety of equipment fitted
- the portable fire extinguishers required upgrading and relocating to better locations
- the underside of the engine cover and the rear face of the rear passenger seat should have a non-flammable lining
- petrol tank vents needed relocating away from passenger areas
- a variety of jet units were fitted to the boats, including locally manufactured components and some units with a mix of components from different manufacturers
- low grade turnbuckles, incorrectly fitted shackles and excessively slack cables in the steering systems
- some engine mounts did not comply with Rule Part 80
- seating arrangements in some boats did not comply with Rule Part 80
- improved footrests were required on some boats
- lack of standardisation of safety equipment and survival gear may be undesirable in an emergency
- some safety equipment required by Rule Part 80 was either not carried or not operational
- electrical wiring installations on some boats were generally substandard.

1.11.22 The managing director of Shotover Jet Limited sent the report to the QLDC harbourmaster under a covering letter. The letter indicated that he thought the consultant’s report supported his view rather than the harbourmaster’s.

1.11.23 In March 2000 the MSA commissioned an audit into the Shotover Jet subsidiaries operating in the Queenstown region. The report identified a number of safety issues, which are summarised as follows:

- the fire extinguishers in virtually the whole fleet did not comply
- the poor state of repair and cracking of many hulls, particularly with one subsidiary
- lack of engine collision chocks in all boats and inadequate engine mounting on several Shotover boats [The engine in *Shotover 14* shifted in the collision and resulted in the boat starting to fill with water]
- excessive water leakage, particularly in the boats of one subsidiary
- poorly designed fuel systems in the boats of one subsidiary
- one boat with a hull design unsuitable for the type of operation
- poor standards in LPG installations
- poor marking and condition of some safety equipment
- a large number of boats with cracked seat frames and mounts.

1.11.24 On 3 April the managing director of Shotover Jet Limited wrote to the director of Maritime Safety in response to the draft audit report. In the letter he made several references to identified examples of non-compliance with Rule Part 80 that would be addressed in future. Referring to one item of non-compliance, the managing director wrote, "Our staff consider that fitting a bow rope may be a distraction and that it would not add to any safety issues. We do not therefore agree that it is unacceptable practice".

1.11.25 In response to several perceived criticisms contained in the audit report, the managing director of Shotover Jet Limited used the rationale that the company standards must have been acceptable because a particular item or boat "had been approved by the MSA inspector". In response to perceived criticism over the poor standards of the boat LPG installations, the managing director wrote, "As a final comment, when Rule Part 80 refers to a non-applicable standard, it is difficult to see how our proven best practice can be criticised".

1.11.26 The Shotover Jet Limited policy and procedures manual current at the time of the 2 accidents contained the company policy and some procedures, but it did not include work instructions often found in a quality assurance manual. The manner in which maintenance was conducted and the allowable deterioration of components before repair was deemed necessary was left to the workshop staff. There was no reference to the manufacturers' recommended maintenance and inspection programmes.

1.11.27 Inspection of the maintenance records for all boats showed that most maintenance was carried out on the engines and jet units, but comparatively little time was spent on the hull structures and safety equipment.

1.12 Authorised persons and Rule Part 80

1.12.1 The introduction of the Maritime Transport Act 1994 marked a move away from the tradition of Government setting standards and then inspecting participants in the industry to ensure the standards were met. The Act placed a much greater responsibility upon operators to conform to those standards.

1.12.2 With the introduction of the safe ship management system for domestic shipping in New Zealand, it was recognised that for the operators of specific types of vessels a full safe ship management system was not practicable. Instead such vessels were allowed to operate under a Safe Operational Plan approved by an MSA authorised person. Commercial jet boats fell into this category. Prior to this the jet boat industry was essentially unregulated, except by local government in 2 regions, one of which was Queenstown.

1.12.3 The MSA developed Rule Part 80, Marine Craft Used For Adventure Tourism after consultation with the commercial jet boat industry. The rule came into force on 11 February 1999, with full compliance required by 14 July 1999, some 3 months before the first of these 2 accidents. The rule set minimum standards for design, construction, equipment and operation of commercial jet boats. It did not establish what was or was not an acceptable type of activity for commercial operators to use those jet boats for.

1.12.4 The MSA certified a number of authorised persons to inspect or audit operations. Such persons had to have the appropriate technical qualifications and practical experience in the applicable operation including, "a knowledge of auditing principles". No audit qualification was required.

1.12.5 Recognising that the QLDC had some history of regulating commercial jet boat operations in the Queenstown District, Rule Part 80 required any person inspecting or auditing an operation in that district to have been employed or contracted by the QLDC for that purpose. The QLDC harbourmaster was effectively the only person who was so contracted.

1.12.6 During the industry consultation process for making Rule Part 80 the Commercial Jet Boat Association advocated raising the level of some standards contained in the discussion document. Some refining of standards resulted but, recognising the specialist nature of the jet boat industry, the MSA chose to keep the standards to a minimum and rely on the industry expertise of the operators and authorised persons to use their own judgement in applying higher standards if a particular operation justified, rather than take the traditional prescriptive rules approach.

1.12.7 The authorised persons initially attended a half-day seminar hosted by the MSA to explain Rule Part 80. They were not given a set of guidelines or procedures to follow. The form they were required to complete and send to the MSA following an audit required them to assign a risk factor to the operator. None of the authorised persons spoken to knew what this risk factor referred to or what benchmark they were supposed to use.

1.12.8 Frustrated by inconsistencies in standards applied by the authorised persons, the Commercial Jet Boat Association mandated that members must attain higher standards than those required by Rule Part 80 and that members must use only the QLDC harbourmaster for approval and audit of Safe Operational Plans.

1.12.9 During the industry consultation process and in the first year Rule Part 80 was in force the Commission investigated 5 jet boat accidents in the Queenstown District. The Commission soon became aware that some jet boats would not or did not comply with Rule Part 80, and that in some cases Rule Part 80 in the opinion of the Commission needed reviewing. The Commission made a number of safety recommendations to the MSA and the Commercial Jet Boat Association essentially calling for an increase in minimum standards. Most of the recommendations were rejected or put on hold pending further review.

1.12.10 By the time of the second Shotover Jet accident on 12 November, the Commission had 3 current jet boat accidents under investigation. The Commission soon recognised that several of the safety issues identified in past investigations were going to arise again.

1.12.11 On 13 December the Commission made 14 preliminary safety recommendations to the director of the Maritime Safety Authority. The recommendations were based not only on the 3 current investigations, but on past investigations as well. Following consultation with the director one was withdrawn and with some wording changes the 13 remaining preliminary safety recommendations were finalised. These have been included in section 4 of this report.

2. Analysis

2.1 *Shotover 14* accident (99-212)

2.1.1 The river conditions at the time of the accident were relatively high, but within company guidelines. The driver felt comfortable operating in those conditions. He had adequate rest and was on his first trip for the day.

2.1.2 The steering lock-up was a result of a shackle in the cable steering system catching on a bracket behind the dashboard. The slack in the steering cables probably allowed them to bounce as the boat encountered the turbulent water. The shackle appears to have bounced up and caught on the bracket just as the driver was beginning his right turn to set the boat up for working the first rock in the canyon.

2.1.3 The driver had never before experienced a steering lock-up from a nozzle jam at planing speed in deep water. During his training he had been taught to shake the wheel from side to side to clear a nozzle jam. Had the driver done this it was likely that the shackle would have fallen down off the bracket giving him full steering control again, possibly in time to avoid colliding with either rock. A steering cable catching near the transom caused the driver's only previous high-speed steering lock-up. Given the rarity of steering nozzle jams at high speed in deep water, and the driver's limited experience, his actions were predictable.

2.1.4 With the canyon wall looming close on his left side the driver's natural instinct to turn away from potential collision appears to have prevailed over his training. This can be likened to a pilot of a stalled aircraft who may be reluctant to push the control yoke forward toward the ground to regain control before pulling out of a dive. At high speed and in the close confines of a canyon, a jet boat driver could not be expected to know for sure the cause of a steering lock-up when it occurs. Driver training might need reviewing to ensure drivers are aware that steering lock-ups can occur for reasons other than the jet unit ingesting debris.

2.1.5 By applying considerable force to the steering wheel, the pin of the shackle pulled through the thimble of the cable end, allowing it to come free of the bracket. The resulting sharp turn to the right caused the stern to strike the rock and send the boat into the left-hand sliding turn into the rock face.

2.1.6 The shackle had been catching on the bracket for some time, evidenced by the numerous marks on the bracket. It is surprising that drivers had not felt the shackle catching before and reported it to the workshop.

2.1.7 The shackle would not have struck the bracket when inspecting the boat on the trailer, which is probably why workshop staff had not picked up the problem. A look under the dashboard would have shown the steering system was intact and serviceable. A little lateral thinking when installing the steering system could have identified the potential problem, as would a more critical inspection.

2.2 *Shotover 15* accident (99-213)

2.2.1 The river conditions on the day of this accident were similar to those on the day of the *Shotover 14* accident. The driver was well rested and had driven only 2 trips before the accident trip.

2.2.2 The driver said that until the steering locked up in the second canyon *Shotover 15* had been operating normally.

2.2.3 The Commission was not able to conclusively establish whether the steering arm of the steering nozzle fractured and caused the steering to lock, or whether the steering nozzle locked up and the steering arm fractured when the driver applied considerable force to the steering wheel.

2.2.4 Whichever scenario was correct is of little importance. The steering arm of the nozzle was significantly weakened by pre-existing fatigue cracks and if it did not fail and cause this accident, it was highly likely that it would have failed shortly after.

2.2.5 The driver was essentially in the same situation as just before the *Shotover 14* accident. Having just rounded Mary's Rock, his boat was converging with the canyon wall, only this time on his right side. When he tried to turn left he found the steering would not turn in that direction.

2.2.6 The driver again did not shake the wheel as he was taught to do in his training; his mind had transposed to the previous accident and he thought the same problem had occurred again with the shackle catching behind the dashboard. With this in mind he applied considerable force to the wheel to fix what he perceived to be the problem.

2.2.7 If the jet unit had ingested debris and locked the steering nozzle, shaking the wheel may have freed it in time to recover the situation. With only about 1.2 seconds to respond, this was the only action likely to have either avoided or lessened the impact of the collision.

2.2.8 If the steering arm had broken and locked the steering system, shaking the wheel would have been pointless. Even if whatever was causing it to jam had dislodged, the steering nozzle would no longer have been connected to the steering system. Once the steering arm had fractured, the water efflux from the jet impeller would have caused the steering nozzle to centralise in its housing. This would have had the effect of steadying the heading of the boat, with any residual sideslip from the previous manoeuvre dissipating naturally dependent on the hull form. Being a Mark III boat with a deeper vee this would probably have occurred reasonably quickly.

2.2.9 The fractures appeared to have propagated through about 70% of the steering arm section before final overload occurred. It is difficult to estimate what load would have been required to initiate total failure. The manufacturer described normal operating forces on the steering arm as low. The forces opposing the nozzle turning were:

- hydrodynamic force of the nozzle deflecting the water efflux away from the line of the jet unit stator
- the residual mass of the nozzle and the water in the nozzle
- friction in the nozzle bearings
- side impact of the nozzle against its casing at full steering lock.

2.2.10 The hydrodynamic forces on a turning nozzle were semi-balanced. Shotover Jet had replaced the bushes with sealed ball bearings to reduce friction, but the condition of the bearings found after the accident probably negated any advantage so gained.

2.2.11 The driver stated that the turn around Mary's Rock was only slight, to prevent the stern of the boat striking the rock. It is unlikely that full lock was required to achieve this.

2.2.12 It may have been possible for the steering arm to have finally failed due to normal operating loads but if this occurred the driver should have noticed the steering give way before it locked up, which he did not. He described a normal turn to the right, followed by a total lock-up to the left.

2.2.13 Post-accident testing on a steering arm that was cut to a similar shape to the failed one showed that once failure had occurred the broken steering arm was free to rotate about the steering ball crank. The steering would not lock up by turning the steering wheel alone, but did when the simulated broken steering arm was physically placed in a position likely to jam. It was possible for the broken steering arm to rotate 160 degrees about the steering ball crank and jam under the studs securing the nozzle casing to the tailpipe. This scenario could explain the marks on top of the failed component, which were consistent with the pitch of the thread on the securing bolt.

2.2.14 There were 2 such marks where only one would have been expected if this had been the cause of the steering jam. It is possible that one or both of these marks were made while the driver was attempting to beach the craft after the accident. It would have been instinctive of him to try and use the steering to achieve this. The driver's memory of events immediately after striking the bank was understandably vague.

2.2.15 Jet boat drivers do experience steering lock-up from time to time caused by ingestion of debris. Opinions varied on how often this happens. The failed steering nozzle and casing fitted to *Shotover 15* were extensively worn internally by high-velocity water erosion. This erosion had enlarged the clearance between the nozzle ring and casing, making it more susceptible to lock-up from larger debris.

2.2.16 From the driver's account of events it seems more likely that he had suffered such a lock-up and that the steering arm finally failed when he applied considerable force to the steering wheel to clear what he perceived as being a lock-up due to a steering cable hang-up.

2.2.17 During the boat recovery after the accident the steering wheel turned freely. The driver was unable to recall when the wheel became free. It is possible that this occurred at or near the time of impact, unnoticed by him.

2.2.18 With some 70% of the steering arm section fractured, it is somewhat surprising that the driver and others had not noticed some deterioration in steering performance beforehand similar to that described by the other operator in the district who had cracking problems in the same type of nozzle.

2.2.19 If the jet boat had been in a level plane and the passengers were seated, the deceased passenger should have passed under the rock overhang by about 0.44 m. It appears that either the rear of the boat reared up on impact or the passenger was thrown up out of his seat, or a combination of both.

2.2.20 The passenger's head struck the rock overhang at a speed of about 60 km/h. Death was instantaneous. The head injuries sustained made this accident for him, not survivable.

2.3 Design and failure of the steering nozzle

2.3.1 The crack in the steering arm had started in a number of locations under the steering arm, which was consistent with the applied loads bending the arm up away from the steering nozzle. The multiple origin nature of the cracking indicates that the applied surface stresses were relatively high, but because about 70% of the section had fractured before final failure in overload occurred, this indicates that the average stresses on the arm were low.

2.3.2 The steering arm appeared to have been bent by controlled deflection rather than under a constant load. The fatigue crack probably started and propagated in the right side of the arm first. When the fatigue crack propagated across this section the loads were consistent with in-plane bending, resulting in a fracture nearly parallel to the change in section. When the fracture propagated in the left side, the right side was already cracked and loading was in torsion, causing the direction of the fracture to change.

2.3.3 The fatigue cracking in the web under the steering arms had propagated from both the front corners of the web. This was consistent with the steering arm being repeatedly bent and twisted. The loads that caused the fatigue cracking in the steering arm were on at least one occasion high enough to stress the alloy at the surface of the casting above its yield point and permanently deform the steering arm. The series of marks in the clearance hole on the steering arm where the ball bearing and its retaining bolt sat indicated that the steering arm was already bent the last time the bolt was removed (see Figure 10).

2.3.4 The fracture in the failed steering nozzle from Huka Jet in March 1998 bore a remarkable resemblance to the one off *Shotover 15*. The initial response from Hamilton Jet was that it had been subject to abuse, but the metallurgist's report indicated that the initial failure was in fatigue. It would appear the steering arm was already cracked in fatigue and the reported hammer strike was merely the load required for the arm to fail in overload.

2.3.5 Hamilton Jet appeared to have recognised that the fracture was caused in part by fatigue cracks, but it had already decided to thicken the web and the section of the steering arm to solve the cracking web problem, so it did not make a general recall of the product. Hamilton Jet appeared to have initially not appreciated the importance of the web to the design of the steering arm.

2.3.6 The web appears to have been critical to the design of the nozzle. By cracking it allowed the whole steering arm to be bent further upwards by the steering ball crank at or near full deflection. This caused the steering ball crank to slide lower in the swaged bush and its stem to contact the upper edge of the bush, effectively locking and preventing full deflection of the nozzle being achieved. Once the steering ball crank became locked in this fashion the upward bending load became a torsion load along the change in section of the steering arm, which contributed to the fatigue failure. The wear on the steering ball crank from *Shotover 15* was typical of high loads being applied. Some material had spalled off the surface and been rolled out as flake material. This probably occurred as the ball slid lower in the swaged bush under high load near full nozzle deflection.

2.3.7 Hamilton Jet gave operators the impression that the failure of the Huka Jet steering nozzle was due to abuse of the product and that cracked webs were not critical. A recall of all nozzles would have been appropriate for such a critical component, or at very least, a service bulletin warning all owners to check the component routinely and consult with the manufacturer if cracks were found.

2.3.8 There were a number of effects that could have contributed to the loading on the steering arms that had failed:

Shock loading as the nozzle impacted the casing at full steering lock - this would produce a high load in line with the thick section of the arm. The stress analysis report on the steering arm indicated that at maximum working loads the nozzles would fail on first application. This has clearly not happened, otherwise a greater number of failures would have occurred. Hamilton Jet inferred that aggressive driving technique was the cause of the cracked webs and bent steering arms. There appears little doubt that this was a factor. The operator who first brought the cracked webs and bent steering arms to the manufacturer's attention did not have the same problems with his second boat of similar age, which was driven only by himself. However, every used steering nozzle inspected had impact marks where the nozzle had been impacting with its casing. Clearly this was going to occur during normal use and the components should have been designed to withstand such stresses.

Steering ball crank locking in steering arm bush – this had been happening on the *Shotover 15* unit and others inspected. Wear marks on the stem of the crank and the top lip of the swaged bush were evidence that the ball cranks were locking before the steering nozzle reached full lock. The problem arose when the steering arm was bent up, as the ball sat lower in the bush and the nozzle could pass through a smaller angle before the stem contacted the bush.

Leverage on the steering arm from the steering wheel – the nozzle and water had an effective mass. Rapid turning of the wheel to effect aggressive boat manoeuvres would result in lateral in-plane stress on the steering arm.

Impact loads on the nozzle resulting from contact with foreign objects – the nozzle on *Shotover 15* had hit a foreign object hard enough to distort the nozzle out of round. This could cause high loading on the steering arm if the steering ball crank was locked in its bush, or if the driver had a tight grip on the steering wheel and happened to be turning the nozzle in the opposite direction to the impact.

Nozzle jam due to jet unit ingesting debris – this causes stiffening of the wheel, or in some cases a full lock. Drivers are required to exert above-normal operating torque through the steering wheel to clear the debris.

Reaction forces from the water jet on the nozzle when the boat was turning – these were not particularly high with the HJ-212 unit as the nozzle was semi-balanced.

Flutter of the nozzle – this would have increased as the casing and bearings wore allowing water to leak around the outside of the nozzle.

Seizure of the swivel bearings – this could have increased the leverage on the steering arm.

2.3.9 The most significant of these loads was likely to have been nozzle casing strike and steering ball crank jam, although impact with a foreign object could have produced the highest single load.

2.3.10 The suggestion by Hamilton Jet for operators to fit steering limit stops to the tiller on the transom would have prevented loads on the steering arm due to nozzle casing strike, but not loads caused by nozzle impact from a foreign object. The stresses placed on the steering arm when the steering ball crank locked in its bush could also have been avoided by adjustment of a steering limit stop, but a better solution would have been to address the reason why it was locking in the first place.

2.3.11 If steering limit stops had been fitted to *Shotover 15* when Hamilton Jet recommended, the steering arm would have been unlikely to be so weakened. Whether this would have prevented this accident depended on whether the nozzle broke first and caused the accident or whether it broke as a consequence.

2.4 Driver training and company culture

2.4.1 The Queenstown Shotover Jet trip was advertised as the world’s most exciting jet boat trip. The natural environs and the noise, speed and manoeuvres performed by the jet boats created much of the excitement for the passengers. Shotover Queenstown placed a high emphasis on the working of rocks and other features to set its product above that of other operators.

2.4.2 Drivers were taught to drive a line that created a perceived risk of colliding with designated rocks and other features while using the sideways momentum of the boat to carry past them. Drivers were encouraged to pass close to the rock being worked in this fashion. There are a number of safety issues with this style of driving.

2.4.3 Despite being warned not to place limbs outside the boats, passengers will sometimes see rock walls passing close by at high speed and reach out to touch them without thinking of the consequences. The driver has no control over this except for keeping the rock wall out of reach.

2.4.4 Another safety issue was that in some areas of the trip the driver must have the boat either heading or drifting towards the canyon wall in order to set the boat up to work the next designated rock. Experienced drivers minimise this by driving a good line. New drivers often over compensate and end up closer to the canyon wall between working rocks. They can put as much effort into setting the boat up for each manoeuvre as they do into executing the manoeuvre.

2.4.5 The Commission has investigated several accidents caused by drivers losing control for various reasons in between rocks being worked. The jet boat has often collided with the rock the driver intended to work because of some problem beforehand rather than the driver misjudging the manoeuvre itself. This was the case in the accident involving *Shotover 14* on 21 October 1999.

2.4.6 Another safety issue was that operating with such fine margins when working rocks would require intense concentration by the driver. For a short period the driver's attention can become focused almost totally on the rock being worked. The driver's awareness of other factors affecting or likely to affect the progress of the boat is reduced at that time. If bigger margins are used, drivers can afford to widen their field of vision to gain a better perspective of the route ahead and use their peripheral vision to monitor the boat's position and movement in relation to the rock.

2.4.7 The driver's experience and natural ability will determine to a certain extent how close the boat can pass off a rock and maintain an appropriate level of safety. However, even the most experienced driver is subject to human failings. People do make mistakes and experienced drivers will have off days due to possible emotional and physiological factors.

2.4.8 Driver fatigue is not considered to have contributed to either of these 2 accidents, but the driver roster showed that a real potential existed for drivers to be operating while fatigued. Drivers could be required to drive for 11 hours or 22 trips in one day, for a total 15 hours' duty time if passenger numbers dictated.

2.4.9 Driving jet boats on the Shotover trip is a physically demanding task requiring intense concentration for most of the time. It is likely that a driver operating towards the end of a 15-hour shift would be suffering some degree of fatigue and would be more susceptible to reduced performance. Such long shifts were not commonly necessary, but nevertheless must have been considered by management to be appropriate for it to have been documented in the Safe Operational Plan. The driver of *Shotover 15* made 20 trips on his 10th day of driving with passengers on board.

2.4.10 A back-up driver was available at all times who normally drove the relief trips. Management suggested that this driver was available to do other trips for the prime shift drivers if they required. People can be the worst judge of how fatigued they are. Drivers were unlikely to ask for a relief driver on the grounds that they were tired. To do so might signal an admission of inferiority amongst their peers.

2.4.11 The driver training at Shotover Jet Queenstown was more than twice that required by Rule Part 80 and almost 5 times that required by the QLDC. The programme appeared to be working well, with drivers coming out with a good basic knowledge and practical experience in boat handling and a good knowledge of the route.

2.4.12 The Commission has noted a trend over the last 5 years whereby almost without exception the jet boat drivers involved in accidents it has investigated have had about one years' driving experience. This trend has been attributed to drivers reaching a critical time in their career where confidence can exceed ability. Notably the driver of *Shotover 14* and *Shotover 15* had been driving for about one year.

2.4.13 With a regular turnover of jet boat drivers in the industry there will always be inexperienced drivers and drivers passing through that critical period where their confidence may exceed their ability. The industry needs a driver-training programme that not only produces competent new drivers, but also provides a system of ongoing assessment and peer review to help them through those periods where they are exposed to an elevated risk of having accidents.

2.4.14 There was no formal maritime qualification available for driving jet boats, yet there was for craft of similar size used for lower risk activities. A formal qualification would help jet boat drivers take ownership of their responsibilities and help them resist pressure from companies to drive outside their comfort zone, rather than their driving style being owned by the company that trained and employed them.

2.4.15 When the MSA imposed the one-metre restriction on Shotover Jet boats, Shotover management and a number of other industry participants opposed the restriction citing that going closer to rocks was safer. Their rationale was that if a mechanical failure occurred then it would be better to be close in to the canyon wall so that any contact was a glancing blow rather than a possible front-on collision. This may be so if the canyon wall was straight and smooth, but it was not. In almost every case the Commission has investigated, the jet boat has glanced off a rock and made a direct hit on the next rock outcrop jutting out into the river.

2.4.16 Even if the canyon wall was straight and smooth, the difference between 0.1 m and 1.0 m off will not appreciably alter the angle at which a jet boat glances off the wall, but it does make a significant difference to the distance the boat will travel before contacting the wall, which would give the driver more time to react and possibly recover, or give the passengers more time to brace.

2.4.17 Further, if the stern of a jet boat strikes the canyon wall, as happened in the *Shotover 14* accident and several others, this has the effect of spinning the boat into the canyon wall. The likelihood of a stern strike increases significantly the closer to the wall the boat operates.

2.4.18 Was it necessary for the jet boats to pass so close to rocks to achieve a level of thrill? Ask passengers who have just stepped off a jet boat having completed an incident-free trip and the reaction is likely to be mixed. Ask the same question of passengers who have been involved in an accident and the answer is highly likely to be no. It would appear that in trying to meet its objective of providing the world's most exciting jet boat trip Shotover Jet Limited may have been exposing its passengers to a higher than necessary level of risk.

2.4.19 It was disappointing that the MSA withdrew the one-metre restriction on the advice of experts in the industry. Equally disappointing was the intimation from the operator that the MSA may be "adding an unnecessary element of danger to the trip" by imposing the rule. While it may not be practicable to set a minimum distance that will cater for all situations, the one-metre rule was as good a target as any for drivers to achieve, and was preferable to them striving to reduce the distance off rocks to the detriment of passenger safety.

2.4.20 The reaction of senior management to the one-metre rule was in common with its reaction to the various external inspections and audits by regulating authorities. The impression was that the imperative was to defend the status quo and resist externally imposed change by challenging or discrediting perceived criticism. Evidence of this was in senior management illogically using the various audit reports to justify its position despite comments to the contrary contained in the reports.

2.4.21 The managing director of Shotover Jet Limited intimating that company standards were acceptable because they had at some time in the past been "approved by an MSA inspector" indicated a poor understanding of the current maritime legislation. The current legislation promoted operators building safety into their operations from the start, rather than relying on it being inspected in at the end, during an annual survey or after an accident for example.

2.4.22 The managing director's apparent acceptance that items of maintenance required to make some Shotover Jet Limited jet boats comply with Rule Part 80 could be postponed until the off season, and his disputing the efficacy of one requirement of the rule, demonstrated either a lack of understanding or a lack of respect for the statutory framework.

2.4.23 Such a management culture was likely to have flowed down to front line staff over time. The potential existed for front line staff to observe management attitude towards authority and adopt a similar approach to rules themselves.

2.5 Maintenance

2.5.1 Shotover Jet Limited did have documented procedures for conducting maintenance on its jet boats, but there was a lack of some documented work instructions and standards to follow in the day-to-day maintenance. The company relied largely on its mechanics' accumulated knowledge. Such a system is vulnerable when staff turns over and knowledge is lost.

2.5.2 The workshop staff appeared dedicated to their task and keen to maintain the jet boats in good order, but much of the maintenance was focused on keeping fast and mechanically reliable boats on the water to achieve the marketing objectives. The maintenance department appeared to be under-resourced to achieve anything more, particularly when faced with an ageing fleet.

2.5.3 The results of the various inspections, audits and these 2 accident investigations bear testimony to a jet boat company that has not provided sufficient resources to maintain an appropriate level of maintenance in its fleet.

2.5.4 Questionable maintenance standards contributed to the accidents involving *Shotover 14* and *Shotover15*. A well maintained and inspected steering system was critical to passenger safety.

2.5.5 The age of the cracks in the steering arm on *Shotover 15* could not be determined, but it was probable that they had been there for some time. The steering nozzle would have been removed 3 times in the 3 weeks before the accident. The cracks in the steering arm web and those that propagated to failure were probably present on each occasion. The marks caused by the washer inside the clearance hole when the top pivot pin was removed indicated that the steering arm was bent up at the time, probably on each occasion.

2.5.6 With the history of cracked webs under steering arms and the failure of a steering arm on a jet boat operated by its own subsidiary, it is surprising that Shotover Jet Limited did not include an inspection of the steering nozzle as part of one of its service schedules.

2.5.7 In not detecting obvious flaws, or examining known problem areas, it would appear that staff making the checks were doing so with a degree of automation, on the basis that items were "present and correct" rather than making a critical inspection. This could in part have been due to time constraints. The new system of checking boats at the end of the day made good sense, but staff were then doing the checks at the end of what was often a long day. There is evidence that already some drivers did not take part in the checks, but busied themselves with other tasks. It would be unwise for drivers to be left out of the inspection regime. They do after all have a vested interest in the boat being in reliable condition the next day.

2.6 Summary

2.6.1 According to records, the jet boat industry has enjoyed a reasonable safety record over the 30 years it has been a commercial activity. Commercial jet boating has developed from being an adventure activity where most of the participants were genuine enthusiasts performing feats as much for their own enjoyment as that of their passengers, to a highly commercial and competitive adventure tourism industry.

2.6.2 In its infancy the industry was largely self-regulated, with some regions later regulated to some extent by local government. With the growth of the activity into a highly commercial and competitive industry came the inevitable situation where safety standards struggled to keep pace with progress.

2.6.3 Shotover Jet Limited was one of the first commercial jet boat companies in New Zealand, and has since grown to be the largest single operator. The evidence suggests that in the past the Shotover Jet operation had been efficient and well run. Some erosion of safety in some aspects of its operation had been identified following these latest 2 accidents.

2.6.4 Rule Part 80 was introduced to set minimum standards for commercial jet boat operators after consultation with the industry. There will always be certain participants in any industry that would prefer minimum regulation. During the consultative process some participants wanted Rule Part 80 to set higher mandatory standards. The MSA opted for minimum mandatory standards that did not place an onerous burden on jet boat operators. For some jet boat activities such as low-speed transport or low-risk scenic operations the standards were probably adequate but for other high-speed activities such as “slicing through the waterway at incredible speeds, skimming the natural walls with only millimetres to spare”, higher safety standards are essential for the public’s best interest.

2.6.5 With the current status of Rule Part 80, it would appear that neither the MSA nor an authorised person has the ability to impose any higher standards than those prescribed in the current Rule.

2.6.6 By imposing special conditions on its members the Commercial Jet Boat Association attempted to raise standards in the industry, but this action had the potential to create a rift in the industry to its detriment. Operators could simply leave the association and employ another authorised person.

2.6.7 A better solution would be to review Rule Part 80 and increase its standards to a level commensurate with each type of jet boat activity, and then ensure that all authorised persons work to the same aims and guidelines.

2.6.8 Rule Part 80 was a code of practice that relates to the design, construction, equipment and operation of marine craft used in the adventure tourism industry. The code did not cover the type of activity commercial jet boat operators offered. Put another way, the rule inferred that as long as an operator had a Safe Operational Plan to cover the contingency of something going wrong, then that provided an acceptable level of public safety. The rule did not address what was the likelihood or consequence of those things going wrong. Rule Part 80 and the regulatory approach to the commercial jet boat industry could benefit from a review.

2.6.9 Some organisation needs to accept responsibility for distinguishing what is or is not an acceptable jet boat activity under the rule.

3. Findings

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

3.1 The driver of *Shotover 14* and *Shotover 15* had received a good standard of initial training. With one years' experience behind him he was driving at a time when driver confidence has been known to exceed their ability, which was not catered for in the Shotover Jet Limited training system.

3.2 The river conditions on the day of each accident were suitable for the type of jet boat operation.

Shotover 14 accident

3.3 *Shotover 14* collided with a rock outcrop when a shackle in the steering system caught on a bracket and momentarily locked the steering in one direction.

3.4. Had the driver used techniques for clearing a steering lock-up taught during his training he may have regained steering in time to avoid or lessen the impact.

3.5 Had the boat been driven further away from the canyon wall, impact probably would have been avoided.

3.6 More time spent and more critical examination during daily boat inspections should have identified the potential steering lock-up on *Shotover 14*.

Shotover 15 accident

3.7 *Shotover 15* collided with the canyon wall at about 60 km/h and glanced off when the driver experienced a steering lock-up and could not turn away from the canyon wall.

3.8 The passenger in the back right seat struck his head on the canyon wall. The injuries he sustained were not survivable and death was instantaneous.

3.9 The steering arm on top of the steering nozzle had fractured, which would have rendered the steering unserviceable. It could not be established conclusively whether the steering arm broke and caused the accident, or whether the steering nozzle was jammed by debris and the steering arm broke as a consequence of the accident.

3.10 The driver's description of events indicated that it was more likely that debris jammed the nozzle and the steering arm fractured during the collision sequence.

3.11 Fatigue cracks had propagated through about 70% of the steering arm section before the accident occurred. If the steering arm had not failed in this accidence sequence, it was highly likely to have failed shortly after.

3.12 The steering arm on the steering nozzle was under-designed for its intended purpose.

3.13 The designer of the steering nozzle became aware of its design deficiencies, but did not fully appreciate the manner in which the nozzles were failing. A recall of the product or a service bulletin alerting users to the safety issue would have been a prudent measure.

3.14 Shotover Jet Limited had previously returned to the manufacturer 6 cracked steering nozzles and one that had failed. It would have been prudent to include a check on this safety-critical component in its inspection and maintenance system.

3.15 Fatigue cracks in the steering arm were probably present and probably easily detectable to the eye when maintenance had been carried out on the jet unit 3 times in 3 weeks prior to the accident.

General

3.16 In both accidents the jet boat was operating closer to the canyon wall than necessary to achieve an appropriate level of thrill for the passengers.

3.17 Shotover Jet Limited designed its trips with less than acceptable distance off features for a passenger-carrying operation.

3.18 The circumstances of these 2 jet boat accidents and others investigated by the Commission demonstrated that some form of regulating the type of activity in which commercial jet boat operators were engaging was required.

3.19 The history and circumstances surrounding these 2 accidents indicate there may be some benefit in an early review of Rule Part 80 and the way it is administered.

3.20 The general standard of the Shotover Jet Limited jet boat fleet had fallen below what is considered safe for carrying passengers on the type of trips offered. Some boats did not comply with Rule Part 80.

3.21 The resources put into maintaining the Shotover Jet Limited jet boat fleet were not sufficient to maintain the boats in a condition appropriate for their intended use.

3.22 Attempts by the regulatory authorities to improve safety standards in Shotover Jet Limited were hindered by the management's attitude toward authority and its resistance to externally imposed change.

4. Safety Recommendations

4.1 On 10 June 2000 it was recommended to the director of the Maritime Safety Authority that he:

4.1.1 Conduct a risk analysis on the various jet boat activities of commercial operators in the New Zealand jet boat industry and set a benchmark of identified risk against which a risk assessment for each operator can be measured. (098/99)

4.1.2 Conduct an independent review of the jet boat activity each commercial jet boat operator in New Zealand is offering, to measure the type of activity and the manner in which it is conducted against the benchmark of identified risk. For any operations carrying more than the identified level of risk, either take the necessary action to reduce the risk level, or allow the operation to continue but require the operator to give passengers an appropriate warning of the high risk factor, before they commit to embarking on the trip. The content of any such warning and the method used to convey it should be approved by the MSA. (099/99)

4.1.3 Produce a manual of procedures and guidelines for those MSA-approved authorised persons to follow when assessing, approving or auditing commercial jet boat operators' activities and Safe Operational Plans. (100/99)

4.1.4 Require MSA-approved authorised persons to have undergone safety audit training. (101/99)

4.1.5 Develop an MSA Commercial Jet Boat Driver Licence, which every commercial jet boat driver must hold. The licensing system should be structured with:

- a detailed training syllabus and a driving test, for the basic licence
- several levels of endorsement, each dependent on specified numbers of driver hours and a further driving test
- restrictions on all-up weight (boat and passengers) for each endorsement
- endorsements for each river on which the holder intends to operate, following a specified number of hours on each river
- experience requirements, and a training syllabus and test for jet boat driver instructors
- a requirement for subsequent periodic check trips
- a requirement for drivers who do not accumulate a specified number of driving hours within a specified period, to undergo revalidation training. (102/99)

4.1.6 Require all commercial jet boat drivers to keep a logbook of hours and training. (103/99)

4.1.7 Submit to the Minister for approval, a change to Rule Part 80 that will require:

4.1.7.1 Commercial jet boat operators to identify on each jet boat all components that are critical to the safe operation of the boat, and to have a documented inspection and maintenance system in place that covers those critical components. The inspection and maintenance system should complement rather than replace any existing system of daily checks. (104/99)

4.1.7.2 Commercial jet boat operators to incorporate any manufacturer's recommended maintenance schedule in their own inspection and maintenance system. (105/99)

4.1.7.3 Commercial jet boat operators to use only authentic or approved parts when replacing worn or damaged critical components, or to use parts reconditioned, either to the manufacturer's specifications or to the approval of an appropriate surveyor. (106/99)

4.1.7.4 Commercial jet boat operators to have a system for recording and tracking in-use and spare critical components that enables the history of any critical component to be monitored and traced. (107/99)

4.1.7.5 All new commercial jet boats intended to be operated in braided rivers, or existing boats being purchased for operation on braided rivers, to be constructed with roll protection that allows sufficient occupiable space under the boat for its full complement, should it roll. (109/99)

4.1.7.6 The fitting of an inclined footplate in front of each passenger seat, having first assessed the optimum angle for such a footplate. (110/99)

4.1.7.7 An independent inspection of all commercial jet boats by suitably qualified persons, to assess the compliance with Rule Part 80 with regards to occupant protection in the event of collision, and withdraw any operator's certificate of compliance where their boats do not comply. (111/99)

4.2 On 14 September 2000 the director of the Maritime Safety Authority replied:

4.2.1 We do not propose at this time to respond to [the safety recommendations] individually or in detail. Some of these have been proposed to and commented on by MSA in relation to previous reports.

We would however, consider it helpful at this time to outline the course of action initiated by MSA on 28 July 2000, where a formal safety review of the Commercial Jet Boat Industry was commissioned by the director of Maritime Safety.

This review is an MSA initiative response to the recent accidents experienced by the industry and a desire to evaluate the performance of Rule Part 80. Terms of reference for the review are listed hereunder:

Purpose: Review the commercial jet boat industry to identify actual and potential current safety issues, assess any adverse safety trends and propose recommendations and any new initiatives to ameliorate adverse safety trends.

1 Document the safety performance of the commercial jet boat industry and identify its relative performance in the maritime industry (other adventure tourism activities, other passenger vessels, and commercial maritime operations), taking into account relevant technical, environmental and social considerations.

2 Develop benchmarks for the commercial jet boat industry by reviewing the performance of the industry overseas.

3 Identify and assess possible areas of concern within the commercial jet boat industry, in terms of safety performance and perceived future trends.

4 Contextualise the safety performance of the commercial jet boat industry by identifying past, present and future trends within the industry.

5 Review the current operation and effectiveness of legislation (Rule Part 80 and Maritime Transport Act/local bylaws) where appropriate.

6 Provide recommendations on any new safety initiatives based on lessons learned from the review.

The review will involve evaluation of all incident and accident data held on file, active surveying of operators in the industry and undertaking passenger expectation surveys. It will also involve data collection from international operators in an attempt to benchmark the local industry.

The review will be detailed, it has been given a high priority by MSA and it will involve an in depth examination of the effectiveness of Rule Part 80. The review will also involve careful evaluation, including costs and benefits, of all safety recommendations made by TAIC in this and previous reports.

4.3 On 26 September 2000 it was recommended to the managing director of Shotover Jet Limited that he:

4.3.1 Critically review the design of the jet boat trips offered by all its subsidiaries and ensure that passengers are exposed to a lower level of risk than they were on the Shotover Queenstown operation at the time of the accidents involving *Shotover 14* and *Shotover 15*. (068/00)

4.3.2 Upgrade the Shotover Jet Limited fleet to a level that both complies with Rule Part 80 and is commensurate with the type of trip being offered. (069/00)

4.3.3 Review the company policy on driver working hours to reduce the possibility of drivers operating fatigued. (070/00)

4.3.4 Ensure that sufficient resources are put into maintaining the Shotover Jet Limited fleet in a state of repair appropriate for its intended use. (071/00)

4.3.5 Fit steering limit stops to all boats in the Shotover fleet fitted with HJ-212 jet units. (078/00)

4.3.6 Identify on each jet boat all components that are critical to the safe operation of the boat, and have a documented inspection and maintenance system in place that covers those critical components. The inspection and maintenance system should complement rather than replace any existing system of daily checks. (079/00)

4.3.7 Incorporate any manufacturer's recommended maintenance schedule in the Shotover Jet inspection and maintenance system. (080/00)

4.3.8 Use only authentic or approved parts when replacing worn or damaged critical components, or use parts reconditioned, either to the manufacturer's specifications or to the approval of an appropriate surveyor. (081/00)

4.3.9 Implement a system for recording and tracking in-use and spare critical components that enables the history of any critical component to be monitored and traced. (082/00)

4.4 The managing director of Shotover Jet Limited replied in part:

4.4.1 Safety recommendation 068/00

Shotover Jet Limited (SJL) considers that the use of the word "design" is incorrect and should be replaced by the word "content". SJL also considers that the intent of this question is to examine all aspects of the business including training, standard and type of craft, maintenance, decision making operational conditions, "drive lines" and all other relevant factors. The company engaged in a thorough process of examining all aspects of its business in April 1999, but which continues now on an ongoing basis. As a result of the implementation of this programme, many of the issues raised in the draft report have already been dealt with and new systems and procedures put in place.

As an initial step in reviewing the content of the company's jet boat trips, an extensive Risk Management Assessment evaluation has been completed.

Specific issues [were] undertaken (completed and ongoing) as part of the critical review of trip content. As part of the company's Q20/20 system of reviewing its operations, the company has made a number of changes to its procedures, its craft, and its training and maintenance systems. These measures were accelerated as a result of the accidents involving Shotover 14 and Shotover 15 in October and November 1999, and as a result of the unsatisfactory audits of the SJL fleet earlier in 2000. In brief, these issues are:

Existing fleet

After undergoing tree external audits and several internal audits identifying areas where the fleet required upgrading, all existing craft in all subsidiaries in SJL have been upgraded to ensure, at minimum, compliance with MSA Rule Part 80.

The only exceptions are the exemptions referred to in [our response to safety recommendation 069/00] as granted by the director of Maritime Safety.

Apart from issues of compliance with MSA Rule Part 80, all craft have been critically reviewed in the interests of ensuring compliance with good engineering practices.

Regular reviews are taking place to ensure that the programme of off-season upgrade of craft is consistent with the timetable presented to the director of Maritime Safety in April 2000.

Despite the decision to replace the fleet at Shotover Jet Queenstown (SJQ) within the next 12 to 18 months, the fleet at SJQ currently consists of two craft less than one year old, two craft which are older but which have been subjected to complete strip and refurbishment to "as new" condition and will see the introduction before the end of the calendar year 2000 of two brand new craft of the existing design. Other remaining craft have been substantially upgraded and reviewed as part of the process described earlier.

In view of the lack of suitable standards governing LPG installations, SJL had contracted an expert in the field of LPG management and installation to advise on installations in SJL boats. This arrangement was made despite the fact that LPG is likely to be phased out as a fuel at SJQ within the next 12 months and at Huka Jet Limited (HJL) within two years. Any recommendations by the LPG expert will be incorporated into the existing fleet.

All major changes and structural componentry will be approved by an external qualified professional engineer.

Technical

SJL has made substantial changes to the make up and numbers of personnel at its workshops at Queenstown, Glenorchy and Taupo. SJL considered that the staffing levels were adequate but has approximately doubled its technical staff numbers in the past eight months.

The decision to expand capacity recognises the work required to bring the existing fleet up to standard, as well as a desire to consistently exceed the standards set in MSA Rule Part 80.

SJL now operates four workshops: SJQ in Queenstown, Dart River Jet Safaris Glenorchy and HJL in Taupo with a boat refurbishment/major maintenance division at the Frankton Marina, Queenstown.

Technical staff rosters have been changed to ensure availability of technical staff to participate in after operation checks and urgent maintenance required to be done overnight prior to re-commencement of operations the next day.

Qualifications of technical staff have been reviewed to assess their suitability.

New workshop manuals have been drawn up using external professional assistance.

Systems

A new boat checking system is now in place. Craft are signed off jointly by a driver and technician.

All operational staff have been retrained in boat inspections and the critical areas to be observed.

All operational staff have been retrained to ensure that boat checks are capable of identifying problems rather than a system which simply ticks off lists of observations.

A system of "surprise" audits is now in place where all operations are subject to four internal checks per year (in addition to the MSA external checks) with one internal check undertaken by an independent suitably qualified expert.

SJL has introduced a system of monitoring incidents where any incident, no matter how small, is analysed, logged and reviewed with results monitored by SJL management and board. This system allows cross referencing of incidents which occur involving specific drivers, craft, components, sections of the rivers, manoeuvres etc to observe any recurrent factors. The system is designed to reduce incident occurrence to a minimum.

An aviation based safety engineer is to be appointed to the Audit and Compliance Committee of the SJL Board to assist and advise on issues of safety and compliance.

All critical components are now internally identified and date stamped on installation for replacement at the "use by" date.

SJL has contracted a suitably qualified external expert to examine the list of critical components drawn up internally, adding items where appropriate and providing an assessment of the components' operational life times. This system is designed around that used in the aviation industry.

SJL has re-engineered the company's maintenance systems to provide for replacement of critical components as required by "lifetime" assessments.

SJL has re-engineered the company's maintenance systems to ensure the periodic testing of critical components by suitably qualified independent experts.

Personnel

SJL has critically reviewed driver-training systems and introduced changes where necessary.

SJL has critically reviewed the system of checking drivers (particularly new drivers) by the senior driver and confirmed it as adequate.

SJL has reinforced the drivers' option to operate or otherwise depending on conditions.

SJL has reinforced to operational staff, and in particular drivers, their responsibility for boat condition and the decision whether or not to operate craft.

SJL has introduced a system of psychological assessment for new drivers.

Operations

SJL has reviewed all aspects of its subsidiaries' trips to ensure strict adherence to company specified "drive lines".

SJL has reviewed the appropriateness of "drive lines" internally and with a suitably qualified independent expert.

SJL has reinforced drivers need to adopt a more conservative line in high water conditions.

SJL has discussed with operational staff any suggested changes and implemented them where appropriate.

SJL has reviewed the adequacy of its safety briefings.

SJL has reassessed its safety equipment and made improvements where appropriate.

SJL has reviewed the company's Safe Operating Plan and rewritten it. It is now MSA/QLDC Harbourmaster approved.

SJL has reviewed its crisis management plan and confirmed that it is adequate.

SJL has reviewed its pre-departure facilities and upgraded these where appropriate.

Hamilton 212 Jet Units

SJL has, immediately after the Shotover 15 accident discarded all Hamilton 212 "Mk I" nozzles and replaced these with "Mk II" [nozzles].

SJL has commissioned a comprehensive independent report from a suitably qualified professional engineer on the design of Hamilton 212 jet unit [steering nozzles].

The report concluded the [steering nozzle] is under designed for its function.

Copies of the independent report have been provided to appropriate authorities.

SJL has requested a complete redesign of the 212 nozzle by CWF Hamilton.

Pending a complete redesign, SJL has commissioned external professional advice on the continued use of Mark II 212 nozzles.

SJL continues to use Mark II nozzles subject to rigorous daily inspections, and removal for crack testing at 250-hour intervals.

SJL has fitted steering stops to all SJL craft using Hamilton 212 units.

New Craft

SJL has completed a review of all design aspects of existing craft and elected to replace virtually its entire fleet.

While existing craft are adequate, it is recognised that they are evolutions of craft introduced in the 1970's and it is time for a complete redesign.

The only common factor between new craft and existing craft is the shape of the below water hull.

Two prototype boats are now under construction at Dickson Marine of Nelson.

Depending on the success of these craft, a contractual agreement will be entered into to construct between 20 and 25 craft of the new design.

A critical path for delivery will see Dart River Jet Safaris and SJQ fleets replaced by June 2002.

The SJL board has approved a capital expenditure programme to cover the new boats.

Extensive external testing of a kevlar carborundum composite material has proved satisfactory, with strength, weight and durability factors far exceeding those of comparable aluminium, resulting in a decision to construct hulls from this material.

The new craft will include ergonomically designed seats to assist with passenger safety and comfort with "soft" plastic fittings internally to protect passengers.

The new craft will incorporate crumple zones in bows, "positive buoyancy cell" and redesigned fuel systems to improve safety incorporating "anti explosion" fuel tanks.

The steering systems will be completely redesigned to incorporate a system of shafts and gearboxes replacing existing cables and pulleys. The new system will be considerably more robust, easier to maintain and less susceptible to failure. The system has been designed by a professional engineer and certified.

The motor and jet unit packages have been considered and this is likely to result in a decision (after testing) to install twin engines and twin jet units to improve safety through duplicated systems, allowing continuation of one engine/jet unit in the event of failure of the other.

All equipment installed in boats will be either certified by a suitably qualified professional engineer or will carry suitable manufacturer warranties.

Seatbelts

SJL has commissioned an extensive and comprehensive external report on the installation of seatbelts.

If installation proceeds, it will be in conjunction with an "automatic release" system, which provides for release in the event of swamping of the craft or by central driver control as well as individual passenger control.

A final decision on this issue will be made when all factors including an independent report have been considered.

4.4.2 Safety recommendation 069/00

All SJL craft comply with MSA Rule Part 80 except where provided for by exemptions. The exemptions are as follows:

a. Dart River Jet Safaris Ltd is exempt, until 30 June 2001, from the requirement in Rule 80.6(1)(a) and Appendix 1, 2.2(h) to have a petrol tank filling connection on jet boats operated by that company that is located such that no spillage will enter the boat when in use, provided that –

b. No jet boat operated by Dart River Jet Safaris Ltd will be fuelled on the water; and

c. No jet boat operated by Dart River Jet Safaris Ltd will be fuelled with passengers on board or in the vicinity of the boat.

d. Dart River Jet Safaris Ltd is exempt, until 1 November 2000, from the requirements in Rule 80.6(1) and Appendix 1, 2.6(a) to have fitted 2 submerged electric pumps of at least 4400 litres per hour capacity in the jet boats that are operated by that company, provided that existing electric pumps of at least 3,337 litres per hour remain fitted and functioning correctly.

NB: All Dart boats except Nos 5 and 6 now comply with MSA Rule Part 80. Dart 5 and 6 will comply by 1st November 2000.

e. SJL is exempt from the requirement in Rule 80.6(1)(a) and Appendix 1, 8.3(c) to have a safety briefing card on any boat operated by that company that is readily available to any passenger who may have difficulty in understanding a verbal briefing, provided that fixed signs are in place on such boats providing safety briefing information to any passenger who may have difficulty in understanding a verbal briefing.

4.4.3 Safety recommendation 070/00

SJL has reviewed its policy on working hours for drivers and considers that in practice the possibility of drivers being fatigued is low. However, SJL notes that theoretically it is possible for excessive hours to be worked and will therefore introduce into its Safe Operating Plan a requirement that no driver will work more than nine operational hours in any one day.

4.4.4 Safety recommendation 071/00

As stated earlier in this submission, at no stage did SJL maintenance division suffer from lack of resources. However, as SJL notes in its comments on [safety recommendation 068/00] it has substantially increased its maintenance resources. In any case, SJL has taken such action (implemented in December 1999) to ensure a timely upgrade of its fleet and to ensure that SJL's operations exist at a safety level well above that required in MSA Rule Part 80.

4.4.5 Safety recommendation 078/00

All craft in the SJL fleet fitted with Hamilton 212 units have steering stops installed. The company notes however that steering stops are not a good long-term engineering solution to this problem. Steering stops rely on being correctly set to be effective and are an added complexity that only partially solves the problem. A better solution is to re-engineer the complete steering system. SJL notes the new system described in its submission [on safety recommendation 068/00].

4.4.6 Safety recommendations 079/00, 081/00 and 082/00

The company has approached these matters in the following manner:

a. Of its own volition, immediately following the accidents involving Shotover 14 and 15, SJL as a matter of urgency internally identified those components that it considered were critical. The definition of "critical" was that the failure of them would have a high probability of leading to an incident or accident. These critical components were replaced during the fleet upgrade earlier in 2000 and identified with an installation date stamp. The total operational hours of each craft were noted at the time and the hours since are logged, enabling SJL to accurately record the operational hours of each component as well as the individual history of the component.

b. The second step in this process has been the contracting out to an independent, suitably qualified expert a detailed identification of all critical components and the assessment of a reasonable life expectancy of those components. These procedures are based largely on the aviation industry. Obviously the system provides for mandatory replacement or critical assessment once the nominated time limits are reached. A good example of this is the Hamilton 212 nozzle where this item was identified as critical. A limit of 500 hours was initially identified before crack testing took place but recent concerns have seen this limit lowered to 250 hours. On completion of the assessment process, all parts will be stamped with a unique identifier enabling lifetime tracing.

c. As noted earlier, SJL has rewritten its Safe Operating Plan and its workshop manuals. The systems of daily and other periodic inspections are noted in these documents.

d. Use of "genuine" parts or reconditioned parts to a satisfactory standard is addressed in the "critical parts" exercise currently being undertaken by an independent expert. The outcome of this assessment will be added to the Safe Operating Plan when finalised. In the meantime all SJL maintenance staff have been instructed to use only "certified" parts or where certification is not available, the manufacturer supplied spare or the best available where manufacturers' parts are not accessible. In addition, no modifications take place to any component without manufacturer or qualified professional engineer sign off.

4.4.7 Safety recommendation 080/00

All manufacturers' recommended maintenance schedules have been included in the SJL inspection and maintenance system.

The company has, where possible withdrawn from its practice of altering externally supplied components and endeavours now only to fit suitably certified manufacturer-supplied parts.

4.5 On 14 September 2000 it was recommended to the managing director of CWF Hamilton and Co. Limited that he:

4.5.1 Critically review the design of the new steering nozzle and associated components on HJ-212 jet units and ensure that it is strong enough for its intended purpose. (072/00)

4.5.2 Consider either recalling all old HJ-212 steering nozzles or producing a service bulletin warning users of possible failure and the consequences. (073/00)

4.5.3 Recommend the fitting of steering limit stops in the installation manual for all HJ-212 jet units, and other model jet units as appropriate. (083/00)

4.6 On 13 October 2000 the managing director of Hamilton Jet replied:

4.6.1 **072/00** This review has been completed and we are satisfied that the design is strong enough for its intended purpose.

4.6.2 **073/00** A recall is proceeding on old steering nozzles. However we wish to point out that this is a purely a precautionary measure as it appears to us that the Shotover failure was most likely the result of poor maintenance. We have recently examined the bush in the Huka Jet nozzle arm, which we believe is one of the nozzles mentioned in your accident report in which cracks were found. We found clear evidence that the steering crank was jamming in the nozzle arm before the nozzle could reach full lock in the same way as the failed Shotover nozzle. For this to happen the nozzle had to sustain considerable damage and for the steering system to be operated in this condition once again indicates a serious lack of maintenance.

4.6.3 **080/00** The fitting of steering limit stops as described is in the process of being implemented.

Approved for publication 27 September 2000

Hon. W P Jeffries
Chief Commissioner