Report 01-202

commercial jet boat *Shotover 6*

engine failure and collision with river bank

Shotover River, Queenstown

12 February 2001

Abstract

On Monday 12 February 2001, at about 1115, jet boat *Shotover 6* was proceeding down Shotover River at about 75 km/h with the driver and 10 passengers on board, when the engine suddenly stopped. As a result the driver lost steerage of the boat and it continued for about another 50 m before colliding with rocks and overhanging trees on the riverbank. One passenger suffered moderate injuries and the driver and other passengers suffered minor bruising. The boat was slightly damaged.

The exact cause of the engine failure was not established.

Safety issues identified included:

- the need to isolate the ignition system before undertaking electric welding on boats
- the inherent risk of loss of directional control due to engine stoppages in jet boats with single propulsion systems.

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.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

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Shotover 6

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List of Abbreviations

cm	centimetre(s)
km	kilometre(s)
km/h	kilometres per hour
LPG	liquefied petroleum gas
m	metre(s)
mm	millimetre(s)
UTC	co-ordinated universal time
VHF	very high frequency

Glossary

port	left-hand side when facing forward
starboard	right-hand side when facing forward
track	the path intended or actually travelled by a ship
true left	the left-hand side of a river looking downstream
true right	the right-hand side of a river looking downstream

Data Summary

Boat particulars:

Name:	*Shotover 6*
Type:	commercial jet boat
Class:	passenger (under 6 m)
Limits:	Shotover River
Allowable occupants:	driver plus 12 passengers (at driver's discretion)
Length:	5.8 m
Construction:	aluminium
Built:	1996
Propulsion:	a single Chevrolet 502 engine powered by liquid petroleum gas, driving a series HJ-273 Hamilton water jet unit fitted with an HJ-274 tail housing
Normal operating speed:	75 km/h
Operator:	Shotover Jet Limited

Location:	Shotover River	
Date and time:	Monday 12 February 2001 at about 1115[1]	
Persons on board:	crew:	1
	passengers:	10
Injuries:	crew:	1 (minor)
	passengers:	1 (moderate)
		9 (minor)
Nature of damage:	slight to starboard bow and hull	
Investigator-in-charge:	Captain W A Lyons	

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

1. Factual Information

1.1 History of the trip

1.1.1 On the morning of Monday 12 February 2001, the driver of *Shotover 6* arrived at work at 0700. He conducted the daily safety checks on the boat, launched it, warmed the engine through and took it for a short test run. Everything appeared to him to be in order and as the boat was not required immediately he left it secured to the jetty.

1.1.2 At about 0900 the driver again started the engine of *Shotover 6* and warmed it through. He then completed 3 passenger trips of about 25 minutes each, without incident.

1.1.3 At about 1100 a group of 10 passengers were taken to the jetty, fitted with life jackets and introduced to the driver, who assisted them aboard *Shotover 6* for its fourth trip. Once seated the passengers were given a safety briefing by the driver, who instructed them to hold on tightly, keep their arms inside the boat and to brace themselves with their feet. They were also shown the hand signal the driver would use to indicate he was about to put the boat into a spin[2].

1.1.4 After departing the jetty *Shotover 6* proceeded upstream for about 200 m before turning and running back downstream. The trip downstream and the return trip upstream followed the planned route with the driver taking the boat close to the canyon walls and putting it into spins, as was the usual practice.

1.1.5 *Shotover 6* travelled past the jetty again and proceeded up to the Oxenbridge Tunnel, which was as far upstream as the trip went. The driver again idled the boat while he gave the passengers some information about the tunnel and its history.

1.1.6 Downstream from the tunnel the path of the river followed virtually a straight line for about 800 m before it turned about 90 degrees to the right. On the true right side of the river, there was a shallow patch of shingle, which extended across the river for about three-quarters of its width. The intended path of *Shotover 6* was to the left of this shallow patch. (See Figure 1)

1.1.7 After leaving the tunnel *Shotover 6* proceeded down the straight section of the river at a speed of about 75 km/h. The driver was lining the boat up for the bend, when the engine suddenly stopped. The driver immediately tried to restart the engine with the key but it did not respond.

1.1.8 A jet boat is steered by the efflux of water from the jet unit being deflected left or right via the steering nozzle at the back of the jet unit tailpipe. If the engine stops there is no efflux of water and consequently no directional control.

1.1.9 With no steering *Shotover 6* continued in a straight line. The driver could see that a collision with the riverbank and overhanging trees was imminent so he turned around, shouted a warning to the passengers, pushed the head of the passenger next to him down and leant across to shield the passenger from the impact. *Shotover 6* collided with the true left bank of the river, the starboard bow hitting rocks and the port side overhanging trees. The driver later estimated that the boat was still on the plane travelling at about 25 km/h when it collided with the riverbank.

1.1.10 Immediately after impact *Shotover 6* drifted clear of the riverbank. The driver called another company boat, which was at the jetty, on the radio and reported the accident. By that time *Shotover 6* was visible from the jetty as it drifted downstream. The driver of the boat at the jetty asked if an ambulance was required. As a passenger seated in the row behind the driver appeared to be in pain the driver gave a hand signal to the other boat indicating the affirmative.

[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 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 the trip.

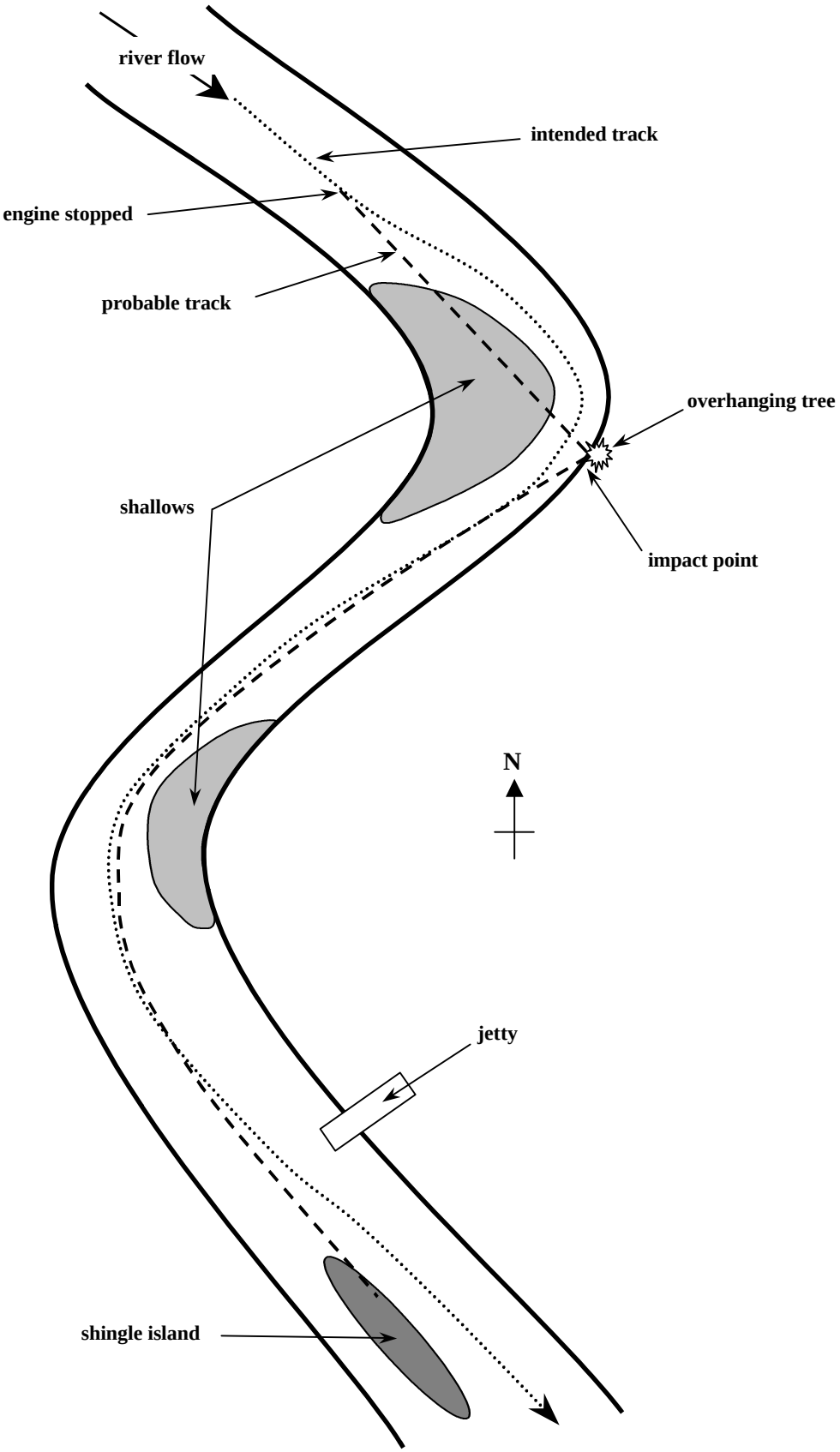

Figure 1
Drawing of accident site and surrounding area
(not to scale)

1.1.11 The driver of the boat at the jetty notified the base of the accident and requested they call an ambulance. He then departed the jetty and proceeded towards *Shotover 6*. Meanwhile, the driver of *Shotover 6* checked the passengers and tried a number of times to restart the engine.

1.1.12 As *Shotover 6* drifted downstream, towards the bend in the river above the jetty, the driver managed to restart the engine. He left the engine idling with the intention of keeping the boat in the channel and manoeuvring it towards the jetty but the engine only ran for a short time before stopping again.

1.1.13 The driver of the other boat manoeuvred his boat alongside *Shotover 6* and guided it onto the shingle island just down stream of the jetty. The passengers were transferred to his boat, taken the short distance to the jetty and disembarked. The driver of *Shotover 6* lifted the engine hatch and saw that the engine exhaust pipes had dislodged from the transom and water was entering the boat through the openings so he plugged them with towels to stop the ingress.

1.1.14 The passengers were taken back to the base where their injuries were attended to. A passenger who was seated inboard in the middle row of seats was taken to hospital by ambulance for further observation. The driver of *Shotover 6* was also treated for a leg injury.

1.1.15 *Shotover 6* was towed back to the jetty where mechanics inspected the engine. They could not find any obvious reason why the engine suddenly stopped so the boat was put on its trailer and taken to the workshop for further investigation.

1.2 Damage

1.2.1 Damage to the hull of *Shotover 6* was minor. The belting around the starboard bow was bent and the hull underneath dented. There were also scratches and minor dents on the port bow and down the starboard side (see Figure 2).

1.2.2 Both engine exhausts had become dislodged from the hull penetrations at the flexible rubber joining sections.

1.3 Weather and river conditions

1.3.1 Weather conditions at the time of the accident were fine with light winds. As there had been no recent rain in the area the river flow was low.

1.4 Personnel information

1.4.1 The driver of the *Shotover 6* was 23 years old at the time of the accident. He was employed by the company in June 1998 and commenced his training as a jet boat driver. Prior to that he had had little boating experience.

1.4.2 His training consisted of 124 hours supervised jet boat driving in the area of normal operation as well as familiarisation and instruction on safety and maintenance checks. In August 1998 he successfully completed a check trip with the Queenstown Lakes District Council harbourmaster and was licensed to operate jet boats on the Shotover River.

Figure 2
Damage to the starboard bow of *Shotover 6*

1.4.3 He made his first commercial trip on 20 August 1998, and had accumulated about 2030 hours driving experience on Shotover River at the time of the accident. He was promoted to head jet boat driver in July 2000. This position entailed the training of new drivers, conducting peer reviews of drivers and acting as operations manager when required.

1.4.4 According to records he had not been involved in any previous accidents or incidents. His last peer review was conducted on 16 November 2000.

1.5 Boat information

1.5.1 *Shotover 6* was purpose built in 1996 for the company. The hull was constructed by an outside contractor and the boat was fitted out by the company. It had 3 bench seats with a separate driving compartment at the front left. Next to the driving position was a short bench seat capable of seating 2 passengers. The other 2 bench seats sat 5 adult passengers in each. The engine compartment was at the stern.

1.5.2 The boat was powered by a Chevrolet 502 V8 engine, which ran on liquefied petroleum gas (LPG). Propulsion was achieved using a Hamilton HJ-273 water jet unit fitted with an HJ 274 tail housing. An impeller housed within the jet unit tailpipe drew a high volume of water into the tailpipe through a grill-covered intake positioned near the stern of the boat. The water was then ejected near the water surface at high pressure through a restricting nozzle at the after end of the tailpipe to produce forward thrust.

1.5.3 The boat was steered by deflecting the efflux from the jet unit left or right through a steering nozzle at the back of the jet unit tailpipe. The steering nozzle was rotated laterally through a tiller connected to the steering wheel by a system of wires and pulleys.

1.5.4 At the end of March 2000 *Shotover 6* had been removed from service by the Maritime Safety Authority (MSA). It underwent an extensive refit and was back in service by the end of October 2000.

1.5.5 On 30 October 2000 the engine of *Shotover 6* was fitted with a Multiple Spark Discharge (MSD) 6M2 marine ignition system and a MSD 55E5 soft touch marine rev limiter. The ignition system provided the spark plugs with high energy multiple sparks to increase power and engine reliability, provide the correct timing advance and prevent the spark plugs from "oiling up". The rev limiter was designed to prevent the engine from over speeding when the drive unit came out of the water or cavitated during operation.

1.5.6 On 4 January 2001, a small aluminium plate was welded to the hull of *Shotover 6*. The boats electrical system was isolated and the electric welder was earthed during the welding operation.

1.6 Post accident checks

1.6.1 While *Shotover 6* was still on the river after the accident the company maintenance manager and an electrical contractor inspected the fuel system, which appeared to them to be functioning correctly. The boat was then taken to the workshop where they systematically checked the electrical system, which also appeared to them to be functioning correctly. While at the workshop the exhaust pipes were reconnected.

1.6.2 *Shotover 6* was then returned to the river for further tests. The engine started immediately and was warmed through. The engine revolutions were then increased and the engine was run for about 5 minutes without any recurrence of the problem. *Shotover 6* was then run on the river for a distance of about 6 km without problem.

1.6.3 *Shotover 6* was then returned to the workshop for a more detailed inspection of the fuel system. The LPG converter, lock off valve, multi valve, and carburettor were all dismantled, checked, re-kitted as necessary and reassembled. The boat was again tested on the river, again without recurrence of the problem.

1.6.4 The MSD units were both sealed solid-state units and could not be dismantled and checked, so a portable MSD ignition tester was sent from Auckland to test them. They were initially tested while on the boat and then removed and re-tested. The tests revealed no problem with either unit.

1.6.5 The units were refitted to *Shotover 6* and the boat was again tested on the river. During the testing, the vacuum supply to the lock-off valve was removed while the engine was at maximum power to simulate a fuel system failure. The engine ran for about 5 seconds before stopping. The driver for the accident trip reported this was not like the instantaneous stoppage that occurred on the day of the accident.

1.6.6 The inspection of the engine fuel and electrical system, the testing of the MSD units and the boat tests on the river revealed no fault. The MSA requested that both MSD units be replaced and the boat be run for 20 hours on the river before carrying passengers. At the time of writing this report the fault had not recurred.

1.6.7 The Commission had both MSD units tested by an independent auto electrical company, which specialised in ignition systems. The equipment was bench tested under various conditions, including high ambient temperatures, for long periods without any loss of spark evident.

1.6.8 While inspecting the distributor cap it was found that the central carbon terminal had been partially eroded away. This was reported by the operator as an ongoing problem, which had occurred since the MSD units had been fitted. The company had contacted MSD both in New Zealand and the USA regarding the problem and at the time of the accident the problem had not been resolved.

1.6.9 On 19 February 2001, *Shotover 19*, another company boat, suffered a similar engine stoppage while being tested by company mechanics during maintenance. *Shotover 19* had recently undergone an extensive refit during which electric welding had been carried out on the boat on numerous occasions.

1.6.10 While checking the maintenance records of both boats it was discovered that *Shotover 6* and *Shotover 19* were the only boats that had undergone welding since the MSD units had been fitted. When the welding was undertaken on both boats the electrical systems had been reportedly isolated.

1.6.11 The MSD units from *Shotover 19* were removed from the boat and sent to MSD in the USA for testing. MSD reported that during testing they found a fault in the units that indicated that they had been affected by very high current passing through the unit. Whether that was from welding, improper battery charging or a defective alternator could not be determined.

1.6.12 The auto electrical company contracted by the Commission were advised of this development and contacted MSD in the USA to verify that their testing methods were similar to those undertaken in the USA. Part of the auto electrical company report stated:

> They [MSD USA] were able to confirm that the test conditions are substantially the same as they use. Additionally they suggested I subject the equipment to some vibration or impact while it is running and that I check the connector pins to confirm none of them are "backing out" from their housing and losing contact. With the equipment running I have since repeatedly hit it with a rubber hammer – no loss of spark was evident. The pins are well located.

1.6.13 An independent jet boating consultant was requested by the Commission to review the testing and fault finding procedures undertaken by the company and the auto electrical firm contracted by the Commission. He analysed the documented test procedures and spoke to various employees of the company and the auto electrical firm. In his report he stated in part the following:

> In discussions with the driver it was found that the boat suffered complete and instantaneous engine cut. Total and instantaneous engine cut points to electrical failure.
>
> The boat history records show evidence of on-going problems with the distributor cap centre carbon burning / deterioration. It is understood that Shotover Jet are working closely with MSD to rectify the problem. This would not directly cause an ignition cut . . .

2. Analysis

2.1 On the day of the accident, *Shotover 6* was driven by one of the company's most experienced drivers. He had completed 3 trips and nearly completed the fourth before the engine stopped without warning. There had been no previous indication of a problem and the boat had been maintained and tested in accordance with company guidelines.

2.2 The actions of the driver after the engine stopped were appropriate. He tried to restart the engine to regain control but when he realised that a collision with the riverbank was imminent he warned the passengers and tried to protect those close by him. After the boat drifted free he was able to make a radio call and check the injuries to the passengers.

2.3 It was fortunate that when the engine stopped the boat was on a relatively open section of the river, about 50 m, in a straight line, from the riverbank. Had the stoppage occurred in one of the canyons, which *Shotover 6* had recently passed through at full speed, the outcome could have been significantly worse.

2.4 The driver estimated that *Shotover 6* was travelling at about 75 km/h when the engine stopped and had slowed to about 25 km/h when it collided with the riverbank. This equates to a loss of speed of about one km/h for every metre travelled after the engine stopped. Due to the cushion effect of the shallow water the boat travelled over before hitting the riverbank, it would not have shed speed as quickly as it would have if travelling in deeper water.

2.5 After the engine stopped initially and again immediately after the boat had collided with the riverbank the driver attempted to restart the engine without success. As the boat drifted down the river he did manage to restart it but it stopped again shortly after. Immediately after the accident the mechanics systematically checked the fuel and electrical systems before restarting the boat, without finding any problem. It is possible that during the initial check by the mechanics a loose wire or faulty connection was inadvertently corrected and the fault unknowingly rectified.

2.6 Despite intensive testing and investigation after the accident, the cause of the engine stoppage suffered by *Shotover 6* could not be conclusively identified and, at the time of writing this report, had not recurred. As the engine stopped instantaneously it was assumed to be an electrical fault rather than one caused by the fuel system. The driver substantiated this after the accident when a fuel stoppage was simulated during testing.

2.7 The MSD units from *Shotover 6* were tested under varying conditions by the company and an independent auto electrician and no faults were found. The burning and deterioration of the distributor cap centre was unlikely to have directly caused the engine to stop, but does point to a design fault in the system, which is being addressed.

2.8 The tests undertaken on the MSD units from *Shotover 19* in the USA revealed a fault probably caused by a very high current passing through the unit, possibly caused by electric welding. The auto electrician contracted by the Commission could not identify the same fault with the MSD units from *Shotover 6* even though the test procedures were similar. These were the only 2 boats that had undergone electric welding since the units were fitted. On *Shotover 6* a small patch was welded to the hull whereas *Shotover 19* underwent a refit, with electric welding conducted on many different occasions, any one of which may have allowed a very high current to pass through the unit.

2.9 Although electric welding was not thought to have contributed to the engine stoppage on *Shotover 6*, the investigation did identify this as a potential safety concern for the commercial jet boat industry. This safety concern has been addressed by the MSA by sending a letter to all known commercial jet boat operators in New Zealand making them aware of the potential problem.

2.10 This accident demonstrates the vulnerability of jet boats in the event of an engine stoppage. Without motive power, a jet boat has no directional control. While unplanned engine stoppages can be minimised by stringent maintenance regimes, the possibility of an engine stopping at an inopportune moment will always exist and becomes part of the inherent risk of commercial jet boating.

2.11 A number of commercial jet boats in New Zealand have recently been constructed with twin engines and twin jet units. Such boats will be less at risk of loss of directional control in the event of a single engine stoppage.

2.12 The idea of commercial jet boats being fitted with twin propulsion systems was raised in a recent review of commercial jet boating in New Zealand conducted by the MSA. The recommendations arising from this review had not been released at the time of publishing this report.

2.13 The Commission supports the idea of the mandatory installation of twin propulsion systems in newly constructed commercial jet boats engaged in high risk adventure operations.

3. Findings

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

3.1 The driver of *Shotover 6* was suitably qualified and experienced for his position.

3.2 The driver was fit and not suffering from fatigue at the time of the accident.

3.3 The river and weather conditions were suitable for the trip.

3.4 *Shotover 6* collided with the riverbank after the engine stopped causing a loss of directional control.

3.5 The cause of the engine stoppage could not be conclusively identified.

3.6 The drivers actions during and after the collision were appropriate.

3.7 Loss of directional control caused by engine stoppages is an inherent risk for commercial jet boats with single propulsion systems.

4. Safety Actions

4.1 The company issued a directive for the complete ignition system to be removed from the boats before welding is undertaken.

4.2 The Maritime Safety Authority issued a letter to other jet boat operators warning them of the potential for damage to be caused by current spikes caused by welding.

4.3 MSD in the USA are working closely with Shotover Jet Limited and are sending representatives to New Zealand to analyse the problems they have experienced.

5. Safety Recommendation

5.1 On 31 August 2001 the Commission recommended to the director of maritime safety that:

5.1.1 Maritime Rule Part 80 is changed to require mandatory installation of twin propulsion systems in all newly constructed commercial jet boats engaged in high risk adventure operations. (033/01)

5.2 On 5 September 2001 the director of the Maritime Safety Authority replied:

5.2.1 MSA notes that it has recently completed a formal review of the Safety Performance of Commercial Jet Boating in New Zealand, and that the submissions received were being assessed.
This process is now completed and the review team have passed its recommendations, after considering the comments received, to the Manager Safety and Environment Standards, to commence formal industry consultation for amendment of Maritime Rule Part 80.

The issue of twin propulsion (engine) systems was seriously considered by the review team for high adventure operations.

Indeed the review team made note in section 13.4 that:

"The compulsory use of lap belts and twin engine boats for high adventure activities should be regularly reviewed by MSA in light of operational experience."

The review team did not include twin engine boats for high adventure activities in its recommendations, as it was not satisfied that such a recommendation would meet the MSA's charter of "A Safe and Clean Maritime Environment at reasonable cost", where "Reasonable Cost" is defined in Section 430(b) of the Maritime Transportation Act 1994 as a meaning, "when the value of the Cost to the nation is exceeded by the value of the resulting benefit to the nation."

As part of the review process, reported accidents were considering along with possible initiatives which could have prevented the accident from occurring. ON the basis of that study, and bearing in mind MSA's charter, the review team determined the compulsory use of twin engine boats for high adventure activities did not achieve the "Reasonable Cost" criteria.

Comments received from industry as a result of the consultation document would also support this view.

The review team nor MSA have not dismissed the concept of twin engine boats, rather it is our view that this technology should be embraced as it is developed, and operators be encouraged to adopt it as the technical challenges are overcome.

MSA is working with Shotover Jet, industry in general and the New Zealand Commercial Jet Boat Association to achieve this goal.

Considering the above we regret to advise that MSA is not able to accept the final recommendation 033/01.

Approved for publication 5 September 2001

Hon. W P Jeffries
Chief Commissioner