



A U S T R A L I A N T R A N S P O R T S A F E T Y B U R E A U

INVESTIGATION REPORT
199904538

Boeing 747-438, VH-OJH Bangkok, Thailand



23 September 1999



Department of Transport and Regional Services

Australian Transport Safety Bureau

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The Australian Transport Safety Bureau (ATSB) is a multimodal Bureau within the Federal Department of Transport and Regional Services that is treated as a Division for administrative purposes. The ATSB is entirely separate from transport regulators, and ATSB investigations are independent of regulatory or other external influence.

In terms of aviation, the ATSB is responsible for investigating accidents, serious incidents, incidents and safety deficiencies involving civil aircraft operations in Australia, as well as participating in overseas investigations of accidents and serious incidents involving Australian registered aircraft. The ATSB also conducts investigations and studies of the aviation system to identify underlying factors and trends that have the potential to adversely affect safety. A primary concern is the safety of commercial air transport, with particular regard to fare-paying passenger operations.

The ATSB performs its aviation functions in accordance with the provisions of the *Air Navigation Act 1920*, Part 2A. Section 19CA of the Act states that the object of an investigation is to determine the circumstances surrounding any accident, serious incident, incident or safety deficiency to prevent the occurrence of other similar events. The results of these determinations form the basis for safety recommendations and advisory notices, statistical analyses, research, safety studies and ultimately accident prevention programs. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and conclusions reached. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment, with the need to properly explain what happened, and why, in a fair and unbiased manner.

This report was produced by the Australian Transport Safety Bureau (ATSB), PO Box 967, Civic Square ACT 2608.

Readers are advised that the ATSB investigates for the sole purpose of enhancing safety. Consequently, reports are confined to matters of safety significance and may be misleading if used for any other purpose.

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EXECUTIVE SUMMARY

Overview

On 23 September 1999, at about 2247 local time, a Qantas Boeing 747-438 aircraft registered VH-OJH (callsign Qantas One) overran runway 21 Left (21L) while landing at Bangkok International Airport, Thailand. The overrun occurred after the aircraft landed long and aquaplaned on a runway which was affected by water following very heavy rain. The aircraft sustained substantial damage during the overrun. None of the three flight crew, 16 cabin crew or 391 passengers reported any serious injuries.

The Aircraft Accident Investigation Committee of Thailand delegated the investigation to the Australian Transport Safety Bureau (ATSB) on 18 November 1999. In accordance with this delegation, the ATSB conducted the investigation according to the standards and recommended practices of *Annex 13 to the Convention on International Civil Aviation* and the *Australian Air Navigation Act 1920, Part 2A*.

In terms of overall accident statistics, runway overruns are a relatively common event. Of the 49 accidents involving western-built high-capacity jet aircraft reported during 1999, 11 were landing overruns. Landing overruns typically occur when the runway is wet or contaminated and/or the aircraft is high and fast during final approach.

The accident flight (see part 1)

The first officer was the handling pilot for the flight. The crew elected to use flaps 25 and idle reverse as the configuration for the approach and landing, in accordance with normal company practice (since December 1996).

At various stages during the approach to runway 21L, the crew were informed by air traffic control that there was a thunderstorm and heavy rain at the airport, and that visibility was 4 km (or greater). At 2240, a special weather observation taken at Bangkok airport noted visibility as 1,500 m and the runway visual range (RVR) for runway 21 Right (21R) as 750 m. The Qantas One crew was not made aware of this information, or the fact that another aircraft (callsign Qantas 15) had gone around from final approach at 2243:26. At 2244:53, the tower controller advised that the runway was wet and that a preceding aircraft (which landed at approximately 2240) reported that braking action was 'good'.

The Qantas One crew noted no effect from the weather until visibility reduced when the aircraft entered very heavy rain as it descended through 200 ft on late final approach. The aircraft then started to deviate above the 3.15 degree glideslope, passing over the runway threshold at 169 kts at a height of 76 ft. Those parameters were within company limits. (The target speed for the final approach was 154 kts, and the ideal threshold crossing height was 44 ft.)

When the aircraft was approximately 10 ft above the runway, the captain instructed the first officer to go around. As the first officer advanced the engine thrust levers, the aircraft's mainwheels touched down (1,002 m along the 3,150 m runway, 636 m beyond the ideal touchdown point). The captain immediately cancelled the go-around by retarding the thrust levers, without announcing his actions. Those events resulted in confusion amongst the other pilots, and contributed to the crew not selecting (or noticing the absence of) reverse thrust during the landing roll. Due to a variety of factors associated with the cancellation of the go-around, the aircraft's speed did not decrease below the touchdown speed (154 kts) until the aircraft was 1,625 m or halfway down the runway.

The investigation established that, during the landing roll, the aircraft tyres aquaplaned on the water-affected runway. This limited the effectiveness of the wheelbrakes to about one third of that for a dry runway. In such conditions and without reverse thrust, there was no prospect of the crew stopping the aircraft in the runway distance remaining after touchdown. The aircraft overran the 100 m stopway (at the end of the runway) at a speed of 88 kts, before stopping 220 m later with the nose resting on an airport perimeter road.

The depth of water on the runway when the aircraft landed could not be determined but it was sufficient to allow dynamic aquaplaning to occur (i.e. at least 3 mm). The water build-up was the result of heavy rain on the runway in the preceding minutes, and possibly because the runway was ungrooved.

During the examination of the performance of the aircraft on the runway, it became evident that the flaps 25/idle reverse thrust landing procedure used by the crew (and which was the 'preferred' company procedure) was not appropriate for operations on to water-affected runways. The appropriate approach/landing procedure was flaps 30/full reverse thrust. This had the characteristics of a lower approach speed, of being easier to fly in terms of speed control and runway aim point (for most company pilots), and of providing maximum aerodynamic drag after touchdown when the effectiveness of the wheelbrakes could be reduced because of aquaplaning. Had this configuration been used, the overrun would most probably have been avoided.

As with other company B747-400 pilots, the crew had not been provided with appropriate procedures and training to properly evaluate the potential effect the Bangkok Airport weather conditions might have had on the stopping performance of the aircraft. In particular, they were not sufficiently aware of the potential for aquaplaning and of the importance of reverse thrust as a stopping force on water-affected runways.

Significant active failures

Significant active failures associated with the accident flight were:

- The flight crew did not use an adequate risk management strategy for the approach and landing. In particular, they did not consider the potential for the runway to be contaminated by water, and consequently did not identify appropriate options and/or landing configurations to deal with the situation. That error was primarily due to the absence of appropriate company procedures and training.
- The first officer did not fly the aircraft accurately during the final approach.
- The captain cancelled the go-around decision by retarding the thrust levers.
- The flight crew did not select (or notice the absence of) idle reverse thrust.
- The flight crew did not select (or notice the absence of) full reverse thrust.
- The runway surface was affected by water.

Significant inadequate defences

Significant inadequate defences associated with Qantas Flight Operations Branch activities were:

- Company-published information, procedures, and flight crew training for landing on water-affected runways were deficient.
- Flight crew training in evaluating the procedural and configuration options for approach and landing was deficient.

Post-accident events and cabin safety issues *(see part 2)*

The main areas of damage to the aircraft were the lower forward fuselage, the nose and right wing landing gear and landing gear bays, and the engines. Numerous cabin fittings dislodged during the accident sequence. As a result of the nose landing gear collapsing rearwards and upwards into the lower fuselage, the cabin passenger address system and the interphone system for communications between the flight deck and the cabin became inoperable.

No evidence of fire was found during the post-accident examination of the aircraft.

After the aircraft came to a stop, the flight crew initiated a process of gathering information from the cabin concerning the extent of the aircraft damage. The failure of the passenger address and cabin interphone systems was a major hindrance to the crew's efforts to assess the situation in the cabin. Some important information regarding the cabin environment and the external condition of the aircraft did not reach the flight crew. In addition, there were gaps in the information available to the flight crew, the possible significance of which was not considered by them in deciding whether or not to keep the passengers on the aircraft. The captain assessed that the appropriate response was to wait for outside assistance and then conduct a precautionary disembarkation, rather than initiate an immediate evacuation.

Normal radio communications between the aircraft and the control tower were lost for a few minutes after the aircraft came to a stop. Additionally, the aircraft could not be seen from the tower because of the reduced visibility and the emergency response vehicles were restricted to sealed surfaces by the wet conditions. These issues contributed to the emergency response vehicles arriving at the aircraft about 10 minutes after the accident.

Approximately 20 minutes after the accident, the crew initiated a precautionary disembarkation from the right side of the aircraft using the emergency escape slides. Although the disembarkation was achieved largely without incident, there were arguably sufficient 'unknowns' concerning the condition of the aircraft, and possible related hazards, for an earlier evacuation to have been conducted.

Significant active failures

Significant active failures associated with the post-accident events were:

- The cabin interphone and passenger address systems became inoperable (due to impact damage).
- The flight crew did not consider all relevant issues when deciding not to conduct an immediate evacuation.
- Some crewmembers did not communicate important information during the emergency period.

Significant inadequate defences

Significant inadequate defences associated with Qantas Flight Operations Branch activities were:

- Procedures and training for flight crew in evaluating whether or not to conduct an emergency evacuation were deficient.
- Procedures and training for cabin crew in identifying and communicating relevant information during an emergency were deficient.

Another significant deficiency involved the aircraft cabin interphone and public address system. The redundancy provided by the normal and alternate cabin interphone and public address systems in B747-400 aircraft was compromised because some components for both systems were co-located in the same relatively damage-prone position in the lower fuselage aft of the nosewheel. Aircraft design standards in the USA and Europe currently contain no requirements for system redundancy in this sense. The report includes a recommendation to the FAA and JAA regarding this deficiency.

Organisational factors: Qantas *(see part 3)*

The ATSB investigation examined the processes of the Qantas Flight Operations Branch for any systemic organisational issues that may have allowed the deficiencies mentioned above to occur. That examination included a detailed review of the company's introduction of the flaps 25/idle reverse procedure, as well as company procedures and training relating to water-affected runways. The aim of the new procedure was to reduce costs (e.g. brake maintenance, noise levy charges at Sydney Airport, and thrust reverser maintenance) without affecting safety levels. Examination of the project development process revealed that a proper risk assessment of the new procedure was not undertaken, and that other important considerations were overlooked. There were also significant deficiencies in the manner in which the company implemented and evaluated the new procedures.

Overall, the investigation identified five deficiencies related to the organisational processes of the Qantas Flight Operations Branch:

- The processes for identifying hazards were primarily reactive and informal, rather than proactive and systematic.
- The processes to assess the risks associated with identified hazards were deficient.
- The processes to manage the development, introduction and evaluation of changes to operations were deficient.
- The design of operational procedures and training was over-reliant on the decision-making ability of company flight crew and cabin crew and did not place adequate emphasis on structured processes.
- The management culture was over-reliant on personal experience and did not place adequate emphasis on structured processes, available expertise, management training, and research and development when making strategic decisions.

Organisational factors: Civil Aviation Safety Authority *(see part 4)*

Significant latent failures associated with CASA's regulatory operations were:

- The regulations covering contaminated runway operations were deficient.
- The regulations covering emergency procedures and emergency procedures training were deficient.
- The surveillance of airline flight operations was deficient.

In June 1997, CASA began developing a systems-based approach to surveillance because of deficiencies with the previous approach (which focussed on the end products of the aviation system). However, the new system had not reached maturity at the time of the accident. In 1998 and 1999, there were serious shortfalls in CASA's planned product-based surveillance of Qantas flight operations. However, because of the significant limitations in the effectiveness of product-based audits to identify the type of systemic and organisational

deficiencies highlighted during this investigation, it was unlikely that a higher level of surveillance activity would have revealed these deficiencies.

Safety action *(see part 5)*

On 5 December 2000, Qantas advised that all deficiencies identified during the investigation and highlighted in this report either had been, or were being, addressed. Qantas Flight Operations Branch had introduced substantial changes and was examining further changes to its management policies and procedures in the following areas:

- operational training and procedures
- hazard identification
- risk assessment
- change management
- design of procedures and training programs
- management decision-making processes

Some of these changes were in progress in the period before the accident. The ATSB raised a number of safety analysis deficiency notices (SADNs) concerning Qantas operations as a result of the investigation. Four of these SADNs remained open pending advice from the company on the progress of their change activities.

CASA was also in the process of making substantial changes to its surveillance processes and the Australian aviation safety regulations. Many of these changes were in progress at the time of the accident. The ATSB made four recommendations where it considered that there remained safety matters that were yet to be adequately addressed.

INTRODUCTION

Background to the investigation

In December 1944, 52 States (or countries) signed the Convention on International Civil Aviation. In 1947, the International Civil Aviation Organisation (ICAO) was established, and it became a specialised agency of the United Nations in the same year.

Annex 13 to the Convention on International Civil Aviation is titled 'Aircraft Accident and Incident Investigation'. It outlines ICAO's standards and recommended practices for these types of investigations. Those standards and recommendations include the obligations on contracting states to the Convention. Thailand (State of Occurrence) and Australia (State of Registry and State of Operator) are both contracting states.

Paragraph 5.1 of Annex 13 (Eighth Edition, July 1994) stated:

The State of Occurrence shall institute an investigation into the circumstances of the accident. Such State shall also be responsible for the conduct of the investigation, but it may delegate the whole or any part of the conducting of such investigation to the State of Registry or the State of the Operator. In any event the State of Occurrence shall use every means to facilitate the investigation.

On 18 November 1999, the Aircraft Accident Investigation Committee of Thailand delegated the investigation to the Australian Transport Safety Bureau (ATSB) on condition that:

- The ATSB regularly inform the Thailand Department of Aviation of the development of the investigation;
- The final report of the accident was reviewed by the Committee prior to its release.

The Committee indicated that the investigation by the ATSB should be conducted in accordance with ICAO Annex 13 and Australian Legislation.

Investigation team

The ATSB investigation team consisted of specialists in flight operations, engineering, cabin safety, human factors, organisational factors, and flight recorders.

In addition, personnel from Qantas, CASA, the Australian and International Pilots Association (AIPA) and the Flight Attendants Association of Australia (FAAA) were 'participants' in the investigation, as defined in Annex 13, paragraph 5.25. These personnel assisted in the collection of factual information. The Thailand Department of Aviation and the Boeing Airplane Company also provided information and comment.

Collection of factual information

Sources of factual information included:

- Site inspection and wreckage examination;

- Detailed analysis of recorded information from the digital flight data recorder (DFDR), quick access recorder (QAR), cockpit voice recorder (CVR), and the central maintenance computer on board the accident aircraft;¹
- Reviews of recorded air traffic control communications, a recording of air traffic control radar, meteorological forecasts and recorded weather information;
- Interviews² with:
 - the flight crew and cabin crew from the accident aircraft;
 - approximately 40 other personnel in Qantas (primarily senior management, check and training personnel, line pilots and flight safety personnel within the company's Flight Operations Branch); and
 - six personnel from CASA (primarily from its Compliance Branch);
- Reviews of documentation from Qantas, CASA and Boeing.
- A survey of Qantas B747-400 flight crew. The survey consisted of 42 questions on issues that were associated with the accident. A total of 240 questionnaires were returned, a response rate of 39%. Further information on this survey is provided in attachment K.
- A survey of the 391 passengers on board the accident aircraft. The survey consisted of 45 questions to obtain information on the sequence of events. Replies were received from 276 passengers, a response rate of 71%. The response was fairly uniform across all zones of the aircraft. A summary of the responses to the questionnaire is provided in attachment L.

Analysis methodology

The development of an occurrence (accident or incident) typically involves a number of different events and conditions. These events and conditions can be described in many different ways, the most common being the model of organisational accidents as outlined by James Reason and others.^{3,4,5} Although this model has several different versions, they all contain the following four components:

- **Active failures:** Unsafe acts, technical failures, or other operational events/conditions that have a direct and immediate influence on the development of an occurrence. Most serious occurrences involve a number of unsafe acts (errors or violations). It is preferable to view them as actions that should not be repeated in similar scenarios, rather than consider them 'failures' of the individuals involved.
- **Local factors:** Events and conditions that have a relatively direct or immediate influence on the occurrence of the active failures. For example, fatigue, insufficient knowledge or skill, or high workload are often associated with unsafe acts.

¹ With the agreement of the flight crew and the Australian International Pilots Association (AIPA), two Qantas pilots and three AIPA representatives assisted the ATSB investigation team analyse the CVR information.

² Interviews were conducted by ATSB investigators with no other person present, unless specifically requested by the interviewee.

³ D. Maurino, J. Reason, N. Johnston, & R. B. Lee, *Beyond Aviation Human Factors*, Ashgate, Aldershot (UK), 1995.

⁴ J. Reason, *Human Error*, Cambridge University, Cambridge, 1990.

⁵ J. Reason, *Managing the Risks of Organizational Accidents*, Ashgate, Aldershot (UK), 1997.

- **Inadequate defences:** Failures or absences in the measures taken by an organisation to ensure safe, reliable and effective operations. Appropriate defences can minimise the likelihood (and the severity of the consequences) of local factors and unsafe acts. Defences include processes and conditions such as procedures, training, task design, work schedules, equipment design and equipment availability. They also include 'last-line' defences such as warning systems, emergency equipment, and emergency procedures.
- **Organisational factors:** Management decisions or processes that created or influenced the deficiencies in the organisation's operational defences. In addition to the factors within an organisation, decisions and processes of other organisations (e.g. regulators or manufacturers) may have an influence.

During an investigation, active failures and local factors need to be identified. However, from the perspective of safety enhancement, it is more important to identify the inadequate defences and organisational factors. These deficiencies are often termed 'latent failures'. It should be noted that a detailed investigation of any organisation's processes is likely to identify deficiencies.

Factors can also be classified in terms of the extent that they influenced the development of the occurrence. In this report, the following two levels of influence are used:

- **Significant factor:** The occurrence would probably have been avoided (or the actual or potential consequences would have been much less serious) if the factor had not existed.
- **Minor factor:** The factor probably had some influence on the development of the occurrence (or the seriousness of its actual or potential consequences). However, the level of influence was not significant or could not be reliably determined.

In addition to discussing significant and minor factors, the report also discusses other salient issues that were ultimately not considered to have had an influence on the development of the occurrence (or there was insufficient evidence to make any such conclusion). However, such issues may still indicate a safety deficiency.

The Bureau does not use the term 'cause' to describe its conclusions as this term is often misused. Similarly no attempt is made to rank the significant factors in order of importance.

Review process

The ATSB investigation team developed a draft copy of the report that was reviewed by other ATSB personnel using a strict review protocol to ensure that all factual information was supported by documentary evidence.

The draft report was then sent to 'interested parties' for comment on 25 October 2000. Interested parties normally comprise the flight crew, the operator, CASA, and any other person or organisation whose reputation is likely to be directly affected following public release of the report. For this particular report, interested parties included the aircraft flight crew and cabin crew, Qantas, CASA, Boeing, AIPA, FAAA, and the Aircraft Accident Investigation Committee of Thailand.

The objectives of circulating draft reports to interested parties are:

- to ensure that any errors or inaccuracies are detected and rectified prior to release of the public report;

- to ensure that the principle of natural justice is followed, particularly with regard to those who were involved in any way in the events or conditions that led to the occurrence;
- to promote confidence within the industry and the public that ATSB conducts its investigations in an open and accountable manner.

Following the examination of these comments, minor modifications were made to some sections of the report. No changes to the significant active and latent failures were required. The safety action part was updated to reflect the latest advice regarding action to address the identified deficiencies.

Following the interested party process, the report was delivered to the Aircraft Accident Investigation Committee of Thailand for final review on 12 February 2001, in accordance with its letter of delegation, prior to public release. On 2 April 2001, the Aircraft Accident Investigation Committee of Thailand agreed to the release of the report as presented to them by the ATSB.

Report structure

Previous ATSB aviation occurrence investigation reports have closely followed the suggested report structure in the appendix of ICAO Annex 13. That suggested structure splits the report into four sections: factual information, analysis, conclusions and safety recommendations. Annex 13 also states that the Final Report 'may be prepared in the format considered to be the most appropriate in the circumstances' (chapter 6).

In this context, the factual information is divided into four main parts:

- Part 1—the accident flight;
- Part 2—cabin safety issues;
- Part 3—organisational issues associated Qantas;
- Part 4—organisational issues associated with CASA.

The ATSB analysis of this information is included throughout the report, either as 'observations' at the end of particular sections or an analysis section at the end of each part.

1. THE ACCIDENT FLIGHT

1.1 History of the flight

1.1.1 Departure and en route

A Boeing 747-438⁶ aircraft, registered VH-OJH, departed Sydney, Australia, as flight QF1 (callsign Qantas One) at 1647 local time on 23 September 1999 on a scheduled passenger transport service to Bangkok, Thailand. There were 391 passengers, 16 cabin crew, and three flight crew (captain, first officer and second officer) on board. The estimated flight time was 8 hours 28 minutes and fuel endurance was 9 hours 53 minutes. The first officer was the handling pilot for the flight.

The departure and en route segments of the flight proceeded normally.

Before commencing descent, the crew obtained the Bangkok Airport weather information. The wind was from 240 degrees at 10 kts, and visibility was 9 km. It was raining at the airport and there were thunderstorms in the area.

The first officer completed the approach briefing shortly before the top of descent. The crew was expecting to land on runway 21R.

During the descent, the captain, first officer and second officer were seated in their appropriate seats – the left control position, right control position and first observer's seat (behind and between the captain's and first officer's seats) respectively. The second officer's wife was seated in the second observer's seat (behind the captain) for the descent, approach and landing.⁷

1.1.2 Descent

Explanation:

The chronology of events during the descent, final approach and landing roll, are detailed below. This information was obtained from the cockpit voice recorder (CVR), solid state digital flight data recorder (SSDFDR), quick access recorder (QAR), a recording of the air traffic control communications, a recording of the air traffic control radar, meteorological reports, and post-accident interviews with the crew of Qantas One and other parties. All events refer to Qantas One unless stated otherwise. Information obtained from interviews is presented in italics.

Local Bangkok time is used throughout the remainder of the report.⁸ Altitudes above 1,000 ft are based on pressure altitude above mean sea level (to the nearest 100 ft). Altitudes below 1,000 ft are the radio altitude (to the nearest 10 ft) of the aircraft mainwheels above the runway. Speeds are knots calibrated airspeed (KCAS). Descent rates are reported to the nearest 100 ft/min.

⁶ Most Qantas B747-400 aircraft are designated B747-438.

⁷ There was no evidence to indicate that the presence of the second officer's wife on the flight deck adversely influenced any aspect of the flight.

⁸ Bangkok time was Coordinated Universal Time (UTC) plus 7 hours, and 3 hours behind Australian Eastern Standard Time.

- 2216:18 Qantas One commenced descent from Flight Level 350 (i.e. 35,000 ft).
- 2217:53 Qantas One was transferred to the Bangkok Approach frequency.
- 2219:46 Approach advised Qantas One and Thai 414 (an Airbus 330) that they would be landing on runway 21L. At this stage, Qantas One was next in the approach sequence behind Thai 414.
- 2221:38 The first officer conducted a briefing with the other pilots on the differences between runway 21R and 21L. He noted that the glideslope to runway 21L (3.15 degrees) was slightly steeper than normal (3.0 degrees) and that the runway was narrower than runway 21R (see section 1.3). The crew noted that they would have to roll through to near the end of the runway to exit via taxiway Sierra, and should therefore select the auto-brakes to position '2'. The captain made this selection. (Attachment B provides a description of the auto-brakes and other relevant aircraft systems.)
- 2225:38. Approach advised Thai 414 and Qantas One that there was heavy rain at the airport.
- 2226:53 The auto-brake selection was changed to position '3' after the captain suggested that it be increased 'for the water'.
- 2227:33 Approach advised that the visibility observed from the control tower was 4 km.
- 2227:59 The first officer suggested to the captain that they could go around and hold off to the south if the rain looked 'bad' during the approach. The captain replied that the visibility of 4 km was fine and that it was 'just a shower'.
- The crew reported that they were not concerned about the weather at this stage of the approach. Rain and thunderstorms were common events at Bangkok and it was still about 20 minutes before landing. The first officer said that he was considering the possibility of encountering reduced visibility on final approach and gave no consideration to the possible runway surface conditions or their potential effect. The second officer expressed similar views. The captain also said that, aside from changing the auto-brakes setting from '2' to '3' he also had given no other consideration to the possible runway surface conditions and their potential effect. The captain said that the initial approach briefing (prior to top of descent) had included a detailed discussion regarding go-around issues, and he did not think that this issue required any further discussion at that time. He noted that the reported aerodrome visibility at the time was 4 km, well in excess of the company's limit for first officers (1,500 m).*
- 2229:22 The aircraft levelled at Flight Level 130, heading 360 degrees. The speed stabilised at 250 kts soon afterwards.
- 2230:00 Approximate time of a routine weather observation taken at Bangkok Airport. The reported wind was from 280 degrees at 9 kts, and visibility was 5 km. Thunderstorms with rain were in the area, and there was a thunderstorm over the aerodrome.
- 2232:43 The captain commented to the other crew that there was a 'CB' (meaning a cumulonimbus cloud) over the airport. The aircraft was more than 70 km from the airport at this time.

- 2233:28 The crew completed the approach checklist. The planned landing configuration was flaps 25, with a reference speed (V_{REF}) of 149 kts. The 'target' speed for the final approach was 154 kts (V_{REF} plus 5).⁹
- 2234:51 Approach instructed Qantas One to change radio frequency to Bangkok Arrivals.
- 2235:21 Arrivals instructed Qantas One to descend to 2,500 ft and to proceed direct to position fix BD101 (approximately 10 NM on the final approach path for runway 21L).
- 2236:33 Arrivals advised Thai 414 that there was heavy rain over the aerodrome, that Information Tango was current, and that visibility was 5 km. At this stage, Thai 414 was approximately 3 minutes 20 seconds ahead of Qantas 15 (a Boeing 747-300), which was approximately 3 minutes ahead of Qantas One in the approach sequence to runway 21L.¹⁰ Information Tango included information from the routine weather observation taken at 2230. It also stated that tower and ground controller training was in progress.
- 2237:05 Between 2237:05 and 2239:10, the second officer obtained Information Tango.
- 2238:28 Arrivals cleared Qantas One for an ILS/DME approach to runway 21L.
- 2239:08 The captain again commented to the other crew members that he could see the 'CB' over the airport.
- The captain recalled that, after they had turned inbound, he had a clear view of the airport environment. They were not in cloud at that point, and there was no rain. However, the storm cell over the airport was clearly visible and was also evident on the flight deck weather radar display. The crew stated that such conditions were a common occurrence in Bangkok and other tropical locations and they were conscious of the possibility of turbulence, windshear, and reduced visibility.*
- The crew of Qantas 15 reported that, when they were approaching the aerodrome, their weather radar was showing a cluster of well-defined storm cells over the aerodrome.*
- 2239:12 Over the next 3 minutes, the captain made suggestions to the first officer that he should reduce speed. The first officer acknowledged these comments. The crew applied speedbrake during this period to reduce speed.
- The first officer reported that he was aware of the need to reduce speed, but he thought that the situation was under control and that the speed would reduce to the appropriate level during the approach.*
- 2240:00 Approximate time when Thai 414 landed.

⁹ V_{REF} is determined primarily by the aircraft configuration and weight. The *Qantas B747-438 Flight Crew Training Manual* stated that pilots should endeavour to be at the target speed at the 'last look' (just prior to the flare) (page 02.66). If gust or windshear conditions existed, then additional airspeed up to a maximum of V_{REF} plus 20 kts could be used provided the runway length was not limiting. According to the *Qantas Flight Administration Manual* (page 9-11), the company tolerance for the approach speed was between V_{REF} and ' $V_{REF} + 20$ kts at 500 ft or lower'.

¹⁰ Qantas 15 was initially behind Qantas One in the approach sequence but was radar vectored in front of Qantas One by the approach controller. This change in sequence, however, had no bearing on subsequent events other than to delay the landing time for Qantas One by a few minutes.

- 2240:00 Approximate time that a special weather observation was taken at Bangkok Airport. The observation noted visibility as 1,500 m and the runway visual range (RVR) for runway 21 as 750 m. This information was included in aerodrome Information Uniform which became current at 2240. The arrivals controller did not advise the crew of Qantas One that Information Uniform was current or that the visibility was now 1,500 m.¹¹
- 2240:02 The second officer passed relevant parts of Information Tango to the other crewmembers, including telling them that there was a thunderstorm overhead the aerodrome.
- 2240:06 Altitude approaching 7,100 ft, speed decreasing below 250 kts.
- 2240:45 The crew selected flaps 1 (the first stage of flaps).¹²
- 2241:05 The second officer overheard a conversation between the Qantas Bangkok ground engineer and the company agent on the Qantas company frequency. The engineer stated that it was ‘raining quite heavily’ at the time. This information was not passed to the captain or the first officer.
- The second officer stated that he did not think the information would have added significantly to the other pilots’ knowledge of the weather conditions. He recalled that the information regarding heavy rain had been broadcast at least twice before and had been discussed by the crew. He noted that the other pilots’ workload was increasing at this stage of the approach, so he chose not to distract them from their primary task.*
- 2241:49 Speed 207 kts. The crew selected flaps 5.
- 2242:22 The aircraft intercepted the glideslope and the autopilot then maintained the aircraft on the glideslope.
- 2242:27 Arrivals instructed Qantas One to contact Bangkok Tower when they reached the final approach point (also the outer marker for the ILS approach, located 4.1 NM from the runway threshold).
- 2243:17 Altitude 3,000 ft, speed 199 kts. The crew selected flaps 10.
- 2243:26 Qantas 15 told the tower that they were ‘going round’. The crew of Qantas One did not hear this transmission because, at that time, they had not reached the final approach point, and had not transferred to the tower frequency. The Qantas 15 go-around commenced from late final approach, at approximately 250 ft above ground level. The controller did not inform Qantas One that Qantas 15 had gone around;¹³ nor was there any communication between Qantas 15 and Qantas One on the company frequency regarding the go-around or weather conditions.

¹¹ Runway visual range is the range over which the pilot of an aircraft on the centreline of a runway can see the runway surface markings or the lights delineating the runway or identifying its centreline. The Airports Authority of Thailand advised that RVR (for runway 21R only) was measured automatically and displayed on a monitor in the control tower. There was no system for measuring RVR for runway 21L. The arrivals controller did advise aircraft of the change in visibility after Qantas One had transferred to the tower frequency (2244:40).

¹² There are seven flap positions—up, 1, 5, 10, 20, 25, and 30. At flaps 5, all wing leading edge flap groups are extended. Flap positions 10 to 30 include leading edge and trailing edge groups.

¹³ The tower controller was not required to advise other aircraft that Qantas 15 had gone around. Also, the Qantas 15 crew was not required to advise the reason for the go-around. The workload of both the tower controller and the Qantas 15 crew would have increased at this time as a result of the go-around.

The crew of Qantas 15 later indicated that, prior to encountering the rain, conditions had been clear. They had declared visual procedures at about 2,000 ft. They entered rain at approximately 700 ft, and the rain became very heavy at about 500 ft. The primary reason for the go-around was a loss of visual reference in the heavy rain when only the Precision Approach Path Indicator (PAPI) lights had been visible—they could not see any runway lights.

2243:32 Altitude 2,700 ft, speed 201 kts. The Qantas One crew extended the landing gear.

2243:59 Altitude 2,200 ft, speed 182 kts. The first officer disengaged the autopilot and autothrottle. The crew selected flaps 20.

The first officer reported that he decided to fly the approach ‘manually’ in order to maximise the opportunity for some ‘hands-on’ flying. There was no concern about visibility at this stage.

2244:25 Altitude 1,900 ft, speed 165 kts. The crew selected flaps 25.

1.1.3 Final approach

Fig. 1 outlines the flight profile of the aircraft during the final approach and landing from the middle marker.

2244:38 Altitude 1,600 ft, speed 163 kts, on glideslope. The aircraft passed over the outer marker.

2244:53 Tower advised ‘caution runway wet and braking action reported by Airbus three three is good’.¹⁴ They reported the wind as being from 260 degrees at 11 knots, and cleared Qantas One to land on runway 21L.

The crew reported that they had assumed the Airbus mentioned by the tower controller had landed immediately in front of them in the approach sequence. They considered that they had no reason to think that the runway conditions were not appropriate for landing. They had landed in rain on many occasions (at Bangkok and other locations) and had not experienced any braking difficulties.

The crew said that the aircraft had not flown through any rain during the descent to that stage.

2245:12 The crew completed the landing checklist. They confirmed that the speedbrakes were armed, landing gear was down, and that the flaps were set at flaps 25.

The crew reported that the option of a flaps 30¹⁵ approach was not discussed at any stage during the descent or final approach. Similarly, the use of full reverse thrust after landing was not discussed. It was assumed by all the crew that flaps 25 and idle reverse thrust would be used. The crew stated that, based on the company procedures, their experience, and the information available to them at the time, they had no reason to think that a different approach/landing configuration was required.

¹⁴ The callsign of the Airbus 330 was Thai 414.

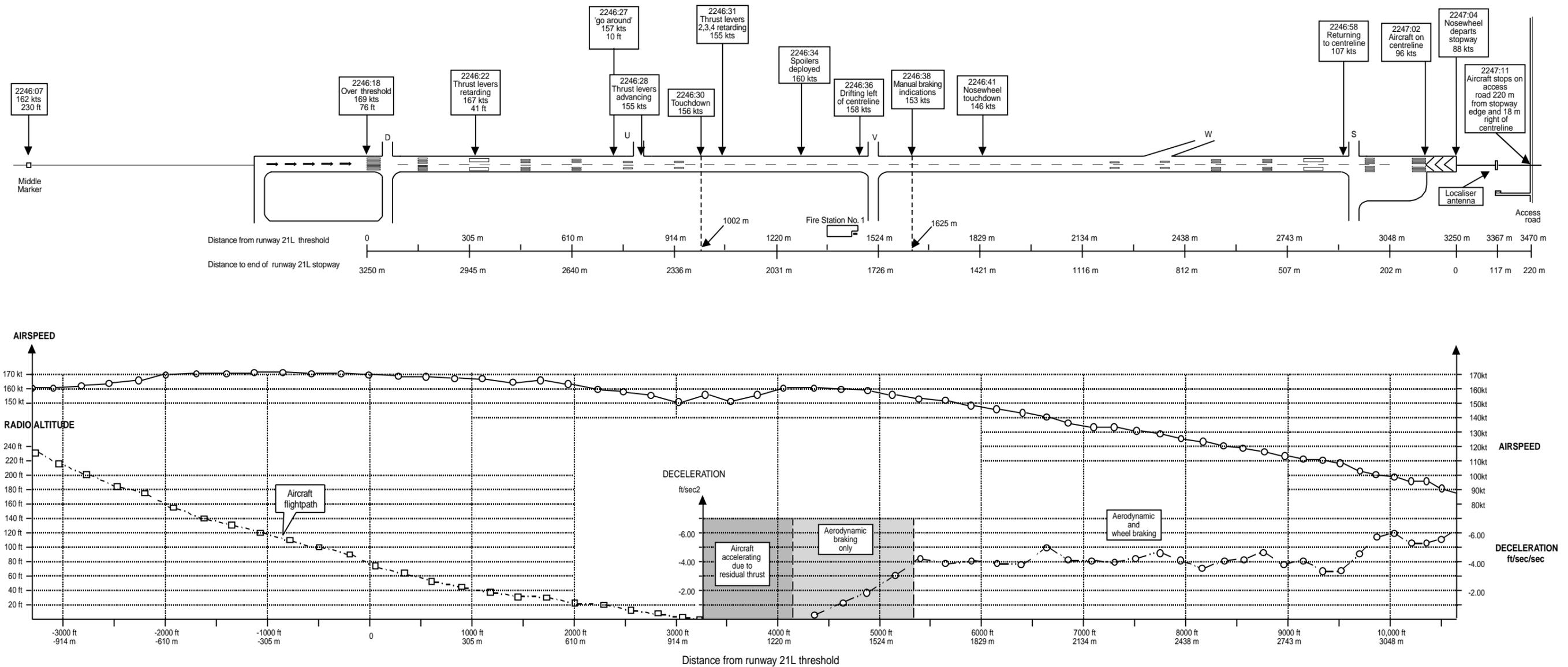
¹⁵ Flaps 30 requires a slower approach speed (approximately 6 kts) than flaps 25. The company’s flaps 25/idle reverse procedures are discussed in section 1.7.

- 2245:20 Altitude 970 ft, speed 163 kts. The crew agreed that the approach would be flown in accordance with 'visual procedures'.¹⁶
- 2245:32 Altitude 770 ft, speed 166 kts. The first officer commented that the aircraft 'doesn't want to slow down'. The captain acknowledged this statement.
- The first officer said he was trying to slow the aircraft to the target speed (154 kts). He was becoming a little uneasy about the excess speed, but thought that the captain appeared to be comfortable with the situation. Although still above the target speed, the airspeed was decreasing. Speeds in excess of the target speed were not uncommon during approaches, but on this occasion the speed was a little higher than normal (thus prompting his comment). He had reduced the thrust settings (engine pressure ratios (EPRs)) to 1.09 – 1.10.¹⁷ He did not want to reduce the thrust any further.*
- The captain said that he was aware that the speed was high, but it was within company limits and was decreasing. He thought the situation was under control.*
- 2245:58 Altitude 350 ft, speed 164 kts. The first officer called for the windscreen wipers to be turned on. The captain selected the wipers to the 'high' setting.
- The crew reported that there was only light rain at this stage, but that the rain intensity increased soon afterwards (see 2246:08). To this stage, they had not seen any rain and the visibility had been good. All the runway lights had been visible.*
- 2246:07 Altitude 230 ft, speed 162 kts, descent rate 900 ft/min, on glideslope. The aircraft passed over the middle marker (located 1,000 m from the runway threshold). The average EPR increased from 1.15 to 1.19 and remained at this level until 2246.13.
- 2246:08 Altitude 200 ft, speed 164 kts, descent rate reducing. The onset of heavy rain could be clearly heard as background noise on the CVR. The different altitudes at which QF1 and QF15 encountered heavy rain (see 2243:26) was probably due to movement of the storm cells in the period between their approach times.
- The first officer stated that the approach and runway lights were visible only for brief intervals immediately after each pass of the wiper blades across the windscreen. The first officer and second officer stated that the rain was the heaviest they had ever experienced during an approach.*
- 2246:12 Altitude 140 ft, speed 170 kts, descent rate 600 ft/min. The aircraft began to deviate above the ILS glideslope.

¹⁶ According to the *Qantas Flight Administration Manual* (page 11-2 and 11-3), 'visual procedures' means that the aircraft is flown manually and both pilots are 'head free' (or 'placing increasing emphasis externally as the aircraft progresses down the approach path'). No 'visual' call is required at the decision height. If visual procedures are not called, then the non-flying pilot is 'head down' (or monitoring instruments) until the 'visual' call.

¹⁷ The cockpit indications of engine parameters include displays of EPR for each engine. EPR provides an indication of engine thrust. The typical EPR range during a 3 degree glideslope approach with flaps 25 selected is 1.13–1.14.

Figure 1:
Flight profile during approach and landing (adapted from Qantas Flight Safety Department diagram)



- 2246:16 The captain commented ‘you’re getting high now’.
- The captain reported that he had noticed that the rate of descent had ‘broken’ (decreased) after they hit the heavy rain. The PAPI¹⁸ was showing four white lights at this stage, whereas before the rain there had been three white and one red (the normal ‘on glideslope’ indication for a B747). He noted that, as they were getting close to the threshold, the PAPI was not a reliable indicator of glideslope deviation.*
- 2246:16 The automatic altitude advisory call ‘100 feet’ sounded. Speed 170 kts.
- 2246:17 The captain said ‘you happy?’ to the first officer. The first officer replied ‘ah yes’.
- The captain could not recall exactly what prompted his comment, but thought it may have been the reduced visibility. However, he believed that the visibility was always above the minimum required for a first officer (1,500 m). The first officer stated that he was probably getting near his personal limits by this time, but he was happy to continue with the approach as the captain appeared to be happy. The first officer had the feel of the aircraft and it made more sense for him to continue rather than hand over control at that point. The second officer also reported that he was comfortable with continuing the approach at that stage.*
- 2246:18 Altitude 76 ft, speed 169 kts, descent rate 600 ft/min. The aircraft crossed the runway threshold. The aircraft was 20 kts above V_{REF} and 32 ft above the ideal threshold crossing height for a 3.15 degree glideslope.
- 2246:21 Speed 166 kts. The automatic altitude advisory call ‘50 feet’ sounded on the flight deck. The aircraft pitch angle increased from 3 degrees nose up to 3.6 degrees nose up.
- 2246:22 The captain said ‘get it down, get it down, come on you’re starting your flare’.¹⁹ The first officer acknowledged this statement. He also began to retard the engine thrust levers in preparation for touchdown. The descent rate was approximately 300 ft/min, and remained at that rate until touchdown.
- The first officer reported that the reduced visibility made it difficult to judge the landing flare. Because he was already in the flare, he decided to allow the aircraft to settle onto the runway. He believed they still had more than enough runway remaining to stop the aircraft.*
- 2246:24 Speed 166 kts. The automatic altitude advisory call ‘30 feet’ sounded. The captain increased the auto-brake selection to ‘4’, but did not advise the other crewmembers of this adjustment.
- The crew reported that they were aware of a longer than normal time interval between the ‘50 feet’ and ‘30 feet’ advisory calls, confirming a slower than normal rate of descent.*

¹⁸ The PAPI provided pilots with a visual indication of the aircraft’s position with respect to the glideslope. The *Qantas Flight Administration Manual*, page 9.12 stated that visual approach slope indicators, including PAPI, are ‘guidance systems only and their continued use below 300 ft is secondary to a visual 3-degree approach path to a normal touchdown point for the aircraft type’. See also section 1.3.2.

¹⁹ The *Qantas B747-438 Flight Crew Training Manual* (page 02.57) stated that the landing flare should be initiated when the main gear is approximately 30 ft above the runway.

2246:27 Altitude 10 ft, speed 157 kts. The captain instructed the first officer to 'go around'. The first officer started to manually advance the thrust levers within one second of the captain issuing the 'go-around' instruction. The first officer did not activate the TO/GA (take-off/go-around) function. (See attachment B for a description of the TO/GA system.)

The captain reported that he made the go-around decision because the aircraft was 'floating' and the visibility had decreased to the extent that he was not sure that he could see the end of the runway. He had also not been totally comfortable with the aircraft speed. It had been within company prescribed limits, but at the upper limit of what he was personally prepared to accept.

The first officer said that his reason for manually advancing the thrust levers (rather than using TO/GA) was that he intuitively thought that method would commence the go-around quicker. His intention was to increase the thrust manually, and to then select TO/GA.

1.1.4 Landing roll

A large number of events occurred during the initial phase of the landing roll. As a result, these events are reported to within one tenth of a second (based on the CVR) wherever possible.

2246:30.1 Speed 156 kts, 1,002 m from threshold.²⁰ The sound of the 'lever latch' (which locked the landing gear lever in the down position) was recorded on the CVR, indicating that the main wheels had contacted the runway. The nosewheel was tracking within 1 m of the runway centreline. The engine EPR values had just started to increase as a result of the go-around response. The aircraft attitude at touchdown was 4.6 degrees nose-up.

The crew reported that the touchdown was smooth. The captain reported that, simultaneous with the touchdown, the intensity of the rain decreased such that he could see the far end of the runway. However, it continued to rain heavily during the remainder of the landing roll.

2246:31.6 The sound of the thrust levers for engine numbers 2, 3 and 4 hitting the idle stop was recorded on the CVR. This was the result of the captain retarding the thrust levers because he decided to continue the landing rather than go around. The captain gave no verbal indication of this action or of his intentions, and did not take control of the aircraft from the first officer.

The crew reported that the captain placed his right hand over the first officer's left hand (which was on the thrust levers) and retarded the thrust levers. However, the number one thrust lever was inadvertently left in the advanced position, probably because it was not within the grasp of the first officer's hand.²¹ The captain then removed his hand.

²⁰ The *Qantas Flight Crew Training Manual* stated that touchdown should ideally occur 'approximately 1,000 to 1,500 ft (305 to 458 m) beyond the threshold'. Boeing performance data is based on touchdown occurring 1,200 ft (366 m) beyond the threshold.

²¹ The width of the four thrust levers is such that it may be difficult for a pilot to keep fingers on each thrust lever all the time, particularly the thrust lever further from his body (and which is being controlled by the pilot's little finger).

The captain said that he thought the aircraft had touched down about 3,000 ft down the runway. When the intensity of the rain decreased, he assessed that there was sufficient runway remaining to stop.²² He noted that he had extensive base training experience, which frequently involved decisions of this nature (see attachment F). The captain was aware that the first officer had not used TO/GA, and he also thought that the engines had not ‘spooled up’ sufficiently to accelerate the aircraft by that time. Thus, he believed his decision to reject the go-around was not a reflex action but the result of a deliberate thought process. He thought that there was no need for him to say anything as it should have been evident that the first officer retained the role of handling pilot.

The first officer also thought that there was sufficient runway remaining to stop the aircraft. He reported that, when the captain retarded the thrust levers, he was initially confused as to who was in control of the aircraft and whether the intention was to go around or continue the landing. The second officer expressed a similar view.

2246:31.9 The first officer said ‘ok, we’re on’.

2246:32.0 The EPR values for engine numbers 2, 3 and 4 reached 1.29, their highest average value (following the go-around command). The engines had continued to ‘spool up’ briefly after the thrust levers were closed, in accordance with normal engine operation.

2246:32.7 The captain said ‘got it?’ to the first officer.

2246:33.0 Speed 160 kts. The EPR for the number 1 engine reached 1.50, its maximum recorded value following the go-around command. This occurred 1.4 seconds after the number 2, 3, and 4 thrust levers reached the idle position. The first officer retarded the number 1 engine thrust lever to the idle position.

The first officer stated that he closed the number 1 thrust lever after observing that it remained forward of the idle position.

2246:33.1 Automatic spoiler deployment was initiated. Deployment would normally have been triggered by mainwheel touchdown. However, the spoiler system logic prevented this because (at the time of mainwheel touchdown) the number 1 engine thrust lever was not in the idle position (see attachment B).

2246:33.3 The auto-brake selector automatically moved to the ‘disarm’ position. This deactivated the automatic braking system and occurred because the number 1 thrust lever had been advanced for more than 3 seconds while the aircraft was on the ground (see attachment B). The brakes could still be operated manually.²³

None of the crew noticed that the auto-brake system had disarmed.

2246:33.5 The sound of a take-off configuration warning commenced. The sound ceased 1.6 seconds later. The warning occurred because the flight management system sensed that the thrust levers had been advanced to the

²² There was sufficient runway distance remaining to stop the aircraft on a ‘dry’ or ‘wet’ runway, but not for conditions worse than wet (see section 1.5).

²³ See attachment B, paragraph B.2.2 for a description of the wheelbrakes system.

take-off range, but that the flaps were not in the take-off position and the spoiler lever was not in the 'down' detent.

Neither the captain nor the first officer could recall hearing the takeoff configuration warning. The second officer thought he heard it amongst other noises.

2246:34.5 The first officer responded 'yeah I've got it' to the captain's question at 2246:32.7 (1.8 seconds earlier).

2246:36 Speed 158 kts, 1,460 m beyond the threshold. The aircraft began to deviate left of the runway centreline.

2246:38 Speed 153 kts, 1,625 m beyond the threshold (half way along the runway). First indication that the speed had decreased below the touchdown speed. The first indications of brake torque were also recorded at this time just after the crew commenced manual braking. At no stage during the landing roll did the crew attempt to select either idle reverse thrust or full reverse thrust. There was no comment on the CVR regarding reverse thrust.

The first officer reported that the reason he commenced manual braking was that the aircraft did not appear to be slowing down. However, even after he started manual braking, there did not appear to be any change in the rate of deceleration. The captain and first officer reported that they were both applying maximum manual braking soon after this point. The first officer also reported that he was pulling back on the thrust levers at the same time.

The crew reported that they did not realise that idle reverse had not been selected. They did not think of using full reverse thrust at any stage of the landing roll. They all said that they were looking down the runway and could not understand why the aircraft was not decelerating.

2246:41 Speed 146 kts, 1,836 m beyond the threshold. The nose landing gear squat switch indicated 'ground' mode. This indicated that the nosewheel had contacted the runway.

2246:42 The nose landing gear squat switch changed to 'air' mode, indicating a slight bounce of the nosewheel. The squat switch returned to 'ground' mode 1 second later.

2246:45 Speed 134 kts, 2,133 m beyond the threshold (and 1,017 m from the end of the runway). The nosewheel was 4 m left of the runway centreline. It reached a maximum distance of 7.4 m left of the centreline at 2,682 m beyond the threshold. The nosewheel continued to track 5 m or more left of the centreline until the aircraft was 3,020 m beyond the threshold. (The landing gear track width of the aircraft is 11 m.)

2247:02 Speed 96 kts. The nosewheel regained the centreline as it crossed the end of the runway and entered the 100 m stopway.

The crew said that they had not been aware that the aircraft was left of the centreline (and the runway was not equipped with centreline lighting).

2247:04 Speed 88 kts. The aircraft overran the stopway.

2247:07 Speed 79 kts. The aircraft collided with an ILS localiser antenna structure about 117 m beyond the end of the stopway. It continued for a further 103 m through very wet, boggy soil before coming to a stop 18 m right of the

runway extended centreline, with the nose resting on an airport perimeter road.

2247:11 Sound of impact noises stopped. The first officer then commenced the checklist actions and shut down the engines by selecting the fuel control switches to 'cut-off'.

2247:20 Loss of power to SSDFDR and CVR.

Events after this time are discussed in part 2 of the report. Fig. 2 shows the aircraft at its final resting position.

1.2 Aircraft and wreckage information

The aircraft sustained substantial damage during the overrun. The collision with the ILS localiser antenna initiated the collapse of the nose and the right wing landing gear. The left wing landing gear and both main body landing gear remained extended and attached. Loss of the right wing landing gear caused the aircraft to adopt a slight right wing low attitude, allowing the right inboard engine nacelle, and then the right outboard engine nacelle, to contact the ground as the aircraft slowed.

Inspection of the aircraft soon after the accident confirmed that the spoilers had deployed, the wing flaps were in the flaps 25 position, and all of the engine thrust reversers were in the stowed position.

A comprehensive examination of the aircraft and its systems did not reveal any fault that might have affected any aspect of the approach and landing sequence.

No significant injuries occurred during the landing or subsequent precautionary disembarkation. Some minor injuries were reported (see section 2.3.1).

Attachment B provides background information on the aircraft and relevant aircraft systems. Attachment C provides a more detailed description of the damage that occurred during the overrun.

Figure 2:
Accident aircraft in its final resting position: (a) rear view; (b) side view.



Figure 2 (continued):
Accident aircraft in its final resting position: (c) front view; (d) close view of number 3 engine.



1.3 Aerodrome information

1.3.1 Runway information

Bangkok International Airport has two parallel runways—runway 03L/21R and 03R/21L (see attachment E). The aerodrome elevation was 9 ft above mean sea level. At the time of the accident, runway 21L was being used for arrivals and runway 21R was being used for departures.

Runway 21L was 3,500 m long and 44.8 m wide, with a slope of less than 0.1% over the full length. The runway 21L threshold was displaced 350 m (1,000 ft), meaning that the landing distance available was 3,150 m (10,335 ft). There was a 100 m stopway at the end of the runway. Runway 21R was 3,700 m long.

Runway 21L had an asphaltic concrete surface and a 1.5% transverse slope from the centreline to either edge. The runway was not grooved or porous friction concrete (PFC) coated.²⁴ A thick coverage of grass 80 to 100 mm high grew up to the runway edge and protruded slightly above runway level. In the zone between about 350 and 750 m from the threshold (where most touchdowns occur), the surface contained heavy rubber deposits from landing aircraft. Beyond about 750 m, the deposits became progressively lighter until they disappeared completely past the exit for taxiway 'S'. The rubber deposits extended about 8 m either side of the runway centreline.

The airport authority did not provide friction-coefficient information on the runway surface. Such information is provided at some European and North American airports, predominantly those affected by snow and/or ice but is not provided at most international airports in the Asia-Pacific region, including Australian airports.

The surface beyond the stopway of runway 21L was a relatively flat, grass covered area which extended for 220 m to a narrow sealed road elevated about 0.25 m. There were a few small trees and bushes on either side of the road. The area beyond the road was part of a golf course. It contained minor undulations and a shallow pond. At the time of the accident, the overrun area was very wet and soft.

The ILS localiser antenna array was 1.5 m high and situated approximately 117 m beyond the end of the stopway. It was mounted on a 3-m wide concrete base which extended across the full width of the runway.

1.3.2 Lighting

Approach lighting guidance to runway 21L included a high intensity approach light system and a precision approach path indicator (PAPI) system. The PAPI was installed on both sides of the runway with a nominal approach slope angle of 3.15 degrees (the same as the ILS glideslope).²⁵ The runway lights consisted of threshold and runway edge lights. The runway was not equipped with touchdown zone or centreline lighting.

²⁴ Grooving or PFC coating can increase runway friction characteristics when water is present. ICAO does not require or recommend that runways are 'grooved'. Annex 14, Volume 1 (*Aerodrome Design and Operations*) states that the surface 'shall be constructed without irregularities that would result in loss of friction characteristics' (paragraph 3.1.21) and that the surface 'shall be so constructed as to provide good friction characteristics when wet' (paragraph 3.1.22). A Qantas management pilot reported that approximately half of the runways they use (outside of Australia) are ungrooved.

²⁵ The standard approach slope angle is 3 degrees. The slope may be varied to ensure adequate obstacle clearance for aircraft.

1.3.3 Aids to navigation

There were no reported anomalies concerning the aerodrome navigation or approach aids at the time of the accident. The Department of Aviation, Thailand, reported that the ILS calibration was tested the day following the accident and met the required performance criteria.

1.3.4 Communications

The recording of air-ground communications between Qantas One and Bangkok ATC revealed that there were instances where instructions were not initially understood and had to be repeated. None of these events had any influence on the accident sequence. Pilots with experience in operating into Bangkok described the communications as typical for operations in many areas of Asia where English was not the official language. There were communication difficulties between the flight crew and air traffic control after the aircraft stopped (see section 2.2.2).

1.3.5 Previous runway overruns at Bangkok

The Department of Aviation, Thailand, advised that there had not been a runway overrun event at the Bangkok Airport for at least 10 years.

1.3.6 Qantas operations into Bangkok

In the *Qantas Route Manual Supplement*, Airport Notes, the following note was included in the section on Bangkok (page 2-B-01):

Caution:

Due to limited visibility from the tower, do not transfer to Ground Control on arrival until instructed to do so and when west of Rwy 21R.

Runways slippery when wet.

Some taxiways do not have edge markings.

Similar notes regarding 'slippery runways' were included in the manual against 12 other airports, all of which were listed as useable airports for Qantas B747 aircraft. However, Bangkok was the only airport regularly used by Qantas B747 aircraft which contained the 'slippery when wet' caution in the *Route Manual Supplement*.

During interviews with company pilots, most indicated that they had never experienced any difficulties during approach and landing on runway 21L at Bangkok. No pilots interviewed during the investigation reported having been aware of any deceleration difficulties during landing on runway 21L, even during periods of rain.

1.4 Aircraft landing performance: background information

1.4.1 Landing overrun accident statistics

Between 1970 and early 1998 there were at least 111 landing overrun accidents worldwide involving 'western-built jet airline' aircraft.²⁶ These figures did not include those events in

²⁶ Information obtained from Airclaims Group Limited.

which a mechanical failure, such as a landing gear collapse, led to the overrun. The accidents included:

- 42 overruns in which the aircraft landed long and/or fast on a water-affected runway.
- 36 overruns in which there was an apparent or assumed normal touchdown on a water-affected runway.
- 33 overruns in which the landing was long and/or fast on a dry runway.

Preliminary data was obtained for accidents during 1999 involving western-built high capacity (greater than 37 seats) jet aircraft.²⁷ These accident descriptions were not official accident reports, and are often only based on initial information and press reports. Of the 49 accidents listed, 11 were landing overruns (excluding Qantas One). This number did not include those accidents where a mechanical failure or hard touchdown was the initiating event, or those accidents involving a loss of directional control on a water-affected runway. The 11 overrun accidents included:

- five overruns in which the aircraft landed long and/or fast on a water-affected runway;
- two overruns in which there was an apparent or assumed normal touchdown on a water-affected runway;
- two overruns in which the landing was long and/or fast. 'Poor' weather was reported, but no information was available on the runway conditions;
- one overrun in which the landing was long but no weather details were provided.
- one overrun for which no details were provided.

In each instance, water on the runways was due to rain, not snow or ice. Six of the 11 accidents involved passenger-carrying operations.

A study of accident and movement data for airports in western Europe examined 91 runway overruns and veer-offs. The study concluded that there was a fourfold increase in accident risk for aircraft operating on water-affected runways compared to dry runways.²⁸

Observations:

Runway overruns remain a relatively common event in accidents involving western-built high capacity jet aircraft. Frequently, long and/or fast landings and water-affected runways were factors in these accidents.

1.4.2 Types of water-affected runways

The International Civil Aviation Organisation (ICAO) has published the following terms and definitions for water-affected runways:²⁹

DAMP – the surface shows a change of colour due to moisture.

WET – the surface is soaked but there is no standing water.

WATER PATCHES – significant patches of standing water are visible.

FLOODED – extensive standing water is visible.

²⁷ Information obtained from Airclaims publication 'Blue Print'.

²⁸ G. W. H. van Es, A. L. C. Roelen, E. A. C. Kruijsen, & M. K. H. Giesberts, *Safety Aspects of Aircraft Performance on Wet and Contaminated Runways*, National Aerospace Laboratory (NLR), Amsterdam, 1998.

²⁹ ICAO, Annex 14, vol. 1, *Aerodrome Design and Operations*, 1999, paragraph 2.9.4.

These ICAO definitions were also included in the Australian Aeronautical Information Publication (AIP) and the *Jeppesen Route Manual* for Australian operations, but not in the *Jeppesen Route Manual World-wide Text* that is carried in the aircraft on-board library on Qantas international services.

It is practice within the aviation industry for pilots to report braking action as 'good', 'medium' or 'poor' when referring to water-affected runways. Various definitions of these terms exist. The definitions in the Australian AIP and the *Jeppesen Route Manual* for Australian operations were:

GOOD – pilots should not expect to find the conditions as good as when operating on a dry runway, but should not experience any directional control or braking difficulties because of the runway conditions.

MEDIUM – braking action may be such that the achievement of a satisfactory landing or accelerate-stop performance, taking into account the prevailing circumstances, depends on precise handling techniques.

POOR – there may be a significant deterioration both in braking performance and directional control.

The European Joint Aviation Administration (JAA) has published the following descriptive criteria:³⁰

Dry runway. A dry runway is one which is neither wet nor contaminated, and includes those paved runways which have been specifically prepared with grooves or porous pavement and maintained to retain 'effectively dry' braking action even when moisture is present.

Damp runway. A runway is considered to be damp when the surface is not dry, but when the moisture on it does not give it a shiny appearance.

Wet runway. A runway is considered wet when the runway surface is covered with water, or equivalent, less than specified... [for a contaminated runway] or when there is sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water.

Contaminated runway. A runway is considered to be contaminated when more than 25% of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by the following:

- i Surface water more than 3 mm deep, or by slush, or loose snow, equivalent to more than 3 mm of water;
- ii Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow); or
- iii Ice, including wet ice.

Neither the US Federal Aviation Administration (FAA) nor CASA had published any definitions for water-affected runways.

Boeing uses the term 'slippery' to describe water-affected runways and describe different levels of runway 'slipperiness' as shown in table 1. This data is a function of the 'airplane braking coefficient', or the percentage of the aircraft's weight on the wheels which is

³⁰ JAA, JAR-OPS 1, Commercial Air Transportation (Aeroplanes), Section 1, Subpart F, 1.480 (Terminology).

converted into an effective stopping force. Boeing has equated different values of the coefficient to pilot reported braking action and a general runway description. The company advised that the relationships listed in the table were subjective and intended only to provide aircraft operators with an understanding of the different terms.

A study of airline operations in Western Europe has shown that there is no correlation between pilot reports and the actual friction values of a runway.³¹

Table 1:
Boeing runway descriptors

<i>Airplane braking coefficient</i>	<i>Pilot-reported braking action</i>	<i>Runway description</i>
0.4	–	Approximate dry runway friction certification values
0.2	Good	Wet runway
0.1	Fair/Medium	Ice
0.05	Poor/Nil	Wet Ice/Melting Compacted Snow

1.4.3 Aircraft stopping forces

There are three forces available for stopping the aircraft on a runway:

- aerodynamic drag
- reverse thrust
- wheel braking

Table 2 shows, in general terms, the extent to which the three forces contribute to the total instantaneous deceleration force on dry and wet runways as a function of ground speed. Aerodynamic drag and reverse thrust are most effective at higher speeds, and provide a greater proportion of stopping force on wet compared with dry runways.

1.4.4 Aircraft systems

This section provides a brief description of the aircraft systems that contribute to stopping the aircraft, and the reasons for these conditions.

Spoilers. The primary role of the spoilers is to destroy wing lift, thereby placing aircraft weight on to the tyres. Spoilers also provide a significant contribution to aerodynamic drag. They should be deployed as soon as possible after touchdown. They are typically deployed automatically 1–2 seconds after touchdown.

Flaps. Flaps also contribute to aerodynamic drag. On B747-400 aircraft, landing with flaps 30 provides a 6–7% shorter stopping distance compared with landing with flaps 25 (assuming all other parameters remain unchanged). The shorter stopping distance is primarily due to the lower approach (V_{REF}) speed for the flaps 30 configuration.

³¹ G. W. H. van Es, A. L. C. Roelen, E. A. C. Kruijzen, & M. K. H. Giesberts, *Safety Aspects of Aircraft Performance on Wet and Contaminated Runways*, National Aerospace Laboratory (NLR), Amsterdam, 1998, p.8.

Table 2:
Contribution of stopping forces to stopping performance³²

<i>Runway condition</i>	<i>Ground speed (kts)</i>	<i>Contribution to total instantaneous stopping force (%)</i>			<i>Total instantaneous stopping force available compared to reference condition(in bold) (%)</i>
		<i>Drag</i>	<i>Reverse thrust</i>	<i>Brakes</i>	
Dry	140	30	15	55	120
Dry	100	20	10	70	100
Dry	60	10	10	80	85
Wet	140	40	20	40	90
Wet	100	25	20	55	70
Wet	60	10	15	75	55
Icy	140	55	20	25	70
Icy	100	35	25	40	50
Icy	60	20	25	55	35

Thrust reversers. Reverse thrust provides a retardation force by deflecting engine fan airflow forwards.

Wheel brakes. The brakes provide the primary means of stopping the aircraft, but their contribution to the total stopping force varies significantly with runway condition and groundspeed as indicated in table 2. The amount of braking force on the tyre depends on the tyre to runway surface friction and the weight on the wheel. The presence of contaminants on a runway such as water, ice or slush can cause the tyre to ride above the runway surface on a wedge or film of water. This phenomenon is referred to as 'aquaplaning' or 'hydroplaning'. This report will use the term 'aquaplaning'.

1.4.5 Aquaplaning³³

The increase in landing distance on water-affected runways is primarily due to reduced braking effectiveness caused by a reduced coefficient of friction between the tyres and the runway. The reduced friction coefficient can affect deceleration and directional control. The extent of the reduction depends on the depth of water, the aircraft ground speed, and type of aquaplaning. There are three types of aquaplaning: viscous, dynamic, and reverted-rubber.

Viscous aquaplaning. This is the most common type of aquaplaning. It refers to the reduced friction coefficient that occurs due to a thin film of water on the runway acting as a lubricant. It can occur on damp to contaminated runways, and at speeds down to low taxi speeds. It is most severe on runways with a smooth texture.

³² Information provided by Boeing for B747-400 aircraft, rounded to nearest 5 %.

³³ Much of the information in this section came from the Boeing (February 1977) publication 'Landing on Slippery Runways'.

Dynamic aquaplaning. This occurs when the tyre is lifted off the runway surface by water pressure and acts like a water ski. It requires surface water depth greater than tyre-tread depth and sufficient ground speed to prevent the water escaping from the tyre's contact patch or footprint. Under these conditions, the tyre is wholly or partly buoyed off the pavement by hydrodynamic force and results in a substantial loss of tyre friction. Dynamic aquaplaning can occur in depths of water as little as 3 mm.

In the case of a landing aircraft, where the wheels are not rotating and the depth of water is greater than the tyre tread depth, dynamic aquaplaning can occur at speeds greater than $V_p = 7.7\sqrt{Pt}$ (where V_p is the critical dynamic aquaplaning speed in knots and Pt is the tyre inflation pressure in pounds per square inch (psi)). For B747-400 aircraft with a tyre pressure of 210 psi, the critical dynamic aquaplaning speed is about 111 kts. Above this speed, braking efficiency can be as low as 5%.

Reverted-rubber aquaplaning. This occurs when a wheel 'locks up' (or stops rotating) and is dragged across a wet surface, generating steam. The steam pressure lifts the tyre off the runway surface. Heat from the steam causes the rubber to revert to its unvulcanised state, leaving a black, gummy deposit of reverted rubber on the tyre. Reverted-rubber aquaplaning will also typically leave distinctive marks on the runway, with black marks on the edges of the contact patch and a clean section in the middle where the runway has effectively been steam cleaned. This type of aquaplaning can occur at any speed above about 20 kts and results in friction levels equivalent to an icy runway.

1.4.6 B747-400 brake system operation on water-affected runways

Each mainwheel on the accident aircraft was equipped with carbon brakes. The nosewheel was not equipped with brakes. The wheel brakes could be operated by either pilot using foot pedals or automatically by the auto-brake system.

There are 16 mainwheels on B747-400 aircraft. These wheels are arranged in four dual tandem 'trucks', as shown in attachment C . This truck arrangement reduces the risk of aircraft aquaplaning on contaminated runways because the path clearing action of the forward wheels of each truck reduces the depth of water encountered by the rear wheels. This increases the surface friction available to the rear wheels. As a result, the rear wheels spin up, or gain rotational speed synchronous with aircraft speed, more rapidly than the front wheels. Tests have shown that the front wheels can take up to 30 seconds after touchdown to achieve synchronous speed on contaminated runways, whereas the spin-up on the rear wheels is achieved in about 10 seconds.

Boeing advised that the logic of the antiskid braking system was designed to take advantage of the path clearing action of the front wheels. Direct aquaplaning/touchdown protection is applied only to the aft wheels of a tandem pair and will release the aft wheelbrakes whenever the measured wheel speed is 50 kts lower than the computed ground speed of the aircraft. Locked wheel protection will fully release a brake when the measured wheel speed is less than 30% of the other wheel in the tandem pair, provided the tandem pair wheel speed is above 25 knots. Under true aquaplaning conditions, path clearing will result in the aft wheels spinning up first. Once this occurs, the locked wheel protection will prevent application of the forward brake until the forward wheel spins up.

In less severe wet runway conditions, the fore-aft wheels in a tandem pair may generate similar brake torque, but differ from their axle-mates because each tandem set on the truck is sampling a slightly different path down the runway.

1.4.7 Certified landing data

Aircraft are required to meet certain minimum standards during certification and operation. The standards are defined in regulations specified by the state of registration. They apply to variables such as takeoff and landing distances, climb gradients and stall speeds, and include performance requirements that determine aircraft landing criteria. The Australian *Civil Aviation Regulations* (CARs) allow aircraft that have been granted certification under the USA *Federal Aviation Regulations* (FARs) and/or the *European Joint Aviation Regulations* (JARs) to be operated on the Australian register. Boeing aircraft are certified under FARs.

The certified landing distance is the horizontal landing distance from where the aircraft is 50 ft above the landing surface, in the landing configuration, and at an airspeed of 1.3 V_{s1g} (V_{s1g} = stalling speed at 1g), to where the aircraft is brought to a stop on the landing surface using maximum wheel braking. Reverse thrust is not used in these calculations because it is considered as an additional safety factor.

For large turbine engine aircraft engaged in charter or regular public transport operations, the landing distance available must be equal to or greater than 1.67 times the certified landing distance. The 1.67 factor accounts for the normal operational variability that can be expected in day-to-day operations and reduces the chances of a landing overrun. If the runway is wet, the required landing distance is 1.15 times the required dry runway landing distance. The landing distance required must not exceed the landing distance available.

The operational data that aircraft manufacturers provide to operators (in the aircraft operations manual) includes landing performance data. The *Boeing 747-400 Airplane Flight Manual* and the *Boeing 747-400 Operations Manual* include charts to determine the maximum landing weight as limited by runway length for flap positions 25 and 30, and anti-skid operative and inoperative. This data was certified.

All the certified landing data required by Boeing and Qantas to meet operating compliance with FARs and CARs was included in the *Qantas Boeing 747-400 Performance Limitations Manual*. Page 2-5-4 of this manual contained the Landing Field Length Chart (Flaps 25). According to this chart, the landing field length required for VH-OJH to land at Bangkok was 2,280 m.³⁴

Boeing did not provide (and was not required to provide) any certified landing data for conditions worse than wet.

1.4.8 Advisory landing data

In addition to the certified data referred to in section 1.4.7, Boeing also provided operators with various types of advisory data relating to aircraft performance on water-affected runways. This information was not established from flight tests but was based on theoretical calculations. As such, it had a lower status than certified data. However, it did provide supplementary information to complement certified data and to assist operators and crews appreciate the likely effect of various scenarios on aircraft performance.

Boeing provided advisory information on 'Slippery Runway Landing Distance' in the *Boeing B747-400 Operations Manual*. It was provided in tabular form, as shown in table 3. The data in table 3 is for flaps 25. The reverse thrust landing distance adjustments were 15 to 20% less for the flaps 30 configuration.

³⁴ Based on a landing weight 250,000 kg, flaps 25, wet runway, ambient air temperature 25 deg C, nil wind, brakes and antiskid serviceable, and no reverse thrust.

Observations:

According to the advisory landing data for flaps 25, the reference weight (250 tonnes) landing distance for 'poor' braking action (2,562 m) was less than the landing distance available (3,150 m). In other words, assuming touchdown occurred 366 m into the runway at the target speed, and if the spoilers were deployed and full reverse thrust applied, then there was sufficient runway length for the aircraft to stop (even if braking action was 'poor'). If idle reverse or no reverse thrust was used and braking action was poor, then there was insufficient distance available.

Table 3:
Slippery runway landing distance for flaps 25³⁵

Reference Landing Distance (m)

<i>Braking configuration</i>	<i>Reported braking action</i>		
	<i>Good</i>	<i>Medium</i>	<i>Poor</i>
Maximum manual braking	1,482	1,986	2,562
Auto-brake setting 3	1,992	2,126	2,586
Auto-brake setting 4	1,751	2,047	2,586
Maximum auto-brake	1,583	2,031	2,580

Landing Distance Adjustments (m)

<i>Conditions</i>		<i>Reported braking action</i>		
		<i>Good</i>	<i>Medium</i>	<i>Poor</i>
Weight	Per 10,000 kg above 250 t	+ 55	+ 79	+ 107
	Per 10,000 kg below 250 t	- 52	- 76	- 101
Airport pressure altitude	Per 100 ft above sea level	+ 64	+ 92	+ 122
Wind	Per 10 kts headwind	- 76	- 107	- 168
	Per 10 kts tailwind	+ 290	+ 442	+ 717
Approach speed	Per 10 kts above VREF	+ 153	+ 183	+ 198
Slope	Per 1% downhill slope	+ 46	+ 107	+ 259
	Per 1% uphill slope	- 31	- 76	- 153
Reverse thrust	2 reverse, 2 idle	+ 85	+ 220	+ 464
	4 idle	+ 192	+ 549	+ 1,278

³⁵ This data was taken from the *Boeing B747-400 Operations Manual* and converted to metric units. The data assumes maximum reverse thrust and manual spoiler deployment. The data was also unfactored (i.e. did not include the 1.67 or 1.15 factors discussed in section 1.4.7). The reference landing distance included an air distance of 366 m (or 1,200 ft) from the threshold to the touchdown point.

1.5 Aircraft performance: specific information associated with the accident flight

1.5.1 Overview of approach landing performance

The actual approach and landing performance of the aircraft was obtained from the recorded flight data. Some of this data is presented in the third column of table 4. The left and centre columns show the Boeing recommended landing procedure for slippery runways.³⁶

Table 4:
Boeing recommended landing procedure compared with accident flight data

<i>Recommended procedure</i>		<i>Accident flight data</i>
Approach	On speed	The target speed for the final approach was 154 kts (V_{REF} plus 5). The aircraft crossed the threshold at 168 kts (or V_{REF} plus 19 kts). Landing distance increases by approximately 30 m for each knot above the target speed.
	On centreline	The aircraft was on the centreline during the final approach. The effect of it diverging left of the centreline during the landing roll is discussed in subsection 1.5.6.
	On glide path	The aircraft was 32 ft above the ideal height above the runway when it crossed the threshold. Landing distance increases by approximately 6 m for each foot above the ideal threshold crossing height.
Touchdown	Moderately firm ³⁷	The recorded vertical acceleration at touchdown was 1.239 g. This was a 'very soft' touchdown and occurred because of the low rate of descent, because go-around thrust had been applied and the aircraft attitude had not yet changed significantly from the landing attitude.
	On target	The reduced rate of descent that occurred when the aircraft entered the rain on late final approach, the early landing flare, and the initiation of the go-around all contributed to touchdown occurring 1,002 m from the threshold. The ideal touchdown location was 366 m (1,200 ft) from the threshold.
Stopping	Immediately lower the nose ³⁸	The nosewheel did not contact the runway until 11 seconds after touchdown.
	Spoilers	Automatic spoiler deployment did not occur until 3.2 seconds after touchdown because the number 1 thrust lever remained forward of the idle position for this period.
	Brakes, when nose down and spoilers up, and aircraft tracking correctly	'Nose down' and 'spoilers up' - as above. Braking was initiated 7 seconds after touchdown when the aircraft was 1,625 m beyond the threshold. ³⁹
	Reverse thrust	Reverse thrust was not selected.

³⁶ Boeing, *Landing on Slippery Runways*, February 1977.

³⁷ A firm touchdown helps the tyres to break through the surface tension of the water and assists in better tyre/surface contact compared with a gentle touchdown, thereby promoting better wheel spinup.

³⁸ Lowering the nosewheel on to the runway reduces wing lift and places more weight on the wheels. This should be achieved within 5–6 seconds after mainwheel touchdown.

³⁹ Manual braking techniques typically involve a 4–5 second delay between main gear touchdown and brake pedal application, even when actual conditions reflect the need for a more rapid initiation of braking.

1.5.2 Meteorological information

During September, Bangkok weather is influenced by the southerly passage of the Inter-tropical Convergence Zone that brings the Southwest Monsoon or 'wet season' to an end. Conditions during this period are characterised by high rainfall and frequent afternoon/evening showers and thunderstorms. The frequency of thunderstorms is highest during May and September with the passage of the convergence zone.

The Thai Department of Meteorology weather station at Bangkok Airport conducted weather observations on the hour and half hour. Some parameters were measured automatically while others were measured manually. The measurements were passed to ATC electronically (and continually displayed on monitors) immediately after an observation was taken.

The observations for 23 September between 2216 (when a special observation was taken) and 2300 noted thunderstorms and rain overhead the airport. A rainfall measurement taken at 2400 was 28.1 mm. This measurement covered the period between 2216 and 2400.

Table 5 shows details of weather observations taken between 2216 and 3200, along with relevant events concerning Qantas One, Qantas 15, and Thai 414.

Table 5:
Weather observations and pertinent weather-related events

<i>Time</i>	<i>Event</i>
2216 approx	Special weather observation logged. (Recorded aerodrome visibility was 8,000 m.)
2230 approx	Routine weather observation logged. (The observation included visibility 5,000 m, thunderstorm overhead the aerodrome.)
2236:33	Bangkok Arrivals advised Thai 414 that aerodrome Information Tango was now current, that visibility was 5,000 m, and that there was heavy rain over the aerodrome. (Information Tango included details from the weather observation taken at 2230.)
2237:05	Qantas One second officer obtained Information Tango.
2240 approx	Thai 414 landed and reported runway braking action as 'good'.
2240 approx	Special weather observation logged. Aerodrome visibility was recorded as 1,500 m, and RVR (runway 21R) as 750 m. This information was included in Information Uniform, which then became active. (At this time, Qantas One was descending through 7,000 ft.)
2241:05	Qantas One second officer overheard a Qantas Bangkok ground engineer (on company frequency) say that it was raining quite heavily at the aerodrome.
2243:26	Qantas 15 reported 'going around'. (The crew later said that they entered heavy rain at about 700 ft altitude.)
2246:08	Qantas One entered heavy rain. (At this time, the aircraft was descending through 300 ft.)
2300 approx	Routine weather observation logged. Aerodrome visibility recorded as 2,000 m.

Plots from the Bangkok weather radar for the period 2140–2310 showed the development of several thunderstorm cells to the west, southwest, and south of the airport at 2140. These cells moved slowly in an easterly direction with the 2240 plot showing a cell over the airport. This cell dissipated over the next 30 minutes as it moved in a south-easterly direction.

People who were at the airport around the time of the accident reported that the rain was ‘very heavy’ and ‘extremely heavy’. They were residents of Bangkok and accustomed to the local weather conditions.

Research has indicated that a smooth, ungrooved runway with a 1.5% crown (such as runway 21L), can become flooded to a depth greater than 3 mm in the area 4.5 m either side of the centreline by a rainfall rate of less than 10 mm per hour.⁴⁰ Rainfall rates from tropical thunderstorms can exceed 100 mm per hour.

Observations:

The different altitudes at which Qantas 15 and Qantas One encountered heavy rain indicate that the weather conditions were changing fairly quickly at the time. Had the Qantas One crew been aware of the visibility conditions recorded during the 2240 special observation, and of Qantas 15 going around, the expectations they had gained from Information Tango and from their view of the runway lights may have altered. In turn, this may have influenced their response when they encountered the heavy rain.

The meteorological information available did not allow any definitive conclusion concerning the depth of water on the runway and its distribution along and across the runway surface at the time the aircraft landed. Based on the witness reports, there was sufficient rainfall to cause the surface water depth to exceed 3 mm. It was likely that distribution of water on the runway changed during the 6 minutes 20 seconds between 2240 when Thai 414 landed (and apparently experienced no braking difficulties) and the time that Qantas One landed (i.e. by then braking action is more likely to have been closer to ‘poor’).

1.5.3 Tyre information

The mainwheel tyre pressures were within the normal range. Tyre tread depths varied from 1 mm to 10 mm. Tyre wear characteristics were normal. Damage to the main landing gear tyres (see attachment C) did not include any evidence of reverted-rubber aquaplaning.

1.5.4 Tyre marks on the runway

Examination of the runway surface showed clear evidence of mainwheel and nosewheel tyre marks from the aircraft. The marks were evident for about the last 1,200 m of the runway. These marks were characteristic of a ‘pressure washing’ effect that occurs when water is trapped under a tyre and squeezed out under pressure as the tyre moves along the surface. They were not characteristic of reverted-rubber aquaplaning.

Boeing advised that a nosewheel steering demand of 6 degrees or greater would leave skid marks on a wet runway. The marks were consistent with the crew steering the aircraft back towards the centre of the runway, as supported by the DFDR data which showed that there was a nosewheel steering input of 7 degrees right (equivalent to the limit of nosewheel steering angle achievable through the rudder pedals).

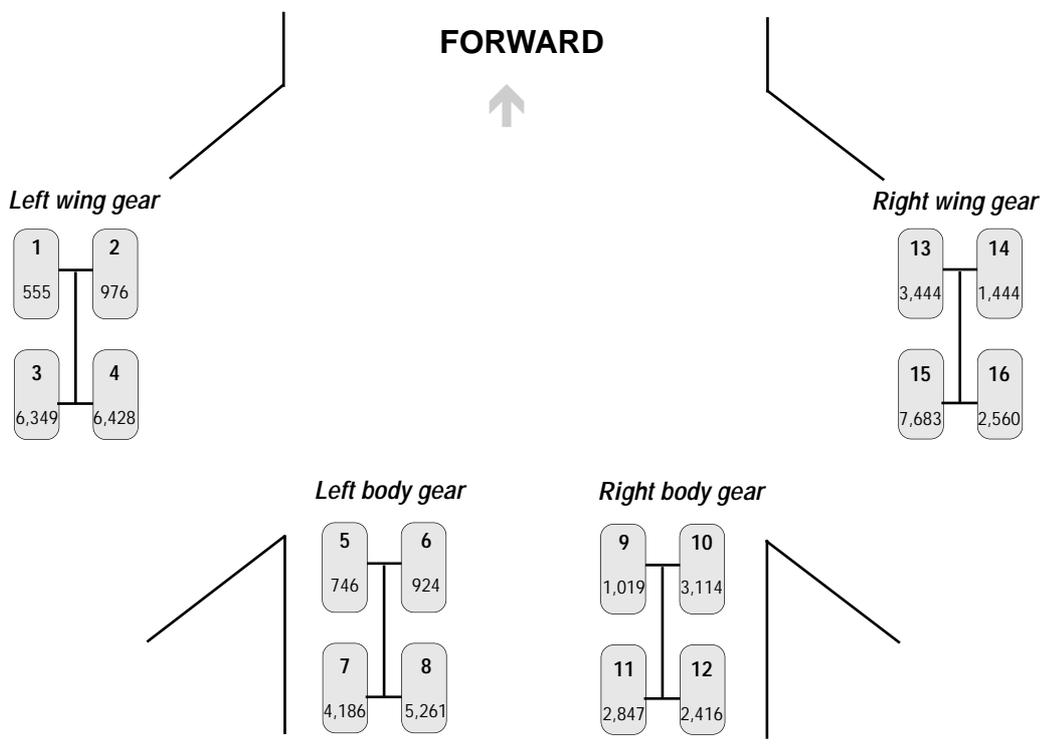
⁴⁰ T. T. Yager, *Factors Influencing Aircraft Ground Handling Performance*, NASA Technical Memorandum 85652, 1983, p. 20.

1.5.5 Brake operation during the landing roll

Examination of the aircraft's central maintenance computer, braking system electronic components, wheels, tyres and brakes did not reveal any fault with the aircraft braking system.

The brake torques were recorded at 4-second intervals by the QAR from the initial brake application during the landing roll until the last recorded data (see attachment C), which occurred approximately 296 m before the end of the runway (and 396 m before the end of the sealed overrun area). The average recorded brake torques over this period for each wheel are shown in fig. 3. The maximum torque value recorded was 10,475 N.m while there were several zero values recorded.

Figure 3:
B747-400 mainwheel configuration and average recorded brake torques (N.m) during the landing roll



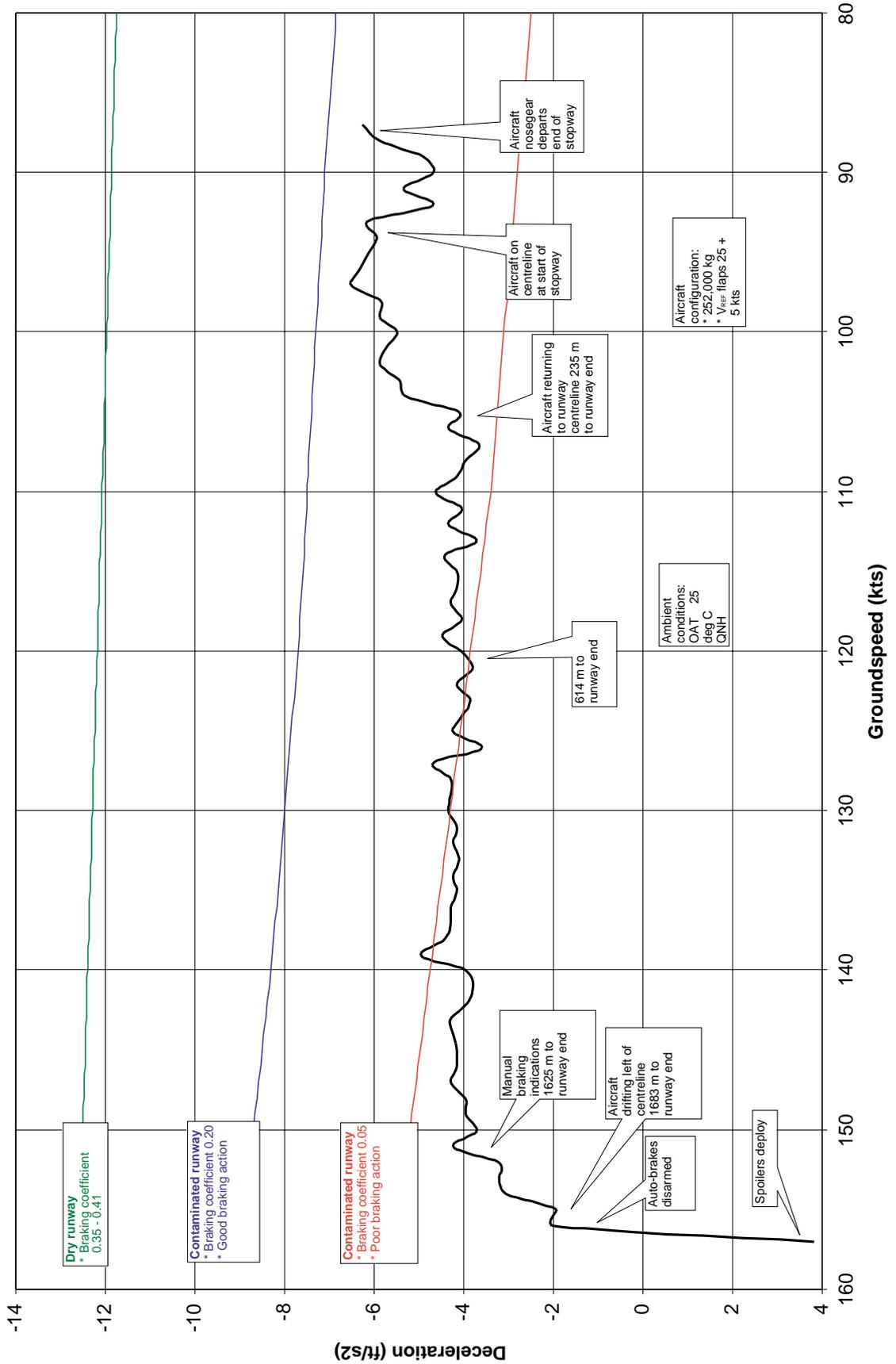
During the previous (normal) landing of the aircraft on a dry runway, the average brake torque values recorded were approximately 20,000 N.m. Boeing advised that this value was typical for dry runway conditions.

Boeing provided the following interpretation of the recorded brake torques for the accident flight:

Although the QAR torque is only recorded every 4 seconds for an individual tyre, the left wing and left body brake torque data shows that the measured brake torque for the forward wheels on each truck are significantly less than for the aft wheels. This implies that on the left side of the airplane there was sufficient... [depth of] water to prevent generation of much brake torque on the forward wheels, and that there was a path clearing effect for the aft wheels in each tandem pair.

In more usual wet conditions, Boeing has seen that the fore-aft wheels in a tandem pair generate similar brake torque, but differ from the axel-mates because each tandem set on the truck is sampling a slightly different path down the runway. This is more consistent with what was seen in the recorded brake torque data for the wheels on the right side of the airplane.

Figure 4:
Comparison of rollout deceleration with dry and contaminated runways (adapted from Qantas Flight Safety Department diagram)



1.5.6 Rate of deceleration on the runway

Fig. 4 shows the rate of deceleration achieved by the aircraft compared with data supplied by Boeing for braking performance on dry, wet, and flooded runways. The initial rate of deceleration stabilised at about 4 ft/s² during the period of manual braking and approximated an airplane braking coefficient of .05. This equated to 'poor' braking action. Between approximately 350 m and 200 m before the stopway end, the deceleration rate increased to about 6 ft/s², approximating 'medium' to 'good' braking action. The deceleration rate started to increase as the aircraft speed was reducing through 108 kts.

Observations:

Recorded brake torque values during the landing at Bangkok were, for the most part, less than 25% of the torque values typically seen during dry runway landings. The fluctuations in the brake torques indicated that the wheel brake antiskid system was operating and that the crew was applying sufficient pedal pressure for maximum braking effectiveness to be achieved. In these circumstances, the only likely explanation for the low torque values is that wheel spin-up, and therefore braking action, was affected by water on the runway. The very soft touchdown and the delay in lowering the nosewheel probably also delayed wheel spin-up.

The nature of the tyre marks on the runway, and the low deceleration rate achieved as the speed reduced towards the dynamic aquaplaning speed (approximately 111 kts) suggests that the aircraft was experiencing dynamic aquaplaning for much of the landing roll. The extent and rate of fluctuation of the recorded brake torques was typical of 'partial' dynamic aquaplaning as the tyres encountered water of changing depth caused by runway surface and rainfall variations. The tread depth of each tyre, and its position on the landing gear trucks, would also have influenced the brake torques. Once the aircraft was below the dynamic aquaplaning speed, the deceleration rate increased, but remained below that for a dry surface. This suggests that the tyres were also experiencing viscous aquaplaning during the landing roll.

The difference in the pattern of brake torques between the left and right gear sets was probably due to the left wing and body gear experiencing a greater depth of water than the right gear sets as the aircraft tracked left of the centreline. Even though the left wheels were probably running through deeper water than the right wheels, the average braking action achieved on both sides was similar. Therefore, the aircraft's deviation from the runway centreline did not appear to have significantly affected the deceleration performance of the aircraft.

Because the crew did not apply the brakes until the aircraft was 1,625 m past the threshold, the rubber deposits on the runway around the normal touchdown position had no bearing on the accident.

1.5.7 Landing distance data

Table 6 compares landing distance information for criteria relevant to the accident. It provides an indication of the effects on the landing distance of the various events and conditions. The information is based on calculations using certified performance data and advisory information and actual performance details from the DFDR. Corrections have been applied for the 3.15-degree glideslope. It is emphasised that the status of the Boeing advisory information and the absence of precise data concerning the depth of water on the runway limit the accuracy of the calculations. The distances do, however, provide an indication of the order of magnitude of the various factors.

As noted in section 1.3.1, the available landing distance (threshold to end of runway) was 3,150 m. The intended touchdown point was 366 m (1,200 ft) from the threshold.

Table 6:
Landing distance data ⁴¹

<i>Braking action</i>	<i>Flaps setting</i>	<i>Engine thrust</i>	<i>Other factor</i>	<i>Effect on landing distance</i>	<i>Total landing distance (3,150 m available)</i>
Expected performance					
1. good	25	Idle reverse	nil	–	1,693 m
Actual performance					
2. poor	25	Idle reverse	nil	–	3,320 m
3. poor	25	Idle forward	nil	+ 755 m	4,075 m
4. poor	25	Idle forward	Late touchdown	+ 636 m	4,711 m
5. poor	25	Idle forward	7-second delay before deceleration began	+ 546 m	4,621 m
6. poor	25	Idle forward	Late touchdown and 7-second delay before deceleration began	+1,182 m	5,247 m
Other scenarios					
7. poor	25	Full reverse	nil	–	2,572 m
8. poor	30	Full reverse	nil	–	2,419 m
9. poor	30	Idle reverse	nil	–	2,994 m

Observations:

From table 6, the following conclusions can be drawn. All observations assume touchdown occurred in the normal touchdown zone.

1. For flaps 25/idle reverse under poor braking conditions, the landing distance required was about twice that required under good braking conditions (condition 2 versus 1).
2. For flaps 25/idle reverse under poor braking conditions, there was insufficient runway available for landing (conditions 2 to 5).
3. For flaps 25/full reverse or flaps 30/full reverse, under all braking conditions, there was adequate runway available for landing (conditions 7 and 8).
4. For flaps 30/idle reverse under poor braking conditions, there was probably sufficient runway available (condition 9).

⁴¹ Assumptions: Aircraft weight 250,000 kg, temperature 25 deg C, 3.15-degrees approach slope, nil runway slope, automatic spoiler deployment, maximum manual braking, touchdown 366 m (1,200 ft) from threshold, and touchdown speed $V_{REF} + 5$ kts.

1.6 Company B747-400 operations: landing on contaminated runways

An overview of Qantas Flight Operations Branch is provided in attachment G. This attachment also provides information on the company's procedures and training.

1.6.1 Procedures

No definitions for 'wet', 'icy', 'slippery', 'water patches', 'flooded' or 'contaminated' runways were provided in the *Qantas B747-438 Performance Limitations Manual*, or any other Qantas publication which formed part of the company operations manual.

No information was provided in the *Performance Limitations Manual* or other parts of the company operations manual to calculate landing distances for conditions worse than 'wet'. The Boeing Slippery Runway Landing Distance information (see table 3) was not included in Qantas publications.

The *Qantas B747-438 Operations Manual* included a Supplementary Procedures section titled 'Adverse Weather' that contained subsections titled 'Hot Weather Operations' and 'Cold Weather Operations'. The 'Hot Weather Operations' subsection contained no information regarding runway surface conditions and relevant approach and landing procedures. However, the 'Cold Weather Operations' subsection contained a unit titled 'Landing on Wet, Icy or Slippery Runways'. This section provided detailed guidance for landing on water-affected runways, including the following (page 02.05.11):

- Do not float or allow drift to build up during the flare.
- Get the wheels on the runway at approximately 1,000 feet from the approach end of the runway. The airplane should be flown firmly onto the runway at aiming point even if the speed is excessive.
- If a touchdown far down the runway is likely, consider a go-around.
- Immediately lower the nose gear onto the runway and hold light forward control column pressure.
- When reverse interlocks release, apply maximum symmetrical reversing.

Boeing originally provided these procedures to operators in 1975 in response to a FAA Bulletin. Boeing placed these procedures separately from the sections on Cold Weather Operations and Hot Weather Operations. Boeing later limited the amount of general airmanship information provided in their aircraft operations manuals and Flight Crew Training Manual for two-crew aircraft. As a result, these procedures were never issued as part of the *Boeing 747-400 Operations Manual*. However, Qantas had included the information in the 'Cold Weather Operations' section of the *Qantas B747-438 Operations Manual* when Qantas first introduced the aircraft into its fleet in 1989⁴²

It became evident during the investigation that many Qantas pilots (including the crew of Qantas One) viewed this section of the *Qantas B747-438 Operations Manual* as relevant only to cold weather operations, such as those encountered in winter in Europe or Japan, or when strong crosswind conditions existed. They did not associate the information with water-affected runways at locations in warmer climatic areas.

The *Qantas B747-438 Flight Crew Training Manual*, based on the Boeing version of the same document, outlined certain operational factors which influence landing distance (page 02.68).

⁴² Boeing's version of the procedures was titled 'Landing on Wet or Slippery Runways'. Qantas reported that, at some stage prior to 1989, it had introduced the term 'icy' into the title and moved the information to the 'Cold Weather Operations' section of its operations manual.

These factors, labelled as 'improper landing techniques', were listed as adding distances to a 'normal' flaps 30 landing as follows:

- overextended flare (3 seconds float after flare) - 752 ft [229 m];
- high over threshold (100 ft altitude) - 1,058 ft [323 m];
- delayed nose wheel touchdown (5 seconds) - 1,233 ft [376 m];
- speedbrakes not extended - 983 ft [300 m];
- speedbrakes not extended and thrust reversers not deployed - 1,210 ft [369 m];
- one half brake pressure - 1,292 ft [394 m]; and
- high approach speed (+10 kts) - 415 ft [127 m].

There was no mention of water-affected runways in this reference.

There was no other information in company documentation for the B747-400 (including the *Performance Limitations Manual*, *Flight Crew Training Manual*, and *Quick Reference Handbook*) provided to pilots regarding the techniques for landing on water-affected runways and the importance of reverse thrust as a stopping force in such conditions.

1.6.2 Training

Qantas advised that all company pilots received comprehensive training regarding the effects of thunderstorms. This included such issues as windshear and emphasised the avoidance of conditions conducive to windshear and microburst activity, and the precautions and recovery techniques relevant in such conditions. The hazards associated with landing and taking off in thunderstorms were discussed in promotional and command training. However, check-and-training personnel reported that contaminated runway issues had not been covered during crew endorsement, promotional or recurrent training in recent years. Some Qantas personnel reported that these issues had been covered extensively in ground training in the 1960s and 1970s.

A review of the recurrent and endorsement simulator session outlines from the end of 1996 until the date of the accident revealed that none of the formal handling exercises or discussion items involved landing on 'contaminated' (or 'icy', 'flooded' or 'slippery') runways. Check-and-training personnel reported that they could not recall such training being provided in the simulator in recent years. They noted that the simulator did not simulate heavy rain and slippery runway conditions with a high level of fidelity. However, they indicated that training in contaminated runway operations could be effectively covered as discussion items.

A Boeing educational document for flight crew titled *Landing on Slippery Runways* (see sections 1.4.4. and 1.4.5) was distributed to all Qantas pilots in May 1977. However, this document had not been reissued, and company pilots interviewed during the investigation were unaware of its existence. General information on aquaplaning and contaminated runway operations was provided to pilots from time to time in newsletters, industry journals and other forums.

Some company management pilots believed that line pilots should have possessed adequate knowledge and understanding of water-affected runway operations, simply on the grounds that they were professional pilots and, as such, should take some personal responsibility for maintaining their knowledge and expertise.

The following information and comments were obtained from interviews with a sample of Qantas management, check-and-training, and line pilots:

- Many pilots believed the term ‘contaminated’ was associated with snow, ice or water to a depth of 13 mm, and generally associated this with cold weather operations in locations such as Europe and Japan. They expressed surprise that the figure was only 3 mm.⁴³
- Most pilots were not aware of the Boeing Slippery Runway Landing Distance advisory information (see table 3) prior to the accident. Many were surprised (when they examined this information) of the significance of reverse thrust for water-affected runway operations.
- Pilots were familiar with the term ‘aquaplaning’ but most were not aware of, or could not recall, many details concerning the phenomenon. For example, most were not aware of the dynamic aquaplaning speed for the B747-400 and its implications on aircraft braking.
- Some check-and-training pilots commented that many line pilots believed that reverse thrust was of limited use on the B747-400 due to the effectiveness of the auto-brakes, and the fact that the auto-brakes provided a rate of deceleration (irrespective of reverse thrust input) rather than a specified braking force. They were not fully aware of the relationship between braking effectiveness and runway conditions.
- Some pilots commented that Qantas B747-400 aircraft generally operated in good weather and to aerodromes with long and good quality runways. Crews rarely operated to limiting runways. Pilots rarely experienced, or heard about others experiencing, significant reductions in braking effectiveness due to the presence of water on runways.

The B747-400 pilot survey conducted during the investigation (see attachment K) revealed that many pilots ‘strongly disagreed’ (61%) or ‘disagreed’ (30%) with the statement that their training had included adequate exposure to landing on contaminated runways.

1.6.3 Information from the Qantas One flight crew

Consistent with the other company pilots interviewed and surveyed, the Qantas One flight crew reported that they had not received any simulator training for landing on contaminated runways. They had received little other education or training concerning the nature of contaminated runways and appropriate procedures for landing, particularly for the B747-400. They also stated that their understanding of a contaminated runway was where the water depth was 13 mm. The crew was not aware of the extent to which reverse thrust was a critically important stopping force on water-affected runways. None of the crew could recall ever having seen the Boeing 1977 document *Landing on Slippery Runways*.

1.7 Company B747-400 operations: flap and reverse thrust settings

1.7.1 Procedures

On 6 December 1996, Qantas introduced revised approach and landing procedures for the B747-400. In summary, these involved:

- the use of flaps 25 instead of flaps 30 as the ‘preferred’ procedure;
- the use of idle instead of maximum reverse thrust as the ‘normally used’ procedure; and
- a change in the preferred auto-brake setting for landing, and modifications to braking techniques.

⁴³ Page 2-3-6 of the *Qantas B747-438 Performance Limitation Manual* stated that ‘operation in greater slush depths than 13 mm is not permitted’ in a section titled ‘Takeoff on Contaminated Runways’. Some pilots reported that this statement was the basis of their understanding of a contaminated runway.

The rationale, development and introduction of these procedures is reviewed in attachment H.

In terms of the approach flap setting, the procedures current at the time of the accident were published in the *Qantas B747-438 Performance Limitations Manual* (page 2-5-1 dated 1 October 1997):

PREFERRED LANDING FLAP IS 25. This will normally be used. The wear characteristics of the B747-400 carbon brakes are such that maximum life is obtained by maximising energy absorption and minimising the number of applications. This leads to the choice of Flap 25 with its higher landing speeds as the preferred landing flap setting. Use of Flap 25 also reduces fuel, time, and noise.

Flaps 30 gives lower landing speeds and hence the shortest landing distances. This setting should be used when:

- landing field length requirements are critical;
- landing at HGK [Hong Kong] R/W [runway] 13;
- landing on a contaminated runway; and
- landing in LOW VIS [visibility] conditions.

In terms of reverse thrust, a subsection of the *Qantas Flight Administration Manual* titled 'Landing Roll Reverse Thrust' (page 9-16, 17) stated the following:

At times and locations as specified in Company manuals, reverse thrust may be left at the reverse thrust idle position after touchdown. Sufficient runway must be available to provide the required Performance Manual landing field length increment. The Pilot-In-Command shall also consider runway surface conditions and be satisfied that a safe operation is assured.

Page 2-5-2 of the *Performance Limitations Manual* stated (dated 1 October 1997):

IDLE REVERSE THRUST Idle Reverse Thrust should normally be used for all landings provided at least 300 metres of surplus runway is available. Use of idle reverse maximises carbon brake life by putting more energy into the brakes, reduces noise and reduces reverser maintenance costs.

This does not preclude the use of full reverse thrust should abnormal conditions exist.

In a section on auto-brake operation, the *Qantas B747-438 Flight Crew Training Manual* included the following information on reverse thrust settings (page 02.69-70):

...the autobrake system on the B747-400 aircraft sets a particular deceleration rate and modulates the brake pressure to provide that programmed rate. If the thrust reverser is achieving a higher deceleration rate than required by the autobrake setting, the autobrake system will then reduce the pressure to the brakes. Therefore, to maintain a relatively high brake pressure, a comparatively lower reverse thrust setting is now desirable.

Initiation of idle reverse thrust after main gear touchdown will nullify all forward thrust from the engines, and permit the carbon brakes to operate at their peak efficiency.

In cases where landing field length is limited, or if any other operational considerations are likely to affect the landing roll or procedures, the Captain should elect to use full reverse thrust during the landing roll.

1.7.2 Training

A simulator session introduced after the approach and landing procedures changed in December 1996 included the discussion item 'brakes, thrust reversers and flaps'. All company B747-400 pilots would have received this session at some stage between January

and June 1997. Check-and-training pilots reported that they received no information additional to that provided to other pilots about the introduction of the new procedures. No guidelines were provided on exactly what was to be discussed in terms of 'brakes, thrust reversers and flaps'.

After the revised landing procedures were introduced in December 1996, all of the simulator exercises included flaps 25 and idle reverse as the 'standard' procedure. No simulator exercise required the use of full reverse thrust or flaps 30 during landings. There was no formal exercise content which required consideration of when to use flaps 30 instead of flaps 25, or when to use maximum reverse thrust instead of idle reverse thrust.

Responses to the B747-400 pilot survey conducted during the investigation included the following:

- Most pilots 'strongly disagreed' (57%) or 'disagreed' (22%) with the statement that their training included a variety of situations where flaps 30 and full reverse were required.
- Many pilots (36%) said that they had received adverse comments from captains or check-and-training personnel for nominating flap 30 for landing in conditions less restrictive than those specified in the *Qantas B747-438 Performance Limitations Manual* (see section 1.7.1).
- Some pilots (16%) said that they had received adverse comments from captains or check-and-training personnel for selecting reverse thrust above idle in conditions less restrictive than those specified in the *Qantas B747-438 Performance Limitations Manual*.
- Most pilots said that they 'never' (37%) or 'rarely' (48%) practised a landing using maximum stopping capability in the flight simulator in the 12 months prior to the accident.

Interviews with a sample of company B747-400 management, training and line pilots produced similar results to the survey. In addition, it was established that:

- Many pilots noted that flap and reverse thrust settings were rarely discussed during simulator sessions, and flaps 30 and full reverse thrust were rarely used.
- Some check-and-training pilots noted that scenarios occasionally arose during simulator sessions where flaps 30 and/or full reverse thrust were reasonable options (e.g. short runway at Sydney or Melbourne with rain or crosswind).
- Some check-and-training pilots believed that many pilots needed more training in how to make decisions regarding flap and reverse thrust settings. They also noted that some other check-and-training personnel provided inappropriate advice on this issue, emphasising the use of flaps 25 and idle reverse thrust rather than encouraging pilots to consider appropriate options.

1.7.3 Line operations

With respect to line operations, responses from the B747-400 pilot survey conducted during the investigation included the following:

- Most pilots said that they 'never' (16%) or 'rarely' (53%) used flap 30 for landing in the 12 months prior to the accident.
- Most pilots said that they 'never' (35%) or 'rarely' (49%) used full reverse thrust in the 12 months prior to the accident.
- Many pilots (50%) believed flaps 30 provided an advantage relative to flaps 25 with 'glide path maintenance' (48% had no preference).

- Most pilots (80%) believed flaps 30 provided an advantage relative to flaps 25 with 'airspeed control' (16% had no preference).
- Many pilots (46%) believed flaps 30 provided an advantage relative to flaps 25 with 'landing flare' (44% had no preference).
- Most pilots (69%) believed that flaps 30 provided an advantage relative to flaps 25 with 'touchdown point' (28% had no preference).
- There was no reported advantage for either flaps 30 or flaps 25 for 'touchdown quality'.

During interviews with a sample of check-and-training pilots and line pilots, it was evident that most pilots did not consider flaps 25 as 'unsafe'. However, many considered flaps 30 to offer advantages compared with flaps 25. One senior pilot noted that at flaps 30, the aircraft 'wants to land' while at flaps 25 it 'wants to fly'. If a flaps 25 approach was not stabilised (on target speed and on glideslope) by 500 ft altitude, it was then difficult to achieve the correct threshold speed and touchdown position. Pilots noted that, with experience, they were able to adapt to flaps 25. Pilots also reported that there was no difficulty in conducting a flaps 30 approach even if this configuration had not been flown for some time.

Some very experienced management and check-and-training pilots reported that they had not noticed any significant difference between the handling characteristics of flaps 25 versus flaps 30. Many of them had previously flown the B767, and believed that a B747-400 with flaps 25 had similar handling characteristics on approach to a B767 in the landing configuration with flaps 30. This contrasted with the views of pilots who had not flown the B767.

1.7.4 Information from the Qantas One flight crew

The captain of Qantas One reported that he had only used flaps 30 once during line operations, and this was during his initial B747-400 line training (June 1998). He had also asked a first officer to conduct a flaps 30 approach after he learned that that pilot had never conducted one. The captain reported that he had inadvertently used full reverse thrust on a couple of occasions during his initial B747-400 training in the simulator (May, 1998). He said this was a carry-over from his previous flying on the B767, where the use of full reverse thrust was standard practice. Check-and-training personnel advised him that full reverse thrust had little effect on the B747-400 because the auto-brakes provided a preselected rate of deceleration irrespective of the use of reverse thrust. He had never used full reverse thrust during line operations or recurrent simulator training on the B747-400.

The first officer reported that he had only used or observed flaps 30 twice since the flaps 25/idle reverse procedure had been introduced (December 1996). On one of these occasions it was used to slow the aircraft down for traffic separation. He stated that he found that the approach speed was more difficult to control with flaps 25 relative to flaps 30. The first officer reported that he had not conducted or observed the use of full reverse thrust during line operations or recurrent simulator training after the procedures were changed.

The second officer reported that he had rarely observed the use of flaps 30 or full reverse thrust after the procedure changed.

1.7.5 Information from Boeing

During the investigation, Boeing reported that their specialist pilots had not found any difference between flaps 25 and flaps 30 handling characteristics, with the exception that flaps 25 had a slightly longer touchdown and landing distance due to the 5–6 kts higher touchdown speed.

When asked by Qantas in April 2000 to comment specifically on the flaps 25/idle reverse procedure, Boeing responded as follows:

Regarding the 747-400, Boeing recommends Flaps 30 be used to minimise landing distance and landing speed. Flaps 25 will provide better noise abatement and reduce flap wear. Therefore, flaps 25 is an acceptable flaps setting as long as the crew is satisfied that there is ample runway available for the given conditions.

Boeing does not consider the standard practice of going to reverse idle (idle detent) only to be patently unsafe, but does think that it reduces the existing performance margins. It is acceptable pilot technique to do this (using good judgement) as an exception to the normal procedures when landing on a long, dry runway. We perceive, however, that there is a human factors issue of developing a habit pattern of not using reverse thrust beyond the idle detent. The pilot may then fail to respond quickly when such reverse thrust is needed during an RTO [rejected takeoff] or landing in some type of performance-critical situation. We therefore do not provide a "No Technical Objection" for this as the standard operating policy.

If the reverse idle technique is adopted, it should be taught as the exception rather than the rule. Further, we would encourage simulator drills to be incorporated into the transition and recurrent training courses that would require pilots to use judgement to use full reverse thrust as the best successful means of stopping the airplane. This would periodically reinforce this concept of using that capability when needed.

Observations:

At the time of the accident, the flaps 25/idle reverse landing procedure had, by and large, become 'the company norm'. For a significant proportion of company B747-400 pilots, the flaps 25 configuration was more difficult to fly than the flaps 30 configuration with respect to speed control and runway aim point.

Although the company procedures for flaps 25 and idle reverse did note that alternative configurations should be used for 'contaminated runways' and 'abnormal conditions', these special conditions were not adequately defined. In addition, company training did not ensure that crews knew when other configurations (i.e. flaps 30 and/or full reverse thrust) should be used. Training in recent years had emphasised the capability of the aircraft's braking system, but had neither emphasised adequately the situations in which braking effectiveness could be reduced nor the importance of using maximum reverse thrust on water-affected runways.

The company's pre-1996 policy of using flaps 30 and maximum reverse thrust as standard practice provided inherent defences for contaminated runway operations. The introduction of the flaps 25/idle reverse procedures enhanced the potential for the reduced level of knowledge of contaminated runway issues within the company to become problematic.

Although Qantas provided procedures and training regarding many aspects of operations in adverse weather, it did not have in place appropriately documented information and procedures for B747-400 crews regarding operations on to water-affected runways. Training in this area was minimal and did not adequately equip crews for such operations. These deficiencies culminated in the crew of Qantas One not possessing the appropriate level of knowledge to properly evaluate the effects that weather at the aerodrome might have on landing performance.

Responses to the pilot survey, along with information obtained during interviews, indicated that the Qantas One flight crew were not atypical of most other company B747-400 pilots. There was, therefore, an unquestionable link between the performance of the crew and the company flight operations system in which they trained and operated.

1.8 Company 747-400 operations: other issues

1.8.1 Go-around procedures and practices

The 'go-around procedure' section of the *Qantas B747-438 Operations Manual* included the following actions (page 02.02.21):

<i>Pilot flying</i>	<i>Pilot not flying</i>
Push TO/GA switch. Call for "FLAPS 20".	Position flap lever to 20.
Verify rotation to go-around attitude and thrust increase.	Verify thrust adequate for go-around; adjust if necessary.

A description of TO/GA (and its advantages over manual thrust control during go-around) is included in attachment B.

During interviews with a sample of check-and-training pilots and line plots, it was established that:

- Go-arounds occurred relatively rarely during line operations. When they did occur, they were usually done as missed approaches prior to reaching the minima.
- Go-arounds were practised on a regular basis during recurrent simulator sessions. A variety of scenarios requiring go-arounds were provided, including poor visibility, unstable approaches, or vehicles/objects on the runway.
- Go-arounds below 200 ft were rarely practised in the simulator except during low visibility automatic landing exercises. However, 'rejected landings' were practiced during endorsement training.

Pilots typically selected the TO/GA mode as the first action when executing a go-around in the simulator. However, when conducting a missed approach prior to the minima, the manual application of thrust was often used as it provided a 'smoother' ride for passengers.

Observations:

Given that the first officer manually initiated the thrust increase within a second of the captain completing the command, it is not likely that the TO/GA mode would have provided a faster go-around response. Therefore, the first officer's deviation from the published procedure to use TO/GA was not considered to have had any influence on the initiation of the go-around. However, it may have influenced the captain's action of retarding the thrust levers because of the mechanical resistance that TO/GA applies to rearward movement of the levers. On the other hand, the use of TO/GA could have led to further confusion if the captain had attempted to retard the thrust levers.

1.8.2 Recency and currency

Skill maintenance or retention has been recognised as an important issue in flying operations. Research has shown that skill retention is generally better for perceptual-motor skills (e.g. manual flight control during an approach) than for procedural skills, or tasks that require a sequence of steps.⁴⁴ The introduction of advanced technology aircraft such as the B747-400 has meant that maintaining manual control skills has become more difficult due to the less frequent need for such skills. This effect is more pronounced for long haul operations, for which crews already receive a relatively low frequency of opportunities to practice certain manual control skills. However, there has been little applied research that has specifically examined these issues.

To minimise the likelihood of skill degradation, regulatory authorities and companies have requirements for pilots to maintain certain recency levels, or perform a minimum frequency of certain tasks in a specified period. Civil Aviation Regulation (CAR) 5.170 stated that a captain was required to have completed at least three take-offs and three landings at night in the previous 90 days prior to conducting a flight at night. Alternatively, the captain could complete a proficiency check at night. Civil Aviation Order Part 40 Section 2.1 Paragraph 11.4 stated that a holder of an IFR rating shall not carry out an ILS approach in IMC as pilot in command unless they had completed an ILS approach (in the aircraft or the simulator) in the previous 35 days.⁴⁵ Qantas procedures stated that a pilot was required to complete at least one takeoff and one landing at night every 90 days (and this requirement could be met in the simulator).

The company had no additional formal policies, procedures or guidance information regarding the maintenance of recency for management pilots (such as the Qantas One captain), or other pilots who consistently conducted flying as only a part of their work duties.

The captain and first officer met all the recency requirements of CASA and the company (see attachment F for crew recency details).

During interviews, company pilots reported that it was difficult to maintain their preferred level of proficiency in B747-400 operations due to the inherent nature of long haul operations. There was a low frequency of takeoffs and landings for each pilot on line operations.

At the beginning of 1999, Qantas reduced the number of recurrent simulator sessions for B747-400 pilots from one every 3 months to one every 4 months (see attachment G). However, this change probably did not effect the number of recurrent simulator sessions that the captain or first officer received in the 12 months prior to the accident.

Results from the B747-400 pilot survey conducted during the investigation included the following:

- Many pilots 'strongly agreed' (31%) or 'agreed' (31%) with the statement that they found it difficult to maintain effective recency/currency on the B747-400.
- Many pilots 'strongly disagreed' (19%) or 'disagreed' (29%) with the statement that they had sufficient simulator time to maintain a personal level of proficiency.

⁴⁴ A. M. Rose, 'Acquisition and Retention of Skills', in *Applications of Human Performance Models to Systems Design*, eds G. R. McMillan et al., Plenum Press, New York, p. 421.

⁴⁵ All Qantas flights are conducted under IFR (instrument flight rules).

Observations:

A low frequency of recent landings can influence a pilot's skill levels. Although both the captain and first officer had relatively low levels of recent flying in the 30 days prior to the accident, the extent to which this affected crew performance during the approach could not be reliably determined. Aside from the runway surface conditions (see observation at end of sections 1.7 and 1.9), the captain appeared to maintain a high level of situational awareness at all times during the approach. Based on this information, it is unlikely that the low level of recent flying affected his performance. However, it may have been one of the factors that contributed to the approach speed being high as the first officer manually flew the aircraft on final approach.

1.8.3 Second officer roles and procedures

The B747-400 aircraft was designed to be operated by two pilots (captain and first officer). Depending on the length of the sectors on a trip, additional pilots may be carried to relieve the captain and first officer during long sectors. On Qantas operations, a second officer fulfils this role on certain sectors. Second officers are not allowed to occupy either of the control positions during taxi, takeoff, landing, airborne below 3,000 ft (in visual meteorological conditions), airborne below 5,000 ft (during instrument meteorological conditions), or during an instrument approach (in instrument meteorological conditions).

The *Qantas B747-438 Operations Manual* provided no specific duties for a second officer during the approach and landing phases. In the company *Flight Administration Manual*, the following was stated (paged 4-7):

Second Officers will draw the attention of other Flight Crew members to any particular factor that may have been overlooked by them...

The Second Officer duties will be allocated by the Pilot-In-Command or First Officer. The Second Officer, whilst not included in standard crew operating procedures, is expected to monitor and assist the operation in ALL respects. The Second Officer will carry out all commands and requests as directed by the Pilot-In-Command and First Officer.

B747-400 and 767 Second Officers are not to be allocated any duties that affect the integrity of two pilot standard operating procedures.

Results from the B747-400 pilot survey conducted during the investigation included the following:

- Many pilots 'strongly disagreed' (24%) or 'disagreed' (29%) that the role of the second officer is clearly specified in company documentation.
- Many pilots 'strongly agreed' (38%) or 'agreed' (32%) that the role of the second officer should be more clearly defined in the takeoff and approach/landing phases of flight.
- Many pilots 'strongly agreed' (20%) or 'agreed' (27%) that second officers are not adequately trained for their role.

Management pilots, check-and-training pilots and line pilots, commented that the level of involvement of second officers during approach and landing phases on line operations varied. In general, there was a reluctance to interfere with the two-pilot operational philosophy, and therefore a reluctance to assign key operational duties to second officers (who were not carried on all flights). Some experienced pilots commented that B747-400 second officers were generally less involved than had been the case on earlier aircraft types, on which second officers had more clearly specified duties during the approach and landing phase.

Second officers did undertake recurrent simulator training (see attachment G). This involved handling practice and pilot support from both control positions. They did not receive regular training or checks of crew performance as an additional crewmember in a non-control seat.

Observations:

Like the other two pilots, the second officer did not notice the absence of reverse thrust during the landing roll. Because Qantas B747-400 operations involve both two-pilot and three-pilot operations, it is difficult to assign specific duties to second officers during takeoff, approach and landing phases. However, the role of the second officer during these phases could be more clearly defined and reinforced in simulator training and line flying checks. Such initiatives would increase the level of effective involvement of second officers during these phases. The extent to which such initiatives might have influenced the Qantas One second officer's performance could not be determined.

1.8.4 Crew resource management

Crew resource management (CRM) is generally defined as 'the effective use of all available resources, i.e. equipment, procedures and people, to achieve safe and efficient flight operations'.⁴⁶ It is associated with principles such as communication skills, interpersonal skills, stress management, workload management, leadership and team problem-solving. These principles have been taught in major airlines since the late 1970s.

It is generally recommended that CRM programs consist of initial awareness training, recurrent awareness training, practical training exercises, and incorporation of CRM elements in normal check-and-training activities. Most Australian high-capacity operators (including Qantas) provide their flight crews with some form of CRM training. CASA currently provides no regulatory requirements or guidelines for how this training should be conducted or incorporated into check-and-training systems in Australia.⁴⁷

A description of the Qantas CRM program is at attachment G. In summary, the program did not contain all the elements of what is currently regarded as best practice in this area.

The captain and first officer completed the Qantas initial CRM awareness course in 1989, and the second officer completed the course soon after starting line operations in 1995. Each of the flight crew had attended the annual update training since their initial course.

None of the pilots had flown together before the accident flight.⁴⁸ The flight crew reported that there were no difficulties in their relationship during the flight, and they considered, from their recollection and after listening to the CVR, that the CRM exhibited during the approach was good. A review of the CVR revealed that relationships between the crew appeared to be cordial and that crewmembers were focussing their attention on the task at hand. There were several instances of each crewmember volunteering information to the other pilots. There were also several instances of the crew identifying relevant operational issues, such as excess speed and altitude, and providing supportive behaviour. The crew reported that the weather conditions and potential options had been discussed during the

⁴⁶ ICAO, *Flight Crew Training: Cockpit Resource Management (CRM) and Line-Oriented Flight Training (LOFT)*, Circular 217-AN/132, 1992, p.4.

⁴⁷ In 1995, the Bureau recommended that CASA require operators involved in multi-crew operations to ensure that pilots receive effective training in CRM principles (Interim Recommendation 950101). This recommendation was still classified as 'open' by the ATSB at the time of the accident (i.e. the ATSB had not received an appropriate response from CASA). See also section 5.5.

⁴⁸ As is the case in any large airline, it is common for crews not to have flown together previously.

approach briefing (that occurred before the period recorded by the CVR). Weather related issues were also discussed to some extent on the CVR (see section 1.1.2).

In the first officer's last recurrency check (19 September 1999), a check-and-training captain commented that the first officer needed to be more authoritative and organised in his management of non-normal situations. The first officer noted during the investigation that, in response to comments of this nature, he had been attempting to improve his level of assertiveness by adopting a more positive manner and suggesting options for consideration by other crew members.

Observations:

Because the Qantas One crew had not been given appropriate training on contaminated runway operations (see section 1.6 and 1.7), it would be unreasonable to expect them to have held more extensive discussions about potential runway conditions and risk management options before and during the approach into Bangkok.

With respect to visibility, windshear, turbulence, and the possibility of a go-around, a higher standard of CRM was possible. For example, the captain could have encouraged more discussion of the potential effects of the reported thunderstorm and heavy rain on visibility and go-around options (2227:59). The second officer could have passed on the information regarding the continued heavy rain to the other crew (2241:05), and the first officer could have indicated that he was approaching his personal limits on late final approach (2246:17). Such communications may have enhanced the crew's management of the final approach after the aircraft entered the heavy rain, but would not have influenced the crew's understanding of the runway surface conditions.

A more extensive company CRM training program may have resulted in a higher standard of CRM during the approach but it is impossible to assess whether this would have affected the development of the accident.

The captain's action of cancelling the go-around was considered to be a basic flight procedural issue rather than a CRM issue. This is discussed further in section 1.9.1.

1.8.5 Flight and duty times

Fatigue can arise from a number of different sources, including time on task, time since awake, acute and chronic sleep debt, and circadian disruption (i.e. factors which affect the normal 24-hour cycle of body functioning). A recent review of fatigue research relevant to flight operations has noted that fatigue can have a range of influences, such as increased anxiety, decreased short-term memory, slowed reaction time, decreased work efficiency, reduced motivational drive, increased variability in work performance, and increased errors of omission.⁴⁹ However, many of these symptoms generally only appear after substantial levels of sleep deprivation have been imposed. The review also made the following observations:

- A common symptom of fatigue is a change in the level of acceptable risk that a person tolerates, or a tendency to accept lower levels of performance and not correct errors.
- Error rates increase during the period 0000 to 0600.
- Most people need eight hours sleep each day to achieve maximum levels of alertness and performance.

⁴⁹ Battelle Memorial Institute, *An Overview of the Scientific Literature Concerning Fatigue, Sleep, and the Circadian Cycle*, 1998. (Report prepared for the Office of the Chief Scientific and Technical Advisor for Human Factors, Federal Aviation Administration, USA.)

- Decrements in alertness and performance intensify if the time awake is 16 to 18 hours. Performance decrements of 'high time-since-awake' crews tended to result from ineffective decision-making rather than a deterioration of aircraft handling skills.
- Fatigue is cumulative.
- There is a discrepancy between self-reports of fatigue and actual fatigue levels, with people generally underestimating their level of fatigue.

To minimise the likelihood of fatigue influencing crew performance, regulatory authorities and companies have restrictions on the flight and duty times for pilots.

The flight and duty times of the Qantas One crew complied with the requirements of CAO 48 (Flight Crew Limitations).

Details of the recent work and rest history of the crew are provided in attachment F. As noted in this attachment, the captain had been awake for almost 21 hours, and the first officer for about 19 hours, at the time of the accident. The accident also occurred at 0145 in their normal sleep cycle. In addition, the captain's management duties involved a high workload over the previous weeks. The flight crew all reported that they did not think their performance had been affected by fatigue.

CAO 48 provided requirements for non-flying duties, but only for situations where the flight crew included not more than two pilots. These requirements were:

1.13 – An operator shall not roster a pilot to fly when completion of the flight will result in the pilot exceeding 90 hours of duty of any nature associated with his employment in each fortnight standing alone. For the purposes of this paragraph, duties associated with a pilot's employment include reserve time at the airport, tours of duty, dead head transportation, administrative duties and all forms of ground training. The operator shall designate the day on which the first of the fortnightly periods shall start.

During the investigation, the Qantas Flight Operations Branch reported that there were no formal company policies, procedures or guidance information regarding duty or work limits for pilots who conducted both flying and non-flying duties for an operator. Some management pilots believed that paragraph 1.13 of CAO 48.0 applied only to work duties which were directly associated with a flight, whereas others believed it related to all work-related activities.

Observations:

It is possible that both the captain and first officer were experiencing some fatigue due to their number of hours of continued wakefulness, the time of day, and the captain's recent non-flying workload. However, there was insufficient evidence to draw any definite conclusions with respect to fatigue affecting specific events or behaviours during the approach and landing. There were no overt symptoms of fatigue, and all of the crew behaviours could be adequately explained in terms of factors other than fatigue (see section 1.9).

1.9 Analysis summary

1.9.1 Active failures and local factors

This section outlines the significant active failures that occurred during the flight, and the local factors that contributed to these failures. Fig. 5 provides a summary of these issues.

The flight crew did not use an adequate risk management strategy for the approach and landing. Given the minimal level of procedures and training provided to the crew regarding landing on water-affected runways, they were not equipped to appropriately handle the

situation they faced. It is, therefore, unreasonable to expect the crew to have developed an adequate risk management strategy for the approach and landing.

Ideally, they should have taken the available information regarding the weather conditions and runway type (ungrooved and 'slippery when wet'), and concluded that the braking action could have been less than 'good'. They then should have considered options to deal with this situation, such as holding off until the weather improved, electing to use the other (longer) runway, or selecting an appropriate approach and landing procedure to achieve the slowest touchdown speed and shortest landing distance. The use of flaps 30 and full reverse thrust would have produced the shortest landing distance and most probably avoided the overrun.

The first officer did not fly the aircraft accurately during the final approach. The high approach speed, low descent rate on late final approach, and premature flare, led to the long and soft landing. Although the speed was within company limits, it was not appropriate for contaminated runway conditions. Based on the reports from many Qantas B747-400 pilots, the speed exceedance (and the extent of the 'long' landing) was much less likely to have occurred if a flaps 30 configuration had been used. The slightly steeper than normal glideslope was a relatively unusual situation, and may have made a minor contribution to the excessive speed on final approach. The first officer's level of currency may also have contributed.

The reduction in the descent rate when the heavy rain was encountered appears to have been a response by the first officer to the reduction in visibility and the distractions of the rain and windscreen wipers. The subsequent runway aimpoint control problems (e.g. early landing flare) were probably the result of degraded visual cues due to the presence of the rain on the windscreen and absence of touchdown zone lighting.⁵⁰

It could be argued that the captain should have taken over control from the first officer during the final approach, or ordered a go-around earlier. However, the captain was continually monitoring the situation, and was satisfied that the visual conditions were adequate. The captain was also actively assisting and communicating with the first officer during this critical phase, and was satisfied that the progress of the approach was within company limits and adequate in terms of landing distance until he made the decision to go around. It is likely that the actual aircraft performance (such as speed and glideslope) would have had far greater prominence in the minds of the crew had they had appropriate awareness of wet/contaminated runway operations. In the event, they continued with the approach, without the captain taking over, on the faulty assumption that potential runway conditions were of no significance.

The captain cancelled the go-around decision by retarding the thrust levers. It is very widely accepted that a decision to conduct a go-around should not be reversed. In this case, the cancellation action had a number of side-effects. It resulted in excess thrust after touchdown, a slight delay in spoiler deployment, cancellation of the auto-brakes (due to the number 1 thrust level being advanced for more than 3 seconds), and increased workload and confusion amongst the other crew members. This confusion resulted in reverse thrust

⁵⁰ The Qantas One and Qantas 15 crews reported that they did not see the rain, or experience any reduction in their ability to see the runway lights, until they entered the rain. This indicated that the reduced visibility occurred due to a buildup of water on the windscreen, rather than the actual rain itself. Chemical rain repellent on windcreens is used by some operators to assist with visibility during heavy rain. However, reports on its effectiveness varied. Qantas ceased using the repellent and deactivated the rain repellent systems in its B747 aircraft in 1996. The repellent system used chemicals that contained chloro-fluorocarbons and a world wide ban on the non-essential use and purchase of such chemicals was introduced.

not being selected (see below). This confusion may have been lessened had the captain taken control of the aircraft at this stage, or provided clearer instructions regarding his intentions.

The captain's rejection of the go-around appeared to be a considered but rapid response to a unique situation. The fact that the aircraft had touched down, and visibility had suddenly improved, removed the initial reasons for going around. The touchdown clearly acted as a prompt. However, the response time did not indicate that the captain's response was a purely reflex action. In addition, the captain had previously conducted a significant amount of base training. During such training, it is not unusual for the training pilot to override the flying pilot's actions if difficulties are being encountered at critical phases of flight. This previous experience probably increased the likelihood of the captain retarding the thrust levers in this high workload situation (and without making any comment regarding his actions).

The flight crew did not select (or notice the absence of) idle reverse thrust. The crew intended to use the company's normal landing configuration, which included the use of idle reverse thrust. The use of idle reverse thrust (with flaps 25) would have reduced the landing distance, and the magnitude of the accident, but would not have prevented the overrun (based on table 6). However, if the first officer had selected idle reverse thrust and kept his hand on the reverse thrust levers, it is more likely that he would have selected full reverse thrust during the landing roll.

The omission of idle reverse thrust was a direct result of the confusion that occurred after the captain retarded the thrust levers. The first officer's normal action sequence was disrupted, and he may have unconsciously substituted the action of retarding the number 1 thrust lever for the initiation of idle reverse thrust. The failure of the crew to detect this omission during the landing roll was due to high workload and confusion,⁵¹ which led to their attention being focused towards stopping the aircraft by applying the wheelbrakes. The sound of rain, wipers and other noises such as the takeoff configuration warning could have added to the workload and confusion.

The flight crew did not select (or notice the absence of) full reverse thrust. As discussed in section 1.5, the use of full reverse thrust would have substantially reduced the landing distance on a runway with poor braking action. The failure of the crew to consider the use of full reverse thrust during the landing roll appeared to be primarily due to the high workload they were experiencing. Had the crew received more training in the importance of reverse thrust on water-affected runways, or recent experience in the use of reverse thrust, it is reasonable to expect that the crew's awareness of the importance of reverse thrust (and therefore the likelihood of them selecting full reverse thrust) would have been greater.

The runway surface was affected by water. As discussed in section 1.5, it is clear that there was sufficient water on the runway to affect braking action. However, the actual depth of water could not be determined. Indirectly, it is reasonable to conclude that if the runway had been grooved, there may have been better drainage of the runway surface. However, given the witness reports concerning very heavy rainfall in the period immediately before the aircraft landed, it does not automatically follow that grooving would have prevented the water accumulation.

⁵¹ During interviews, several company training pilots noted that omission of reverse thrust was not uncommon when distractions occurred during landing or when high workload or inexperience on type were present.

Other issues. Several other issues were considered to have had a minor (but not significant) effect on the development and outcome of the accident:

- The crew was not made aware of the deterioration in aerodrome visibility at 2240.
- The crew was not aware that Qantas 15 had gone around.
- The crew did not notice that the auto-brakes had disarmed.
- Manual braking was not initiated until 7 seconds after touchdown.
- The nosewheel did not contact the runway until 11 seconds after mainwheel touchdown.

Because these issues were not considered to be significant factors, they are not discussed further in this report.

1.9.2 Inadequate defences

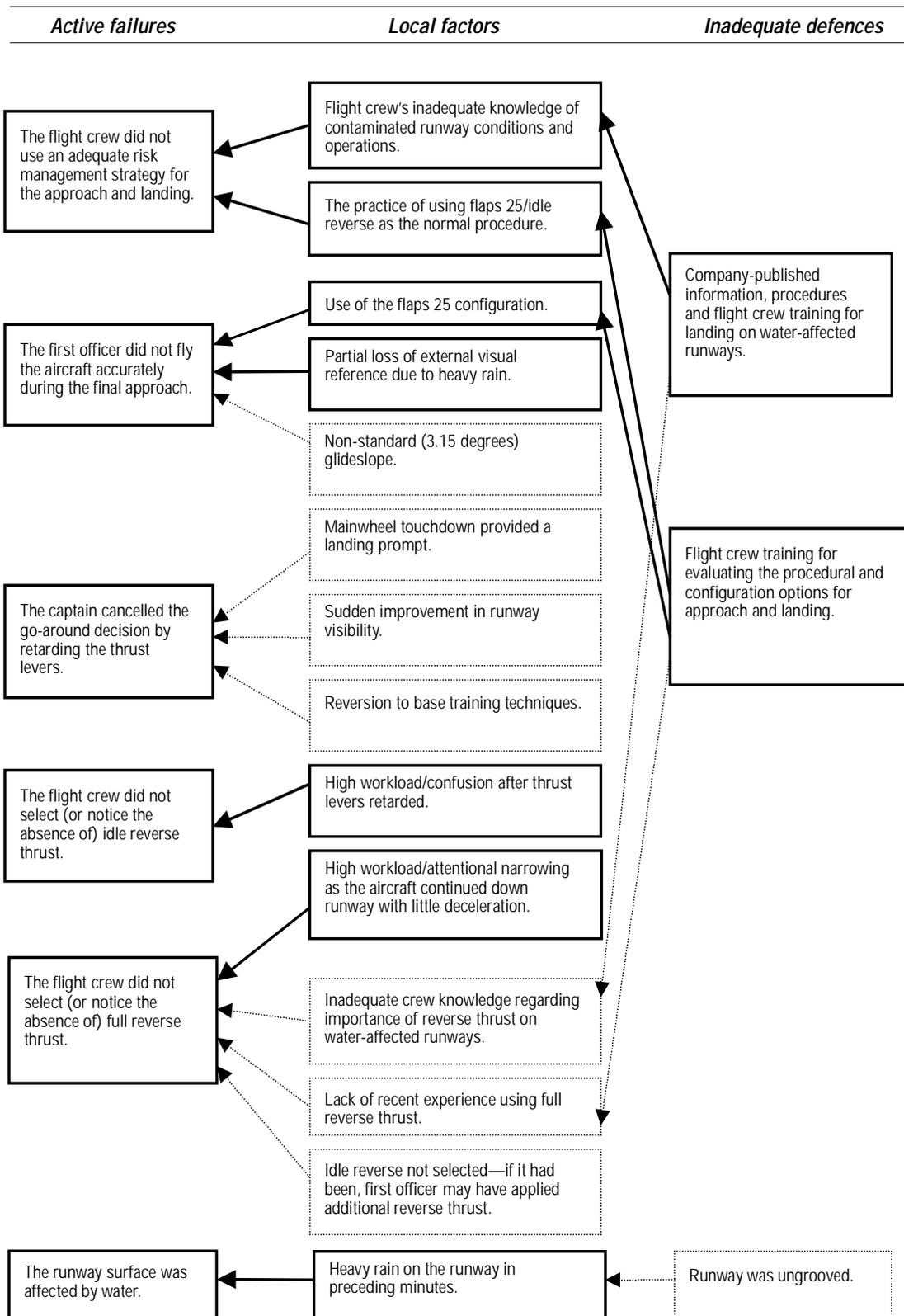
As shown in fig. 5, the investigation concluded that deficiencies in two primary defences had a significant influence on the development of the accident. These were:

- Company-published information, procedures, and flight crew training for landing on water-affected runways (see section 1.6).
- Flight crew training for evaluating the procedural and configuration options for approach and landing (see section 1.7).

The reasons for (or organisational factors associated with) these inadequate defences are discussed in part 3.

Weaknesses in a number of other defences such as the company's CRM program, the training and role definition of second officers, and procedures concerning recency, possibly contributed to the development of the accident. However, as discussed in section 1.8, there was insufficient evidence to conclude that these issues had any role in the development of the accident.

Figure 5:
Summary of the active failures, local factors and inadequate defences associated with the accident flight (significant factors are in fully enclosed boxes)



2. POST-ACCIDENT EVENTS AND CABIN SAFETY ISSUES

2.1 Background information on aircraft cabin and cabin crew

2.1.1 Cabin layout and passenger disposition

The passenger cabin was divided into six zones designated A to F. Fig. 6 shows the cabin layout, including zones, door positions, and seating configuration. Zones A to E were on the main deck and zone F was on the upper deck.

Six passengers were infants being nursed by an adult. The remaining 385 passengers were distributed in the six zones as follows:

Zone A	14 (14-seat capacity, 'first' class)
Zone B	33 (35-seat capacity, 'business' class)
Zone C	73 (73-seat capacity, 'economy' class)
Zone D	102 (102-seat capacity, 'economy' class)
Zone E	133 (140-seat capacity, 'economy' class)
Zone F	30 (30-seat capacity, 'business' class)

There were 10 doors on the lower deck and two doors on the upper deck. All 12 doors were equipped with emergency escape slides. The doors were numbered from the front to the rear of the aircraft and designated left or right, as shown in fig. 6.

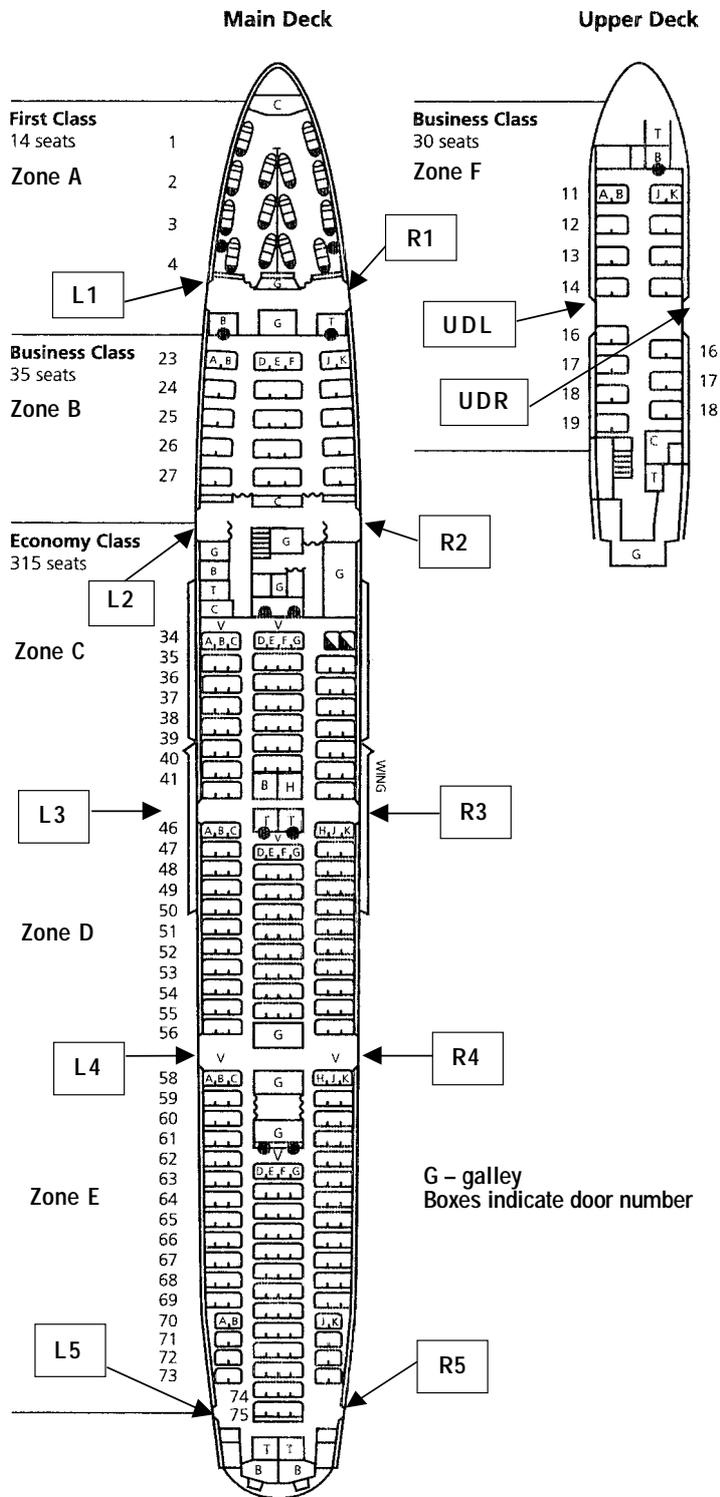
2.1.2 Cabin crew

There were 16 cabin crew on the aircraft. These included the customer service manager (CSM) who had management responsibility of the aircraft cabin and cabin crew. His deputy was the customer service supervisor (CSS).

The prime responsibility of cabin crew is the safety of passengers. This statement was affirmed in the company's *Flight Administration Manual* (page 4-8).

Figure 6:
VH-OJH cabin layout

Boeing 747-438



2.1.3 Cabin crew seating positions

Either single or double cabin crew seats were located adjacent to each door. Cabin crew occupied these seats for all takeoffs and landings. Single crew seats were located left and right side at doors 1, 2 and 5. Double crew seats were located left and right side at doors 3 and 4. On the upper deck, the cabin crew for the left and right doors were positioned mid-cabin right side.

All cabin crew seats were rearward-facing except those at L5 and R5, which faced forward.

Cabin crew seating positions were designated according to the door that the crewmember was assigned. The crewmember responsible for opening a particular door in an emergency was designated the door 'primary' (P). There was a primary cabin crewmember at each door. At doors where an additional crewmember was positioned, that crewmember was designated as the 'assist' (A) to the door primary.

On Qantas B747-400 aircraft, the CSM was assigned the L2 Primary (L2P), with no assist, and the CSS the L4 Primary (L4P) position, with an assist.

The cabin crew seating positions and designations for the aircraft are shown in table 7. The abbreviations for the crew positions referred to in this table are used in the remainder of this section.

Table 7:
Cabin crew seating positions and designations

<i>Seating position</i>	<i>Cabin crew designations</i>
Doors 1 (Rear of zone A). Aft facing.	Left side (L1P) Right side (R1P)
Doors 2 (Rear of zone B). Aft facing.	Left side (L2P-CSM) Right side (R2P)
Doors 3 (Rear of zone C). Aft facing.	Left side (L3P) and (L3A) Right side (R3P) and (R3A)
Doors 4 (Rear of zone D). Aft facing.	Left side (L4P-CSS) and (L4A) Right side (R4P) and (R4A)
Doors 5 (Rear of zone E). Forward facing.	Left side (L5P) Right side (R5P)
Upper Deck (Mid-cabin zone F). Right side.	Upper Deck Left Primary (UDLP) Upper Deck Right Primary (UDRP)

2.2 Sequence of events

The information regarding the sequence of events was obtained from the flight crew, cabin crew, passengers, and the airport authority. Information was also obtained from the CVR and a recording of air traffic control communications and from an examination of the aircraft cabin after the accident.

2.2.1 Events during the landing roll

As the aircraft landed (2246:30), the CSM commenced the 'Welcome to Bangkok' passenger address (PA) announcement. He stopped part-way through when he sensed that the landing was not normal. Some cabin crewmembers at the rear of zones A, C and D also sensed that the landing was not normal and adopted the 'brace for impact' position.⁵²

When the aircraft left the paved surface, there was a series of impacts and noises before it came to a stop 8 seconds later in a nose-down, slight right wing-low attitude. Normal cabin lighting failed and emergency cabin lighting illuminated.

After the first impact, six cabin crew seated at the rear of zones C and D started calling 'heads down, stay down' or 'brace brace brace'. They continued these calls until shortly after the aircraft came to a stop. No other cabin crew made any calls, even though all perceived aspects of the landing to be abnormal.

Fifty per cent of passengers from zone D, 27% from zone C, and 3% from zone E reported hearing instructions from the cabin crew during the landing roll. No passengers from zones A, B or F reported hearing any instructions. Forty-five per cent of all passengers, predominantly from zones C and D, reported that they braced or put their heads down during the impact sequence. Seventeen per cent said that they 'just held on tight' while 38% remained in their normal seated positions and 'did nothing', even though some heard the brace calls.

In some areas of the cabin, the placement of galleys and bulkheads prevented cabin crew and passengers from observing one another. One cabin crewmember did not call brace because his seating position faced a wall and he could not see passengers. He reported that this situation created doubt in his mind regarding the efficacy of issuing brace commands.

Early in the impact sequence, two cabin crew at the rear of zone C and about 20 passengers in zone D observed a ceiling panel dislodge and fall into an aisle. Some indicated that this panel narrowly missed striking a nursed infant. Four other ceiling panels were also dislodged, but did not fall to the floor. All passengers in zone D reported seeing passenger service units⁵³ (PSUs) fall from their stowage. Four passengers in this zone said that they were struck by a PSU.

Further information on damage and injuries is provided in section 2.3.

Other information that came light concerning the landing included:

- On the flight deck, three flight crew emergency escape reels dislodged from their overhead stowage. At least one struck the second officer on the shoulder.
- A cabin crewmember seated on the right side of the cabin observed 'flashes' from an engine during the landing roll. This issue is discussed further in section 2.5.
- A passenger in zone A reported that she fell to the floor after she undid her seat belt during the landing roll to put down her blanket.
- Three passengers reported that as the wheels touched down, an infant was passed across the aisle to a passenger seated in the adjacent aisle seat.
- Throughout the cabin, overhead lockers opened and some contents were spilled, although heavier items remained in the lockers.

⁵² Because cabin crew wear a shoulder harness restraint, their brace position is different from that for passengers. In addition, most cabin crew are seated facing rearwards, and consequently lean back rather than lean forward to brace for impact.

⁵³ Passenger service units house flight attendant call lights, reading lights, and passenger emergency breathing masks.

- Passengers near the door 2 galley reported that the doors to galley cupboards were ‘opening and shutting’. Passengers also reported that they noticed rubbish and ice on the floor of the door 2 galley during the disembarkation.
- Throughout the aircraft, small items including dislodged cabin fittings, books, magazines, handbags, blankets, pillows and small plastic service items littered the floor.
- In zone A, some passenger seat assembly trim panels came loose, and some life jackets were forced out of their stowage.

Observations:

Passenger and cabin crew observations of events in the cabin varied according to where they were seated. This reflected the fact that impact loads, damage and perceivable events varied throughout the cabin.

Use of the handset during the landing may have prevented or delayed the CSM adopting the brace position and presented an exposure to injury from crash impact. It could also have led to the handset being dropped or left unstowed and becoming a source of injury or obstruction.⁵⁴ Similarly, the dislodgment of the emergency escape reels could have caused injury to a member of the flight crew.

From the available information, two passengers (one adult and one infant) were unrestrained when the aircraft overran the runway. These two passengers were exposed to a higher risk of injury during the impact sequence. The cabin safety briefings conducted before and during the flight, and the passenger safety cards at each seat, included clear instructions regarding seat belt security. These passenger actions appear to have been instinctive and not the result of any operator or cabin crew deficiency.

Galley, cabin service items and articles of cabin baggage are required to be securely stowed for each takeoff and landing. Cabin clutter can cause obstruction to exits and obstruction or slipping hazard in aisles. Based on the available evidence, it is possible that not all items were securely stowed in the cabin.

The cabin crew’s use of the brace command is discussed further in section 2.7.1.

2.2.2 Events immediately after the aircraft came to a stop

As far as could be determined, the following events are in chronological order. However, because the CVR ceased operating (at 2247:20) shortly after the aircraft came to rest, there was no means of accurately determining the timing of events after this point. Estimated times of particular events (by crew, passengers and others) varied greatly.

Flight deck. At about 2247:11, when the aircraft came to a stop, the first officer commenced the checklist items and shut down the engines by operating the fire switches. The captain twice attempted to make a passenger PA announcement, and then tried to contact the CSM on the crew interphone, but without success. At about 2247:26, the tower controller asked Qantas One to report whether they had vacated the runway (because the aircraft could not be seen from the tower). The first officer twice replied that they had overrun the runway and required assistance, but these transmissions were weak and not understood by the controller.⁵⁵ At 2248.00, the tower controller made two further requests for Qantas One to

⁵⁴ Company procedures suggested PA calls should be made ‘Before descent’ and ‘Approaching the terminal’, but did not state that calls should not be made during the actual landing.

⁵⁵ Initially the crew had the right VHF system selected, and the power to this system was lost when the engine shutdown drills were completed. The crew switched to the left VHF system which was powered by another electrical source. Although this system was functioning normally, the crew did not establish communications with ATC until 6 minutes later, when the captain made a transmission. No technical reason for this problem was identified.

report clear of the runway, but each time the reply from the aircraft was weak and could not be understood.

In the meantime, the captain dispatched the second officer to relay instructions to the CSM. The second officer returned to the flight deck and reported that there was no sign of fire and that the situation in the cabin was under control.

The CSM went to the flight deck with the second officer. He told the captain that the cabin crew were at the exits and were ready to evacuate. As far as the CSM knew, there were no injuries. The captain said that there was no sign of fire, the engines had been shut down, and the fuel turned off. He instructed the CSM to assess the condition of the passengers and cabin. When the CSM returned, he reported to the captain that there was some damage in the cabin, but that passengers and crew were uninjured.

During this initial period, the flight crew discussed the option of either an immediate evacuation or a precautionary disembarkation (see section 2.5).

Cabin. After the aircraft came to a stop, the cabin crew left their seats and assumed their assigned emergency positions at their respective doors in the event that an immediate evacuation became necessary, in accordance with company emergency procedures. The CSM and some cabin crew attempted to communicate with each other and the flight deck using the interphone, but without success. After approximately 1 minute, the second officer came down the stairs and told the CSM at door L2 to instruct passengers to remain seated, and to tell cabin crew to remain by their doors and await further instructions. The CSM instructed the R2P cabin crewmember to relay the instructions to all other cabin crew. The second officer returned to the flight deck. Shortly after, the second officer returned to door L2 with instructions from the captain for the CSM to report to the flight deck. When the CSM went to the flight deck with the second officer, door L2 became unattended.

When the CSM returned from the flight deck, he conducted a cabin assessment, moving through the upper deck and main deck. He told crew and passengers that there was no sign of fire or danger and that the situation was being assessed before disembarkation. He then returned to the flight deck.

The following events also occurred in the cabin in the first few minutes after the aircraft stopped:

- Some passengers began making calls from mobile telephones. They were directed by cabin crew to turn the equipment off.
- The L3A cabin crewmember observed that the fallen ceiling panel in the aisle in zone D was blocking an exit way, and moved the panel to the door 2 galley.
- Some crew called out to ask passengers if anyone had been injured, but were reluctant to leave their assigned emergency positions to check the cabin for injuries in case an immediate evacuation was required. Others moved a short way into their zones to check the status of passengers.

External to the aircraft. The Airport Authority of Thailand reported that a ground traffic officer on duty near the end of runway 21L saw the aircraft overshoot the runway. At approximately 2248:30, he contacted the control tower and reported what he saw. The tower then closed runway 21L and activated the emergency services in accordance with the airport procedures for aircraft accidents. Emergency service vehicles then left Fire Stations 1 and 2 to attend to the situation. The vehicles attempted to reach the aircraft by proceeding to the end of runway 21L. However, the very wet conditions prevented the vehicles leaving sealed

surfaces and they had to proceed to the aircraft via the perimeter road. Attachment E provides a map of the airport that shows the location of the aircraft and the fire stations.

Observations:

The failure of the PA and cabin interphone systems had a significant impact on communications between the cabin and the flight deck. The reasons for the failures are discussed in section 2.4. The effects these failures had on crew communications are discussed further in sections 2.5 and 2.6.

During this critical emergency period, there were intervals when doors L2 and R2 were unattended as the cabin crewmembers responsible for these doors performed other tasks. It is important for doors to be attended during emergency periods in case an immediate evacuation has to be initiated. In this context, the practice of assigning the CSM to a door without an assist could make it difficult for a CSM to manage some emergency situations.

2.2.3 Other events prior to disembarkation

Inside the aircraft. At 2253, approximately 6 minutes after the aircraft came to a stop, the captain told the tower that emergency services and steps were required as soon as possible. The tower replied that the emergency services were already on their way. Later, the captain contacted the company airport office by radio and requested that buses be sent to the aircraft.

During the investigation, cabin crew reported that they had been concerned about the possibility of fire and were reluctant to leave their doors in case an immediate evacuation was required. By 'scanning' their zones, they could see that no passengers appeared to have been seriously injured. The flight crew and cabin crew noted that the passengers were calm and that there were no signs of panic.

The majority of passengers reported experiencing high levels of apprehension during the period before the disembarkation. Their principal concern was fire. They were critical of the lack of information they were given about the situation and the delay in commencing the disembarkation. Many also commented on the conduct of the cabin crew who remained at their doors apparently 'doing nothing'.

During the pre-disembarkation period, there were a number of events associated with smells in the cabin:

- The L3P crewmember became aware of a smell 'like burning wires' in the mid- cabin area of the main deck. He decided to inform the CSM but could not find him on the main deck and proceeded to the flight deck. While the CSM was talking to the captain, the L3P crewmember entered the flight deck and told the second officer that there was a 'strong smell' in the vicinity of door 3 that was of concern to passengers and cabin crew. The captain instructed the CSM to assess the area.
- Before the L3P crewmember returned from the flight deck, passengers and crewmembers located near the L1 and R1 cabin doors (above the area where damage had been caused by the collapsed nose landing gear) became aware of what they described as 'fumes'. One of the passengers in zone A was an off-duty company pilot travelling as a passenger. He expressed his concerns regarding the fumes to the L1P and R1P crewmembers, suggesting that they should inform the flight deck. On his way back from the flight deck (see first dot point), the L3P crewmember told the L1P that the captain and CSM knew about the fumes.
- After an assessment of the area around door 3, the CSM told the captain that the conditions there were hot and stuffy. He reported that there was an unpleasant smell, a

mixture of outside air and maybe 'a smell of friction', but not smoke. The captain then instructed over-wing doors L3 and R3 to be opened for ventilation of the cabin. The CSM returned to the cabin and disarmed and opened both L3 and R3 doors. He instructed the cabin crew to stay and manage the doors.

- In response to the L3P crewmember's report on a smell, the second officer went down to the main deck to investigate. His understanding was that the reports were coming from zone A. After examining this zone, he noted that some people were experiencing eye irritation and there was a faint smell of electrical origin, but he did not detect any fuel smells. He went back to the flight deck satisfied that there was no fumes or smells of concern.
- The R1P crewmember relayed information regarding the fumes to the R2P crewmember, who said that the flight crew knew about the fumes. The R1P crewmember later indicated that he would normally have passed this information to the CSM but was unable to because the CSM was on the flight deck at the time.
- Cabin crew and passengers in zones A and B reported that the fumes became stronger over time and caused breathing difficulties, and burning and watering of the eyes.
- A passenger in zone A, who had experience as an aircraft engineer, recognised the smell of hydraulic fluid but did not pass this information to any crewmember.
- The captain later said that he was never made aware of the presence of fumes in the cabin.

Reports describing events that occurred before the disembarkation included the following:

- A cabin crewmember located at the opened overwing exit door at R3 observed that the number 3 engine pod was resting on the ground. Cabin crew at the overwing doors saw dirt and mud on the upper surface of the wings. Other cabin crew noted that the galley floor between doors L1 and R1 had been deformed upward. None of this information reached the flight crew.
- In their response to the passenger survey, several passengers in rows 53 and 54 on the left side, where ceiling panels had been dislodged, reported seeing sparks or flashes in the ceiling void after the aircraft came to a stop. There were some reports in the survey of passengers taking flash photographs in that area of the cabin (see section 2.3.3).
- Some cabin crewmembers reported that they received little ongoing information about what was happening in the period prior to the disembarkation.
- Some cabin crew left their assigned emergency stations to check passengers in the immediate area, to relay messages throughout the cabin, or to assist other crewmembers. Some cabin crew reported that other crew stood at their doors when they left, while some doors were not 'covered' in the absence of the assigned crewmember.

External to the aircraft. At approximately 2253, when the captain was talking to air traffic control, the tower controllers could see that a procession of fire vehicles had reached the southern most point of taxiway 'T' near the accident site. The rain had eased and visibility had improved. The Department of Aviation, Thailand reported that the emergency services vehicles arrived at the aircraft at approximately 2257. This is consistent with passenger reports (see attachment L). A few minutes after the fire vehicles arrived, a vehicle with floodlights arrived on the right side of the aircraft.

Some airport personnel had arrived at the aircraft and conducted an initial inspection before the fire vehicles arrived. The fire vehicles parked on the sealed road on the right side of the aircraft. Personnel from the vehicles assessed that there was no fire but ran hoses from

the fire vehicles as a precaution. They attempted to communicate with the crew by tapping on the fuselage of the aircraft. The crew did not notice these communication attempts. The chief of the emergency services contacted the control tower to inform the pilot to open the doors, but this communication apparently did not reach the aircraft. The emergency service personnel then waited for the evacuation to commence.

ICAO Annex 14, Aerodromes, July 1999 edition, para. 9.2.19 addressed aerodrome emergency services response times. It states:

The operational objective of the rescue and fire fighting service should be to achieve response times of two minutes, and not exceeding three minutes, to each end of the runway, as well as to any other part of the movement area, in optimum conditions of visibility and surface conditions.

Observations:

Two important issues arose during this phase of events: the decision not to conduct an emergency evacuation, and the effectiveness of intra-crew communications. These issues are discussed further in sections 2.5 and 2.6 respectively.

Many passengers were critical of the lack of information they received, and of the cabin crew seemingly standing at their doors and not doing anything. However, an emergency situation requires an instantaneous change in focus of cabin crew from being a service provider to being a safety professional. By remaining at their doors, the cabin crew were following standard procedures and ensuring that they were in the best position to initiate an evacuation if that was required.

When the overwing exits doors (L3 and R3) were opened for cabin ventilation, it was necessary to disarm the doors (to deactivate the emergency escape slides) before they were opened. Had there then been a need to conduct an immediate evacuation, the escape slides could not have been deployed until the doors had been closed, rearmed, and opened again. The time taken to complete this process could have been critical. In addition, closure of the door could have been restricted by structural deformation of the doorframe.

There was an interval of about 10 minutes between the accident and when the emergency service vehicles reached the aircraft. Although a quicker response time was clearly desirable, the situation was affected by the initial uncertainty regarding the aircraft's status and location (caused by reduced visibility and communications difficulties), and the difficulty in reaching the aircraft due to the wetness of the ground.

2.2.4 The disembarkation

Inside the aircraft. The captain reported that he initiated the disembarkation when he received advice from the company that buses were on the way. He directed the CSM to use slides at doors R2 and R4 to carry out a 'precautionary disembarkation' (see section 2.5). Doors on the left side were not used because there were no lights on that side, these doors were further from the ground, and there were trees outside some of these doors. Door R5 was not used initially because it was further from the ground, and the slide would be at a steeper angle. Door R1 was not used initially because an emergency service vehicle was parked near that exit. The Department of Aviation, Thailand reported that the disembarkation commenced at approximately 2307.

The CSM went to zones C and D and briefed the cabin crew and passengers simultaneously about the precautionary disembarkation and instructed the CSS to open door R4. The CSM then opened door R2. The CSS repeated to passengers in zone E the CSM's instruction regarding the disembarkation and then opened door R4. The R4P crewmember reported that, before the CSS had finished speaking, some passengers began moving towards the

door. Some passengers in the rear zones reported that other passengers moved quickly forward, leading to queues forming at some exits.

Other details concerning the disembarkation included the following:

- The L1P and R1P cabin crewmembers reported that they were unaware that the disembarkation had commenced until they heard the sound of evacuation slides being activated.
- A tour group leader translated cabin crew instructions to a group of Italian passengers near door 3.
- Passengers were instructed by cabin crew to move to the exits, remove high-heeled shoes and leave cabin baggage behind. Cabin crew reported that some passengers ignored instructions to leave bags. Where the crew attempted to enforce these instructions, the passenger flow to exits was less orderly.
- Duty free and other bags were taken from passengers as they moved towards exits, and some items were placed in galleys or on seats. Some cabin crew allowed passengers to take cabin bags. One crewmember reported that a passenger was permitted to send a bag down a slide before disembarking. Passengers with infants were also allowed to take bags. One passenger, who was amongst the last to leave the aircraft, was permitted to take a bag containing medication.
- As passengers reached the exit doors, various instructions were given by the cabin crew, such as 'sit and slide', 'cross arms', and 'put hands on knees' and 'lean forward'. One passenger reported that she was instructed to sit on the slide with her handbag around her neck.
- Cabin crew reported that they allowed some passengers latitude to carry small articles because the disembarkation was not a 'full emergency' situation, or because they did not wish to confront or upset passengers. They also reported that some passengers argued with cabin crew who tried to enforce the company safety requirements.
- Some passengers with infants and young children were told to place the child on their lap or between their legs. Others were given no specific instructions. A mother carried her 15-week old baby in a pouch on her chest down the slide.
- As the evacuation commenced, some cabin crew stationed at doors on the left of the aircraft crossed over to assist crewmembers at the right side doors.
- The captain and second officer proceeded to the main deck to assist with the disembarkation. The first officer remained on the flight deck to ensure it was secured.
- During the disembarkation, door R5 was opened when a buildup of passenger numbers occurred in mid-cabin. Door R1 was opened to improve the passenger flow when a bottleneck arose at door R2 because of passengers coming down the stairs from the upper deck cabin. The upper deck slides (UDL and UDR) were not deployed.⁵⁶
- Because of the aircraft attitude, the slope of the R1 and R2 slides was shallow, while the R5 slide was steep. Passengers who exited through R1 and R2 reported that they needed to push their way down these slides. Some walked down the slides. Crewmembers at the rear of the aircraft observed that the slide at door R5 was steep but considered it useable. Crewmembers directed some families and elderly passengers from this exit to slides that were not as steep. One passenger was reported to have somersaulted down the R5 slide.

⁵⁶ The UDR slide was later deployed by ground personnel at some point after the disembarkation.

- Cabin crew stationed at the disarmed and opened overwing exit doors, L3 and R3, stayed at the exits to prevent passengers attempting to use the exits. Cabin crew stationed at door L3 attempted to shut the door. They reported that the door was difficult to close (see observation at 2.2.3).
- An off-duty pilot (crewmember travelling out of uniform as a passenger) relieved a cabin crewmember at door R2 and assisted with the evacuation of the last passengers through that door while the cabin crewmember checked the area for other passengers.
- Two passengers reported that no crewmembers were present when they evacuated through door R1.
- Before the last crewmember had left the aircraft, some members of the cabin crew, who were to operate the aircraft on the next sector, travelled from the airport terminal by bus to offer assistance. They entered the cabin before the last crewmember had left the aircraft and before telling the captain of their presence. The captain instructed them to leave the aircraft.
- After all passengers had disembarked, the remaining crew completed a final cabin check to ensure that all passengers had left the aircraft. At this time, the emergency cabin lighting was still functioning. The life of the emergency batteries was nominally 20 minutes.

Outside the aircraft. As the disembarkation began, emergency service personnel stationed themselves at the bottom of the slides to assist passengers. At some stage during the disembarkation, three cabin crewmembers were directed to leave the aircraft to assist passengers on the ground. Seventy-six per cent of passengers reported that they received assistance at the bottom of the slides.

Fifty-two per cent of passengers reported they received instructions after they left the aircraft regarding where to go and what to do. Most said that emergency services personnel directed them to move around the front of the aircraft to the other (left) side of the aircraft, to wait for buses. Forty-five per cent of the passengers said they received no instructions regarding where to go and what to do after they left the aircraft. Some commented that they simply followed other passengers as they assumed that they had received instructions. There were many reports of some passengers remaining in the vicinity of the aircraft after they had disembarked. There were also a few reports that emergency services personnel were smoking in the vicinity of the aircraft.

The Department of Aviation, Thailand reported that the disembarkation was completed at approximately 2330.

The Airport Authority of Thailand reviewed the emergency response activities associated with the accident. It noted that there were some deficiencies in the coordination between appropriate parties at the accident site.

Observations:

The cabin crew did not uniformly enforce the requirement for passengers to leave baggage behind for the disembarkation. The retrieval of cabin baggage can slow down the disembarkation/evacuation process. Cabin baggage can also damage escape slides and injure passengers at the bottom of a slide.

A number of company personnel boarded the aircraft prior to the completion of the disembarkation. The condition of the aircraft, and the potential hazards associated with the terrain, wreckage and cargo were unknown to them. Their actions in attending the site and boarding the accident aircraft exposed them to potential injury.

Control of the passengers after they left the aircraft was inconsistent and in many cases passengers were not given appropriate directions. All passengers should have received clear directions, from either emergency services or the aircraft's crew, to immediately move away from the aircraft.

2.3 Injuries and cabin damage

2.3.1 Injuries

Thirty-eight respondents to the passenger questionnaire said that they received some form of physical injury as a result of the occurrence. Of these, 17 reported experiencing whiplash or bruising type injuries. Three passengers reported being struck by a dislodged passenger service unit (PSU). Thirteen passengers reported receiving minor injuries during the evacuation. No passenger reported attending a hospital, although four reported subsequently visiting a doctor, either in Bangkok or elsewhere. Based on the available information, all of these injuries were minor.

Fifteen passengers volunteered information relating to psychological distress they had experienced following the accident.

2.3.2 Cabin damage

Numerous cabin fittings were dislodged during the accident sequence. These included ceiling panels and PSUs located in the ceiling above each passenger seat. There was also damage to some toilet fittings. The location of these events is shown in fig. 7. Fig. 8 shows examples of the cabin damage.

Ceiling panels. Five ceiling panels on the left side of the aircraft between rows 48 and 54 were dislodged during the sequence (see fig. 7 and fig. 8). One panel fell and blocked the aisle while the others were misaligned.

The panels were made of composite material. They measured approximately 1 x 1.7 m and weighed approximately 3.5 kg. A rail on top of the centre overhead lockers secured the inboard edge of each panel. The outboard edge was secured by latches. On all of the panels that had been dislodged, the latch hooks had failed. The panels, latches and the rail showed no abnormality and were correctly aligned.

Boeing advised that the damage to the panels indicated that deceleration loads and fuselage deformation, associated with separation of the nose and right wing landing gears, caused the panels to move inboard against the rail. The load transferred to the latches on the outboard side, breaking the hooks and allowing one panel to fall down.

Passenger service units. Most of the dislodged PSUs were in zones A and D. They remained hanging from their respective cables and feed lines. However, the length of cables and feed lines allowed some PSUs to be close to level with the top of the seat back, making them a possible source of injury and hindrance during the disembarkation. The retention mechanisms for the PSUs were undamaged.

The PSUs were attached by hinges and spring-loaded latches onto rails secured underneath the overhead stowage lockers. Aluminium tie-bars ensured that the rails were parallel and maintained the appropriate separation. Boeing advised that the probable reason for the PSUs being released was flexing of the rails during the impact sequence.

Figure 8:
Examples of dislodged cabin fittings: (a) ceiling panels and (b) passenger service units (PSUs)



Recorded impact loads. Table 8 shows the recorded peak decelerations during the impact sequence, as recorded by the DFDR. The accelerometers were positioned at the aircraft centre of gravity (in zone C) and measured the acceleration levels once per second. It is therefore possible that the actual peak loads in different locations along the aircraft may have been higher than the values shown in table 8.

Table 8 also shows the certification standards for cabin fittings, as stipulated in FAR 25.561. The aircraft was certified according to this standard. As shown in table 8, the deceleration values experienced during the impact sequence were below those stipulated by the FAR requirements.

Table 8:
Acceleration loads during impact sequence (g)

	<i>Longitudinal acceleration</i>	<i>Lateral acceleration</i>	<i>Vertical acceleration</i>
Peak acceleration during impact sequence	-1.02	-0.89	+1.52
FAR standard	-9.0 to +1.5	-1.5 to +1.5	-2.0 to 4.5

Observations:

There were failures of cabin fittings at loads below those required by the FARs. However, runway excursion events are likely to involve unusual and unpredictable loads on the aircraft structure. Methods to ensure better security of cabin fitting are discussed in section 5.7.

2.3.3 Fire hazard

No evidence of fire was found either during the post-accident examination of the aircraft or its subsequent repair.

After the aircraft stopped, the flight crew shut down and secured the engines by operating the fuel control switches. The crew then operated the engine fire switches. This isolated the fuel, hydraulic, and electrical connections to each engine, and discharged a fire extinguisher into each engine compartment. All aircraft fuel tanks retained their integrity during the impact sequence. Approximately 68 L of hydraulic fluid were discharged from the severed hydraulic lines in the nose landing gear and the right landing gear bays.

The hydraulic fluid used in the aircraft was a synthetic fluid with fire resistant additives. To be ignited, the fluid would have to be sufficiently atomised and come into contact with a very hot surface (approximately 600 deg C). Exposed parts of the engines or the wheel brakes were considered unlikely to have reached this temperature, given the very wet conditions that prevailed.

No evidence of electrical sparking or burning was found in the ceiling space above rows 48-54 where the ceiling panels were dislodged and ‘flashes’ had been observed (see section 2.2.3).

Observations:

There was no evidence that fire had occurred in any part of the aircraft.

The fumes noted in the aircraft cabin (see section 2.2.3) probably came from discharge of hydraulic fluid, and possibly friction-heated rubber from the rotating nose landing gear wheels briefly contacting the fuselage.

The ‘flashes in the ceiling’ which some passengers reported may have been the result of other passengers taking photographs.

2.4 Public address and cabin interphone systems

The aircraft was fitted with an Advanced Cabin Entertainment Service System (ACCESS). A Passenger Address Controller (PAC) and Cabin Interphone System (CIS) were sub-systems of ACCESS. The PAC and CIS included controllers as part of the ACCESS interface to other systems and inputs. The design of these controllers included a redundant controller card to improve reliability and ensure that if one controller failed, the PA and interphone function would not be lost for the remainder of the flight.

The PA system allowed cabin announcements to be made from the flight deck or handsets located at each cabin crew station. The cabin interphone system permitted communications between the flight deck and cabin crew stations.

The PAC and CIS controllers were co-located in the Main Equipment Centre, which was in the lower fuselage (underneath the main deck) and aft of the nosewheel. Both controllers contained two identical sets of components. These were referred to as the 'normal' and 'alternate' systems. Either system was able to perform the full system functions.

During the impact sequence, the nose-landing gear collapsed rearwards and upwards into the Main Equipment Centre. The circuit boards in both the PAC and CIS controllers were subject to stress and deformation. The damage, which occurred during the impact sequence, rendered both controllers inoperable.

In the 10 days prior to the accident, there were several reports of problems with the PA system on the accident aircraft. At the time of the accident, the PA controller was in 'alternate' mode because the system was not functioning properly in 'normal' mode. This condition, however, had no bearing on the loss of PA and cabin interphone systems which occurred during the impact sequence.

Qantas did not carry megaphones or other portable communication systems on board their aircraft, nor were they required to do so by Australian regulations.⁵⁷ The FAA regulations required that megaphones were carried on aircraft registered in the USA (FAR 91.513, FAR 121.309). Similar regulations exist in Europe and Canada.

During the investigation, Qantas reported that the B747-400 aircraft was equipped with an evacuation alarm that could be activated from the flight deck or door L2. This alarm was independent of the cabin interphone and PA systems.

Observations:

The loss of the PA and cabin interphone systems was potentially hazardous. It disrupted the normal means of communications between the flight deck and the cabin. The loss also forced crewmembers to convey information by moving through the cabin. This, in turn, contributed to various communication difficulties and key personnel leaving their stations (see sections 2.5 and 2.6).

Nose landing gear collapse is likely to be part of the sequence of events in any runway excursion involving collision or rough terrain. In B747-400 aircraft, the loss of cabin PA and interphone systems would be a likely consequence of such a sequence. This highlights a design weakness inherent in having both the normal and alternate system co-located in the equipment centre in the lower fuselage behind the nose landing gear bay.

It is likely that megaphones would have assisted the cabin crew in communicating information to passengers before, during and after the precautionary disembarkation. However, they would have added little, if any, to the effectiveness of communications between the flight deck and the cabin in the absence of the cabin interphone system.

⁵⁷ Some other Australian operators had incorporated the carriage of megaphones into their normal operations.

2.5 Company operations: evacuation versus precautionary disembarkation

Attachment G provides an overview of relevant company manuals, including the *Aircrew Emergency Procedures Manual* (AEPM), provided to all flight crew and cabin crew, and the *Quick Reference Handbook* (QRH), provided to all flight crew.

2.5.1 Procedures

The Common Procedure section of the AEPM contained procedures and checklists for various emergency situations, including 'Land Emergencies'. Page 03.30.1 of the manual provided an overview of the phases and PA calls for the different types of land emergencies (see fig. 9). The diagram showed that, following the initial 'alert' phase, there could be four types of event: an 'evacuation', a 'precautionary disembarkation' (with steps), a precautionary disembarkation (without steps), or cancellation of the alert. The AEPM also provided the PA calls required for each phase and activity along with some general guidelines associated with these activities. There was no definition of 'evacuation' or 'precautionary disembarkation' in the AEPM.

The QRH noted that an evacuation PA was 'used to order immediate rapid evacuation without alert, or upgrade "ALERT" phase'. For a precautionary disembarkation PA, it noted that 'the situation requires the orderly but rapid disembarkation of the passengers and crew'. The term 'rapid' refers to the speed of the disembarkation procedure, not the time of actually commencing the disembarkation.

Both the AEPM and the QRH noted that a 'precautionary disembarkation can be upgraded to an evacuation if the situation requires'. The AEPM also noted that cabin crew could initiate an evacuation at their door if the situation was 'obvious' (see section 2.6).

Neither the AEPM, the QRH, or any other company manual provided flight crews with any guidance to assist them in evaluating available information to decide whether to conduct an emergency evacuation or a precautionary disembarkation.

The US National Transportation Safety Board (NTSB) recently conducted a safety study of emergency evacuations in the USA.⁵⁸ One conclusion from this study was that pilots were not receiving consistent guidance, particularly in flight operations and safety manuals, about when to evacuate an aircraft.

2.5.2 Flight crew training

In 1998–99, one practical exercise during the annual company emergency procedures training involved air traffic control (ATC) advising the flight crew that there was no fire. The expected outcome was for the flight crew to initiate a precautionary disembarkation. In the second scenario, ATC advised that the aircraft was on fire, with the expected outcome being that the crew initiate an emergency evacuation. The scenario of the crew receiving no information from ATC, and not knowing if the aircraft was on fire, was not included.

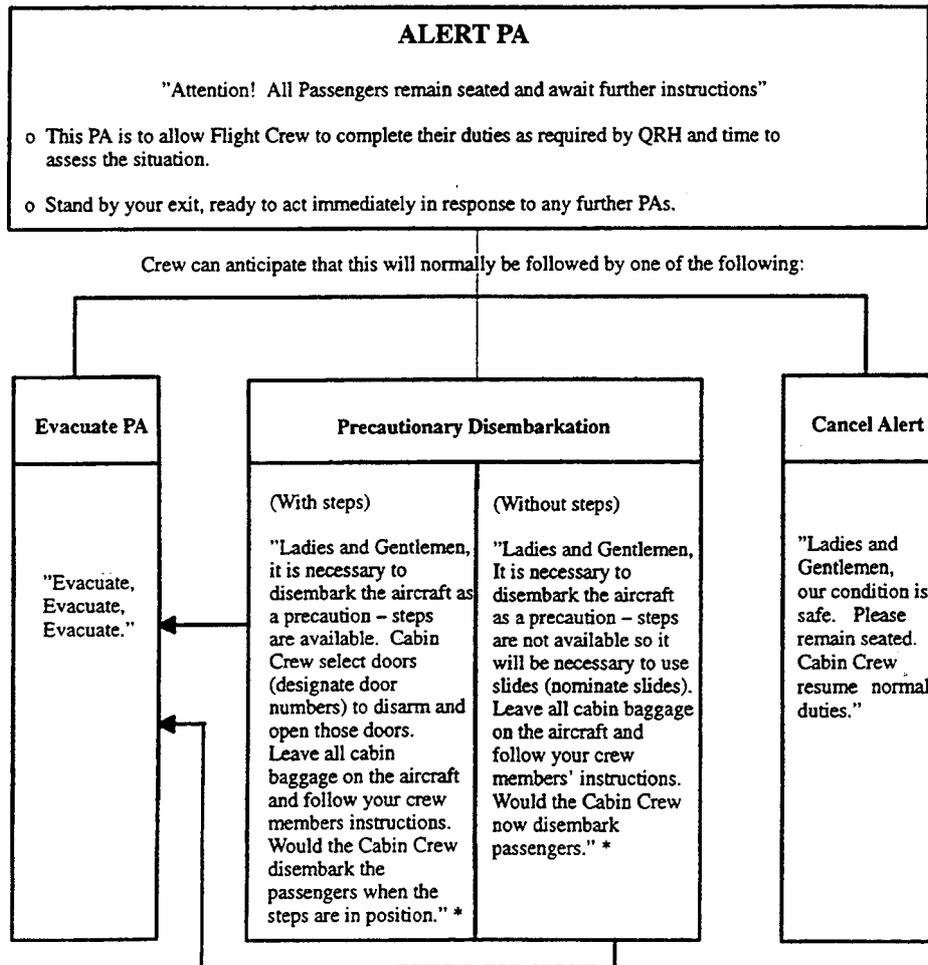
⁵⁸ NTSB, *Emergency Evacuation of Commercial Airplanes*, PB2000-917002, 2000.

Figure 9:
Description of types of emergency response (from Qantas AEPM, page 03.30.1)

LAND EMERGENCIES

EMERGENCY EVACUATION

Emergency PAs Overview



* Precautionary disembarkation may be upgraded to an "Evacuation" if the situation requires.

NOTE: The Evacuation PA may be given without an Alert PA if the situation requires. In severe, time critical, emergency situations the Captain may elect to initiate an evacuation as the initial PA.

Training personnel reported that, during emergency procedures training exercises, the decision had always been clear as to whether an evacuation or a precautionary disembarkation was required. The focus of the training was on the execution of the emergency response, rather than on the decision as to the type of response that was required for the emergency. They noted that the same situation applied to other areas of flight crew training in which emergency procedures were discussed, such as command training and recurrent simulator sessions.

Although no written guidelines or formal training exercises existed, Flight Operations Branch management personnel reported that they believed flight crew knew how to make the appropriate decisions regarding evacuations and precautionary disembarkations. Flight crew were provided with CRM training, which included components on gathering, reviewing and analysing information and then making decisions in a variety of other situations. Management personnel noted that a key criterion used by flight crew in terms of emergency response was that if there was any evidence of fire, then an emergency evacuation was required. They also noted that pilots had been made aware that an evacuation would usually result in some serious injuries.

2.5.3 Perceptions of the flight crew

During the investigation, the captain said that he wanted to 'hasten slowly' regarding the evacuation/disembarkation. He was aware that the aircraft had overrun the runway at about 80 kts, but perceived that the impact loads were quite low. After the aircraft came to a stop, he was aware that there was no lighting outside the aircraft. It was still raining heavily and the emergency services had not arrived. Initial indications on the flight deck were that there was no fire. Subsequent information he received soon after from the CSM and the second officer reinforced this view (see section 2.2.2). He was also aware that the cabin crew were prepared and at their doors. If there had been any indication of fire in the cabin, cabin crewmembers were trained to immediately initiate evacuations at their doors (see section 2.6).

The captain said that he preferred to wait for steps to disembark the passengers as this would lessen the danger of injury and seem 'more regular' to the passengers. He knew that there were very young children and elderly passengers on board, and he was aware that if he ordered an emergency evacuation there could be some panic and there would probably be some serious injuries. He also considered that, if he ordered an evacuation, the passengers might move toward the lights in the terminal area, which was beyond runway 21R. This meant that the passengers would cross a runway which was in use. The outside environment was dark and he was unsure of what hazards there might be.

The captain said that he did not receive any reports concerning 'fumes' in the cabin. If he had, he would have initiated an evacuation. He also said that, after he had disembarked, he was surprised at the extent of the nose-down attitude of the aircraft and by the amount of damage that the aircraft had sustained internally and externally, particularly the damage to the number 3 engine pylon. He indicated that, had he known the extent of the damage, he would have ordered an earlier disembarkation. However, apart from receiving advice from the cabin crew and emergency services personnel, he knew of no other way by which he could have obtained such information.

The other two pilots reported that they were involved in discussions with the captain regarding what type of emergency response was appropriate. They both agreed with the decisions that were made.

Observations:

Whether the crew should have initiated an immediate evacuation, an earlier precautionary disembarkation (e.g. when the emergency service vehicles first arrived), or precautionary disembarkation when they did requires comment. In very difficult circumstances, the flight crew made their decisions with the interests of the passengers' safety as their primary consideration. By initiating a precautionary disembarkation when they did, the crew was able to ensure an orderly process. The absence of any serious injuries during the disembarkation indicated that the result was consistent with the intention.

Although the flight crew considered a number of relevant factors in their decision making process, other factors appeared not to be given appropriate consideration. Most importantly, the crew did not appear to consider what gaps they had in their available information about the condition of the aircraft and possible hazards. They were not able to obtain any information from anyone outside the aircraft, and consequently had minimal information concerning the extent of external damage, particularly underneath the aircraft. The crew only knew that, at the least, the cabin communication systems had been damaged. However, any aircraft which overruns a stopway at over 80 kts is likely to sustain substantial damage. Although the crew had information that no signs of fire had been detected within the cabin, they had no clear understanding of the potential for a fire outside the cabin, particularly during the period before the emergency services arrived.

The flight crew's decisions were based on the information they received about the condition of the cabin. Important available information that did not reach the flight crew included the observations regarding flashes from an engine during the landing roll, the damage to the number 3 engine pod, cabin floor deformation, and the full nature of the 'fumes' detected in zone A. (These communication problems are discussed further in section 2.6.) The absence of information on these issues reduced the ability of the flight crew to make the best decision regarding an evacuation or precautionary disembarkation.

The lack of cabin interphone and PA systems clearly affected the communication process and the ability to gather accurate and timely information. The absence of any communication equipment would have hampered the ability to communicate clearly and quickly any immediate instruction or important information. However, if necessary, the crew could have initiated an evacuation at their individual doors, or a general command could have been issued by activating the evacuation alarm or by passing commands through the cabin.

A further aspect associated with the timing of the disembarkation was that there was no evidence that the crew considered the emergency battery life. Had this power source failed, it could have led to difficulties with passenger control and the disembarkation.

The crew's actions were an understandable response to the situation given the inadequate guidance provided by the company's procedures and training for making decisions regarding the nature of an emergency response when the appropriate choice is not clear. However, the risks associated with an emergency evacuation in this situation were probably outweighed by the potential risks associated with the information gaps, particularly regarding the nature and extent of damage to the aircraft during the period before the emergency services arrived. The most appropriate option in these circumstances would have been to conduct an immediate evacuation.

Many airlines do not include the 'precautionary disembarkation' in their procedures, having the 'emergency evacuation' as the only option available for crews. However, if an airline chooses to include the precautionary disembarkation in its procedures, then it should ensure that its crews are appropriately prepared for deciding when a precautionary disembarkation is appropriate.

2.6 Company operations: crew communications

The AEPM stated that an 'alert' phase existed when the appropriate PA call was made (see fig. 9). It also stated (page 03.30.2):

During this Alert phase decisions are being made regarding the appropriate manner to handle the existing situation.

Information about conditions in the cabin and outside the aircraft are essential to the Flight Crew at this time.

All information should be relayed immediately to the flight deck during this phase.

The AEPM also noted (page 03.30.4-5):

The Captain has the prime responsibility for initiating evacuation.

If Cabin Crew consider that an evacuation is necessary they must advise the Captain of the situation and await his/her direction.

If it is obvious that evacuation is imperative AND NO CONTACT WITH THE FLIGHT CREW HAS BEEN POSSIBLE, only then will Cabin Crew assume responsibility for initiating evacuation.

Therefore the Captain should keep the cabin crew and passengers fully informed of his/her intentions when any situation develops which may require an emergency evacuation or precautionary disembarkation.

It is essential for a cabin crewmember to contact the flight crew upon observing any situation which may endanger aircraft or passenger safety...

CABIN CREW SHOULD NOT INITIATE AN EVACUATION WITHOUT ATTEMPTING THIS COMMUNICATION.

In September 1996, a 'temporary revision' section of the AEPM titled 'Emergency Communications with the Flight Deck' was issued. This revision included the following paragraph:

The Flight Attendant unsuccessfully attempting emergency communication with the Flight Deck should advise the [CSM] of the situation by interphone. As soon as workload permits, the Flight Crew must call the [CSM] to obtain the information.

The AEPM stated that a precautionary disembarkation 'is an emergency and must be treated as such' (page 03.30.4). It also stated that commands used during the disembarkation must be 'loud', 'authoritative' and 'concise' (page 03.30.3).

The AEPM and other company manuals contained no other procedures or guidance for cabin crew in the following areas:

- How they should communicate with each other and the flight deck in emergency situations (in terms of technique, terminology, and methods to ensure that accurate information reached the flight deck).⁵⁹
- How to communicate during an emergency on the ground when there was a loss of PA and interphone communications.⁶⁰
- How to systematically and regularly identify problematic situations in an aircraft during an emergency (including guidelines on what types of information are most important and ensuring that all areas of the aircraft are examined).
- Leadership and coordination functions of the CSM and CSS in an emergency situation. For example, how the CSM and CSS should assess the situation (particularly in circumstances that had not been clearly defined), assign roles and responsibilities amongst the cabin crew, coordinate the gathering of information, and coordinate the distribution of information.

⁵⁹ For some specific emergency situations, the roles and responsibilities of the cabin crewmembers were clearly defined in the AEPM and were reinforced during practical training exercises. For example, there was a formally-defined drill to be followed in response to an in-flight fire (page 03.60.11).

⁶⁰ For the situation where an emergency landing was being prepared for in-flight, the AEPM stated that (in the event of the PA being unserviceable) the cabin crew primaries were to 'conduct individual briefings of passengers' in their zones, covering issues such as brace position, nearest exits, escape slides, and lifejackets and life-rafts (when applicable) (page 03.10.6 and 03.10.10).

- How to effectively obtain information from passengers concerning safety-related issues.
- How to effectively use language and assertiveness for crowd control and managing passenger movement towards exits during emergency situations (that were not an immediate evacuation).

The investigation found no evidence that the company's emergency procedures training or CRM training (see attachment G) provided cabin crew with detailed instruction in any of the points identified above.

Cabin safety personnel reported that the CSM and CSS would function as any other cabin crewmember during a land emergency in the event of some or any other cabin crewmember being incapacitated. An emergency situation in which there was an extended alert phase had not been considered when designing the company's emergency procedures and training.

Training personnel reported that cabin crew were made aware during initial training that if they saw, heard, smelled or felt anything unusual or potentially hazardous they should inform their supervisor or the flight crew. This was reinforced during recurrent emergency procedures training, particularly during the CRM modules.

Observations:

The loss of the PA and interphone systems was a novel and high-workload situation for the crew. They had received no specific training for such an event and there were no relevant company procedures. In the circumstances, the crew appeared to have adapted to the situation relatively well. Most of the doors were attended throughout, some relevant pieces of information were gathered and passed to the flight crew, and the cabin crew and passengers were given an adequate briefing on the situation soon after the accident.

However, some important information did not reach the flight crew (see section 2.5). Similarly, important information did not reach some cabin crewmembers. For example, some were not aware of the disembarkation commencing. In addition, although all the cabin crew treated the disembarkation as an emergency response, some considered that it was not a 'full' emergency. This was contrary to the information in the AEPM (see section 2.6.1).

Some cabin crew could have been more positive in passing on information that they had. However, to provide greater assurance that all relevant information was collected, the process of gathering information should have been more proactive. There was sufficient time to seek information from all cabin crew at regular intervals. Cabin crew could also have been specifically asked if they had information on key issues such as aircraft damage and smells/fumes.

The communication difficulties appeared to arise because there was no system or process in place to ensure that all potentially relevant information was collected and passed on. The CSM took on the role as being the primary information collector, information carrier and coordinator of activities in the cabin. The decision to assume these responsibilities would be a natural instinct for many people. However, it resulted in an excessive workload and restricted the communication channels. When the CSM was on the flight deck passing information on to the flight crew, cabin crew were not able to pass information on to him. His absence from the L2 position at times also meant that there was a gap in the information chain within the cabin. There were resources available to relay information and to ensure information was regularly and actively collected from all cabin crew. These resources included the assist cabin crew, the second officer, and other company personnel travelling as passengers. Alternatively, had the CSM had another cabin crewmember at his door position (i.e. an assist), then he would have been in a better position to manage the situation.

Procedures and training cannot cover all possible situations. However, effective communication is a fundamental component of emergency management. Crews should be provided with adequate tools and training to better equip them to adapt to situations and

ensure effective communication and coordination activities. In this respect, the company's procedures and training for flight and cabin crew were not adequate, even though the procedures were in excess of regulatory requirements (see also section 1.9.2).

2.7 Company operations: other issues

2.7.1 Brace position

There are two primary reasons for bracing for impact. One is to reduce flailing and the other is to reduce secondary impact. Secondary impact can be reduced by pre-positioning the body (particularly the head) against the surface it would strike during impact. Having occupants flex, bend, or lean forward over their legs in some manner can reduce flailing.

The FAA has noted that 'experience has shown that in an attempt to take a brace position of some sort, the passengers can end up in a position that could result in less injury than if no attempt had been made at all'.⁶¹

The AEPM contained the following information about the brace command (page 03.30.7):

BRACE COMMANDS

In an unprepared land or ditching emergency, brace commands may be initiated by flight or cabin crew. Cabin crew must synchronise these commands.

If impact is imminent, commands from cabin crew are:

- "Brace, brace, brace"
- "Heads down"
- "Stay down"
- "Heads down, stay down" is repeated until pax compliance or impact begins.

These commands must be given in unison to ensure they are understood above other noise.

Should flight crew be aware of imminent impact, the PA to be made is:

"Brace, brace, brace"

If PA UNSERVICEABLE in a prepared situation, passengers are briefed that when "Fasten Seat Belt" signs flash, assume brace position.

Company cabin safety personnel advised that the intent of the 'brace, brace, brace' command was to alert all cabin crew of imminent impact, and to signal them to initiate the 'heads down' and 'stay down' commands for passengers. During the investigation, some cabin crew indicated that they did not understand the distinction between the 'brace, brace, brace' call and the 'heads down' and 'stay down' calls.

The brace position was demonstrated in the Qantas pre-flight safety video. This video was screened in all sections of the cabin except zones A, B, and F. These zones had individual in-seat screens not suitable for use before takeoff. However, the audio instructions from the video could be heard in all sections of the cabin. In addition, all passengers were asked to read the safety information cards prior to takeoff. This card was located at each seat and depicted the brace position.

Neither the safety briefing card nor the pre-flight video mentioned the commands passengers would hear from cabin crew if they were required to adopt the brace position; nor was there a regulatory requirement to do so.

⁶¹ FAA, Advisory Circular 121-24B, *Passenger Safety Information Briefing and Briefing Cards*, 1999, Appendix 4.

Observations:

Only cabin crew located in zones C and D issued brace commands. Their positions were above the main landing gear where the transmission of impact shock and noise would have been greatest. Some cabin crew in those zones and in other zones heard the commands but did not join in the brace call. While the developing situation may not have been as clear in other parts of the cabin, there appear to have been sufficient indications for a greater number of cabin crew to call brace commands before the aircraft came to a stop.

Neither the company's *Aircrew Emergency Procedures Manual*, nor the cabin crew training process, clearly reflected the distinction between, and intent of, the 'brace, brace, brace' call and the 'heads down' and 'stay down' calls. Similarly, the importance for crewmembers to issue the commands even when they were uncertain of the precise nature of the situation, or when their field of view of the cabin was limited, was not emphasised.

2.7.2 Handling passengers with special needs

Four passengers were designated on the passenger list as wheelchair passengers. All were mobile to some extent, but required special assistance. CASA regulations required that 'handicapped'⁶² passengers, and passengers travelling with them, receive an individual pre-flight safety briefing regarding procedures to be followed in the event of an emergency evacuation of the aircraft (CAO 20.11, paragraph 14.1.2 and 20.16.3, paragraph 15.2(c)). The four wheelchair passengers reported that they did not receive an individual safety briefing.

During the investigation, cabin crew reported that wheelchair passengers were boarded during the normal boarding of passengers. One cabin crewmember reported that the wheelchair passengers did not receive an individual briefing before takeoff due to time constraints of other duties.

The AEPM section 1.30.4 stated that the individual briefings were usually done before other passengers boarded the aircraft.

2.8 Analysis

2.8.1 Active failures and local factors

The management of the situation after the aircraft stopped, or in the cabin during the landing, did not have any direct impact on the development of the actual accident. However, there were a number of active failures that had the potential to increase the severity of the consequences associated with the accident. Three of these were considered to have had a significant potential for increasing the severity of the accident's consequences:

- The cabin interphone and PA systems became inoperable (see section 2.4).
- The flight crew did not consider all relevant issues when deciding not to conduct an immediate evacuation (see section 2.5).
- Some crewmembers did not communicate important information during the emergency period (see section 2.6).

⁶² CAO 20.16.3, paragraph 2 provides the following definition: 'A handicapped person is a person requiring special attention because of illness, injury, age, congenital malfunction, or other temporary or permanent incapacity or disability which makes that person unable without special facilities or assistance to utilise air transport facilities and services as effectively as persons who are not so afflicted.'

Contributing factors and the potential effects of these active failures are discussed in sections 2.4, 2.5 and 2.6. They are also summarised in fig. 10.

There were several other active failures that had the potential to affect the consequences of the accident. These are listed below in chronological sequence rather than in any order of priority:

- Special needs passengers were not specifically briefed.
- The CSM started to conduct a PA announcement during the landing roll.
- Some cabin crew did not call out appropriate brace-related commands when they probably had sufficient indications to do so.
- A number of ceiling panels and PSUs were dislodged in the cabin during the impact sequence.
- Two doors were left unattended during a critical emergency period. Crew left their assigned emergency stations to check passengers in the immediate area, to relay messages throughout the cabin, and during the disembarkation, to assist other crewmembers.
- The L3 and R3 doors were opened when there was still a likelihood that an evacuation would be required (thus affecting the availability of the emergency slides at those exits).
- The emergency service vehicles did not reach the aircraft until 10 minutes after the accident.
- There were inconsistencies in the control of passengers during the evacuation with respect to cabin baggage and escape slide instructions.
- Control of the passengers after they left the aircraft was inconsistent and in some cases passengers were not given appropriate directions.

The reasons why these active failures were problematic together with the factors that contributed to them, are discussed in the 'observation' boxes in section 2.2 and 2.7. As these active failures were not considered to be significant factors, they are not analysed further in this report.

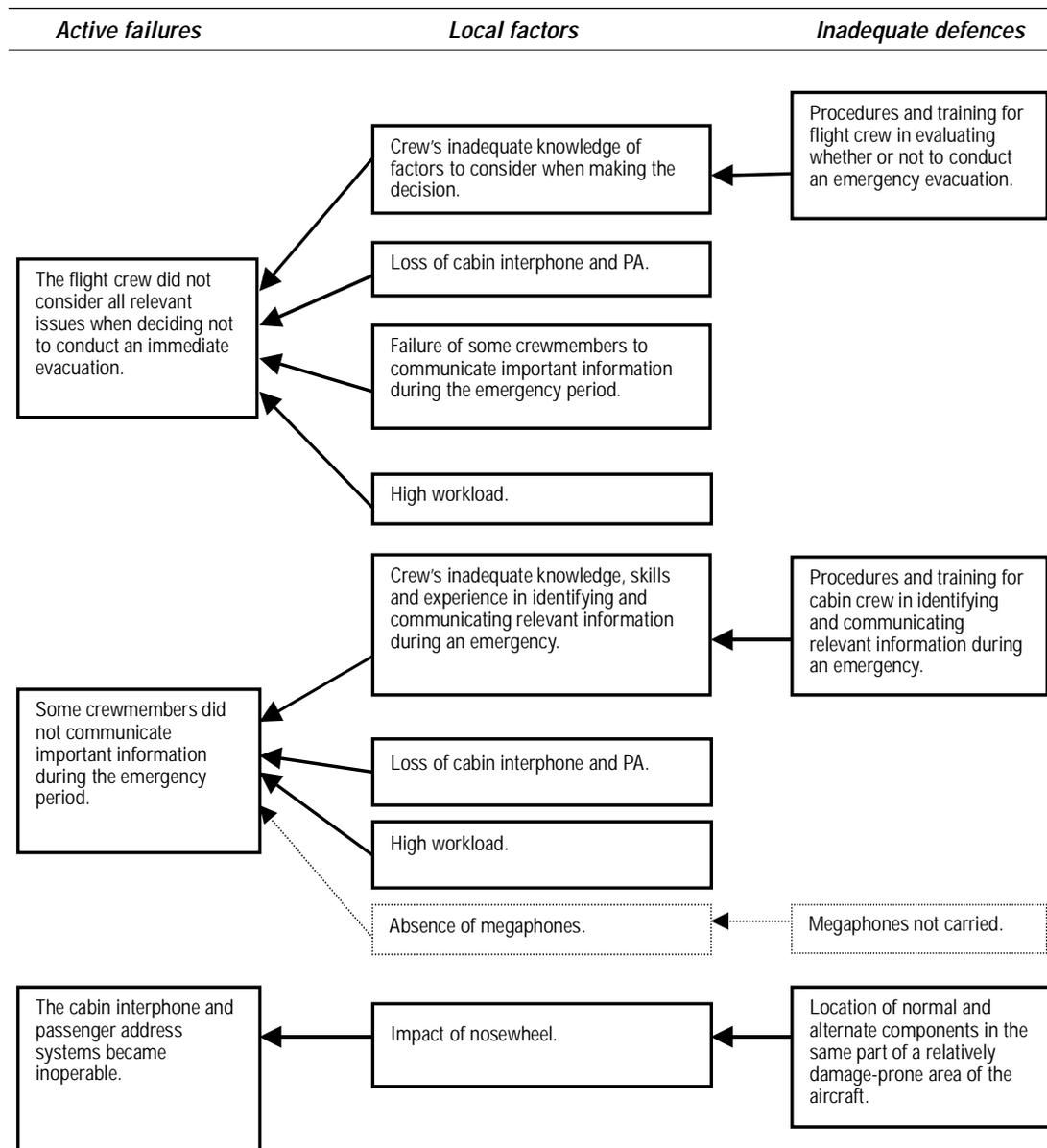
2.8.2 Inadequate defences

The failure of the PA and cabin interphone systems had a significant, direct impact on the performance of the flight and cabin crews. The primary defence that failed in this instance was the positioning of the normal and alternate components of these systems in the same damage-prone location in the aircraft.

The inadequate defences that contributed to the other two significant active failures related to company procedures and training. More specifically, the inadequate defences were in the following areas:

- Procedures and training for flight crew in evaluating whether or not to conduct an emergency evacuation.
- Procedures and training for cabin crew in identifying and communicating relevant information during an emergency.

Figure 10:
Summary of active failures, local factors and inadequate defences associated with post-accident events and cabin safety issues (significant factors are in fully closed boxes)



3. ORGANISATIONAL FACTORS: QANTAS

Parts 1 and 2 identified four significant inadequate defences that influenced the behaviour of the flight and cabin crew:

- company-published information, procedures, and flight crew training for landing on water-affected runways;
- flight crew training for evaluating the procedural and configuration options for approach and landing;
- procedures and training for flight crew in evaluating whether or not to conduct an emergency evacuation;
- procedures and training for cabin crew in identifying and communicating relevant information during an emergency.

Part 3 addresses the management decisions and operational processes within the Qantas Flight Operations Branch that gave rise to these inadequate defences. It focuses on the activities of the Flight Operations Branch because this Branch was responsible for the crew procedures and training associated with the inadequate defences listed above. Background information on the structure and functioning of the Flight Operations Branch and other operational areas of the company is provided in attachment G.

The significant organisational factors which were identified fall within the following five areas:

- hazard identification
- risk assessment
- change management
- design of procedures and training programs
- management culture

Towards the end of 1997, the then chief pilot initiated a series of changes to the Flight Operations Branch's activities. These included an external review of management systems as part of a process of introducing a quality assurance system into the Branch (March 1998). Related changes included the devolvement of the Flight Standards Department, an external review of flight safety processes (July 1999), and ongoing changes to flight training. Attachment G and part 5 provide further details.

3.1 Hazard identification

3.1.1 Organisational awareness of the deficiencies

It became evident from interviews that Flight Operations Branch management personnel were largely unaware of the deficiencies in procedures and training that were identified during the investigation (see parts 1 and 2).

Management personnel reported that procedures for operations onto water-affected runways had been more heavily emphasised during training and line operations in previous years, particularly in the 1960s and 1970s. However, with advances in aircraft braking system technology and the construction of longer runways, there had been a gradual reduction in the training emphasis given to these issues. As a result, pilot (and company)

awareness had decreased. Managers believed this reduction in company awareness was not restricted to their airline, but was common across the airline industry.

During the investigation, information was obtained from six other major B747-400 operators regarding their procedures for landing on water-affected runways and their landing configuration procedures (i.e. flap and reverse thrust settings). An examination of this information showed that these airlines published more comprehensive information for crews and/or had in place more conservative procedures in relation to landing on water-affected runways (see attachment I).

3.1.2 Hazard identification processes

Incident reporting and investigation. The *Qantas Flight Administration Manual* (FAM) specified that an aircraft captain was required to submit an air safety incident report (ASIR) to the company whenever an incident occurred (page 20–1). The FAM also specified the types of events that should generate an ASIR. ‘Loss of braking action’ was one of these events. During interviews, management personnel reported that in the past few years, there had been much effort in emphasising to line pilots that a ‘no blame policy’ was employed by the Flight Safety Department in investigating reported incidents. They also stated that all ASIRs submitted by company pilots were forwarded to the ATSB.

As part of the investigation, a search of the ATSB occurrence database was conducted for all occurrences involving Qantas B747-400 aircraft from the period January 1995 to the date of the accident. The search revealed no reports involving speed control associated with flap selection during approach, a degradation of braking action on a water-affected runway, or any other aspect that could be related to the inadequate defences identified in section 1 of the report (see section 1.9.2).

As part of the survey of company B747-400 flight crew, pilots were asked, ‘have you ever been involved in an occurrence that made you feel uncomfortable?’⁶³ Based on the limited information provided in the responses, there appeared to have been at least 10 events involving a loss of effective braking action, landing long, or some other operational factor that reduced the available landing distance. Other anecdotal evidence of similar events was reported during interviews with some company pilots.

In July 1999, the Flight Operations Branch commissioned an external review of its flight safety processes. The review report noted that there was anecdotal evidence that the incident reporting culture in the airline was not strong, with flight crew appearing to report through the ASIR system only those incidents for which they believed a mandatory reporting requirement existed.

Interviews with both management and line pilots confirmed that crews were generally reluctant to report incidents that may have involved (or been perceived to involve) crew performance issues.⁶⁴

Flight crew reports. The company required captains to submit a Flight Crew Report addressing any matters of concern arising during a trip, including safety issues that did not require an ASIR. The July 1999 review of flight safety examined approximately 500 Flight Crew Reports and noted that only five contained information concerning a potential safety hazard. The remainder of the reports dealt with administrative concerns rather than operational issues.

⁶³ The majority of questions in the survey focussed on approach and landing issues, and therefore most of the anecdotes reported also dealt with these phases of flight.

⁶⁴ This situation is not restricted to any one airline.

During the investigation, management personnel acknowledged that flight crew rarely used Flight Crew Reports to identify safety hazards. There had been no formal surveys of flight crew to identify specific safety deficiencies in the operational system. However, informal reports of safety issues by pilots to fleet or safety management were received several times a week. Most management personnel had not received any informal reports of safety concerns associated with the inadequate defences discussed in parts 1 and 2. Some managers received negative feedback concerning the introduction of the flaps 25/idle reverse procedures (see 'training needs analysis' below).

The July 1999 review of flight safety also noted that there was no consistent method of recording Flight Crew Reports or other reports, or any evaluations and remedial action generated by these reports.

Observations:

Establishing incident and hazard reporting systems with full involvement from all personnel is a difficult task. Some individuals will always be reluctant to submit reports. However, had some of the anecdotal events highlighted during the investigation been reported by ASIR, safety action relating to the inadequate defences may have resulted.

Quick access recorder analysis. Quick access recorders (QARs) were fitted to all the company's B747-400 aircraft. Data from a sample of flights was routinely examined to determine whether certain events (termed 'exceedances') had occurred. By monitoring the patterns of exceedances, problematic trends could be detected and remedial strategies applied. Results summarising the number, rate (per 1,000 sectors sampled) and types of exceedances were provided to management and safety personnel within the Flight Operations Branch on a monthly basis. The list of identifiable events, and the overall process of obtaining the data without identifying the crew, had been developed in consultation with the Australian and International Pilots' Association (AIPA). For the B747-400, the company monitored 40 parameters or types of events. The list of events did not include 'long landings' or 'loss of braking action'.

During the investigation, Qantas advised that it had not systematically evaluated QAR data using formal statistical methods prior to the accident. According to Flight Safety Department personnel, the QAR system had been occasionally used for planned evaluations of specific issues following a change in procedures or other operational issues. However, no evaluations beyond the routine examinations had been conducted for the flaps 25/idle reverse procedures. The company's QAR program for the B747-400 aircraft had not identified any problems associated with the approach and landing phases following the introduction of these procedures.

As part of the accident investigation, the data on two parameters before and after the introduction of the flaps 25/idle reverse procedures in December 1996 were reviewed. The parameters were:

- Parameter No. 159. Approach speed high: 500 ft above ground level (AGL) to 50 ft AGL. A 'soft' alert was equal to V_{REF} plus 30 to 35 kts for 3 seconds or more. A 'hard' alert was greater than or equal to V_{REF} plus 35 kts for 3 seconds or more, and
- Parameter No. 161. Approach speed high: below 50 ft AGL. A 'soft' alert was equal to V_{REF} plus 15 to 20 kts for 3 seconds or more. A 'hard' alert was greater than or equal to V_{REF} plus 20 kts for 3 seconds or more.

The monthly counts of hard alerts, soft alerts and the sectors sampled were obtained for the period from January 1994 to December 1999. The number and rate of hard and soft alerts for both parameters are presented for each year from 1994 to 1999 in table 8. The data were

averaged per year as the data on a month-to-month basis were quite variable. The higher number of alerts for parameter 161 relative to parameter 159 was probably due to the lower level of deviation required (i.e. V_{REF} plus 15–20 kts versus V_{REF} plus 30–35 kts). The number of alerts for parameter 159 was too low to permit any meaningful statistical analysis.

Table 8:
Number (and rate per 1,000 sectors sampled) of QAR ‘alerts’ associated with high approach speed

Year	Sectors sampled	Parameter 159			Parameter 161		
		Hard	Soft	Total	Hard	Soft	Total
1994	10,104	2 (0.2)	0 (0.0)	2 (0.2)	4 (0.4)	96 (9.5)	100 (9.9)
1995	8,730	1 (0.1)	1 (0.1)	2 (0.2)	2 (0.2)	63 (7.2)	65 (7.4)
1996 ⁶⁵	10,212	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.2)	80 (7.8)	82 (8.0)
1997	8,553	1 (0.1)	1 (0.1)	2 (0.2)	8 (0.9)	92 (10.8)	100 (11.7)
1998	7,251	1 (0.1)	3 (0.4)	4 (0.6)	2 (0.3)	80 (11.0)	82 (11.3)
1999	8,207	1 (0.1)	5 (0.6)	6 (0.7)	6 (0.7)	89 (10.8)	95 (11.6)
1994–96	29,046	3 (0.1)	1 (0.0)	4 (0.1)	8 (0.3)	239 (8.2)	247 (8.5)
1997–99	24,011	3 (0.1)	9 (0.4)	12 (0.5)	16 (0.7)	261 (10.9)	277 (11.5)

In terms of the total rate of alerts for parameter 161, there appeared to be a small decrease after 1994, and then an increase from 1997. The flaps 25 procedure was introduced on 6 December 1996. The difference in the rate between 1996 and 1997 was statistically significant.⁶⁶ The overall average rate in the 3 years up to (and including) December 1996 was 8.5, whereas the average rate in the 3 years after this period was 11.5, an increase of 35%.

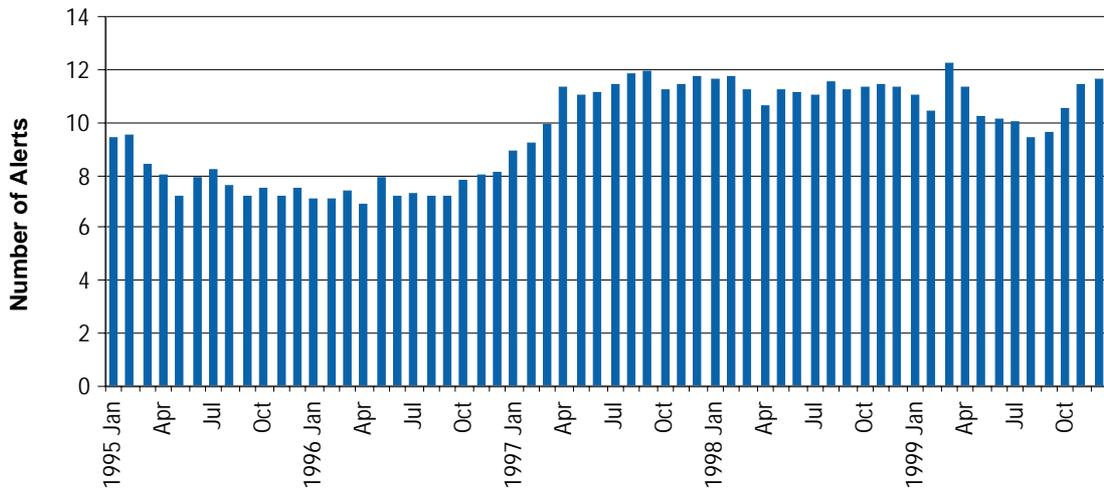
Fig. 11 shows the 12-month moving average rate of parameter 161 alerts for the period from January 1995 to September 1999. That is, the data point for each month represents the rate of parameter 161 alerts for the preceding 12 months (including that month). This figure indicates that an increase occurred near the end of 1996.

During the investigation, Qantas noted that the data acquired for high-speed approaches was not adjusted for environmental conditions. For approaches conducted where a high wind factor was present, it was allowable for the crew to increase the approach speed beyond the V_{REF} target. This reference ground speed technique was part of normal Qantas operational procedures. Qantas stated that its examination of the flight data for ‘hard alert’ events related to approach speed had found that, in most cases, environmental conditions were responsible. Qantas also suggested that the increase in soft alerts for parameters 161 could also be attributed to environmental conditions.

⁶⁵ The flaps 25 procedure was introduced on 6 December 1996. There were nine soft alerts for parameter 161 during this month (out of 897 samples). If this month is removed, then the number and rate of parameter 161 alerts during 1996 was 73 and 7.8 respectively.

⁶⁶ For the comparison between January to December 1996 and January to December 1997 for parameter 161, the Chi Square value was 6.5. This value was interpreted as statistically significant (probability equals 0.01, with one degree of freedom).

Figure 11:
Twelve-month moving average of the rate of parameter 161 alerts



Observations:

The absolute rates of both QAR events listed in table 8 were low. However, statistical analysis indicated that there was a significant difference in the number of alerts for parameter 161 before and after the flaps 25/idle reverse procedures were introduced (December 1996).

The exact reasons for the increase in parameter 161 alerts could not be determined. It is unlikely there was a general change in environmental conditions after December 1996 that resulted in a noticeable increase in the rate of alerts, and was then maintained at a higher level. However, due to the timing of the change, it is reasonable to conclude that the use of flaps 25 (rather than flaps 30) was one of the issues involved. Although the actual flap configuration used on each occasion could not be verified, it is reasonable to conclude, based on the information in section 1.7, that flaps 30 was used almost exclusively before December 1996 and flaps 25 was used predominantly after 6 December 1996.

Regardless of the actual reasons for the increase in 161 alerts, the company's monitoring of QAR data had not detected the increase. The company did not use QAR information to proactively monitor the possible influence of the flaps 25 procedure, and it had not systematically evaluated QAR data using formal statistical methods before the accident. Had it conducted such activities, the increased frequency of high-speed approaches would probably have been detected. The exact reasons for the increase could then have been investigated.

Training needs analysis. During interviews, management personnel indicated that there was no formally defined procedure for developing the content of new simulator exercises and other training programs. The process generally involved the relevant training manager developing the program in line with regulatory requirements, after considering input from various sources. These sources could include comments from check-and-training personnel and fleet management, discussions during training section meetings (every 4 months), incident reports, QAR trends, and changes in regulatory requirements or procedures.

Check-and-training personnel indicated that any problems they noticed would be passed to the training manager or discussed with other personnel. Such issues could also be raised at training meetings. However, there was no formal process for proactively surveying check-and-training personnel to identify possible problems or common themes.

In mid-1999, two senior pilots expressed concern to the Manager B747-400 Training and some other managers that, in certain situations, some first officers did not appear to be considering flaps 30 and full reverse as intelligent options when conducting approach briefings. This issue was raised during the B747-400 training staff meeting in May 1999, and check-and-training staff were asked to 'encourage and develop airmanship' in this area. This instruction was recorded in the minutes of the meeting, which were available to all B747-400 check-and-training personnel. However, during the investigation, a number of check-and-training personnel stated that they could not recall the issue being discussed.

Operational surveillance and audits. Until 1999, the Flight Standards Department (within the Flight Operations Branch) conducted surveillance of line operations and simulator sessions (see attachment J). Observations on these sessions were submitted every bid period to management personnel. Several management personnel reported that the line surveillance conducted by Flight Standards and CASA was of limited value. (This issue is discussed further in section 4.3 and attachment J.)

In 1998, Flight Operations Branch commissioned a review of its management systems as part of a process of moving towards a quality assurance system. The report was completed in April 1998. The review noted that there was frequent checking or surveillance of pilot performance, and auditing to check compliance with regulations. However, not all functions of the branch were audited. The July 1999 review of flight safety noted that safety audits were done from time to time, but not all functions were periodically assessed. The safety program as a whole was not regularly reviewed.

During the investigation, management personnel advised that there was no systematic audit plan for safety issues in the Flight Operations Branch. Audits were done on specific issues as deemed necessary, generally after concerns had been raised about that issue. No recent audits on issues concerning the inadequate defences associated with the accident were identified during the investigation.

Observations:

The Flight Operations Branch had in place a number of processes for identifying operational hazards or deficiencies. These processes had proved successful in ensuring the operator maintained a high level of safety in many areas. However, the processes were predominantly reactive and/or informal. There was no systematic program for evaluating the operational system and actively searching for hazards and deficiencies. As a result, the organisation was ultimately not able to identify all of the deficiencies in its operational system, including the inadequate defences that were identified during this investigation (see parts 1 and 2).

3.2 Risk assessment

The Australian Standard on risk management (AS 4360:1999)⁶⁷ defines risk as the 'chance of something happening that will have an impact upon objectives'. Risk is generally considered to be a combination of adverse consequences and the likelihood of those consequences arising. Risk assessment⁶⁸ is a central component of risk management. It is the process of determining the level of risk, and evaluating the extent to which this level of risk is acceptable. Risk assessments can be conducted in many different ways. However, it is generally recognised that a structured risk assessment process that considers all relevant aspects will provide greater safety assurance than an unstructured process.

⁶⁷ AS4360 was first issued in 1995.

⁶⁸ The term 'safety case' is often used synonymously with 'risk assessment'. However, a safety case is generally expected to also contain information on how the assessed risks are to be managed.

To some extent, risk assessment is an activity undertaken by everyone and every organisation as part of their normal activities. Formal risk assessment processes have been widely used in Australia in some industries for many years. However, such processes have not generally been part of airline flight operations in Australia.

3.2.1 The operator's approach

Management personnel reported that the Flight Operations Branch did not have any formal procedures for conducting risk assessments of identified hazards to existing operations or new procedures. They indicated that risk assessment was a 'new science' to them, and they had only become aware of it in 1999. They believed that, despite the lack of formal processes, their Branch had effective processes in place for assessing the safety impact of issues, particularly with respect to the development of new procedures.

Management personnel reported that proposals for change could originate from a variety of sources, such as CASA and Boeing, or from management, training or line personnel. Proposed changes to operational policies and procedures were processed through a series of independent management groups—the Operations Procedures Committee, the Flight Operations Policy and Procedures Review Board, and the Chief Pilot. The Operations Procedures Committee was chaired by the General Manager Flight Technical, and was composed of several other management pilots and AIPA representatives. The committee coordinated the development of standard operating practices and procedures. The review board consisted of several senior managers within the Branch. Its role was to review and approve the implementation of proposed changes or additions to flight procedures and operating policy, including items processed by the Operations Procedures Committee.

Before May 1999, there were no requirements concerning the format of proposals. Subsequently, proposals had to be forwarded through a department manager, and had to contain supporting documentation (such as manufacturers' recommendations or industry standards) and an implementation plan.

The committees used no formal methods to assess the risks associated with proposals. Management personnel stated that decisions were made on the basis of operational experience. They had not been provided with any training or guidelines in risk assessment processes. The extensive operational expertise on each committee, and the series of independent review steps, helped ensure that any changes were thoroughly evaluated. Further, they expressed the view that the airline was inherently conservative in nature and that the safety aspects of any changes were always thoroughly considered.

The March 1998 review of management systems noted that the Flight Operations Branch had a stronger emphasis on identifying problems than on assessing and solving the 'root cause' of problems.

During the investigation, Qantas reported that it had commenced development of formal risk management processes in August 1999 (see also section 5.11.2). The company advised that this development was part of its ongoing safety management system development. AS4360:1999 formed the basis of this policy development.

3.2.2 Risk assessment of the flaps 25/idle reverse procedures

In a broad sense, Flight Operations Branch was aware that the risks associated with the flaps 25/idle reverse procedures needed to be considered in its evaluation of the proposal. The prime factors considered during the review process (see attachment H) were that flaps 25 was a certified flap setting, that the landing data did not include the use of reverse thrust,

and that some other major airlines had adopted similar procedures. Some personnel considered that the decision to implement the new procedure would probably have not been any different had a formal risk assessment been conducted.

In attachment H, the conclusion is drawn that the informal risk assessment process used by the company in evaluating the flaps 25 and idle reverse proposals contained several weaknesses. These included:

- There is no evidence that Qantas had sought Boeing's opinion regarding the safety impact of the new procedures and their potential effect on carbon brake wear. Management personnel agreed that Boeing's opinion on such issues would be useful, and that they would normally consider the manufacturer's opinion before changing procedures. Boeing has since stated that it does not support the use of idle reverse thrust as a normal procedure as it increases landing distance. It has also stated that modified braking techniques alone would produce almost as much reduction in brake wear as the combined effect of the flaps 25/idle reverse procedures.
- Qantas examined the flaps 25/idle reverse procedures of two other operators as part of the project development process. This examination was incomplete and did not identify that the procedures used by these operators were more conservative than the proposed Qantas procedures, and had additional safeguards in place for operating on water-affected runways (see airlines D and E in attachment I).
- The performance differences between idle and full reverse thrust, and between flaps 25 and flaps 30, were not fully examined. Such an examination would probably have highlighted the significant differences in landing distance on wet or contaminated runways using these various configurations.
- There is no evidence that a systematic attempt was made to identify all the situations for which flaps 30 and/or full reverse thrust would be more appropriate.
- The term 'contaminated' was used in the flaps 25 procedure but was not defined.
- There appears to have been no review of the human factors implications of the new procedures. For example, there appears to have been no consideration of the extent to which the use of flaps 25/idle reverse could become a skill-based habit (i.e. 'the norm'), and therefore might be used by crews when a more conservative configuration was required.

As discussed in section 3.1.2, two senior personnel reported problems with the training of flaps 25/idle reverse procedures in mid-1999. However, there is no evidence that any follow-up action was obtained to assess the significance of this potential hazard.

Observations:

The Flight Operations Branch did not have in place a systematic process for assessing identified risks in its operations. The process of using expert judgement at a series of independent levels probably ensured that most problems associated with new procedures were identified, analysed and evaluated. The shortcomings in the development of the flaps 25/idle reverse procedures clearly indicated the limitations of relying on an informal process. The approach outlined in AS 4360:1999 is highly desirable.

3.3 Change management

An appropriate risk assessment is an integral part of the successful introduction of significant changes to procedures or other aspects of an operational system. Several other processes, such as project management, the development of appropriate corrective measures (e.g. training), and post-implementation evaluation are also required.

The investigation did not identify any formal processes within the Flight Operations Branch for implementing and monitoring changes to procedures or other parts of the operational system. Personnel responsible for project management/change management activities were not provided with any training or guidelines in these areas until August 1999. The March 1998 review of management systems noted that, following the implementation of changes, there appeared to be a lack of visible follow-up action to check whether the changes were effective. The July 1999 review of flight safety drew similar conclusions.

A number of management personnel were consulted about the design of the flaps 25/idle reverse procedures during the development process. Flight crew were also informed of the proposed changes through two newsletters. However, as discussed in attachment H, the process of introducing and evaluating the effects of the new procedures contained a number of deficiencies. In addition to problems with risk assessment (section 3.2) and the design of the procedures (section 3.4), there were the following deficiencies:

- The documentation of the project and its history was disorganised and incomplete. The information was distributed across many files. There were no records of many conversations or meetings held concerning the project. There was no record of the timing and reasons for key decisions, such as the decisions not to use partial reverse thrust and not to conduct any training in flaps 25 approaches.
- The pre-implementation evaluation of flight crew training needs was informal, undocumented and limited in scope. The evaluation appeared to be based on test flights in the simulator conducted by a small sample of experienced pilots (see attachment J). The basis of their analysis was not documented. There was no evidence that the analysis considered how pilots evaluated approach configuration options. There was also no evidence that the opinions of line pilots were considered.
- The post-implementation review of the effects of the changes was shallow, informal, and undocumented. Flight crew were asked in newsletters to provide feedback. Fleet management received limited written and verbal feedback. Although mainly critical in nature, this feedback appeared to be disregarded as the number of sources was relatively small, and many of the sources were perceived to be resistant to change. There was no method of actively obtaining information from flight crew or check-and-training personnel. It is reasonable to conclude that a more detailed and positive feedback program would have identified the strong views of many line pilots about the operational benefits of flaps 30 over flaps 25 (see section 1.7). Such a process should also have identified the lack of flight crew understanding of aspects of the procedures, such as the meaning of the term 'contaminated runway'.

Observations:

The Flight Operations Branch did not have in place an appropriate system to manage organisational change. This resulted in deficiencies in the development of the flaps 25/idle reverse project and the implementation of the new procedures. These organisational deficiencies contributed to the development of the inadequate defences associated with the flaps 25/idle reverse procedures.

As part of the investigation, two other organisational changes initiated by the Flight Operations Branch were examined: the devolution of the Flight Standards Department (see attachment J), and the change in frequency of recurrent simulator checks from every three months to every four months (see attachment G). No link was evident between these changes and the development of the accident.

3.4 Design of operational procedures and training programs

Parts 1 and 2 concluded that the company did not provide flight and cabin crew with adequate procedures and training in several important areas. Clear, easy-to-follow guidelines would have assisted crew decision making. To assess this issue, an examination of the company approach to designing procedures, other operational documentation and training was undertaken.

3.4.1 Flight crew procedures and training

Before 1985, the company developed its own operations manuals. Since then, company policy had been to use Boeing operating procedures as far as possible. However, there remained some areas where Qantas and Boeing procedures differed. Management personnel noted that Boeing procedures were generally designed for the 'less sophisticated' operator and believed that Qantas had the expertise to develop its own procedures where necessary. Nevertheless, Qantas regarded Boeing's views as important and would generally seek its opinion before adopting different procedures. There was no formal policy within Qantas for documenting the differences between their procedures and those of Boeing, or why these differences existed.

During interviews, Flight Operations Branch management was unable to explain why the Boeing advisory information for landing on slippery runways (see section 1.4.8) had not been included in Qantas aircraft operations manuals. Some managers reported that the company was reluctant to publish advisory information, as pilots could possibly interpret such material to mean that it was safe to land when it was not. Another view was that advisory information was not 'certified' or 'approved' data.

Management personnel were asked why operations manuals did not include guidance information to assist the decision-making processes of flight crews when confronted with evacuation/precautionary disembarkation options (section 2.5). They reported that the range of potential situations was very broad and that it would be difficult to provide guidance information for all these situations. In practice, they relied on the experience and judgement of flight crews, particularly aircraft captains, to make such decisions. To provide more prescriptive guidelines could hinder rather than assist captains to make the best decisions. They also noted that flight crew received CRM training, which included components on gathering, reviewing and analysing information and then making decisions in a variety of situations.

Similar views were expressed regarding 'airmanship considerations' for the initial flaps 25/idle reverse procedures (see attachment H), and 'abnormal conditions' for the later idle reverse procedure (section 1.7).

As noted in section 3.1, the method of identifying training needs was primarily reactive and informal.

3.4.2 Check-and-training pilot procedures and training

The *Qantas B747-438 Flight Crew Simulator Training Manual* contained an outline for each simulator training session. The outline included a list of the exercise content (manoeuvres and discussion items) as brief dot-point items, and notes or details on the scenario to be followed for instructors. The notes did not provide any expansion on the brief dot point items (see section 1.7.2). Check-and-training personnel were not formally provided with any other information about what aspects of each manoeuvre or discussion point they were

meant to evaluate or provide information on. Furthermore, the manual contained no objectives or learning outcomes to be achieved in particular simulator training sessions.

On appointment, a check-and-training pilot underwent a 2-day course on 'training skills development' and a 1-day CRM refresher course (if they had not attended such a course recently). Each check-and-training pilot also received individual training, practice and feedback on check-and-training roles and responsibilities. The company provided some check-and-training personnel with a 5-day course on CRM principles, CRM evaluation and facilitation in the early 1990s. No similar training had been provided since, and check-and-training personnel were not provided with any refresher training in CRM or CRM evaluation. The Flight Training Department made LOFT assessment forms available to check-and-training personnel, together with a memory aid to facilitate crew involvement in the debrief of these sessions. During interviews, many check-and-training personnel indicated that they did not use these tools on a regular basis during simulator training.

The importance of providing check-and-training personnel with training on CRM evaluation and facilitation has been noted in industry publications.⁶⁹

3.4.3 Emergency procedures

During the investigation, company cabin safety personnel commented that the design of emergency procedures and emergency procedures training was developed in a similar fashion to other operational procedures. They also reported that Qantas exceeded regulatory requirements in some areas. For example, CRM training had been introduced for all cabin crew in recent years (see attachment G). However, in general, the company training was designed to meet the Australian regulatory requirements (which were inadequate in many areas, see section 4.2) rather than reflect leading world practice in this area. In addition, cabin safety issues had not always been given a high profile in the Flight Operations Branch, which was responsible for the development and conduct of the cabin crew training.

Some cabin safety personnel also noted that 1 day of recurrent training in emergency procedures was not a desirable situation, particularly with the introduction of CRM and other course content in recent years into the training day. As a result, the time available to conduct practical emergency procedures training exercises meant it was often difficult to evaluate the competency of staff in some areas.

During an audit in November 1999 (see section 5.12), CASA noted that there was a 'substantial deficiency' regarding the control of the Qantas AEPM. In particular, there were no formalised or documented procedures regarding responsibility for manual control or manual revision. Company cabin safety personnel also commented negatively regarding the status of the AEPM and the attention it received.

Observations:

The development of operational procedures and training programs lacked structured processes. The lack of appropriate guidelines for flight crew, check-and-training pilots and cabin crew on important operational and emergency procedure issues (see parts 1 and 2) appeared to result, at least in part, from a company philosophy of relying on the expertise and decision-making abilities of these operational personnel. Such a philosophy may have provided an acceptable outcome in most situations; however, it did not demonstrate an appreciation of the potential for crew performance to be variable, particularly in high workload situations.

⁶⁹ For example, ICAO, *Cockpit Resource Management and Line-Oriented Flight Training*, Circular 217-AN/132, 1992.

3.5 Management culture

3.5.1 Decision-making style

As noted in sections 3.3 and 3.4, there were no formal or structured processes in place within Flight Operations Branch for risk assessment or change management processes. During interviews, company personnel indicated that Flight Operations Branch management decisions were usually made informally and on the basis of experience and judgement. The reasons for decisions were often not documented. Some described the decision making as 'intuitive' and 'personality-driven'.

Several personnel noted that decisions were usually made without consultation with line pilots and without utilising the best expertise that was available within the company. This expertise included personnel with tertiary qualifications or other advanced training in aeronautical engineering, instructional design, test flying, teaching, human factors and other areas.

The March 1998 review of management systems noted that the 'modus operandi' of management appeared to be reactive rather than proactive. It also noted that the competencies required of management personnel were not defined. It recommended that these competencies be defined, and that a training needs analysis for these personnel be conducted.

The investigation team noted that all but one of the senior managerial positions within the Flight Operations Branch were occupied by career company pilots. A similar situation existed for lower management positions. The company said that there was no formal management training program in place within the Branch. In the past, management training was provided on an as needed basis with selected managers undertaking specific management development subjects/courses. For example, in June 1999, all Flight Operations Branch managers attended a 2-day project management workshop. As far as could be determined, only a small proportion of these personnel had received formal qualifications in management fields.

3.5.2 Organisational learning

An essential characteristic of most successful organisations is their ability to learn and improve their processes. Effective organisational learning involves comparisons with external organisations, research and development, and processes for ensuring that lessons are learned from past experience.

As noted in section 3.1, the company's processes for identifying hazards was generally reactive and informal rather than proactive and structured. The July 1999 review of flight safety noted that the lack of formal, documented processes in many areas limited the potential for the organisation to learn from its experiences. When solutions to problems were developed, the way the organisation developed the solution was generally not passed on to other personnel.

During interviews, several management personnel expressed the view that the standard of Qantas flight operations was equivalent to leading world airlines. In particular, they noted that the organisation was generally a leader in many technical areas.

Management personnel also reported that the Flight Operations Branch (with the exception of the Flight Safety Department) did not engage in benchmarking activities with other operators on a regular or systematic basis. Comparisons with other operators were conducted from time to time on specific issues. However, the organisation had not

conducted much research and development into issues such as operational procedures and management processes.

Other Qantas management personnel and personnel with expertise in safety management systems considered that the overall level of organisational learning within the branch was low.

Some management personnel commented that there had been little benchmarking in recent years due to high workloads in most management positions. It was also commented that both the Flight Safety and the Flight Technical Departments had been under-resourced in recent years. Some personnel perceived that benchmarking on operational issues between airlines was often difficult due to the reluctance by many to share information on operational procedures.

Observations:

Management decision-making within the Flight Operations Branch relied primarily on the expertise and judgement of management personnel. There was insufficient reliance on structured processes, utilising available expertise within the branch, management training, learning from past experience, and learning from external organisations (both within and outside the aviation industry). Had there been more emphasis on such processes, the deficiencies identified in sections 3.1 to 3.4 (as well as those in parts 1 and 2) were less likely to have occurred.

3.6 Other issues

The March 1998 review of management systems noted that management effectiveness did not appear to be appropriately measured. The review also noted that management personnel had individual key performance indicators (KPIs) in many areas, but these needed to be supplemented. The specific objectives for the Branch as a whole were not defined.

KPIs were developed for the Flight Operations Branch for the years 1998–99 and 1999–2000. No formal KPIs existed before 1998–99. The indicators were:

- Maintain safety and operational standards.
- Increase efficiency and productivity.
- Manage people and processes effectively.
- Meet all customer internal/external expectations.
- Develop appropriate information technology policies and maximise use of technology.

For each of the five KPIs, a small number of specific activities were listed.

The July 1999 review of flight safety noted that there was a general statement in the company's safety policy that safety performance would be measured. However, 'this did not appear to have been translated into specific [safety-related] KPIs for relevant managers and supervisors in their individual performance agreements. During the investigation, Qantas reported that, although Flight Operations Branch managers did not have safety-related KPIs prior to the accident, safety performance issues were included in their position descriptions. It also noted that safety-related items were included in management KPIs in other branches of the company.

During the investigation, some personnel reported that senior management within the Branch had become more focussed on reducing costs in recent years. Senior management indicated that there was a need for the airline to be efficient in its operations, and that this had always been the case. However, they emphasised strongly that there had been no

pressure from higher levels in the organisation for efficiency gains to be made at the expense of reduced safety standards. There had been no intention by senior management to reduce safety standards.

The cost-benefit analysis for the introduction of the flaps 25/idle reverse procedures listed all the benefits of the new procedures in financial terms. No cost items were listed, although some existed (see attachment H). During interviews, persons involved in the project agreed that the procedures were introduced for financial reasons only and that the new procedures provided no operational benefits. However, they believed that the change was justified because their assessment was that the new procedures would have no adverse impact on safety.

Observations:

The investigation found no evidence of any decision to intentionally reduce operational safety standards. It is clear that, in line with many organisations, the Flight Operations Branch was attempting to increase productivity and reduce costs. It is also clear that, in this process, the Branch did not have appropriate mechanisms in place to ensure that risks associated with any changes were appropriately assessed and managed.

3.7 Summary

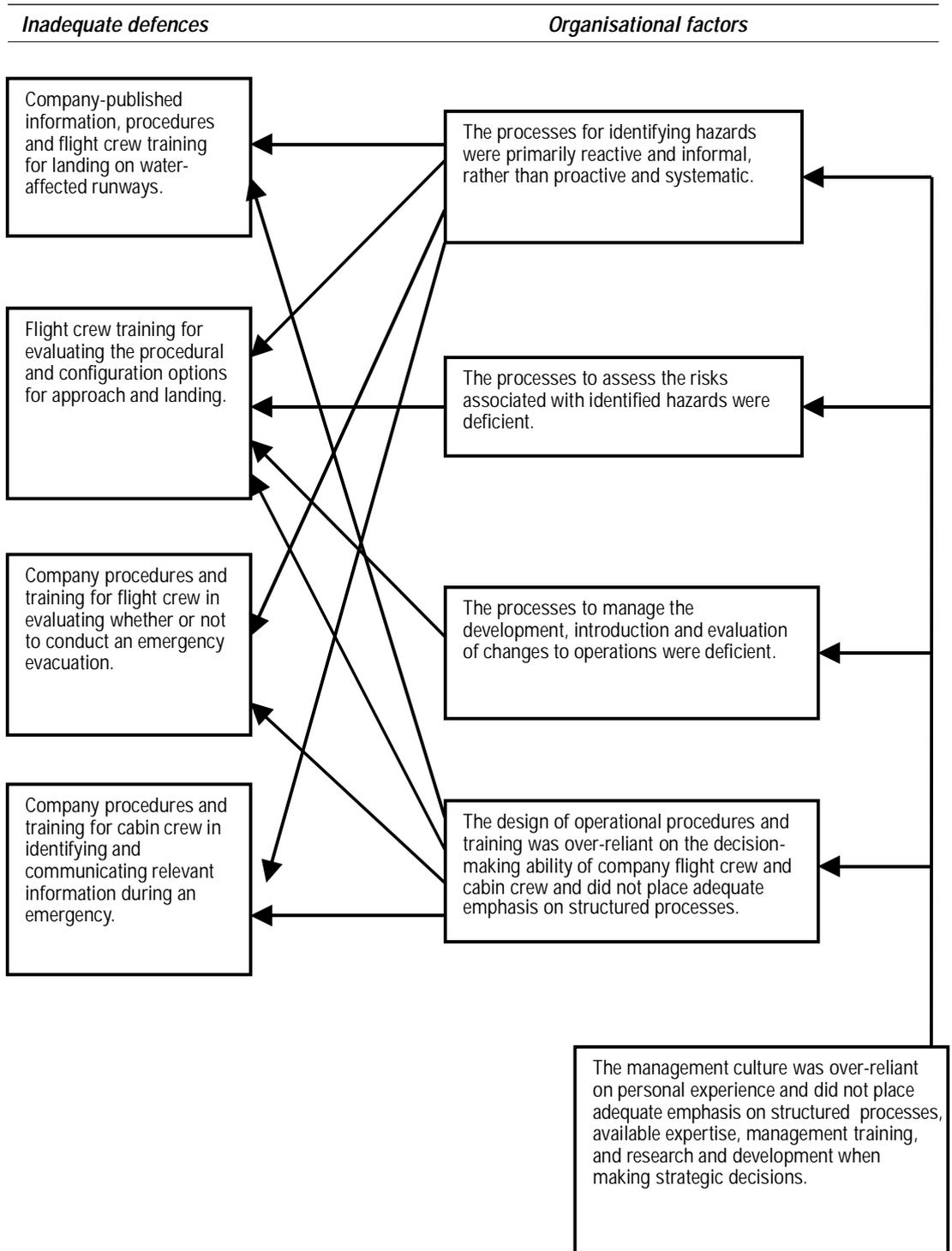
This section has highlighted deficiencies in a number of organisational processes that established the culture or background for the workplace conditions that were discussed in parts 1 and 2. These deficiencies included the following aspects of Flight Operations Branch's activities:

- The processes for identifying hazards were primarily reactive and informal, rather than proactive and systematic.
- The processes to assess the risks associated with identified hazards were deficient.
- The processes to manage the development, introduction and evaluation of changes to operations were deficient.
- The design of operational procedures and training was over-reliant on the decision-making ability of company flight crew and cabin crew and did not place adequate emphasis on structured processes.
- The management culture was over-reliant on personal experience and did not place adequate emphasis on structured processes, available expertise, management training, and research and development when making strategic decisions.

The relationship between these factors and the inadequate defences identified in parts 1 and 2 is outlined in fig. 12.

Actions taken by the company to address the inadequate defences and organisational deficiencies are included in part 5.

Figure 12:
Inadequate defences and organisational factors in Qantas flight operations



4. ORGANISATIONAL FACTORS: CIVIL AVIATION SAFETY AUTHORITY

In Australia, the Civil Aviation Safety Authority (CASA) has the prime responsibility for regulating aviation safety. CASA was established in 1995 as a statutory authority under the *Civil Aviation Act 1988* (as amended). Its regulatory controls are set out in the *Civil Aviation Regulations* (CARs) and the *Civil Aviation Orders* (CAOs).

Parts 1, 2 and 3 of this report have identified a number of workplace and organisational factors associated with Qantas flight operations. Part 4 examines the activities of CASA that may have contributed to these factors.

Three aspects of CASA's activities were examined:

- regulations with respect to contaminated runway operations;
- regulations with respect to emergency procedures and emergency procedures training;
- surveillance of Qantas flight operations.

CASA's functions are outlined in section 9 of the *Civil Aviation Act 1988*. These functions include the following:

- (1) CASA has the function of conducting the safety regulation of the following, in accordance with this Act and the regulations:
 - (a) civil air operations in Australian territory;
 - (b) the operation of Australian aircraft outside Australian territory; by means that include the following:
 - (c) developing and promulgating appropriate, clear and concise aviation safety standards;
 - (d) developing effective enforcement strategies to secure compliance with aviation safety standards;
 - (e) issuing certificates, licences, registrations and permits;
 - (f) conducting comprehensive aviation industry surveillance, including assessment of safety-related decisions taken by industry management at all levels for their impact on aviation safety;
 - (g) conducting regular reviews of the system of civil aviation safety in order to monitor the safety performance of the aviation industry, to identify safety-related trends and risk factors and to promote the development and improvement of the system;
 - (h) conducting regular and timely assessment of international safety developments.

4.1 Regulations concerning contaminated runway operations

There were no definitions in the CARs or CAOs for wet and contaminated runways. CAO 20.7.1B was titled 'Aeroplane Weight and Performance Limitations – Aeroplanes above 5700 kg – All Operations (Turbine and Piston-engine)'. Subsection 11 dealt with 'landing distance required'. This subsection included the following paragraphs:

- 11.1 ...the landing distance required in relation to an aeroplane (other than propeller driven aeroplane) engaged in charter, or regular public transport, operations is a distance equal to or greater than 1.67 times the distance required to bring the

aeroplane to a complete stop...following an approach to land at a speed of not less than 1.3 VS maintained to within 50 feet of the landing surface. This distance is measured from the point where the aeroplane first reaches a height of 50 feet above the landing surface...

- 11.2 The landing distances established under paragraph 11.1 must be increased by an amount approved by the Authority for operations conducted on runways covered by slush, snow, or a depth of water.
- 11.4 Where a runway is covered with slush, snow or a depth of water, the landing distance set out in the manufacturer's data manual and the approved foreign flight manual must be increased by the amount approved by the Authority for the purposes of paragraph 11.2.

Paragraph 11.2 was introduced in the initial issue of the CAOs in 1963, and paragraph 11.4 was introduced in April 1990.

In July 1972, the then Department of Civil Aviation met with the domestic airlines to discuss wet runway operations.⁷⁰ Following this meeting, the Director-General of Civil Aviation wrote to the airlines to advise of new requirements for operators. The letter included the following paragraph relevant to all turbo-jet aircraft (except the Fokker 28):

Landing distance shall be increased by 15% for use under wet/slippery runway operations. The aircraft captain may, at his discretion, dispense with this requirement if, in his judgement, the runway is suitable for dry runway operation.

This requirement was adopted from the United States FAR 121.195(d). It was not incorporated into the Australian CAOs.

During interviews, Qantas performance engineering personnel reported that the 15% increase for 'wet' runways (as per the 1972 letter) was sufficient to cater for the requirements of paragraph 11.2 and 11.4. They stated that this had been the understanding of the Authority's position passed on to them from previous managers of their section. However, this understanding had never been formally documented.

A CASA performance engineering expert advised that his understanding was that paragraphs 11.2 and 11.4 were for conditions worse than 'wet', and an additional increase to landing distance beyond that for a wet runway was required. Such an increase could be another multiplicative factor, or in the form of separate landing charts for such conditions. His superiors had passed on this understanding to him, but no formal position on this issue had been documented. A flying operations inspector (FOI) responsible for conducting surveillance on Qantas reported that his understanding was similar to that of Qantas performance engineering personnel.

Prior to 23 September 1999, no airline had applied to CASA for approval of their landing distances as per paragraph 11.2. There was also no evidence that CASA had specifically requested any such applications.

Another Australian airline reported that, as far as it could determine, it had not made any submission under paragraph 11.2 to the Authority. Its interpretation was that the paragraph made the provision for the Authority to impose a requirement if it saw a need to do so. The airline also noted that, since the mid-1970s, the landing distances for most of their aircraft types had a correction for 'standing water' on the runway. Standing water was defined as a depth of 3 mm. The correction was an additional 24% to the landing distances (on top of

⁷⁰ In 1972, the Department of Civil Aviation was also the civil aviation regulator. At this time, Qantas was engaged solely in international operations. It merged with one of the major domestic airlines, Australian Airlines, in 1992.

the 15% requirement for 'wet' conditions). This additional factor was introduced with the involvement and knowledge of the Authority. This change followed the landing overrun accident of a Fokker 28-1000 aircraft at Broome on 17 January 1974. The correction was used for all aircraft types except the B747-400, for which Boeing landing charts and advisory information for wet/contaminated runways was included in their manuals.

During interviews, senior personnel from CASA's Compliance Branch reported that many of their FOIs would not have had appropriate expertise to be arbiters on performance engineering issues. They noted that CASA had not appropriately used its performance engineering personnel in surveillance activities in the past.

The US FARs had no landing distance requirements for conditions worse than wet. The European JAA requirements are currently being proposed by CASA as new Australian regulations (see section 5.2).

Observations:

A regulatory requirement existed for operators to provide landing distances for conditions worse than 'wet'. However, this requirement was not clearly stated and not clearly understood by CASA FOIs or the airlines. Also, the Authority had not directed operators to comply with the requirement. Had the requirement been more clearly stated and/or consistently applied, then it is likely that Qantas would have had more detailed processes in place regarding contaminated runway operations.

4.2 Regulations concerning emergency procedures and emergency procedures training

Regulatory requirements for emergency procedures and training are outlined in CAO 20.11 ('Emergency and lifesaving equipment and requirements for passenger control in emergencies'). Subsection 12.2 stated that cabin crew (and flight crew) were required to undertake (and pass) a proficiency test on emergency procedures annually. Appendix IV outlined the requirements for the proficiency test. The majority of these requirements related to the use of emergency equipment, and participation in a practical evacuation exercise. There were no requirements relating to how cabin crew obtained or communicated information during emergencies. Paragraph 2.4 of the appendix stated that crewmembers were required to be given theoretical knowledge regarding 'methods of control, e.g. psychological, physical' of passengers during emergencies. No further detail was provided.

In October 1998, the then Bureau of Air Safety Investigation (BASI) issued the following recommendation (Interim Recommendation 980080) as part of a study of the safety of Australian regional airlines:⁷¹

The Bureau of Air safety Investigation recommends that the Civil Aviation Safety Authority reviews the current standards and training syllabus requirements for cabin attendants operating on fare-paying, passenger-carrying aircraft, with a view to widening the scope of those requirements to ensure that all airline operators develop a standard, comprehensive syllabus of training for cabin attendants.

Background information to this recommendation noted the following:

The present regulations on the safety training required for flight attendants are minimal and lacking in detail. Anecdotal evidence suggests that considerable differences exist between the various flight attendant training courses run by the regional airline operators. In part, these differences may be attributed to the lack of a standard, comprehensive syllabus of training.

⁷¹ ATSB, *Regional Airlines Safety Study Project Report*, 1999.

As of September 2000, no response to this recommendation had been received by the ATSB. However, in November 1998, CASA issued a Notice of Proposed Rule Making (NPRM) 9809RP titled 'Proposed Regulations Relating to Passenger and Crew Member Safety'. Page 7 of the NPRM states the following:

This NPRM is necessary because the Cabin Safety / Carriage of Persons project team⁷² ...found current Australian regulatory requirements relating to cabin safety and the carriage of persons in aircraft to be inadequate in many areas when compared to corresponding standards applicable in the USA, Canada and Europe.

The NPRM outlined a series of proposed regulatory changes in a variety of cabin safety areas. In terms of emergency procedures training, proposed new regulations were based on the United States FARs. During the consultation process, there were many criticisms about this approach. As a result, CASA advised in June 2000⁷³ that it had decided to propose the European JAR requirements as Australian regulations. This proposal was issued in the Discussion Paper on proposed Civil Aviation Safety Regulation (CASR) Part 121A (see sections 5.1 and 5.9).

Observations:

The regulations for emergency procedures and emergency procedures training were minimal and lacked detail. More extensive requirements would likely have resulted in fewer and less significant deficiencies in Qantas' procedures and training in this area (see sections 2.5, 2.6 and 2.7).

4.3 Surveillance of Qantas flight operations

4.3.1 Overview of surveillance approach

CASA's approach to surveillance was outlined in its Aviation Safety Surveillance Program (ASSP) manual. This manual was initially introduced in May 1994, with new versions issued in May 1996, September 1997 and August 1999 (version 4.0). Section 1.1.1 (August 1999) stated that the purpose of the ASSP manual was to identify the responsibilities of surveillance personnel, and to provide guidelines and procedures for surveillance planning, conducting surveillance, recording and reporting surveillance activities, and analysing surveillance data. Section 2.1.1 stated that ASSP was a 'surveillance strategy undertaken in a systematic manner to provide an assessment of the aviation industry's safety level and to implement appropriate responses'.

The ASSP manual referred to two main types of surveillance: product audits and systems audits. Product audits focused on inspecting the end-product of a system. They were the traditional type of surveillance activities conducted by CASA and other similar regulatory authorities. For flight operation issues, they primarily included observations of line flights, simulator training sessions and other training courses. The ASSP manual defined a systems audit as 'an audit of the organisational structure, management responsibilities, procedures, processes and resources of the auditee'.

Three external reviews of CASA surveillance activities were conducted in 1999:

- The Australian National Audit Office (ANAO) undertook an 'efficiency audit' of CASA in late 1998 to early 1999. The focus of the audit was on 'compliance with the

⁷² The Cabin Safety/Carriage of Persons project team consisted of approximately 25 persons, including CASA personnel and cabin safety representatives from airlines, cabin crew associations and safety organisations.

⁷³ CASA, *Summary of Responses to NPRM 9809RP*, 2000.

procedures contained in manuals developed by CASA for issuing, re-issuing and varying certificates, the Aviation Safety Surveillance Program (ASSP) and enforcement of regulations'. The report was completed in November 1999.

- The International Civil Aviation Authority (ICAO) conducted an audit of CASA in August 1999. The audit, part of an international program of auditing all states who were signatories to the Convention on International Civil Aviation with the objective of ascertaining the safety oversight capability of Australia, and to ensure that it was in conformity with ICAO Standards and Recommended Practices.
- In November 1999, following the accident to VH-OJH in Bangkok, the CASA Director of Aviation Safety requested an independent review of the 'exchanges between CASA and Qantas during the last 12 months'. The review, titled 'A Report on the Dealings between CASA and Qantas', was conducted by one external consultant and a CASA flying operations inspector (FOI) from Melbourne. The report was completed in December 1999.

The current investigation did not attempt to repeat these previous reviews, but focussed on those issues of relevance to the accident investigation. The previous reviews are referred to where relevant in this section.

4.3.2 Product-based surveillance activities

Prior to the 1990s, it was Civil Aviation Authority⁷⁴ (CAA) policy to conduct product surveillance on one per cent of an airline's operations. This target level was reduced for Qantas during the 1990s on three different occasions. In 1993, Qantas established a Flight Standards Department in consultation with the CAA (see attachment J). The Authority referred to the activities of this department as an 'auditable quality control system' and reduced the target amount of its own product surveillance of Qantas by 50%. The Qantas Flight Standards Department was to conduct the other 50% of required surveillance tasks.

The CAA surveillance targets for Qantas were reduced by a further 50% when the CAA FOIs responsible for the surveillance of Qantas started conducting their flying training with the operator rather than an independent organisation. As a result, the FOIs were able to conduct some of their surveillance tasks during their own training.⁷⁵ The Authority's surveillance targets were also reduced by 20% on the basis that Qantas had Quick Access Recorders (QARs) fitted on their aircraft and crew performance on line operations was therefore being monitored.

The December 1999 review of the relationship between CASA and Qantas noted that, during the financial year 1997–98, 48% of planned surveillance tasks were achieved. For the financial year 1998–99, 22% of planned surveillance tasks were achieved. The report also noted that there was no evidence that surveillance of cabin crew safety training had been conducted in the last 10 years, and there had only been minimal surveillance of cabin crew performance during line operations. During interviews, CASA personnel reported that surveillance targets for Qantas had not been achieved for several years prior to 1999. The ANAO audit found that CASA's surveillance targets were not consistently achieved across all industry sectors.

⁷⁴ The Australian Civil Aviation Authority was divided into the Civil Aviation Safety Authority (the regulator) and Airservices Australia (the service provider) in 1995.

⁷⁵ This reduction in surveillance targets also applied to other airlines.

The December 1999 review noted that the reasons for the low levels of surveillance of Qantas included low staff morale within CASA (due to a variety of reasons) and uncertainty over proposed major changes to the method of surveillance (see section 4.3.4). The ANAO report noted that CASA had advised that their level of surveillance was below ASSP targets in recent years because of resource shortages. In addition, CASA stated that a review of their surveillance tasks for high capacity regular public transport (RPT) operators had demonstrated that 'some of the surveillance planning had been excessive and directed at areas that were unlikely to enhance air safety'.

During interviews, some CASA Sydney office staff noted that their surveillance performance had also been affected by inadequate communications between their office and the Airline Office Branch in Canberra. In particular, they had not been informed (by Canberra) of important changes to Qantas flight operations, such as the devolution of the Flight Standards Department and the reduction in the frequency of recurrent simulator sessions (from every 3 months to every 4 months). During the investigation, CASA commented that communications between CASA's central office (Canberra), the Sydney regional office and Qantas had been unsatisfactory. It noted that this was primarily due to the surveillance arrangements adopted by CASA, where district office staff acted independently without proper administrative procedures and management direction.

CASA's limited product surveillance activities had not detected the inadequate defences and organisational factors identified in parts 1, 2 and 3 of this report (see fig. 12).

4.3.3 Difficulties associated with the product-based approach

During the investigation, senior personnel within CASA's Compliance Branch reported that the ability of the traditional product-based approach to identify safety deficiencies was limited. In effect, the product-based approach meant CASA was performing an external quality control function by trying to identify problems with the end-product of the aviation system. In 1997, CASA conducted an internal review of the Authority's product-based surveillance activities of Qantas and noted that only using these activities had identified very few safety issues. More importantly, the product-based approach was rarely identifying the underlying reasons for end-product failures.

In May and June 1997, CASA Compliance Branch personnel met with representatives of the major airlines to discuss surveillance issues. The meeting attendees agreed that the major airlines should introduce a quality assurance approach to their operations to enhance aviation safety management. It was also agreed that CASA surveillance should focus on an operator's management systems rather than the end product. It was noted that other regulatory agencies, such as the NZ CAA and the European JAA, had been introducing similar approaches.

During the investigation, senior personnel within CASA's Compliance Branch also noted that, due to resource shortages, it was unlikely that CASA would ever be able to conduct product surveillance at the arbitrary levels specified in the ASSP. It seemed more appropriate for the airlines to use their operational experience to detect end-product failures, and for the Authority to focus its activities on ensuring the airlines had appropriate management systems and procedures in place to prevent end-product failures.

Compliance Branch personnel also noted that CASA FOIs had limited qualifications and experience as flight crew in line operations on some of the aircraft types used by the major airlines. As a result, the ability of FOIs to identify operational problems using a product-based surveillance approach was limited.

4.3.4 CASA systems-based surveillance activities

In 1997, because of the deficiencies with the product-audit approach, CASA began developing a systems-based approach to surveillance. General details concerning the new approach and how it was to be implemented were introduced into the ASSP manual in June 1997. However, these procedures were primarily administrative in nature, and provided little guidance to CASA personnel on how to actually audit an operator's systems. Some trial audits using these procedures were conducted around this time.

It was intended that further systems-based audits were to be trialled for two major operators (including Qantas) in the 1998–99 financial year. To accommodate this trial, the traditional product-audit activities were significantly reduced. However, the trial did not commence as planned. CASA personnel reported that there were some difficulties developing an appropriate systems model and guidance material. There was also some resistance to the new approach from FOIs, who believed that it was important for CASA to be conducting a significant amount of end-product inspection activities.

A specialist auditor was appointed to the position of Manager Compliance Practices and Procedures in April 1999 and a formal project (with a project management plan) to introduce the new surveillance approach was commenced in June 1999. The new approach consisted of systems-based audits with product surveillance included. A major component of the new type of audits was the use of multi-disciplinary teams of CASA personnel, including FOIs, airworthiness inspectors (AWIs), cabin safety and engineering experts. Industry was briefed on the proposed approach, and audit guidelines and a 'safety system specification' were developed.

Qantas management was briefed on the new approach in July 1999. The first systems audit of Qantas was conducted in November 1999 (after the accident). Further details on the nature of the new audit approach are presented in section 5.12.

Observations:

The ATSB notes that there are significant limitations on the ability of a product-based audit approach to identify inadequate defences and organisational deficiencies. Such an approach should only be used to complement a systems-based approach.

In the 2 years before the accident, CASA conducted minimal product-based surveillance of Qantas flight operations. Even if CASA had conducted more product-based surveillance in recent years, as per the ASSP targets, it is unlikely that the deficiencies identified in this report (see sections 1.9.2, 2.8.2, and 3.7) would have been detected. Most of these deficiencies had probably existed in Qantas flight operations for many years.

If there had been a mature systems-based surveillance approach in operation in the years before the accident, it is likely that many of the inadequate defences and organisational factors would have been identified.

4.4 Summary

This section has highlighted three aspects of CASA's operations that influenced the development of the inadequate defences and organisational factors in Qantas' flight operations:

- The regulations covering contaminated runway operations were deficient.
- The regulations covering emergency procedures and emergency procedures training were deficient.
- The surveillance of airline flight operations was deficient.

5. SAFETY ACTION

During the course of the investigation, frequent contact between the investigation team, Qantas, CASA, Boeing and the Department of Aviation (Thailand) enabled all parties to become aware of issues relevant to their areas of interest at an early stage. In some instances, further examination of these issues led to safety enhancement action being initiated by the relevant party. Where such action had been taken, a statement outlining the action taken by the relevant party has been included in this part of the report. In the case of Qantas, where some safety action was on-going, the company undertook to provide quarterly reports to the ATSB on the progress of these matters until all items had been satisfactorily addressed.

During its investigation and research activities, the ATSB procedure is to raise a safety analysis deficiency notice (SADN) when a potential safety deficiency which requires further examination and, potentially, safety action, is detected. The ATSB issues recommendations when it perceives that a safety deficiency still exists, or inadequate action had been taken to rectify the situation. In the sections listed below, some recommendations have been made. In addition, some SADNs remain 'open' pending the result of further examination of the issue or the receipt of additional information.

5.1 Background information on CASA regulatory change

In addition to changes to its surveillance processes (see section 4.3.4), CASA initiated the Regulatory Framework Program (RFP) in June 1996. This program has, as its objective, the complete review of the Australian aviation safety requirements contained in the *Civil Aviation Regulations* (CARs) and *Civil Aviation Orders* (CAOs). The revised legislation is called the *Civil Aviation Safety Regulations* (CASRs).

The development of the CASRs is a joint industry and CASA initiative, having as its aim the introduction of regulations that are simple, unambiguous and generally harmonised with those of other major aviation nations.

As part of this process, CASA has recently issued Discussion Papers⁷⁶ (DPs) containing initial drafts of proposed legislation in a number of areas. After receiving feedback on the discussion papers, CASA will then issue a Notice of Proposed Rulemaking⁷⁷ (NPRM) seeking further comment before final rules are made. The discussion papers include the following:

- *Air Operator Certification – Commercial Air Transport*, Proposed CASR Part 119 (DP 00030S, May 2000). CASR Part 119 will subsume into one document all regulatory provisions relating to obtaining and retaining an Air Operator Certificate to conduct commercial air transport operations. Responses were required by 11 August 2000. The DP summarised the most significant rule enhancements from a safety perspective. These included 'the requirement that all operators must instigate a flight safety program and that larger operators must instigate a safety management program.'

⁷⁶ A Discussion Paper is a consultative product used by CASA to seek aviation community/public comment on whether CASA should proceed to initiate a rule change on a particular matter. It is not a notification of rule making.

⁷⁷ A NPRM is CASA's preferred method of articulating the final policy and proposed rules for aviation community and public comment.

- *Commercial Air Transport Operations – Large Aeroplanes*, Proposed CASR 121A (DP 0010S, April 2000). CASR 121A will prescribe the operating and maintenance rules that will apply, in addition to those in CASR Part 91 (General Operating and Flight Rules), to the operation of larger aeroplanes engaged in commercial air transport operations. The operating rules were largely based on those specified by the European Joint Aviation Authorities (JAA). Responses were required by 4 August 2000. The DP summarised the most significant rule enhancements from a safety perspective. These included ‘more comprehensive training and checking requirements for flight crew members and cabin crew members, including mandating CRM training’ and ‘more comprehensive provisions relating to all weather operations, particularly with respect to aeroplane equipment and additional crew training required’.

5.2 Contaminated runway operations and approach/landing configurations *(see sections 1.6, 1.7, 1.9, 4.1)*

5.2.1 Qantas procedures and training

On 22 October 1999, the Qantas Flight Training Department added the following to the instructors’ notes of exercise 137 of the B747-400 recurrent simulator training program:

AS PART OF LOS [line oriented simulation], DISCUSS WITH CREWS THE OPTION OF FLAP 30 V FLAP 25, FULL REVERSE V IDLE REVERSE.

On 8 November 1999, the content of exercise 137 was modified to require captains and first officers to conduct a flaps 30 / full reverse thrust landing at the end of the exercise.

On 3 December 1999, Qantas Performance Engineering submitted an application to CASA (Sydney office) for approval of contaminated runway landing distances to satisfy CAO 20.7.1B paragraph 11.2 (see section 4.2). The landing distances were based on the Boeing advisory information for slippery runway landing distances (see section 1.4.8) with an additional 15% factor. On 23 February 2000, CASA notified Qantas that it had decided not to approve this application.

On 24 December 1999, the Flight Operations Branch issued Flight Standing Order (FSO) 149/99 titled ‘Landing on Contaminated Runways’ to all B747-400 flight crew. This FSO included the following:

- Definitions of a contaminated runway and other types of water-affected runways consistent with the JAA definitions (see page section 1.4.2).
- The Boeing advisory information on slippery runway landing distances (see section 1.4.8).
- Boeing information on the relationship between reported braking actions and airplane braking coefficients (see section 1.4.2).
- A policy statement, which included the following:

As it is not at all times possible to determine the actual condition of a runway, as a precautionary policy, flap 30 and full reverse thrust are to be used whenever:

1. landing on a “wet” runway which is not grooved or PFC coated; or
2. braking action is reported to be less than “good”.

A similar FSO, but without the policy statement, was issued in January 2000 to the flight crew of other aircraft types operated by the company.

On 11 February 2000, most of the content of FSO 149/99 was incorporated into the Supplementary Procedures section of the *Qantas B747-438 Operations Manual*. As part of this change, the procedure for landing on wet, slippery or icy runways (see section 1.6.1) was moved from the Cold Weather section of the manual to a new section titled 'Landing on Contaminated Runways'. The Boeing advisory information on slippery runway landing distances was incorporated into the *Qantas B747-438 Performance Limitations Manual*.

In early 2000, the Flight Operations Branch conducted a risk assessment of the flaps 25/idle reverse procedures. On 16 March 2000, following this exercise, Qantas issued FSO 32/2000 titled 'Landing Configuration' to all B747-400 flight crew. The FSO took the form of a flow chart that provided a process for the flight crew to determine the appropriate configuration for landing. According to the flow chart, if the runway was dry and the required flaps 25 landing field length was less than the landing distance available, the required landing configuration was flaps 25 and full reverse thrust. All other conditions required flaps 30/full reverse thrust or the use of another runway.

There were a number of notes to the flow chart:

- Note 3 stated that idle reverse thrust may be used at locations where there was a State requirement to do so, or airmanship dictated that a 'roll through' to the runway end was desirable (and at least 300 m surplus runway was available).
- Note 5 stated that 'when in doubt about the condition of the runway, be conservative'.
- Note 7 stated 'when landing in very heavy rain on runways which are not grooved..., the runway should be treated as "contaminated" with "poor" braking'.

The flow chart and notes were added to the *Qantas B747-438 Operations Manual* on 30 April 2000.

On 17 May 2000, Qantas issued another amendment to their *B747-438 Performance Limitations Manual*, which removed the 'preferred landing flap is flap 25' procedure (see section 1.7.1).

On 28 August 2000, Qantas advised the ATSB that the *Qantas Flying Manual*⁷⁸ had been updated with a comprehensive chapter covering issues relating to operations on contaminated runways. This information was also produced as a compact disc and was to be issued to all flight crew. In addition, Qantas advised that flight crews' use of the revised procedures for operations on water-affected runways were being assessed during routine line and simulator checks.

On 5 December 2000, Qantas advised that its QAR program was being modified to include the monitoring of fast approaches and long touchdowns. Certain parameters that were already monitored provided precursors for long touchdowns. Long touchdowns would be monitored specifically by agreement with AIPA through existing protocols for any adverse trends.

5.2.2 CASA regulatory reform

The Part 121A Discussion Paper included the definitions of 'contaminated runway' and other types of water-affected runway as per the JAA definitions (see section 1.4.2). The discussion paper also included the following in 'Subpart G – Performance Class A':

⁷⁸ The *Qantas Flying Manual* provided background information of an educational nature to flight crew. It was not considered to be part of the company's operations manual.

121A.520 Landing – Wet and contaminated runways

- (a) Each operator must ensure that when the appropriate weather reports or forecasts, or a combination thereof, indicate that the runway at the estimated time of arrival may be wet, the landing distance available is at least 115% of the required landing distance...
- (b) Each operator must ensure that when the appropriate weather reports or forecasts, or a combination thereof, indicate that the runway at the estimated time of arrival may be contaminated, the landing distance available must be at least the landing distance determined in accordance with sub-paragraph (a) above, or at least 115% of the landing distance determined in accordance with approved contaminated landing distance data or equivalent, accepted by the Authority, whichever is greater.

During the investigation, CASA stated that (as a result of the accident and subsequent investigations) it was examining the current regulatory requirements for procedures and training for operations on water-affected runways. It was also examining the procedures and training used by some airline operators (including Qantas).

Observations:

The ATSB believes that no further safety action is required by Qantas to address the deficiencies identified during the investigation concerning the company's training and procedures for landing on water-affected runways.

While the CASR Part 121A discussion paper appears to address the current deficiencies in the CARs and CAOs regarding wet/contaminated runway landing distances, the uncertain timeframe for the promulgation of the new CASR Part 121A raises concerns about the regulation of these issues in the interim period. Accordingly, the following recommendation is made.

Safety Recommendation R20000239

The ATSB recommends that CASA ensure all Australian operators of high capacity jet aircraft have in place procedures and training to ensure flight crews are adequately equipped for operations on wet/contaminated runways.

5.3 Flight crew recency (see section 1.8.2)

On 10 February 2000, Qantas issued FSO 22/2000 titled 'Night Recency' to all of its flight crew. This FSO reinforced the CAR 5.170 requirements relating to night recency (see section 1.8.2) as Qantas policy for all their captains and first officers for all their aircraft types (except for first officers on the B737 who did not act as pilot in command on line duties). A small number of personnel were provided with additional simulator exercises to ensure that they met this requirement before conducting line flights and that all captains and first officers complied with CAR 5.170 at the time of issue of the FSO.

On 28 August 2000, Qantas informed the ATSB:

A worldwide issue associated with ultra long haul flying is the reduced level of aircraft manipulation that crews experience in this type of operation. Qantas has addressed this issue by making an additional simulator session available [in addition to the current three sessions per year] each year for B744 [B747-400] crews to hone these particular skills. Further, any Captain or First Officer employed in a supervisory or management role in the Training section is required to complete an additional two simulator sessions per year in addition to those required by the approved program.

On 5 December 2000, Qantas stated that it was forming a working group within the Flight Operations Branch to focus on long haul operations and lower performing crews, and to recommend appropriate changes. Qantas also said that Flight Operations Branch management pilots and flight engineers (other than those in the Flight Training

Department) had new recency requirements. These included the completion of at least 30 sectors per calendar year as flying pilot, five sectors as flying pilot per bid period, and four simulator sessions in a cyclic year. The airline also stated that an additional simulator session had been created and that it was available to all B747-400 captains and first officers.

Subpart N of the CASR Part 121A discussion paper included the following reference to recent experience (121A.970):

Each operator must ensure that no pilot operates an aeroplane as pilot in command, or serves as copilot during takeoff or landing, unless he or she has carried out at least three takeoffs and landings as pilot flying in an aeroplane of the same type or a flight simulator, qualified and approved...of the aeroplane type to be used, in the preceding 90 days.

This requirement accords with the ICAO position regarding flight crew recency.⁷⁹

Observations:

The ATSB notes that Qantas is taking a number of steps to address the issues associated with flight crew recency for long haul and management pilots. The ATSB also notes that recency for long haul pilots is a prominent issue within the worldwide aviation community. However, there appears to have been little applied research in this area, particularly in terms of the effects of low recency in combination with fatigue and advanced technology aircraft.

The ATSB has raised SADN 20000049 ('Maintenance of recency for pilots'), and will be examining ways to clarify the nature and extent of the problems associated with this issue.

5.4 **Second officer procedures and training** (see section 1.8.3)

During the investigation, Qantas reported that it had commenced a study in August 1999 to review the role of the second officer with emphasis on training and responsibilities. On 28 August 2000, Qantas informed the ATSB that a special committee within the Flight Operations Branch was addressing the results of this review. Qantas also advised that second officer training now placed a greater emphasis on circuit training, particularly takeoffs and landings.

On 5 December 2000, Qantas stated that a review of second officer roles and responsibilities, as well as second officer line exposure with training personnel, had been completed (in draft form). A training committee was considering the inclusion of second officers in captain/first officer line oriented simulator training.

Observations:

Information provided by Qantas indicates that deficiencies identified regarding second officer procedures and training are being addressed. Consequently, the ATSB does not believe that an immediate safety issue exists. However, it will continue to monitor the progress of Qantas's review of this issue.

5.5 **Crew resource management** (see section 1.8.4)

On 28 August 2000, Qantas informed the ATSB that its CRM training 'will be reviewed and updated to reflect the latest world wide research.' Qantas commenced a review of its human factors awareness training in 1999. A draft 2-day training course was developed to replace the existing CRM course provided to new flight crew. This course has yet to be finalised and implemented. It is intended the training course will also be provided to all areas of aircraft operations (Cabin Services, Flight Operations, Engineering and Maintenance, Airport Operations Resources, and Freight and Catering).

⁷⁹ ICAO, Annex 6, part 1, *International Commercial Air Transport – Aeroplanes*, 1998, section 9.4.

On 5 December 2000, Qantas reported that, during 2000, the second officer CRM course, the initial cabin crew course, and the recurrent training course, had all been updated under the supervision of the Manager Training Human Factors. In addition, a review of all CRM training courses was to be completed by 31 March 2001. Qantas also stated that, in the financial year 2001–2002, the amount of annual CRM training for all flight and cabin crew was to be increased (see section 5.9).

The CASR Part 121A discussion paper included a number of references to CRM training. Following the closing date for responses to Part 121A (August 2000), the Human Factors Advisory Group to CASA noted that the contents of Part 121A did not adequately address CRM issues. As a result, CASA is developing a separate Discussion Paper on CRM requirements. It expects that this will be issued for public comment in mid-2001. In addition, CASA plans to conduct an audit of the CRM programs of several airlines (including Qantas) during 2001.

Issues relating to the training of check-and-training personnel are discussed in section 5.10.

Observations:

The ATSB notes the recent and proposed activities regarding CRM being undertaken by CASA and Qantas. At this stage, the ATSB considers that no further safety action is necessary. However, the ATSB recommendation IR950101 to CASA regarding CRM training (see footnote 43 in section 1.8.4) remains open.

5.6 Flight and duty times (see section 1.8.5)

In April 1999, CASA issued a Discussion Paper titled Proposed Introduction of Operator Formulated Flight and Duty Time Limitation Schemes (Commercial Air Transport Operations, Aeroplanes) (DP9904RP). The introduction included the following paragraph concerning flight time limitation requirements:

Following widespread industry interest, and difficulties encountered in continuing FTL [flight time limitations] compliance, CASA proposes to formulate new rules to govern this complex area. After reviewing the most recent advances in overseas FTL legislation or practices with a view to adoption of that which is seen to be in the best interests of Australian aviation safety, the Authority is considering the use of FTL Schemes for aeroplane and helicopter air transport operations formulated by individual operations. The Discussion Paper aims to identify and discuss the issues involved and to seek aeroplane industry comment on the adoption of this method of FTL regulation.

In May 2000, CASA issued a document titled *Summary of Responses to Discussion Papers DP9904RP and DP9906RP*.⁸⁰ This document included the following (page 5):

On the basis of the responses to the Discussion Papers it is apparent that, while there is some dissatisfaction with the current arrangements for managing FTL, the proposal to introduce operator-formulated FTL schemes is generally unacceptable to the Australian aviation industry...

While the dissatisfaction of some sections of the aviation industry with the current arrangements for managing FTL is acknowledged, it would seem that no urgent flight safety implications have arisen which would mitigate against retention of the current arrangements in the short term.

Accordingly, with the current arrangements for managing FTL in place, the Authority intends to investigate the feasibility of developing Fatigue Risk Management Systems

⁸⁰ DP9906RP was issued for commercial air transport operations (helicopters).

(FRMS) for use in the aviation industry in line with evolving overseas initiatives. To this end, CASA has embarked upon a pilot project to develop such a system in conjunction with certain sections of industry, the scientific community and aircrew representatives.

On 28 August 2000, Qantas advised the ATSB of the following:

In response to the 1999 CASA Discussion Paper that addressed Flight and Duty Time Schemes, Qantas has been instrumental in the initiation of a project that will examine this issue in the context of a fatigue management program... The project has a three-year time frame and hopes to break new ground in the fatigue management of flight crew including management pilots.

On 5 December 2000, Qantas reported that its Fatigue Risk Management Group was progressing well in its deliberation on recommendations for future flight and duty time limitations. The group was working with CASA, Boeing, Ansett Australia, and the University of South Australia to scientifically monitor and evaluate all issues associated with flight crew fatigue flight time limitations. The project (called Fatigue Risk Management System) was examining all fatigue-related issues as they relate to long haul, multi-time zone operations. Its focus was on management of fatigue across the entire roster and would take into account the issue of all duties related to a pilot's employment.

In October 2000, the Australian Standing Committee on Communication, Transport and the Arts released a report titled *Beyond the Midnight Oil: An Inquiry into Managing Fatigue in Transport*. The report made a number of general recommendations to CASA relating to flight and duty issues.

Observations:

The ATSB notes the initiative being undertaken by CASA and Qantas regarding fatigue management of flight crew.

Safety Recommendation R20000235

The ATSB recommends that CASA review the intent of CAO 48 to ensure that operators consider all duties associated with a pilot's employment (including managerial and administrative duties) when designing flight and duty time schedules, and that this requirement not be restricted to situations where there are one or two pilots.

5.7 Cabin fittings (see section 2.3)

5.7.1 Ceiling panels

During the investigation, Boeing informed the ATSB that it had information on 25 events between June 1989 and July 1999 where ceiling panels had become dislodged during abnormal situations on B747 aircraft, such as a heavy landing or turbulence. It indicated that fuselage deformation caused these events. In February 1999, Boeing addressed the situation by issuing Service Bulletin⁸¹ No. 747-25-3212, which provided for additional ceiling panel retention throughout zone D, the area where most dislodgments had occurred.

Boeing believed that the accident circumstances and the mechanism through which the panel became dislodged were unique and did not require an immediate design change. However, the company indicated that it was continuing its investigation of the security of ceiling panels and would pursue design changes if appropriate.

⁸¹ It is not mandatory for operators to comply with Service Bulletins, and no compliance time period is specified.

Qantas reported that, at the time of the accident, the ceiling panels were part of the original aircraft fit. It also said that the modifications suggested in the Service Bulletin had been incorporated into the aircraft during its post-accident repair. Modification of other company aircraft was ongoing.

5.7.2 Passenger service units

During the investigation, Boeing reported that between February 1989 and September 1993 there were 17 events in which PSUs fell into the cabin in B747 aircraft. They had addressed this problem in Service Bulletin 747-25-3111 (February 1996). The Service Bulletin informed operators that Boeing had designed a replacement plastic tie-bar to prevent excessive flexing of PSU rails. The original aluminum tie-bars only held the rails together while the new plastic tie-bars provided positive support in lateral directions. The accident aircraft was fitted with the original aluminum tie-bars.

On 5 December 2000, Qantas reported that it was intending to comply with the Boeing Service Bulletin. It also said that it was reviewing methods to restrict PSU movement in the event of an accident.

Observations:

The ATSB notes the actions being taken by Qantas and believes that no further safety action is necessary at this stage.

5.7.3 Flight crew emergency escape reels

On 5 December 2000, Qantas reported that it was examining means of improving the security of the flight crew emergency escape reels, including redesigning the retention system.

5.7.4 Infant restraint systems

Australian regulations require passengers and crew to wear seat belts during takeoff and landing and at any other time when notified that seat belts must be worn (CAO 20.16.3, paragraphs 3.1 and 4.1). Passengers under 3 years of age may be nursed by an adult passenger, or may be restrained by the use of an approved infant seat. Currently, the use of a 'baby belt' or 'loop belt' restraint (an additional belt looped through the seatbelt of the passenger nursing the infant) is neither required nor prohibited, but left to individual operators to provide at their discretion. The Part 121A Discussion Paper does not propose any change regarding infant restraint. CASA reported that the FAA was expected to publish an NPRM concerning infant restraint by mid-2001 and that CASA would monitor developments in this area.

Observations:

The ATSB believes that the current situation regarding infant restraint systems is unsatisfactory. The ATSB has raised a SADN regarding infant restraint and will assess progress on the matter in mid-2001 pending developments in the FAA and CASA.

5.8 Cabin passenger address and interphone systems *(see section 2.4)*

On 7 August 2000, Section 20.11, Issue 9, of the CAOs, titled 'Emergency Lifesaving Equipment and Requirements for Passenger Control in Emergencies', was issued. The amendment, to come into operation on 1 September 2001, will:

...require aircraft to carry a portable megaphone, if the aircraft is carrying at least one passenger and its passenger seating capacity is more than 60 and less than 100 to two

portable megaphones, if the aircraft is carrying at least one passenger and the seating capacity of the aircraft is 100 or more.

The carriage of portable megaphones is required to provide a back-up system of communications between cabin crew and passengers, independent of the aircraft communications system, should the aircraft's public address system fail.

On 28 August 2000, Qantas advised the ATSB that it was installing megaphones in all its aircraft. On 5 December 2000, Qantas advised that it was investigating the relocation of the control system for the PA/interphone systems to an area less susceptible to damage. The installation of a separate PA/interphone system was also being investigated.

On 30 November 2000, Boeing reported that, at the time the B747-400 was designed, the requirements for the PAS and CIS were defined in FAR 121. The aircraft was to be fitted with a PAS and CIC that were required to perform under normal operating environments. The installation was designed with this intent. The FAR contained no operational requirements for the systems to function under abnormal conditions such as those encountered in the subject accident where the nose landing gear collapsed and damaged electronic components. Boeing advised that, to their knowledge, this was the first occurrence in which the PAC and CIS had been disabled. The company would, however, consider the issue in future aircraft designs.

An examination of FARs and JARs revealed that there was no requirement which specifically addressed PA and cabin interphone system design to require physical separation of normal and alternate system components to enhance system redundancy.

Observations:

The installation of megaphones will assist some aspects of communication if that there is a failure of the PA and/or interphone systems.

However, as discussed in section 2.4, megaphones will do little to enhance communications between the cabin crew and the flight deck. The installation of megaphones does not resolve the inherent design problem of locating the normal and alternate systems of necessary communication equipment (interphone and PA) in a relatively vulnerable part of the aircraft.

The ATSB acknowledges that the costs of redesigning the systems of existing aircraft would be substantial. In addition, the significance of the safety issue depends on the procedures and training an operator provides to its flight crew and cabin crew regarding emergency responses. For example, many operators do not provide their crews with a 'precautionary disembarkation' option. In such situations, the availability of the interphone system may be less critical (though obviously still important).

Nevertheless, the ATSB believes that there is a fundamental design weakness that should be addressed in this regard.

Safety Recommendation R20000231

The ATSB recommends that the FAA and JAA review the design requirements for high-capacity aircraft to ensure the integrity of the cabin interphone and PA systems, particularly with respect to cabin/flight deck communications, in the event of runway overruns and other relatively common types of events that result in landing gear and lower fuselage damage.

5.9 Emergency procedures and emergency procedures training (see sections 2.5, 2.6, 2.7 and 4.2)

On 28 August 2000, Qantas informed the ATSB that it was reviewing its guidelines and procedures concerning evacuations and precautionary disembarkations to 'ensure that best practice was followed'. It noted that the NTSB has suggested that flight crews be given better

guidance on when to initiate an evacuation (see section 2.5.1). Qantas noted that there were conflicting views within the aviation industry regarding the risks associated with a full evacuation compared with a precautionary disembarkation. Qantas also informed the ATSB that it was developing procedures for the use of megaphones.

On 5 December 2000, Qantas stated that:

- It had completed a review of emergency procedures training in early 2000, and that this review recently resulted in the approval of an increase in the duration of the annual emergency procedures training from 1 to 2 days annually.
- The Flight Training Department had conducted a detailed review and strengthened all Human Factors/CRM programs. As a result, annual emergency procedures training courses for 2001/2002 would include new communications modules. The CRM component had been increased from 1 to 3 hours.
- Qantas had established a joint working group with representatives from Emergency Procedures, Safety and Environment, and Cabin Services to review emergency procedures, particularly those identified as issues in the ATSB and company investigation reports into the accident.
- The joint working group would give priority attention to releasing the CSM by allocating a primary flight attendant to the CSM's door.
- A new cabin trainer was in service and this device would allow more realistic training in cabin emergencies.
- The Flight Training Department would validate the current operational decision-making tools as they apply to emergency evacuations versus precautionary disembarkations. This would include a risk assessment of emergency evacuations versus precautionary disembarkations.

The CASA Part 121A Discussion Paper included the following proposed requirements relating to emergency procedures for initial training (appendix 1 to 121A.1005):

- (b) Fire and Smoke Training. Each operator must [ensure] that fire and smoke training includes:
 - (2) The importance of informing flight crew immediately, as well as specific actions necessary for co-ordination and assistance, when fire or smoke is discovered.
- (f) Passenger handling. Each operator must ensure that training for passenger handling includes the following:
 - (2) Methods to motivate passengers and the crowd control techniques necessary to expedite an aeroplane evacuation.
- (g) Communication. Each operator must ensure that, during training, emphasis is placed on the importance of effective communication between cabin crew and flight crew, including technique, common language and terminology.
- (i) Crew Resource Management. Each operator must ensure that appropriate regulatory requirements are included in the training of cabin crew members.

The discussion paper also included proposed requirements relating to emergency procedures for recurrent (annual) training (appendix 1 to 121A.1015). These requirements included practical training every 12 months in evacuation procedures including crowd-control techniques and CRM.

Requirement 121A.1000 referred to 'senior' cabin crewmembers, and stated that such cabin crew were required to complete an appropriate course. The interpretive/explanatory

material for this requirement stated that this training should include 'co-operation within crew', including 'discipline, responsibilities and chain of command' and 'importance of co-ordination and communication'. It should also involve 'human factors and CRM' and 'where practicable, this should include the participation of senior cabin crew members in flight simulator Line Oriented Flying Training exercises'.

Observations:

Information provided by Qantas indicates that deficiencies identified regarding emergency procedures and emergency procedures training are being addressed. Consequently, the ATSB does not believe that an immediate safety issue exists. However, it will continue to monitor the progress of Qantas's review of this issue.

Although the CASA Part 121A Discussion Paper does address some of the issues identified during the investigation, other issues are not adequately addressed. Consequently, the following recommendation is made to CASA.

Safety Recommendation R20000234

The ATSB recommends that CASA consider including the following issues as requirements of operators during its current development of new legislation in the area of emergency procedures training:

- How flight crew should gather and evaluate relevant information and decide which type of emergency response is most suitable.
- How cabin crew should communicate with one another and the flight deck in emergency situations (in terms of technique, terminology, and methods to ensure that accurate information reaches the flight deck).
- How cabin crew should communicate during an emergency on the ground when there is a loss of PA and interphone communications.
- How cabin crew should systematically and regularly identify problematic situations in an aircraft during an emergency (including guidelines on what types of information are most important and ensuring that all areas of the aircraft are examined).
- Leadership and coordination functions of cabin crew supervisors during an emergency situation. For example, how the supervisors should assess the situation (particularly in circumstances that had not been clearly defined), assign roles and responsibilities amongst the cabin crew, coordinate the gathering of information, and coordinate the distribution of information.
- How cabin crew should effectively obtain information from passengers concerning safety-related issues.
- How cabin crew should effectively use language and assertiveness skills for crowd control and managing passenger movement towards exits during emergency situations, as well as passenger control outside the aircraft.
- Provision of cabin crew supervisors with appropriate resources to ensure that they can effectively communicate with other areas of the cabin during emergency situations (e.g. providing the supervisor with ready access to an 'assist' crewmember at their assigned location).

5.10 Development of flight crew procedures and training *(see section 3.4)*

In terms of check-and-training issues, Qantas reported the following on 28 August 2000:

As part of Qantas' continuous improvement process, Flight Training is ensuring that "trainers" are receiving the best possible training and development. (Seeking Australian National Training Association accreditation)...Flight Training will be seeking external accreditation for its quality management system later in 2000.

As noted in attachment G, Qantas is developing new performance indicators to be used when assessing the performance of flight crew during simulator sessions and line checks. It is intended that these indicators will place an increased emphasis on CRM issues.

On 5 December 2000, Qantas advised that the development of Qantas Flight Training programs now followed a structured process which was well documented in the Flight Operations *Quality Assurance Manual*. This process would be further reviewed following a benchmarking study conducted in early 2001 (see section 5.11.2). Qantas also advised that the Flight Training Department had formed a working group to review procedures and design processes for simulator lesson plans.

In the CASR Part 121 Discussion Paper, subpart N is titled 'Flight Crew'. This section contains a proposed requirement for initial, conversion and recurrent CRM training for all flight crew which includes:

- the operator ensuring that the personnel who integrate elements of CRM into conversion training are suitably qualified (121A.945(a)(3)).
- persons conducting line checks being trained in CRM concepts and the assessment of CRM skills (appendix 1 to 121A.965).

The interpretive and explanatory material section of the CASR Part 121A discussion paper on CRM training provides more detailed guidance on CRM assessment issues. This material includes the following:

- CRM skills assessment should be included in an overall assessment of flight crew performance and be in accordance with approved standards. Suitable methods of assessment should be established, together with the selection criteria and training requirements of the assessors and their relevant qualifications, knowledge and skills.
- A training and standardisation program for training personnel should be established.

Observations:

Information provided by Qantas indicates that deficiencies identified regarding the development of flight crew procedures and training are being addressed. Consequently, the ATSB does not believe that an immediate safety issue exists. However, it will continue to monitor the progress of Qantas's review of this issue.

5.11 Management decision-making processes (see sections 3.1, 3.2, 3.3, 3.5, 4.3)

5.11.1 CASA regulatory reform

In the CASR Part 119 Discussion Paper, subpart B ('Obligations of operators') contained a requirement for operators (to whom Part 121A applies) to 'establish and maintain a documented Safety Management, Accident Prevention and Flight Safety system' (119.05(1)). Paragraph 119.05(3) stated:

The documented Safety Management, Accident Prevention and Flight Safety System for Part 121A operators must include procedures to ensure that all operations are being conducted in accordance with all applicable requirements, standards and procedures, and must incorporate the following elements:

- (a) Management Responsibility:
 - (i) Nominated Management Representative;
 - (ii) Responsibility and Authority;
 - (iii) Safety Policy;
 - (iv) Objectives and Safety Planning;

- (v) Review of Safety Management;
 - (vi) Change Management;
 - (vii) Risk Management and Hazard Identification;
 - (viii) Emergency Response Planning;
 - (ix) Internal Communication / Consultation, Control of Documents;
 - (x) Control of Records.
- (b) Infrastructure:
- (i) Personnel;
 - (ii) Information;
 - (iii) Human Factors;
 - (iv) Facilities and Equipment.
- (c) Processes
- (i) Process Elements (including line operations, load control, flight planning, dispatch, aircraft performance, rostering, ground handling and maintenance control);
 - (ii) Service Development processes;
 - (iii) Purchasing/Subcontracting;
 - (iv) Handling and Storage;
 - (v) Measuring Equipment Calibration.
- (d) Monitoring, Feedback, Corrective and Preventive Action:
- (i) Incident and Accident Recording and reporting to identify adverse trends and to address any deficiencies in the interests of flight safety;
 - (ii) Remedial, Corrective and preventive Action;
 - (iii) Internal Audit.

5.11.2 Qantas policies, procedures and training

On 28 August 2000, Qantas informed the ATSB that it began steps in the first half of 1999 to introduce a safety management system that would meet the requirements of the airline well into the future as well as the requirements of the proposed CASR 119.05. More specifically, Qantas reported the following:

- Part of their new safety management system was a 'specific hazard identification model'. The program (titled 'Safety Observation Reporting System') was designed to encourage all flight crew and cabin crew to report hazards and positive safety practices. These reports will be entered into their new 'Aviation Quality Database' (AQD), risk assessed, and where applicable, appropriate safety action initiated. This hazard identification process will supplement the existing processes of identifying hazards during reactive occurrence investigations.
- As part of its ongoing safety management systems development, the Flight Operations Branch had formally adopted a risk assessment program aligned with the Australian Standard AS 4360:1999. As a part of this program, all significant procedural/policy changes had to be accompanied by a safety case when presented to the Operations Procedures Committee and Review Board along with a proposed implementation plan.
- All Flight Operations Branch managers had completed basic training in risk management during the year 2000.

- Following the accident, managers within the Flight Operations Branch had safety-related items included in their individual key performance indicators.

The Qantas chief pilot retired in October 1999, after planning to do so for some time. The new chief pilot, upon taking up the position, requested a detailed examination of the Flight Operations Branch's operations. Several administrative and process deficiencies were identified, and corrective action was initiated.

During the investigation, some personnel noted (in early 2000) that senior management had been more inclined to consult expertise within the Branch when making strategic decisions. However, it was also noted that there were still instances where decisions were made without consulting appropriate sources of expertise within the Branch.

On 5 December 2000, Qantas reported the following concerning the Flight Operations Branch:

- The Branch had commenced (in December 2000) a review of its organisational structure and processes with the assistance of an external organisational development consultant. This process will address the steps that are required to commence a transition to a learning organisation (that embraces strong change management and risk management programs). It will also address the suitability of the current branch structure to support these change steps and the structural changes required to achieve the branch's goal of embracing change management with a learning organisation ethos.
- The Branch would adopt 'benchmarking' as a tool to assist its ability to learn from other organisations. A benchmarking study would be conducted in early 2001.
- The Branch was reviewing its existing communication processes/mechanisms to assess effectiveness, evaluate areas of improvement, recommend revised strategies, and if synergies existed with the Cabin Services Branch communications strategy, to take advantage of those synergies.
- The Branch had undertaken research to identify the key characteristics of a robust change management system. The Flight Operations Branch structure would be reviewed to see if the current structure allowed a robust change management system to exist. Processes and procedures would then be examined to ensure they underpinned a sound change management strategy. The interface of changes within the Flight Operations Branch on other departments would also be examined.
- The Branch was well established on the path of introducing a quality management system. The Flight Safety Department was already accredited, and the Flight Training Department was seeking accreditation in December 2000. Other areas of the Branch would be following as soon as possible.
- The Branch had been involved (with Qantas College) in developing a course specifically suited to managers in the Flight Operations area. Examples of the courses available included decision making and problem solving, managing continuous improvement and innovation, organisational effectiveness, project management, business strategy, managing change, and finance for non-finance managers. Final course approval was scheduled for January 2001. Additionally, the Flight Operations Branch would be conducting induction courses for new 'pilot managers' covering areas such as managing hours of work, regulatory responsibilities, benefits available, and code of behaviour.
- The Branch had introduced a policy requiring proposals for new procedures that varied from Boeing procedures to be risk assessed and to obtain Operations Procedures

Committee approval and appropriate evaluation. An initial exercise was conducted early in 2000 to identify all previous variations and evaluate their continued acceptance.

- In terms of flight crew reports, a full review of Flight Operations Branch communications was under way with the intention of improving both the reporting networks and the reporting culture.
- The Branch was planning a series of surveys to be distributed in early 2001 to all technical flight crew.
- The Branch would be utilising QAR analysis to actively monitor any procedural change to aircraft operation as an ongoing part of safety analysis and evaluation.
- The Branch had commenced a study to examine the feasibility of introducing a Line Operations Safety Auditing program (similar to that developed by the University of Texas Human Factors Research Project and currently used by several American and other international airlines). Such programs involve trained observers sitting in the flight deck during normal line flights and examining the ways in which flight crew's identify threats and errors and then manage these events.

Observations:

Information provided by Qantas indicates that deficiencies identified regarding management processes within the Qantas Flight Operations Branch are being addressed. Consequently, the ATSB does not believe that an immediate safety issue exists. However, it will continue to monitor the progress of Qantas's review of this issue.

5.12 Surveillance (see section 4.3)

5.12.1 CASA surveillance approach

As discussed in section 4.3, CASA has been developing a new surveillance approach that focuses on systems-based audits rather than end-product inspection. The elements to be considered in the systems-based audits are outlined in paragraph 119.05(3) of the proposed CASR Part 119 (see section 5.11).

On 28 September 2000, CASA provided the following advice regarding its move to system-based audits as they relate to high capacity RPT carriers and CASA's monitoring of changes to airlines operating procedures:

In the surveillance of airlines, CASA has changed from inspecting the product of airline processing to auditing the systems that produce safe and effective outcomes. Examples of this approach include audits of training and checking, load control and performance and safety.

Visits by individual CASA Inspectors have been replaced by audits by multi-disciplinary teams. The Safety Systems audit approach includes examination of the systems required to produce consistent, safe outcomes and also includes sampling of the system outputs (products, records, witnessing tasks etc) as an integral part of the audit technique.

Experience with the new approach has revealed to CASA more detailed information regarding operators' safety performance in the last year than information identified in the previous 10 years of surveillance. As an example, in previous years many enroute inspections had been carried out on a operator where the inspection included load documentation. It was not until a systems audit was conducted was it shown that there were fundamental deficiencies with the underlying system behind the issuing of the documentation.

In following these new surveillance processes, CASA is aligning with current international best practice in safety assessment.

Safety systems assessment is based on a solid platform of work in risk assessment, management system assessment in complex technical organisations and accident analysis.

The assessment processes are designed to identify potential problems and latent failures which can contribute to accidents and also emphasises the organisation's management responsibility for safety.

Under the previous surveillance regime, as the inspection mainly focused on the final product (eg by observing flights), any deficiencies reported on inspections were largely identified as isolated examples and any corrective actions instituted by the operators therefore tended to be superficial fixes.

In the last year, through experience with the new scheme, the benefits of this type of audit approach have been recognised.

In addition, CASA has identified the need for operator responsibility in the internal monitoring of risk assessment, management of change and communication of change within management structures. The formal implementation of Risk Assessment and Change Management will be incorporated as part of future legislative change, however, the airline industry has been encouraged to introduce these procedures prior to legislative formalisation.

CASA has also introduced new areas of specialist technical involvement in the form of Cabin Safety and Simulator specialists. The involvement of these new specialists in areas not previously part of surveillance practice is supported by auditor training.

During the investigation, senior personnel within the CASA Compliance Branch reported that their audit personnel were providing positive feedback about the new approach (using multidisciplinary teams and focusing on systems issues) after they had gained some experience with it. They also noted that it would take up to a couple of years for CASA's new audit processes and the skills of their audit personnel to fully mature.

In September 2000, CASA Compliance Branch management reported that their audit personnel have received training in systems audits. This was a 5-day certified training program with an aviation industry focus. Some personnel also received audit training in 1996. Personnel have also been provided with training in system safety concepts. During interviews, senior personnel within CASA's Compliance Branch noted that, at this stage, there was no intention to recruit experts in management systems (e.g. experts in human factors, management processes, instructional design/delivery) to assist with audits, but instead CASA would train existing personnel to be better able to assess system issues.

Compliance Branch management also reported that audit personnel have been instructed to develop audit questions under each of the elements in the audit's scope from the operator's operations manuals and other documentation. They noted that this was in line with standard audit practices and consistent with the techniques used by the New Zealand CAA over the last 5 years. They will develop broad guidelines for each audit element as a further aid for audit personnel.

5.12.2 CASA surveillance of Qantas

As noted in section 4.3, CASA conducted their first audit of Qantas using the new audit approach in November 1999. The executive summary of the audit report (dated February 2000) stated that the audit 'was viewed primarily as a fact finding exercise and introducing Qantas personnel to the systems concept of audits'. The audit focussed on load control issues, but also examined dangerous goods, aircraft performance, crew rostering, flight planning and dispatch, maintenance control and cabin crew support systems.

As noted in section 4.3, the CASA Director requested an independent review of the 'exchanges between CASA and Qantas in the last 12 months' in November 1999. The report was submitted to the Director in December 1999. The report listed 29 recommendations to improve the surveillance of Qantas in particular as well as major operators in general. An action plan to respond to these recommendations was developed by the Assistant Director Aviation Safety Compliance in early 2000. Following on from the independent review, CASA conducted a 'special' systems-based audit of Qantas flight training processes in March 2000.

During interviews in September 2000 as part of the investigation, Compliance Branch personnel also reported that they were conducting a systems-based audit of Qantas focussing on the company's emergency procedures training.

On 28 September 2000, CASA reported that it had developed an action plan to directly address the communication problems between CASA's main airline office and its regional offices, and between CASA and the airlines. It noted that clearer accountability and reporting arrangements were essential features of this action plan.

Observations:

The ATSB notes the significant effort that CASA is making in directing the focus of its surveillance activities towards system issues rather than end-product issues, and believes this to be appropriate. The ATSB also believes that it is important that CASA's audit personnel have relevant expertise in a number of areas to effectively conduct these tasks. Therefore, the ATSB makes the following recommendation:

Safety Recommendation R20000238

The ATSB recommends that CASA consider widening its existing skill-base within the Compliance Branch to ensure that CASA audit teams have expertise in all relevant areas, including human factors and management processes.

5.13 Airport emergency response activities

Following the accident, the Airport Authority of Thailand reviewed aspects of its operations. Based on this review, the authority has made changes to its coordination and decision-making activities.

6. CONCLUSIONS

6.1 Significant active failures

Parts 1 to 4 identified several unsafe acts and active failures that had a significant influence on the development of the accident. These were:

- The flight crew did not use an adequate risk management strategy for the approach and landing.
- The first officer did not fly the aircraft accurately during final approach.
- The captain cancelled the go-around decision by retarding the thrust levers.
- The flight crew did not select (or notice the absence of) idle reverse thrust.
- The flight crew did not select (or notice the absence of) full reverse thrust.
- The flight crew did not consider all relevant issues when deciding not to conduct an immediate evacuation.
- Some crewmembers did not communicate important information during the emergency period.

Other significant active failures were:

- The runway surface was affected by water.
- The cabin interphone and passenger address system became inoperable.

6.2 Significant latent failures

Significant latent failures associated with Qantas Flight Operations Branch activities were:

- Company-published information, procedures, and flight crew training for landing on water-affected runways were deficient.
- Flight crew training in evaluating the procedural and configuration options for approach and landing was deficient.
- Procedures and training for flight crew in evaluating whether or not to conduct an emergency evacuation were deficient.
- Procedures and training for cabin crew in identifying and communicating relevant information during an emergency were deficient.
- The processes for identifying hazards were primarily reactive and informal, rather than proactive and systematic.
- The processes to assess the risks associated with identified hazards were deficient.
- The processes to manage the development, introduction and evaluation of changes to operations were deficient.
- The design of operational procedures and training were over-reliant on the decision-making ability of company flight crew and cabin crew and did not place adequate emphasis on structured processes.
- Management culture was over-reliant on personal experience and did not place adequate emphasis on structured processes, available expertise, management training, and research and development when making strategic decisions.

Significant latent failures associated with CASA's operations were:

- The regulations covering contaminated runway operations were deficient.
- The regulations covering emergency procedures and emergency procedures training were deficient.
- The surveillance of airline flight operations was deficient.

Other significant latent failures were:

- The redundancy provided by the normal and alternate cabin interphone and public address systems in B747-400 aircraft was significantly reduced because components for both systems were co-located in the same relatively damage-prone position in the lower fuselage aft of the nosewheel.

6.3 Safety action

On 5 December 2000, Qantas reported that all deficiencies identified during the investigation and highlighted in this report either had been, or were being, addressed. Qantas Flight Operations Branch had introduced substantial changes and were examining further changes to its management policies and procedures in a number of areas (including operational training and procedures, hazard identification, risk assessment, change management, and management decision-making processes). Some of these changes were in progress in the period before the accident. The ATSB raised a number of safety analysis deficiency notices (SADNs) concerning Qantas operations as a result of the investigation. Four of these SADNs remained open pending advice from the company on the progress of their change activities (see section 5.4, 5.9, 5.10 and 5.11).

CASA was also in the process of making substantial changes to its surveillance processes and the Australian aviation safety regulations. Many of these changes were in progress at the time of the accident.

The ATSB made five recommendations where there remained important safety matters that had not been (or were not being) addressed. These were:

1. Safety Recommendation R20000239

The ATSB recommends that CASA ensures that all Australian operators of high capacity jet aircraft have in place procedures and training to ensure flight crews are adequately equipped for operations on wet/contaminated runways.

2. Safety Recommendation R20000235

The ATSB recommends that CASA review the intent of CAO 48 to ensure that operators consider all duties associated with a pilot's employment (including managerial and administrative duties) when designing flight and duty time schedules, and that this requirement is not restricted to situations where there are one or two pilots.

3. Safety Recommendation R20000231

The ATSB recommends that the FAA and JAA review the design requirements for high capacity aircraft to ensure the integrity of the cabin interphone and passenger address systems, particularly with respect to cabin/flight deck communications, in the event of runway overruns and other relatively common types of events which result in landing gear and lower fuselage damage.

4. Safety Recommendation R20000234

The ATSB recommends that CASA should consider including the following issues as requirements of operators during its current development of new legislation in the area of emergency procedures training:

- How flight crew should gather and evaluate relevant information and make a decision regarding which type of emergency response is most suitable.
- How cabin crew should communicate with each other and the flight deck in emergency situations (in terms of technique, terminology, and methods to ensure that accurate information reaches the flight deck).
- How cabin crew should communicate during an emergency on the ground when there is a loss of PA and interphone communications.
- How cabin crew should systematically and regularly identify problematic situations in an aircraft during an emergency (including guidelines on what types of information are most important and ensuring that all areas of the aircraft are examined).
- Leadership and coordination functions of cabin crew supervisors during an emergency situation. For example, how the supervisors should assess the situation (particularly in circumstances that had not been clearly defined), assign roles and responsibilities amongst the cabin crew, coordinate the gathering of information, and coordinate the distribution of information.
- How cabin crew should effectively obtain information from passengers concerning safety-related issues.
- How cabin crew should effectively use language and assertiveness for crowd control and managing passenger movement towards exits during emergency situations, as well as passenger control outside the aircraft.
- That cabin crew supervisors are provided with appropriate resources to ensure that they can effectively communicate with other areas of the cabin during emergency situations (e.g. providing the supervisor with ready access to an 'assist' crewmember at their assigned location).

5. Safety Recommendation R20000238

The ATSB recommends that CASA consider widening its existing skill-base within the Compliance Branch to ensure that CASA audit teams have expertise in all relevant areas, including human factors and management processes.

ATTACHMENTS

Attachment A: Terms and abbreviations

AEPM	Aircrew Emergency Procedures Manual
AGL	Above ground level
ASIR	Air safety incident report form
ATC	Air traffic control
ATSB	Australian Transport Safety Bureau
CAO	Civil Aviation Orders
CAR	Civil Aviation Regulations
CASA	Civil Aviation Safety Authority
CIC	Cabin Interphone Controller
CRM	Crew resource management
CSM	Customer Service Manager
CSS	Customer Service Supervisor
CVR	Cockpit voice recorder
deg C	Degree Celsius
DME	Distance measuring equipment
EEC	Electronic engine control
EICAS	Engine indicating and crew alert system
EP	Emergency procedures
EPR	Engine pressure ratio
FAA	Federal Aviation Authority
FAM	Flight Administration Manual
FAR	Federal Aviation Regulation
FCTM	Flight Crew Training Manual
FSO	Flight Safety Officer
ft	Feet
Ft/min	Feet per minute
ICAO	International Civil Aviation Organisation
ILS	Instrument landing system
JAA	Joint Aviation Authority
kg	Kilograms
KCAS	Knots calibrated airspeed
KIAS	Knots indicated airspeed
Km	Kilometres
KPI	Key performance indicator
kts	Knots
LOFT	Line oriented flight training

m	Metres
MEC	Main equipment centre
mm	Millimetre
NLG	Nose landing gear
NM	Nautical miles
N.m	Newton metres
PA	Passenger address
PAC	Passenger address controller
psi	Pounds per square inch
PSU	Passenger service unit
QAR	Quick access recorder
QRH	Quick Reference Handbook
RVR	Runway visual range
RWLG	Right wing landing gear
R/W	Runway
SSDFDR	Solid State Digital Flight Data Recorder
TO/GA	Takeoff/go-around
V_{REF}	Reference speed
V_{s1g}	Stalling speed

Attachment B: B747-400 aircraft information

B.1 Accident aircraft description

Airframe

Aircraft type	Boeing 747-438 ⁸²
Serial Number	24806
Year of manufacture	1990
Registration	VH-OJH
Certificate of Airworthiness	SY 38 valid from 30 August 1990
Certificate of Registration	KSA 38/03 issued 30 August 1990
Total airframe hours	41,151.24
Total airframe cycles	6,002
Last 'A' maintenance check	18 August 1999
Last 'D' maintenance check	28 July 1997
Airframe hours since last 'D' check	9,872.24

Engines

Numbers 1,3, and 4	Rolls Royce Turbofan RB211-524G2-19/15
Number 2	Rolls Royce Turbofan RB211-524G2-T-19/15

Weight and balance

Maximum permissible take-off weight	397,200 kg
Take-off weight	342,075 kg
Maximum permissible landing weight	295,742 kg
Landing weight	249,802 kg
Fuel quantity on landing	14,515 kg

The aircraft centre of gravity was within limits.

⁸² Most Qantas Boeing 747-400 aircraft are designated B747-438.

B.2 Aircraft system descriptions

B.2.1 Spoilers/speedbrakes

There were six spoiler panels on each upper wing surface just forward of the trailing edge flaps. The four inboard panels on each wing functioned as speedbrakes during flight. On the ground, all six spoiler panels on each wing acted as ground spoilers to dump wing lift and provide aerodynamic drag to assist aircraft deceleration. A speedbrake lever on left side of the cockpit centre pedestal controlled the speedbrake and ground spoiler functions.

When the speedbrake lever was in the ARMED position, thrust levers 1 and 3 were in the CLOSED position, and main landing gear touchdown had occurred, the speedbrake lever was driven to the UP position, extending all spoiler panels. However, if the thrust levers were advanced before touchdown, and the mainwheels subsequently contact the runway, the speedbrake lever would remain in the ARMED position until the thrust levers were retarded, at which stage the ground spoilers would be deployed. It was this latter sequence that occurred during the accident landing.

B.2.2 Wheel brakes

Boeing 747-400 aircraft had carbon brakes fitted to each mainwheel. The nosewheel was not equipped with brakes. The wheel braking system incorporated full anti-skid, locked wheel touchdown, and hydroplaning protection, plus brake torque limiting. The antiskid system functioned to modulate brake pressure when required, to prevent wheel skid and obtain optimum braking action under various braking conditions. The wheel brakes could be operated by either pilot using foot pedals or automatically by the auto-brake system.

The auto-brake selector switch had 8 positions - OFF, DISARM, 1, 2, 3, 4, MAX AUTO, and RTO (rejected takeoff). The switch was located at the bottom of the captain's instrument panel. The auto-brake system measured the rate of deceleration of the aircraft on the runway and compared this to the rate selected by the crew according to the selector switch position. It then metered the hydraulic pressure to the brakes to provide the selected rate of deceleration, without brake pedal operation, during the landing roll.

A condition for auto-brake operation was that all four engine thrust levers were within the idle range within 3 seconds after touchdown. If this did not occur, the auto-brake selector knob would rotate to the DISARM position, and the auto-brakes would be deactivated. Manual braking was still available. This was the situation during the accident landing.

Any change in auto-brake status was indicated on the Engine Indicating and Crew Alerting System (EICAS) display by a change from the white memo message 'AUTOBRAKES 4' (if '4' was selected) to an amber advisory message 'AUTOBRAKES'. The system design did not include an audible warning accompanying the EICAS message to the pilots that the auto-brake status had changed.

B.2.3 Engine thrust control and reverse thrust

The thrust levers controlled the engines via the electronic engine control (EEC) units. The thrust lever assembly included forward and reverse thrust levers mounted on the control stand. There were switches on the assembly for autothrottle disengagement and the take-off/go-around (TO/GA) functions. The thrust levers could be manipulated forward through an arc of 50 degrees from the idle position to the full forward thrust position; the reverse thrust levers rotated backwards through an arc of 90 degrees. Electro-mechanical interlocks prevented simultaneous selection of forward and reverse thrust.

Each engine had a pneumatically actuated fan air thrust reverser powered by bleed air from the related engine. Reverse thrust was available only on the ground and could not be selected unless the forward thrust levers were at idle and the air/ground logic sensed that the aircraft was on the ground.

B.2.4

TO/GA

The TO/GA function provided a guaranteed level of thrust in a go-around situation. It was activated by pressing either of two switches positioned on the forward side of the thrust levers. The increase in thrust commenced approximately 2 seconds after either switch was pressed and automatically moved the thrust levers forward to the required position. TO/GA also provided guidance on the flight director display to help the pilot fly the appropriate profile. Pushing the TO/GA switch once automatically provided a level of engine thrust sufficient to place the aircraft in a 2,000 ft/min rate of climb. Pushing the TO/GA switch twice provided maximum engine thrust.

In contrast, a manual go-around required a pilot to manipulate thrust manually, and change aircraft pitch angle without the flight director guidance. During the investigation, check-and-training personnel reported that, in terms of the time involved to achieve go-around thrust, there would be no significant difference between using TO/GA go-around or manually moving the thrust levers. Observations of the system in operation in the simulator confirmed this view.

Attachment C: Aircraft damage and post-accident inspection

C.1 Airframe and engines

The main areas of damage to the aircraft were the lower forward fuselage, the nose and right wing landing gear and landing gear bays, and the engines. All damage was caused by impact forces.

The principal impact occurred when the aircraft struck the ILS antenna and its foundations. This initiated the collapse of the nose landing gear (NLG) and the right wing landing gear (RWLG) and shredded most tyres. Further stress was placed on the landing gear as the aircraft decelerated and the wheels sank into the wet muddy soil. The final impact occurred when the nosewheel contacted the edge of the sealed perimeter road.

The NLG collapsed and was forced into the underside of the fuselage aft of the NLG bay, breaching the integrity of the fuselage and forcing the forward cargo bay floor upward by about 50 cm. The main equipment centre (MEC) and the electronic rack support were forced upward by about 30 cm and skewed, damaging some electronic components. The RWLG separated at the design shear points and folded rearwards, damaging the right inboard flap.

Hydraulic lines to the nose and right wing landing gear were disrupted. This allowed the contents of hydraulic system numbers 1 and 4 to be discharged.

All aircraft fuel tanks retained their integrity and there was no leakage of fuel.

Neither of the engines on the left wing (numbers 1 and 2) contacted the ground. However, both ingested mud and water, with the inboard engine (number 2) also receiving damage during the collision with the localiser antenna. The right side engines also ingested foreign matter. The right inboard engine (number 3) contacted the ground heavily after the RWLG collapsed. This caused the diagonal brace forward lug in the support pylon to fail and damaged the main engine gearbox. The number 4 engine also contacted the ground and ingested considerable mud and water. However, the support pylon retained its integrity.

A number of wing leading and trailing edge flaps, landing gear bays doors, antennas, and wing and body panels were damaged by pieces of the localiser antenna and its platform, and small rocks and mud that were thrown up during the accident sequence. None of this damage affected the structural integrity of the aircraft.

Numerous cabin internal fittings such as window reveals, passenger service units that house passenger oxygen masks, air vent outlets and reading lights, and ceiling panels were dislodged as the fuselage flexed and twisted during the overrun sequence (see part 2 for further details).

In addition to the damage to the aircraft, other damage included:

- the destruction of the ILS localiser antenna,
- disruption to the surface of the overrun area, and
- the destruction of a few trees adjacent to the perimeter road.

The collapse of the NLG led to the cabin passenger address and interphone systems being rendered inoperable (see section 2.4).

C.2 Wheel brake system

The complete brake system underwent a comprehensive examination. No fault was found in any component that might have affected normal operation of either the automatic braking system or the manual braking system.

Tables C1 and C2 show the brake torques at 4-second intervals as recorded by the QAR from the initial brake application during the landing roll until the last recorded data which occurred approximately 1,700 ft from the end of runway 21L. Fig. C1 describes the numbering system for the wheels that is used in the tables.

Figure C1:
Layout of mainwheels

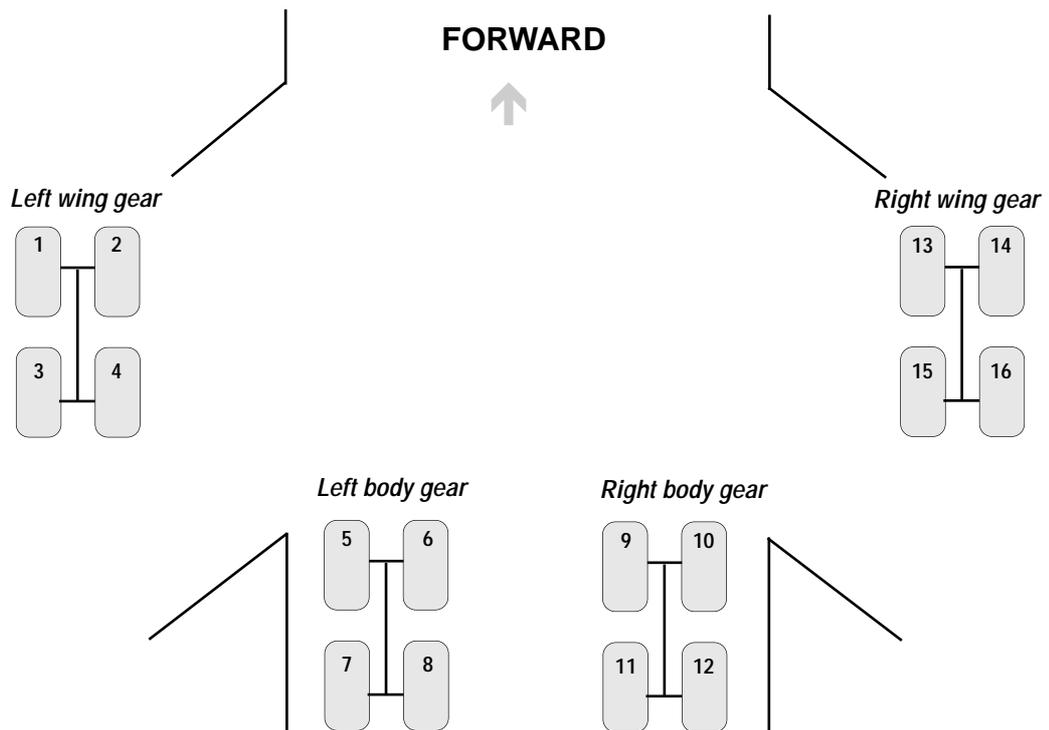


Table C1:
Brake torques (N.m) for wheels 1–8 (left side wing and body gear)

<i>Time</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>
2246.40				10,475				10,020
2246.41	0				0			
2246.42		1,627				694		
2246.43			4,424				9,543	
2246.44				4,424				3,730
2246.45	217				0			
2246.46		0				0		
2246.47			5,118				1,865	
2246.48				6,528				3,253
2246.49	0				0			
2246.50		0				1,627		
2246.51			5,595				2,082	
2246.52				2,559				4,424
2246.53	0				0			
2246.54		933				1,149		
2246.55			10,258				3,253	
2246.56				8,155				4,880
2246.57	2,559				3,730			
2246.58		2,321				1,149		
Average	555	976	6,349	6,428	746	924	4,186	5,261

Table C2:
Brake torques (N.m) for wheels 9–16 (right side wing and body gear)

<i>Time</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>	<i>16</i>
2246.40				0				0
2246.41	0				0			
2246.42		4,424				0		
2246.43			4,880				6,051	
2246.44				2,321				3,253
2246.45	2,798				4,424			
2246.46		3,015				0		
2246.47			1,865				8,610	
2246.48				3,947				1,627
2246.49	455				3,492			
2246.50		2,082				3,730		
2246.51			2,082				8,849	
2246.52				3,015				4,663
2246.53	455				3,015			
2246.54		3,730				1,627		
2246.55			2,559				7,222	
2246.56				2,798				3,253
2246.57	1,388				6,289			
2246.58		2,321				1,865		
Average	1,019	3,114	2,847	2,416	3,444	1,444	7,683	2,560

C.3

Aircraft tyres

The nose landing gear tyres remained inflated and were undamaged. All but one of the main landing gear tyres were damaged. The tyres in positions 2, 4, 5, 7, 9 and 11 had been shredded as a result of the collision with the ILS antenna foundations.

A specialist from the tyre manufacturing company examined the tyres. All were within normal wear limits. There was no evidence of reverted rubber deposits (see Section 1.4.5) on any of the tyres. Heavy braking spots were found on tyres in positions 2, 6, and 15 and may have occurred before the accident landing during wet or dry runway operations. In all other respects, the conditions of the tyres were consistent with normal operational use.

Attachment D: Flight recorder information

The aircraft was fitted with a solid state digital flight data recorder (SSDFDR), cockpit voice recorder (CVR), and a quick access recorder (QAR).

The DFDR was an Allied Signal Commercial Avionics Systems solid state flight data recorder. It contained in excess of 50 hours of recorded data involving 380 discrete parameters covering aircraft performance and systems operation. The quality of the data was excellent.

The CVR was a Fairchild Model A100A. It functioned normally, recording crew conversations and other cockpit sounds that occurred during the last 30 minutes of the flight. The recording ceased when the crew operated the engine fire handles after the aircraft came to a stop.

The recorded audio quality was good. However, the air-ground communications on the crew channels was recorded at a significantly higher level than the crew audio and masked crew conversation whenever a radio transmission took place. Nevertheless, crew conversation during these periods could be discerned from the cockpit area microphone channel. Civil Aviation Order (CAO) 103.20 paragraph 3.1(b)(iii) stated that the audio gain should be adjusted so that 'microphone signal exceeds the level of the headset side tone signal from other sources on a high percentage of the time'.

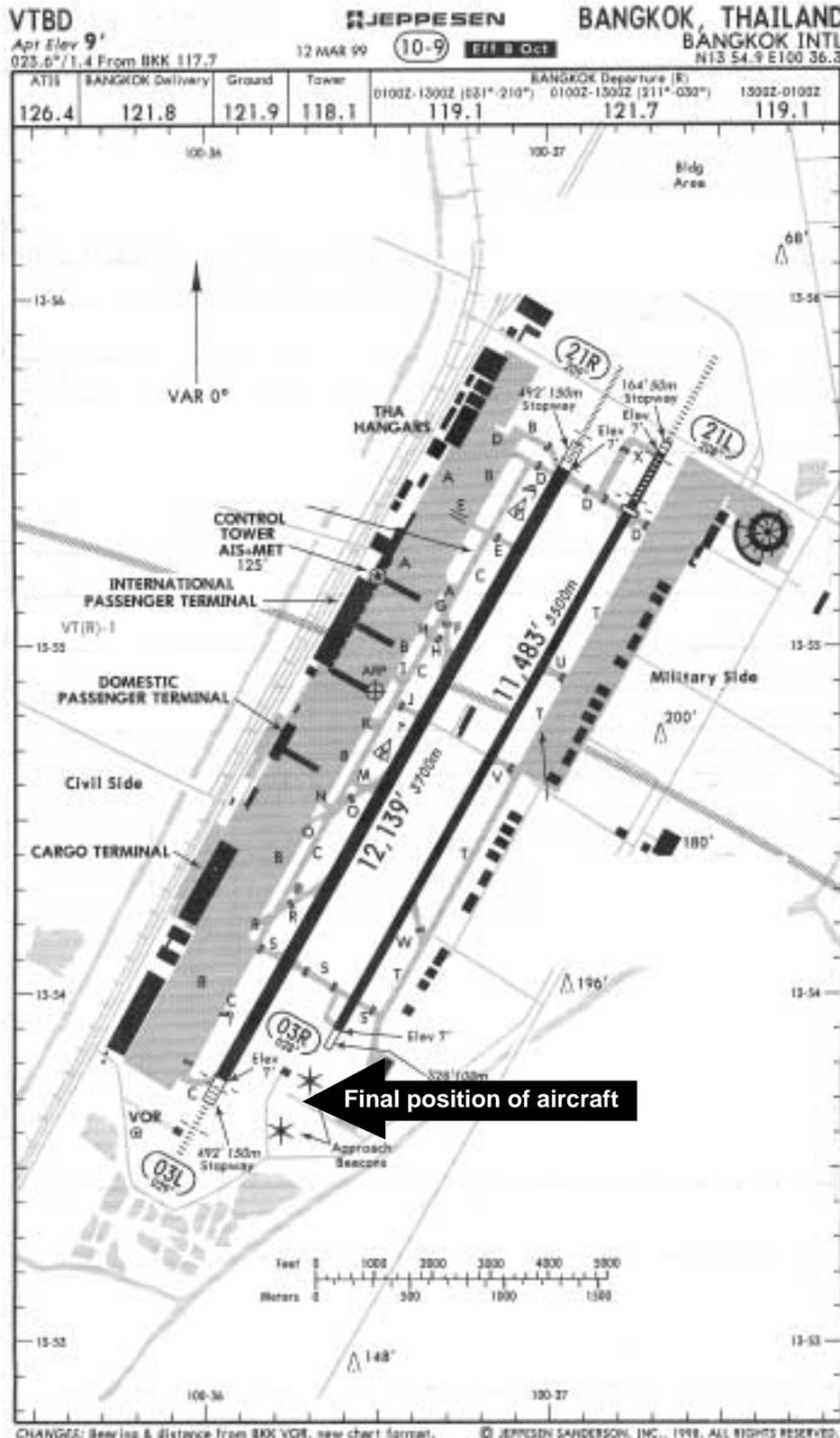
The aircraft was also fitted with a Teledyne Controls Unit Optical QAR that recorded data to an optical floppy disc at a rate of 256 bytes per second. The number of parameters recorded by the QAR was similar to that recorded by the DFDR. However, some of the parameters were unique to the QAR. These included brake temperatures, brake torques and tyre pressures that were recorded once every four seconds.

Data was stored in a 20-second history buffer before it was sent to the QAR for recording. Damage to the aircraft's electronic bay during the impact sequence caused a power interruption and resulted in the loss of QAR data for the last 20 seconds of the landing run.

Attachment E: Bangkok airport chart

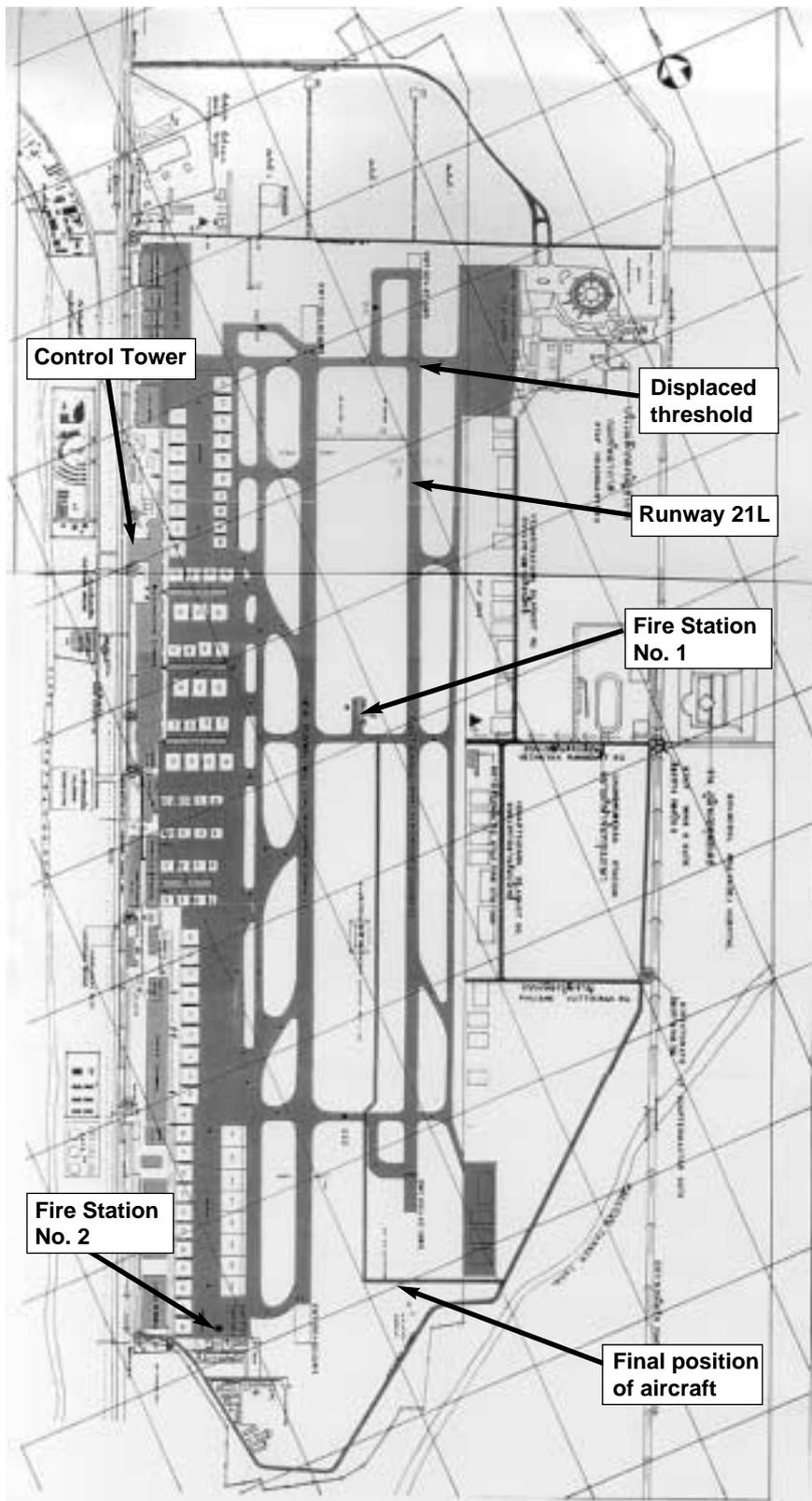
The diagram below shows the airport chart from the Jeppesen Route Manual as used by Qantas at the time of the accident. The location of the final resting place of the aircraft is indicated by the arrow. Irrelevant text has been removed to simplify the diagram.

E.1 Final position of aircraft



CHANGES: Bearing & distance from BKK VOR, new chart format. © JEPPESEN SANDERSON, INC., 1998. ALL RIGHTS RESERVED.

E.2 Bangkok airport map



Attachment F: Crew information

F.1 Captain

Personal details	Male, 49 years of age
Type of licence	Air Transport Pilots Licence (Australian)
Total flight time	15,881 hours
Flight time on Boeing 747-400	724 hours
Flight time last 90 days	82.2 hours (all B747-400)
Flight time last 30 days	23.2 hours (all B747-400)
Last flight	10 September 1999
Last recurrent check	27 July 1999
Last route check	29 July 1999
Medical certificate	Class 1, valid to 24 October 1999
Medical restriction	Vision correction required (glasses were worn)

The pilot in command initially joined the company as a cadet in 1969. He commenced operations as a pilot in command (B767) in June 1989, and became a senior check captain (B767) in September 1993. His training duties also included base training.⁸³ He commenced conversion training to the B747-400 in May 1998, and commenced line flying as pilot in command in June 1998. In February 1999, he was appointed to a senior management position in the Flight Operations Training Department. He was appointed as a senior check captain on B747-400 in March 1999. His role as a management captain meant that he flew approximately one-third of the hours flown by a line captain.

The pilot in command's performance always exceeded the minimum requirements during his initial training, recurrent (simulator) checks and route checks on the B747-400. His performance on most items was assessed as being '3+' (meaning a 'high' standard, maximum is '4'). Pilots on recent flights with the captain prior to the accident flight reported nothing unusual or significant regarding his performance.

During the 90 days prior to the accident flight, the captain had completed 13 line sectors during which he conducted one night landing and seven day landings. He had also completed two night landings in simulator sessions. In the previous 90 days (March to June), he also flew 13 line sectors and conducted four day landings and two night landings. In the 30 days prior to the accident flight, he had completed four line sectors, including two day landings.

The pilot in command reported that on non-flying workdays, he worked from approximately 0700 to 1800 each day. He often worked additional hours on the weekends. He was not required to work additional hours, and did so of his own initiative. He reported that he enjoyed his work, and found it challenging rather than stressful. As a result of his busy work schedule, he had been doing less exercise in recent months.

In the week prior to the accident, the pilot in command reported that he had been eating, sleeping and working as normal. On the day of the accident, he awoke at 0500 as usual, and spent the day relaxing prior to 1500, when he arrived at work to begin preparations for the flight. During the flight to Bangkok he had a 30-minute rest period and a 2-hour rest

⁸³ 'Base training' involves take-off and landing practice in an actual aircraft.

period. He did not sleep during these periods. He reported that he did not feel tired or fatigued during the approach into Bangkok.

The investigation did not find evidence of any physiological or medical condition that was likely to have impaired the pilot in command's performance.

F.2

First Officer

Personal details	Male, 36 years old
Type of licence	Air Transport Pilot Licence (Australian)
Total Flight Time	8,973 hours
Flight time on Boeing 747-400	5,187 hours
Flight time last 90 days	136.3 hours (all B747-400)
Flight time last 30 days	1.3 hours (all B747-400)
Last flight	13 September 1999
Last recurrent check	19 September 1999
Last route check	2 July 1999
Medical certificate	Class 1, valid to 26 November 1999 (no restrictions)

The first officer was recruited into Qantas in July 1988 from a regional airline, following several years as a general aviation pilot and instructor. His initial employment was as a second officer on Boeing 747-200/300 aircraft, and he converted to the B747-400 aircraft in September 1990. He commenced line operations as a first officer on the B747-400 in June 1995.

During the period February 1996 to January 1999, the first officer exceeded the minimum requirements during his recurrent (simulator) checks and route checks. His performance on almost all items was assessed as being around the '3' (meaning a 'good' standard) or '3+' level.

In the 90 days prior to the accident flight, the first officer had completed 17 sectors, which was approximately his normal rate over the previous 2 years. On the sectors in the last 90 days, he completed five night landings and four day landings. He had completed two sectors and one day landing in the 30 days prior to the accident. The first officer reported that he did not consider that his relatively low frequency of recent flying affected his manual control skills on the approach.

The first officer reported that he ate and slept normally in the week prior to the accident. He conducted no flying during that period, except for the recurrent check on 19 September. On the morning of the accident flight, he awoke at 0730. He departed Coolangatta on a commuter flight as a passenger at 1105, arriving in Sydney well before the sign-on time for the flight (1545). During the flight to Bangkok he had a 30-minute rest period and a 2-hour rest period. He did not sleep during these periods. He stated that he often feels a little tired on such trips as the Sydney to Bangkok sector. However, he did not believe he was fatigued at the time of the accident.

The investigation did not find evidence of physiological or medical condition that was likely to have impaired the first officer's performance.

F.3**Second Officer**

Personal details	Male, 35 years old
Type of licence	Air Transport Pilots Licence (Australian)
Total flight time	6,685 hours
Flight time on Boeing 747-400	2,961 hours
Flight time last 90 days	107.0 hours (all B747-400)
Flight time last 30 days	53.0 hours (all B747-400)
Last flight	17 September 1999
Last proficiency check	29 July 1999 (route check)
Medical certificate	Class 1, valid to 20 April 2000 (no restrictions)

The second officer was recruited from the Royal Australian Air Force with experience accumulated on multi-crew aircraft. He completed his B747-400 second officer training in October 1995.

The second officer returned from his previous flying trip on the morning of 17 September 1999. He reported that, between then and the accident, he ate and slept normally. During the flight to Bangkok he had, like the other two pilots, a 30-minute rest period and a 2-hour rest period. He did not sleep during these periods. He stated that he frequently feels a little tired on trips such as the Sydney to Bangkok sector, but he did not believe he was fatigued at the time of the accident.

The investigation did not find evidence of any physiological or medical condition that was likely to have impaired the second officer's performance.

F.4**Cabin crew**

The CSM and CSS both had over 20 years experience with the airline. The average experience of the other 14 cabin crew was 8 years. It was the first flight for one cabin crewmember.

All cabin crewmembers had successfully completed their annual emergency procedures training within the last 12 months.

Attachment G : Overview of Qantas Flight Operations Branch

G.1 Overview of the airline

The Qantas 1999 Annual Report notes that the airline was recognised as one of the world's leading long distance airlines. The Qantas Group, consisting of the core airline and four regional airlines, carried more than 19 million passengers in 1998/99, operating a fleet of 135 aircraft across a network spanning more than 100 destinations. The airline employed more than 30,000 full and part-time staff.

As of 30 June 1999, the core airline consisted of four aircraft types: B747-400 (21 aircraft), B747 (11 aircraft, including 300s, 200s and SPs), B767 (28 aircraft), and B737 (38 aircraft). The B747-400 fleet had 615 pilots, including captains, first officers and second officers.

G.2 Flight Operations Branch

The Flight Operations Branch was located within the Operations Division of the airline. The Branch was responsible for providing properly trained flight crew (i.e. pilots and flight engineers) and procedures for aircraft operations. It was also responsible for providing a check-and-training organisation for flight crew. The organisational structure and accountabilities of key personnel in the Branch were outlined in section 2 of the Branch's *Flight Administration Manual (FAM)*.

The Branch was composed of a number of departments and sections, which reported to the Group General Manager (also chief pilot). These departments and sections included Fleet Management, Flight Technical, Training and Flight Safety.

Fleet Management. The Fleet Management section consisted of a General Manager (for the B747 and B747-400 fleets), and a Manager B747 Operations, Manager B767 Operations, and Manager B737 Operations. These managers were responsible for the safe, efficient and effective performance of fleet operations. Activities included monitoring route structures, crew scheduling patterns and other planning issues, investigating flight crew reports of an operational or technical nature, and receiving and addressing grievances from flight crew.

Flight Technical. The Flight Technical section included a General Manager, and two other technical pilots. Duties included initiating and managing research on aircraft and equipment and managing the content and quality of aircraft operations manuals and the FAM. They were also responsible for coordinating with flight crew, other sections in the company, and manufacturers on technical issues.

Flight Training. The General Manager Flight Training was responsible for the content, conduct and effectiveness of training programs. For each of the four aircraft fleets, there was a 'Manager Training'. At the time of the accident, the B747-400 training section consisted of approximately 50 check-and-training staff. The Flight Training Department also included the Emergency Procedures Training section, which was responsible for developing and conducting emergency procedures training for flight crew and cabin crew.

Flight Safety. The General Manager Flight Safety reported to both the chief pilot and the Group General Manager Safety and Environment. The General Manager Flight Safety (as part of the Safety and Environment Department) was responsible for conducting investigations of all occurrences involving company aircraft, as well as identifying trends and deficiencies in flight operations. He also managed the company's QAR program, and had responsibility for safety policy associated with emergency procedures.

G.3 Other Branches

The Cabin Services Branch was located in the Commercial Division. This Branch was responsible for the in-flight product provided by the cabin crew in terms of safety, service delivery and care of customers. The Branch had input to emergency procedures training and content of the *Aircrew Emergency Procedures Manual* (AEPM). It also investigated cabin safety and security incidents.

The Flight Operations/Cabin Crew Committee was composed of management and safety representatives from the Flight Operations Branch and the Cabin Services Branch. Its duties and responsibilities were to liaise on matters affecting flight crew and cabin crew to ensure a coordinated company approach.

The Safety and Environment Department provided oversight and guidance on the safety management and investigation activities of the various Branches, including the Flight Operations Branch. The Safety and Environment Department reported directly to the Chief Executive.

G.4 Operational procedures

G.4.1 Manuals

In accordance with Civil Aviation Regulation (CAR) 215, Qantas provided an operations manual for use by its operational personnel. The Qantas Operations Manual consisted of several parts:

- Part I – Policy. Consisted of the *Flight Administration Manual* (FAM).
- Part II – Aircraft Operations. For B747-400 operations, this consisted of a series of manuals, including the *B747-438 Operations Manual*, the *B747-438 Performance Limitations Manual*, and the *B747-438 Quick Reference Handbook* (QRH).
- Part III – Route Manuals. Consisted of the Jeppesen Airway Manuals, terminal navigation charts, and the *Route Manual Supplement*.
- Part IV – Supplements. Consisted of a variety of documents, including the *B747-438 Flight Crew Training Manual* and the Flight Standing Orders.
- Part V – Air Legislation. Consisted of a variety of documents, including the Australian Civil Aviation Regulations and Civil Aviation Orders.
- Part VI – Concessions. Concessions issued by CASA.

In section 1 of the FAM, the following was stated (page 1-1):

The Flight Administration Manual sets out Company policy, standards and procedures which are to be adhered to under all circumstances. The Aircraft [B747-400] Operations Manual specifies procedures and crew actions for anticipated normal and non-normal flight conditions. FAM policy may limit or provide additional definition or scope in the application of these procedures.

Page 29-4 of the FAM provided definitions of the various manuals. These definitions included:

[AIRCRAFT] OPERATIONS MANUAL (FLEET)

Company published Operations Manual for the aircraft type, based on the manufacturer's publication but modified to conform with company and CASA operating policies.

PERFORMANCE MANUAL (FLEET)

Company published performance data and operating limitations for the aircraft type based on the manufacturer's publication but modified to suit company and CASA requirements for data presentation and operating performance. [There were two performance manuals for each aircraft type: the Performance Limitations Manual and the Performance Planning Manual.]

ROUTE MANUAL SUPPLEMENT

Company produced route information supplementing the Jeppesen Route Manuals.

FLIGHT CREW TRAINING MANUAL

Company published training manual for the aircraft type based on the manufacturer's publication but modified to suit company and CASA requirements.

AIRCREW EMERGENCY PROCEDURES MANUAL [AEPM]

Company produced manual that supplements the Operations Manual (Emergency Equipment chapter) to provide more detailed information on equipment location, evacuation provisions, in-flight and ground emergencies.

G.4.2 Approach and landing procedures

Policies and procedures relating to approach and landing were contained in the FAM, the *B747-438 Operations Manual*, and the *B747-438 Performance Limitations Manual*. Supplementary information was included in the *B747-438 Flight Crew Training Manual*. These procedures are discussed in sections 1.6, 1.7 and 1.8 of the report.

G.4.3 Emergency procedures

Two company manuals contained information relating to emergency procedures: the AEPM (provided to all flight crew and cabin crew) and the *Quick Reference Handbook (QRH)*, which formed part of the aircraft Operations Manual (provided to all flight crew).

The Flight Operations Branch was responsible for the content of the AEPM. The Flight Technical Department was responsible for administration of the manual, and the Flight Safety Department had responsibility for safety policy associated with emergency procedures.

The QRH was part of the operational documentation carried on the flight deck. As the name implies, it provided a 'quick reference' for flight crew during normal and abnormal operations. In terms of cabin emergency issues, it primarily contained the public address (PA) announcements to be used by the flight crew in various situations (including for an immediate evacuation and a precautionary disembarkation).

G.5 Operational training

G.5.1 Flight crew training

In addition to the training pilots received when they joined the company, they underwent additional training when endorsed on a new aircraft type, or promoted to a higher rank. These courses involved a ground training (theory) component, a simulator component, and

a line training component. All company pilots also participated in a recurrent training program applicable to the aircraft type they operated.

Prior to 1999, the recurrent training program for each B747-400 pilot consisted of 12 simulator sessions (approximately 3 months apart) and three route checks in every 3-year period. These recurrent simulator sessions were of 4 hours duration, with each pilot acting as pilot flying for half of the session and support pilot for the other half. Each session included a different list of sequences to be completed, as well as a series of 'discussion items'. The matrix of which sequences were to be completed in each session were approved by CASA for each 3-year period.

Second officers received a different series of simulator sessions to those provided to captains and first officers. These sessions evaluated the second officer's ability as 'pilot flying' and 'pilot not flying' in both control seats. Their participation as a second officer operating as an additional flight crewmember to the captain and first officer (when in a non-control position) was not evaluated in the simulator (see section 1.8.3 for a discussion of second officer roles).

During each simulator session, a pilot's performance was rated against 10 parameters: pre-departure duties, operational standard – takeoff and climb; operational standard – cruise; operational standard – descent, approach and landing; management; support duties; procedures; instrument flying; and manipulative skills. Generic performance items relevant to each of these parameters were provided in the *Flight Crew Training Manual*. Not all parameters were relevant for each session. A summary of the content of each simulator session was outlined in the *Flight Simulator Training Manual*, which was issued to each pilot. Instructors were provided with additional (but brief) guidelines on how to conduct the session.

Captains, first officers and second officers maintained a valid licence and command instrument rating by completing each of the recurrent simulator sessions, maintaining annual medical examinations as required by CASA, and completing annual route check requirements.

G.5.2 Emergency procedures training

Prior to commencement of 'on-line' flying duties, Qantas cabin crew trainees completed an 11-day 'Initial Emergency Procedures' training program.⁸⁴ Each year thereafter, cabin crew attended a 1-day 'Recurrent' emergency procedures (EP) training course. The cabin services managers (CSMs) and cabin services supervisors (CSSs) did not receive any additional training, such as managing emergency situations.

Flight crew under initial training received three days of EP training. All pilots completed the annual one-day recurrent EP training courses. Since 1997, flight crew and cabin crew have completed most modules of the recurrent EP training together. During training for command, an EP instructor provided pilots with a short (two to three hour) session on relevant issues associated with the aircraft type.

Prior to the mid-1980s, the recurrent EP training for cabin crew consisted of two days. With the approval of the then Civil Aviation Authority, this was changed to one day recurrent training, subject to the cabin crew undergoing periodic emergency procedure checks prior to departure on rostered flights. The checks focused on the operation of various pieces of

⁸⁴ Part of the initial training also covers basic aircraft knowledge issues, including the purpose and perceivable 'sights and sounds' of various components of the aircraft.

emergency equipment. Although only one check was required, most cabin crew received an average of three to four checks per year.

The initial EP training included a variety of practical exercises. The recurrent EP training included one practical in-flight emergency exercise and one practical evacuation/disembarkation exercise in a cabin mock-up evacuation trainer. The nature of these exercises was varied each year.

During some flight simulator training sessions, pilots were presented with situations which required the initiation of an emergency response on land.

G.5.3 Crew resource management training⁸⁵

Awareness training. Qantas introduced a 2-day CRM awareness-training course for all pilots in 1989. Annual refresher courses were provided during the period 1990 to 1993. In 1994, following the merger of Qantas with Australian Airlines, both airlines' courses were revised to ensure a common format and terminology. Work was then conducted to incorporate cabin crew into the CRM training program.

In 1996–1997, cabin crew's annual recurrent emergency procedures training consisted of two days, which included some CRM elements. In subsequent years, the recurrent emergency procedures training provided to flight crew and cabin crew day included a short (approximately 1 hour) CRM component. These components generally involved group discussion regarding a particular incident.

In 1998, a 2-day human factors/CRM course was introduced for cabin crew upgrading to cabin services supervisor and cabin services manager positions. Existing staff in those positions did not receive the training. First officers upgrading to command attended the same course.

Simulator exercises. Prior to 1999, the recurrent simulator training program included an annual line-oriented flight training (LOFT) components. These components consisted of an extended flight segment in which the check-and-training person observed and lead a post-flight discussion on relevant aspects of CRM. Video recordings of the session were often used to assist the debriefings. Performance during the LOFT components was not formally rated due to restrictions agreed between the company and the AIPA. In 1999, the LOFT session was replaced with shorter Line-oriented Simulation (LOS) components in all recurrent sessions as part of a move from a simulator session every three months to one every four months. This move was approved by CASA.

Performance on all recurrent simulator sessions was rated in terms of 10 different parameters (see above). CRM performance was typically evaluated as part of the 'management' and 'support duties' markers. Training of check-and-training pilots in CRM assessment is discussed in section 3.4.2.

Personnel perceptions. During the investigation, a sample of management pilots, check-and-training pilots, line pilots and safety personnel were asked about the Qantas CRM program. It was established that:

- Most personnel reported that the understanding and usage of CRM principles had increased greatly in the last 10 years. Many reported that good CRM principles were an integral part of the way in which most crews operated. Some also noted that the standard was quite variable.

⁸⁵ A description of 'crew resource management' is outlined in section 1.8.4 of the report.

- Personnel with experience in the design, delivery or research of CRM programs stated that the content of the Qantas CRM awareness training was quite basic in nature. It had not been significantly enhanced since it was first developed and it did not reflect the latest research and views on what was best practice for such courses.
- Check-and-training personnel stated that they considered CRM issues during recurrent simulator sessions or line checks, and included these considerations in performance ratings and written evaluation comments where relevant. Pilots reported that there was a noticeable degree of variation between check-and-training personnel on the extent to which they appeared to consider or comment on CRM issues. Several pilots commented that there was a wide degree of interpretation as to what was meant by good 'management'.

The survey of Qantas B747-400 pilots conducted asked pilots whether the CRM training they had received was practical for line operations. Forty-eight per cent agreed or strongly agreed with this statement, whereas 30% disagreed or strongly disagreed. A number of respondents provided written comments on this issue, with the majority being critical of the outdated material and perceived lack of management commitment to the issue.

G.6 Recent changes in organisational processes

In May and June 1997, senior personnel from CASA's Compliance Branch met with representatives from Qantas and another major Australian airline to discuss surveillance issues. The meeting attendees agreed that the major airlines should introduce a quality assurance approach to their operations to enhance aviation safety management. It was noted that such an approach was being introduced as a requirement in New Zealand and Europe.

Soon after this time, the then Qantas chief pilot obtained information on another airline's quality assurance system. According to the chief pilot, this other airline was the only one at that time that had received Internal Standards Organisation (ISO) accreditation for its quality assurance system in a flight operations department. After receiving this information, the Qantas chief pilot initiated a series of changes to the Flight Operations Branch's processes. These changes commenced with an external review of the Branch's management systems in February to March 1998. The report also conducted a gap analysis of the Branch's systems and processes with those required to achieve accreditation under ISO 9000 *Quality Management and Quality Assurance Standards*. A number of strengths and weaknesses of the management systems and processes were identified. These are discussed in part 3 of the investigation report where relevant.

On 24 August 2000, Qantas advised the ATSB that various departments within the Flight Operations Branch were progressively achieving ISO 9000 accreditation. The Branch expected that all parts of the Branch would meet the required standard by the end of 2000 and receive formal accreditation by June 2001.

A number of other activities occurred which were related to the move to a quality assurance system. These activities included the devolution of Flight Standards Department (see attachment J) and an external review of the Branch's flight safety management (July 1999). This review identified a number of strengths and weaknesses of the current flight safety system. These are discussed in part 3 of the investigation report where relevant.

Another major change activity which commenced in 1998 was an internal review of the recurrent simulator training program. In November 1998, three senior training personnel visited the USA to examine three major USA airlines' implementation of the Federal Aviation Administration's (FAA's) Advanced Qualification Program (AQP). The FAA Advisory Circular 120-54 (August 1991) defined AQP as:

An alternative qualification program for personnel operating under FAR parts 121 and 135 and for evaluators and instructors of recognised training centres that will provide such training. An AQP integrates a number of training features and factors aimed at improving airman performance when compared to traditional programs. The principal factor is true proficiency-based qualification and training. The proficiency base (expressed as performance objectives) is systematically developed, maintained and validated.

Following the review, Qantas commenced development of its own version of an AQP called Advanced Proficiency Training (APT). A significant component of this proposed program was the redesign of the simulator training from a set number of sessions and sequences for each pilot to a system where the amount of recurrent training provided is based on the pilot's proficiency level. As part of this proposed change, the number of simulator sessions was reduced from one every three months to one every four months in January 1999 (see section G.5). Another significant component was the redesign of performance markers from their current broad nature (see section G.5) to markers more closely related to desirable performance attributes. The new markers will include more emphasis on CRM issues. As of September 2000, the program was still being developed.

Attachment H : Development and introduction of the flaps 25/Idle reverse procedures

H.1 Pre-December 1996 procedures and training

As stated in section 1.7, the Qantas 747-400 approach and landing procedures were modified in December 1996. Prior to December 1996, the operator's *B747-438 Performance Limitations Manual* contained the following procedure on page 2-5-1:

PREFERRED LANDING FLAP IS FLAP 30. This will be normally used. It gives the lowest landing speeds and hence the shortest Required Landing Field Length.

Note: When Flaps 30 landing speed (Vref 30 plus additives) exceeds 167 KIAS use Flaps 25 to avoid Flap Load Relief operation.

Certified 25 Flap data is included and may be used should circumstances warrant.

The following procedure was included on page 2-5-2 of the same manual:

IDLE REVERSE THRUST At designated locations there is a requirement for operating with no more than idle reverse thrust. In this case the factored landing length increases by 200 metres on wet runways and 180 m on dry runways. Therefore when dispatching with the intent of using not more than idle reverse thrust the field length required should be conservatively increased by 200 m.

During the investigation, check-and-training pilots and line pilots stated that, prior to December 1996, flaps 30 and full reverse thrust was the normal procedure for almost all landings during line operations and simulator training. Flaps 25 was used for certain non-normal procedures. Idle reverse thrust was used at the small proportion of locations that required it for noise-abatement reasons.

Prior to December 1996, the Qantas philosophy had been to use the flap setting which provided the shortest landing distance (i.e. flaps 30 for all 747 aircraft types), although other factors were also considered. In September 1993, a check-and-training manager proposed the use of flap 25 landings for all types of 747 aircraft in many situations. Proposed advantages for the change included reduced fuel consumption, reduced noise levels, reduced flap track wear, and increased pilot experience with the flap 25 configuration. The Operations Procedures Committee and the Flight Standards and Procedures Review Board (see section 3.2) rejected the proposal in 1994. They decided that the disadvantages, such as increased tyre and brake wear and the increased possibility of a tail strike, outweighed the advantages.

H.2 Initiating Events for the Procedural Changes

In June 1996, a representative of the wheel brake manufacturer for Qantas B747-400 aircraft, made a presentation to a selection of Qantas personnel from the Flight Operations Branch and the Engineering and Maintenance Branch. The presentation emphasised the principle that the carbon brakes being used on the B747-400 had very low wear rates at high temperatures, which was in direct contrast to normal steel brakes. This was demonstrated using results from a study on brake temperatures during a flight cycle on an Airbus 320 aircraft. The presentation also emphasised that wear on the carbon brakes could be reduced by decreasing the number of brake applications, and increasing the energy of each brake application. Various means for increasing this energy, such as using flaps 25 instead of flaps 30 and using lower levels of reverse thrust (and therefore higher levels of braking) were also discussed.

Similar presentations had been previously given to a number of other operators using the same type of carbon brakes, leading some of these operators to modify their approach and landing procedures.

Following the presentation at Qantas, there was interest from personnel from both the Flight Operations Branch and the Engineering and Maintenance Branch in further evaluating procedural changes to identify what cost savings could be achieved. There followed a period during which new procedures were researched and developed. The proposed changes were then reviewed by the Operations Procedures Committee and the Flight Standards and Procedures Review Board.

H.3 Research and development activities

The Training First Officer B744, working as an assistant to the Manager Technical B744, took the lead role in the project.⁸⁶ He was a first officer on the B747-400, and had no formal qualifications in engineering or other technical areas. Personnel from the Engineering and Maintenance Branch and the Performance Engineering section also conducted research and analysis activities as part of the project. A senior manager within the Flight Operations Branch requested that the Training First Officer B744 prepare a proposal for new procedures, provided that the brake manufacturer's data was accurate.

The research and development activities were not considered to be a formal 'project' by the engineering personnel. The changes were minor issues from the engineering point of view, as they only involved modifications to operational procedures and did not require any regulatory approval. Only one of the persons involved in the project, an engineer, had received any project management training.

The investigation had difficulty tracking the full nature of the research and development activities as many events were not documented, and the existing documentation was distributed across many personal, as opposed to formal company, files. As part of the investigation, interviews were conducted with most of the people involved in the project although recollections were not detailed due to the long period of time since the project.

As far as could be determined, the following research and development activities occurred:

- Qantas Engineering and Maintenance contacted Boeing for information on tyre wear differences between idle reverse thrust, partial (70% N1) reverse thrust, and maximum (91% N1) reverse thrust (11 June 1996). Boeing replied that they would expect tyre wear to be slightly higher for partial than maximum reverse thrust, but that the difference should not be significant.
- Qantas Engineering and Maintenance contacted the overseas A320 operator mentioned by the wheel brake manufacturer for information on the brake temperature study (19 July 1996). No reply was ever received.
- Qantas replied to a letter from Airservices Australia regarding a potential reduction in noise levies for B747 operations at Sydney airport if flaps 25 was used instead of flaps 30 (July 1996) (see section H.9). It was expected that there would be savings of \$61 per landing, or approximately \$216,500 per year.
- Qantas Engineering and Maintenance contacted personnel in two other airlines which had recently modified their B747-400 approach and landing procedures (9 September

⁸⁶ Following a change in management structures in April 1997, the Training First Officer B744 was appointed as technical pilot for the B747-400. He reported to the General Manager Flight Technical, a newly created position.

1996). Airline E (see attachment I) replied that they had recently changed their normal procedure from full to idle reverse. Although it was 'early days', the reported rates of thrust reverser defects had halved and that passengers had appreciated the quieter landings. They had not seen any reduction in brake wear. Airline D (see attachment I) replied that it had changed from full to partial reverse thrust. It reported that it had achieved brake life of over 2,000 landings on many aircraft. The Qantas average at the time was reported to be 1,594.

- Qantas Performance Engineering asked Boeing for information on stopping distances for the B747-400 for no reverse, idle reverse and full reverse on both dry and wet runways (26 September 1996). Boeing provided information on the deceleration rates for forward idle, idle reverse and full reverse on a dry runway for a 747-200 aircraft. Boeing also provided a page from the *Boeing 747-400 Flight Crew Training Manual*. This page included the following paragraphs:

Immediate initiation of reverse thrust at main gear touchdown and full reverse thrust reduce brake usage, thus minimising brake temperatures.

To minimise wear of carbon brakes, minimise the number of brake applications. Use maximum reverse thrust and operate the autobrakes normally.

The importance of establishing the desired reverse thrust level as soon as possible after touchdown to minimise brake temperatures, tyre and brake wear, and to reduce stopping distance on very slippery runways cannot be overemphasised...

According to Boeing, the use of minimum reverse thrust doubles brake energy requirements and can result in brake temperatures much higher than normal.

- The Flight Standards Department initially considered a proposal to only use flaps 25 at Sydney but use flaps 30 at other locations. However, Flight Standards personnel advised the project team that they wanted the same preferred flap setting at all locations to help ensure standardisation.
- Qantas Engineering and Maintenance contacted the brake manufacturer querying the discrepancy between the *Boeing B747-400 Flight Crew Training Manual* advice and the brake manufacturer's advice on the appropriate way of minimising brake wear (3 October 1996). The brake manufacturer replied that their data had been 'thoroughly reviewed and accepted by various departments at Boeing'. They also stated that they believed Boeing had agreed to modify their *Flight Crew Training Manual* to reflect the new information (see section H.8).
- Qantas Engineering and Maintenance conducted calculations of expected cost savings in terms of reduced brake wear (up to 25% improvement) and thrust reverse damage (50% reduction). In addition, they summarised the results of the research and development activities to date in a 14-page document, each page similar to an overhead transparency (16 September 1996).
- Qantas Performance Engineering provided advice to the Flight Operations Branch on the proposed procedural changes in a memorandum (11 October 1996). This document had only minor changes from a draft version (3 August 1996) which had been distributed for comment. The final version noted that there were several advantages for the procedural changes. It also noted the following:

Disadvantages are the usual ones of an increase in field length of about 100m dry and 112m wet at average landing weight of 244T, earlier application of brakes and increased landing speed of about 6 kt would increase tyre wear, but not to the extent that it would outweigh the brake savings...

Performance manual currently quotes an increase in landing field length when using idle reverse thrust of 180m dry and 200m wet this is a conservative number which could be refined should a reverse idle standard procedure be introduced.

Performance Engineering, based on...[the brake manufacturer's] report and subject to Boeing agreement with it, could support a change of preferred flap setting from flap 30 to flap 25 along with the use of idle reverse as a standard procedure for the B747-400 fleet. Flap 30 should remain as an alternative setting where required for shorter/wet runways, and abnormal configurations i.e. antiskid inoperative etc.

- The Training First Officer B744 met with representatives of airline D to obtain further information on the new procedures, as well as the accuracy of the brake manufacturer's data. It was identified that airline D's procedures included minimising brake applications during taxi, shutting down the number 3 engine after landing, using auto-brakes 2 or 3 for landing (as opposed to 1 or 2), flaps 25 and idle reverse. During the investigation, the Training First Officer B744 reported that he used this airline's procedures as a basis for developing the proposed Qantas procedures.
- Three senior management pilots conducted some simulator flying using flaps 25 to assess its handling characteristics (date unknown). They concluded that no special training was required. There was no documentation of this activity.

During interviews, it was reported that no formal risk assessment was undertaken during the research and development phase. During the investigation, many Qantas personnel noted that flaps 25 was a certified flap setting, and it was used by many B747 operators. They also noted that idle reverse was standard practice at certain aerodromes for noise abatement considerations. In addition, they noted that certified landing data was also calculated without the use of reverse thrust.

H.4 Involvement of the Operations Procedures Committee

The Operations Procedures Committee met on the 14 October 1996 to consider the agenda item '10/96 Brake Life Improvement for Airplanes fitted with Carbon Brakes'. The Training First Officer B744 briefed the committee on the details of the proposal. As far as could be determined, this briefing consisted of a later version of the 16 September summary document (see section H.3). The briefing document contained no discussion of the operational impact of the proposed procedures. The 'summary' page of this version of the document stated the following:

By utilising reverse idle in thrust reverse combined with fewer harder and longer applications of the carbon fibre brakes on the B747-400 the following benefits can be achieved;

- Reduced brake overhaul cost. Saving approximately **\$700,000 P.A.**
- Reduced thrust reverser damage. Saving approximately **\$59,000 P.A.**
- Reduced pylon/interservices damage.
- F25 [flaps 25] at Sydney approx. Cost saving of **\$216,500**
- Increased passenger comfort
- Cost saving from shutdown number #3 engine approx. **\$300,000 P.A.**
- **TOTAL ~ \$1,275,000 PA.**

Hand-written amendments to this page noted that there would also be a fuel saving of \$365,000, and a total saving of \$1,640,000 per annum.

It was reported that the technical pilot briefed the committee on the details of the proposal, using the summary handout. The committee then asked questions and discussed the proposal. The minutes of the meeting state that all the committee members agreed that the projected cost savings were impressive and that the Training First Officer B744 should prepare a submission for the Review Board to consider.

During interviews, persons present at the meeting reported that the issues discussed included airline D's procedures, and the fact that flaps 25 was a certified procedure. There was some discussion about speed control, but no discussions concerning landing distances. There were no disagreements from any of the members about supporting the proposal.

The presentation to the committee noted that one airline (airline D) was using partial reverse thrust and achieving good results. However, the focus of the presentation's handout was on idle reverse thrust. The investigation could not determine exactly when it was decided to focus on idle reverse (rather than partial reverse), and no documentation outlining the rationale for this decision was identified. However, following the Operations Procedures Committee meeting, only idle reverse was considered in the proposed procedures. It was reported during interviews that the rationale for using idle reverse (rather than partial reverse) was to ensure the brakes worked harder, therefore minimising wear and enhancing the brake wear savings.

Following the meeting, the Training First Officer B744 developed a draft set of procedural changes, which was distributed to a number of senior management pilots (including Flight Standards, Flight Training, Flight Safety and Fleet Management) for comment. None of these personnel made any objections to the proposal, or requested any further risk assessment. A revised version was then presented to the Flight Standards and Procedures Review Board.

H.5 Involvement of the Flight Standards and Procedures Review Board

The review board meeting on 17 October 1996 considered the agenda item 10/96. The minutes of this meeting stated the following:

[The Training first officer] was asked to address the Board on this proposal. The proposal to improve Brake life on the 747-438 aircraft included four proposed changes to operating procedures:

1. Brake operational procedures:

ACTION: Autobrake setting commensurate with turnoff, a minimum of '2'.

2. Reverse thrust procedures:

ACTION: At the Captain's discretion, select Idle Reverse Thrust for landing, provided the Performance Limitations Manual indicates at least 200 metres surplus runway available.

3. Landing flaps:

ACTION: Flap 25 should be used for all landings, with the exception of:

- a. HKG R/W 13;
- b. If landing distance is limiting; or
- c. If airmanship considerations dictate otherwise.

4. Engine Shutdown after landing:⁸⁷

ACTION: At the Captain's discretion, after clear of the active runway, the Pilot not flying shall shut down No 3 engine, upon confirmation from the flying pilot.

After considerable discussion, the Board approved, subject to a satisfactory trial of six calendar months, the introduction of items 1, 2, and 3 into the normal operating procedures for the 747-438 aircraft.

Regarding Item 4, the Board agreed that further consideration needed to be given to the possibility of shutting down an outboard engine, and the possible requirements for cooling time at idle before shutting down an engine.

The General Manager B744 Operations is to initiate an educational programme for all B744 Check Pilots and flight crews on Items 1, 2, and 3; and then implement the procedures contained in Items 1, 2, and 3 above. Consideration should be given to include applicable discussion/training in the recurrent training cycle.

The Board complimented [the Training First Officer B744] for his detailed presentation and thanked him for his efforts.

During the investigation, review board members commented that trial periods were not common, but had been done before. They also reported that the purpose of the trial period was to ensure there were no unforeseen problems and that the expected benefits would be obtained. The review board was concerned that, due to the inherent conservative nature of airline pilots, significant effort would be required to promote the procedural changes. They introduced the requirement for an education program to address this issue.

During the investigation, attendees at the meeting reported that each of the four items was discussed in detail individually. There was no formal risk assessment, but it was reported that safety and an evaluation of risks was an inherent part of the evaluation of such proposals. The flaps 25 item was approved primarily because it was a certified flap setting. Idle reverse thrust was included to maximise the advantages achieved by using flaps 25. The ability to stop on a wet runway was discussed, but there was no evidence that contaminated runway issues were discussed by the review board. However, it was understood that maximum reverse thrust would always be available to pilots if required.

Following the meeting, minor modifications were made to the new procedures by the review board, and the resulting procedures formed the basis of the Flight Standing Order (FSO), discussed in section H.6. The changes included the increase of surplus runway required for idle reverse thrust from 200 m to 300 m. The basis of this increase could not be determined.

Members of the review board reported that they did not intend that the conditions specified in the FSO for using flaps 30 and full reverse thrust (see section H.6) were meant to be an exhaustive list. It was their view that pilots would not exclusively use flaps 25 and idle reverse thrust, and that flaps 30 and that there were other combinations of flaps and reverse thrust that could be used at pilot discretion. They reported that the responsibility for the implementation and evaluation of the procedural changes was with fleet management, and the review board had no further role to play unless the issue was raised as an agenda item for the board.

⁸⁷ The intention of this procedural change was to reduce fuel costs. Some background research was conducted in early 1997, but no changes in procedures ever resulted.

H.6 Implementation activities

The Training First Officer B744 was allocated the task of developing a newsletter. The 12-page newsletter titled 'A Study of three methods of improving the way we do Business on the B744' was distributed to all Qantas B747-400 pilots during November 1996. The newsletter provided background information explaining the rationale for the procedural changes and the expected cost savings. Revised calculations of the expected savings were now \$1,389,812 per annum, which included an increased expected brake life of 31.7% instead of 25%. The amount was reduced from the previous figure as the proposal no longer contained item of shutting down number 3 engine during taxi (see section H.5).

On 6 December 1996, Flight Standing Order (FSO) 206/96 titled '747-438 Approach and Landing Procedures' was issued to pilots (valid for a period of 3 months). The FSO stated the following:

The Flight Standards and procedures Review Board has approved, for a six month trial period, the following changes to Standard Operating Procedures as detailed below. The changes in the approach and landing procedures of the B744 aircraft have been made to achieve the benefits outlined in the recent handout.

1. Flaps Selection for Landings:

Flap 25 shall be used for all landings with the exception of:

- a. HKG [Hong Kong] Runway 13;
- b. Any runway where the landing distance is limiting; and
- c. Any situation where airmanship considerations dictate otherwise.

2. Reverse Thrust During Landing Roll:

Idle Reverse Thrust shall be used for all landings provided:

- a. The 747-438 Performance Limitations Manual indicates at least 300 metres surplus runway is available;
- b. Due consideration is given to any Non-Normal procedures which may have been actioned during the flight; and
- c. Any situation where airmanship considerations dictate otherwise.

3. Application of Aircraft Brakes:

To improve the life of the Carbon Brake Units on the 747-438 Aircraft, the following braking procedures shall apply to all landings:

- a. Autobrake setting commensurate with desired turnoff, with a minimum of "2". A higher setting should be considered when planning taxi way turn offs; and
- b. Keep taxi brake applications to a minimum and do not 'ride' the brakes.

Operational Consequences:

- a. Aircraft attitude can differ by approximately one (1) degree;
- b. Touchdown speed will increase marginally; and
- c. The EICAS Advisory Message "BRAKE TEMP" may be displayed. If so, observe the Brake Cooling Schedule in the 747-438 Performance Limitations Manual. BRAKE TEMP indications may require Park Brake release for Brake Cooling Schedule at the terminal.

Crew Feedback:

Crew feedback and suggestions are essential during this trial period to highlight any unforeseen problems, or areas for improvement.

This FSO was reissued on 11 March 1997 for three months, and then 5 June 1997 for another three months.

The General Manager B747-400 Operations attended a meeting of B747-400 check-and-training personnel on 13 December 1996. Such meetings were typically held three times a year. The General Manager outlined the proposed changes, as well as a number of other issues. As discussed earlier, no special training requirements were identified for the changes. Check-and-training personnel reported that there was a heavy emphasis on the new procedures during the cyclic sessions to ensure that pilots developed the appropriate level of manipulative skills. Other details concerning the training of the new procedures are discussed in section 1.7.2.

In February 1997, a four-page newsletter was distributed to all B747-400 flight crew. The newsletter provided supplementary information to the November 1996 newsletter. This information included:

- The use of reverse thrust will decrease wet runway stopping distance when the deceleration is limited by runway friction characteristics. Extremely wet and slippery conditions can result in longer distances than indicated, and the use of reverse thrust is paramount under these conditions.
- Flap 25 approach needs EPR [engine pressure ratio] settings of approx. 1.12 to 1.14 depending on weight. Slot retention becomes more critical. Thrust reduction during landing needs to be positive. Flare height needs a little adjustment to ensure ideal touchdown point, ie, 1500 ft is achieved.
- It is recommended that landings not be attempted when braking action is reported as "poor" except in the case of emergency. If the surface is affected by water, snow, or ice and the braking action is reported as "good", conditions should still not be expected to be as good as on clean dry runways. The value "good" is comparative and is intended to mean that airplanes should not experience braking or directional control difficulties when landing.

On 28 February 1997, the *Qantas B747-438 Performance Limitations Manual* procedures (see section H.1) were modified to incorporate the new procedures. The modified procedures were identical to the 1 October 1997 procedures (see section 1.7), except that only the first of the four specific situations requiring flaps 30 was listed (i.e. 'landing field lengths are critical'). These procedures had been drafted by Performance Engineering personnel, and then reviewed and accepted by Flight Operations Branch management.

H.7 Evaluation and monitoring activities

Although there was a 'trial' period, there was no formal review of the new procedures at the end of the trial period, or at any stage during or after the trial period. The General Manager B747-400 stated that some pilots made informal comments to him about the new procedures after they were introduced. Although negative in nature, the number of comments was low relative to many other changes that had been introduced. Five pilots made written comments about the new procedures. Although the first two were generally positive, the latter three (written in April to July 1997) were negative in nature. The primary concerns of these letters were associated with the flaps 25 procedure.

The General Manager reported that he had discussed the new procedures with a number of check-and-training personnel in the course of other activities, and there did not appear to be any significant problems. Overall, he considered the magnitude of the pilots' reaction to not be of any concern. He had witnessed a much higher level of negative pilot reaction in response to a number of other changes, including administrative issues.

During mid 1999, two senior pilots expressed concern to the Manager B744 Training and some other management personnel regarding the fact that some first officers had never conducted a flaps 30 approach. The issue was raised by the Manager B744 Training in the B747-400 training staff meeting in May 1999. The minutes stated:

Feedback indicates an apparent lack of consideration of Flap30/full reverse as an intelligent option on limiting runways. Training personnel to encourage and develop airmanship in all areas. (Again, some First Officers allege that training personnel insist on F25 [flaps 25] to develop muscle motor memory!!)

No changes were made to the required manoeuvres or discussion points of any of the cyclic sessions prior to the accident. As far as could be determined, there was no noticeable change in the performance of check-and-training personnel. During interviews, some check-and-training personnel stated that they could not recall the issue being discussed.

In terms of evaluating the actual cost savings, the engineering personnel reported that they did not expect to see any reliable trends for a couple of years after the project started. The Training first officer and the engineering staff had occasional discussions concerning how things were progressing after the implementation.

The Engineering and Maintenance Branch distributed a memorandum in December 1996 to senior engineering personnel, informing them of the proposed changes and asking them to complete a survey form on brake wear issues on each occasion that brakes returned to the engineering shop. However, there was some reluctance from engineering personnel to collect the information, and little data was recorded.

In early 1998, the maintenance of Qantas brake components was out-sourced to the brake manufacturer. The contract contained variations for both improvement and deterioration of brake life. Brake life was reviewed at the end of each year and the prices for the following year's maintenance were adjusted up or down according to previous performance. Savings were shared by both the brake manufacturer and Qantas. In September 1999, The brake manufacturer provided Qantas Engineering and Maintenance with information on Qantas B747-400 brake life. The average brake life by 1999 was reported as being approximately 2,000 landings per overhaul, an increase of approximately 25%. However, Qantas was unable to advise the exact savings obtained.

In June 1998, engineering personnel reviewed the statistics on thrust reverse damage and noted that the damage had decreased. This information was passed to the training first officer technical pilot. In October 1999, engineering personnel reviewed the thrust reverser maintenance figures and concluded that the annual savings were consistent with the expected savings.

H.8 Involvement of Boeing

During the investigation, some Qantas personnel stated that they thought that Boeing had given an opinion that they had no problem with the new approach and landing procedures. However, there was no documentary evidence to support this assertion, and no one could recall the nature of any such discussions with Boeing personnel.

During the investigation, Boeing conducted a review of their correspondence with Qantas. The only correspondence with Qantas they could identify associated with flaps 25 or idle reverse procedures was in July 1997. At that time, Qantas reported that they had adopted the policy of idle reverse on their B747-400 aircraft to reduce brake wear, and they were considering adopting the same policy for B767-300 aircraft. They asked for Boeing's comments on using this procedure for the B767-300, and whether any other operators were using it on that aircraft for routine operations.

The Boeing response included the following paragraphs:

Boeing has completed an initial review of our Flight Crew Training Manual techniques for airplane braking, both during landing and during taxi maneuvers. Based on our review, we plan to add emphasis to the importance of minimising the number of brake applications. However, we do not advocate intentionally increasing brake temperatures as a means to increase carbon brake life. We have concerns that such techniques could result in increased occurrences of fuse plug melting and dispatch delays for brake cooling. Additionally, some of the techniques we have heard discussed, such as reduced landing flap settings and the use of idle reverse thrust, have a negative impact on airplane stopping performance. Therefore, these techniques are not recommended as standard practice...

We are aware of the 747-400 operators that have adopted a policy regarding use of idle reverse thrust to address brake wear concerns. We are not aware of any 767 carbon brake operators that have adopted a similar policy.

During the investigation, senior Flight Operations Branch personnel reported that they interpreted the Boeing reply as applying only to B767-300 operations. However, Boeing advised the investigation that their comments related to any aircraft using carbon brakes, including the B747-400. Boeing did not support the use of idle reverse thrust as a standard practice for normal landings or for increasing brake temperatures of carbon brakes. Further, they were concerned with the human factors implications of having idle reverse thrust as the standard practice (see section 1.7.5).

Boeing reported that they had modified the *Boeing B747-400 Flight Crew Training Manual* on 15 March 1998 to incorporate new procedures to increase carbon brake life. These techniques were restricted to auto-brake settings and the manner in which brakes were applied. The manual still advocated the use of full reverse thrust. These modifications were not fully consistent with the changes suggested by the brake manufacturer (see section H.3).

H.9 Involvement of the Department of Transport and Regional Development⁸⁸ and Airservices Australia

The Commonwealth Government introduced the *Aircraft Noise Levy Act 1995*. It imposed an additional landing charge on jet aircraft landing at Sydney airport. The money obtained from the levy was to be used to fund the property acquisition and noise insulation program associated with the airport. Airservices Australia collected the levy from operators on behalf of the Department of Transport and Regional Development. Various factors were used in calculating the levy for a particular type of aircraft. One such factor was the noise signature of an aircraft in the landing configuration.

Airservices noted that certified data was available for some models of B747 aircraft at two different flap settings: 30 degrees and 25 degrees. The Airservices' Board expressed interest in all operators who had a choice of flap setting to choose the lower setting, and asked that these operators be invited to do this in the context of the savings involved. The Manager Environment Branch summarised these issues in a memorandum to the Airservices' Chief Executive Officer in June 1996. The memorandum also noted that there was no realistic, practical means of checking what flap setting was used.

In early July 1996, Airservices contacted the Department and asked for comment on the proposal. Airservices also supplied draft letters to be sent to operators outlining the benefits of a lower flap setting (to those currently using flaps 30) and asking for written evidence that a lower setting was actually part of the airline's operating procedures for Sydney Airport.

⁸⁸ The Department was renamed the Department of Transport and Regional Services in October 1998.

The Department replied in July 1996 that it was previously unaware that documentation on some aircraft provided noise certification figures for different flap settings on approach. The Department was 'in favour of the idea of encouraging use of lower flap settings to reduce aircraft noise'. However, it also noted that it was important that, if operators wished to obtain a reduced levy by using a reduced flap setting, they needed to provide appropriate evidence that these settings were used during normal landing operations at Sydney.

Airservices sent a letter to Qantas regarding the benefits that could be achieved in using flaps 25 for its B747 aircraft in July 1996. As noted in section H.3, this was one of the factors which the Qantas Flight Operations Branch considered when deciding to move towards using flaps 25/idle reverse procedures as their normal procedure. The expected savings from the reduced landing fees was \$61 per landing, or approximately \$216,000 per annum. This was about 16% of the total savings Qantas expected to achieve with the new procedures.

Qantas submitted a formal proposal for the reduced landing fees for its B747-400 aircraft on 17 December 1996, on the basis that their standard operating procedures for the aircraft had been changed to flaps 25 on 6 December 1996. Airservices monitored the noise levels of a sample of Qantas B747-400 approaches in November and December 1996, and noted that the levels with flaps 25 were approximately three decibels (A) lower. Airservices informed the Department of Transport and Regional Development of this outcome and reduced the landing charges to Qantas accordingly.

During the investigation, personnel from the Department of Transport and Regional Services and Airservices Australia advised that they did not consider a need to advise CASA of the new procedures or obtain technical advice on the operational implications of the reduced flap setting. The airline produced documentation which showed that flaps 25 was their standard procedure. The Department and Airservices consequently assumed that such procedures had already been approved by the relevant authority.

H.10 Involvement of CASA

The CASA Flying Operations Inspector (FOI) responsible for oversight of Qantas B747-400 operations reported that he was aware of the procedural changes through the newsletters and manual updates. CASA was provided with no specific advice of the proposed changes. The FOI noted that he had no concern about the new procedures as they were within the operating limits of the aircraft, and they were also phrased in a manner that provided the pilots with options depending on the circumstances. He also understood from the newsletters that Boeing supported the new procedures. He was not aware of any difficulties in the implementation of and training for the new procedures. However, due to the low level of surveillance that was conducted on B747-400 operations (i.e. actual compared to planned), he could not reasonably have expected to detect any problems (see section 4.3).

Senior personnel in CASA's Compliance Branch reported that they did not expect the Department of Transport and Regional Services or Airservices Australia to consult with them on issues such as the noise levy at Sydney airport. As far as they were concerned, the Authority was responsible for auditing each operator's procedures.

Observations:

Based on the preceding information, the following comments can be made in relation to the Flight Operations Branch's management of the flaps 25/idle reverse project:

- There was no evidence that Qantas had sought Boeing's opinion regarding the safety impact of the new procedures, and their potential effect on carbon brake wear. Management personnel agreed that Boeing's opinion on such issues would be useful,

and that they would normally consider the manufacturer's opinion before changing procedures. Boeing has since advised that it does not support the use of idle reverse thrust as a normal procedure as it increases landing distance. It has also stated that modified braking techniques alone would produce almost as much reduction in brake wear as the combined effect of the flap25/idle reverse procedures.

- Qantas examined the flaps 25/idle reverse procedures of two other operators as part of the project development process. This examination was incomplete and did not identify that the procedures used by those operators were more conservative than the proposed Qantas procedures, and had additional safeguards in place for operating on water-affected runways (see airlines D and E in attachment I).
- The performance differences between idle and full reverse thrust, and between flaps 25 and flaps 30, were not fully examined. Such an examination would probably have highlighted the significant differences in landing distance on wet or contaminated runways using these various configurations.
- There was no evidence that a systematic attempt was made to identify all the situations for which flaps 30 and/or full reverse thrust would be more appropriate.
- The term 'contaminated' was used in the flaps 25 procedure but was not defined.
- There appeared to be no review of the human factors implications of the new procedures. For example, there appeared to be no consideration of the extent to which the use of flaps 25/idle reverse could become a skill-based habit (i.e. 'the norm'), and therefore might be used by crews when a more conservative configuration was required.
- The documentation of the project and its history was disorganised and incomplete. The information was distributed across many files. There were no records of many conversations or meetings held concerning the project. There was no record of the timing and reasons for key decisions, such as the decisions to not use partial reverse thrust and to not conduct any training in flaps 25 approaches.
- The pre-implementation evaluation of flight crew training needs was informal, undocumented and limited in scope. The evaluation appeared to be based on test flights in the simulator conducted by a small sample of experienced pilots. The basis of their analysis was not documented. There was no evidence that the analysis considered how pilots evaluated approach configuration options. There was also no evidence that the opinions of line pilots were considered.
- The post-implementation review of the effects of the changes was shallow, informal, and undocumented. Flight crew were asked in newsletters to provide feedback. Fleet management received limited written and verbal feedback. Although mainly critical in nature, this feedback appeared to be disregarded as the number of sources was relatively small, and many of the sources were perceived to be resistant to change. There was no method of actively obtaining information from flight crew or check-and-training personnel. It is reasonable to conclude that a more detailed and positive feedback program would have identified the strong views of many line pilots about the operational benefits of flaps 30 over flaps 25 (see section 1.7.3). Such a process should also have identified the lack of flight crew understanding of aspects of the procedures, such as the meaning of the term 'contaminated runway', to be highlighted.
- The cost-benefit analysis for the introduction of the flaps 25/idle reverse procedures listed all the benefits of the new procedures in financial terms. It did not consider cost items such as tyre wear, and the fact that flaps 25 may not be used on all approaches. It was also not updated after maintenance of the brakes was outsourced.

Attachment I: Procedures and training programs of other operators for contaminated runway operations

As part of the investigation, information was obtained from six other B747-400 operators regarding their procedures for landing on water-affected runways, and their landing configuration procedures (i.e. flap and reverse thrust settings). These operators included five Asia-Pacific airlines and one European airline. All of these operators conducted operations in the Asia-Pacific region, and all their aircraft were equipped with carbon brakes. The results are listed below. They have been de-identified for commercial reasons.

- Airline A: Used flaps 30/full reverse thrust as their normal landing configuration. Boeing advisory information for slippery runways was provided to all pilots. Definitions of water-affected runways were not included in manuals relating to B747-400 aircraft, but were included in manuals for other aircraft types operated by this airline. No information was obtained on the company's pilot training program.
- Airline B: Used flaps 30/full reverse thrust as their normal landing configuration. Boeing advisory information for slippery runways was provided to all pilots. Pilot training placed a strong emphasis on not landing during thunderstorms, and landing techniques for wet/contaminated runways.
- Airline C: Used flaps 30 as their normal landing configuration. Reverse thrust setting was according to pilot discretion on non-limiting runways. Boeing advisory information for slippery runways was provided to all pilots. A 'contaminated' runway was defined as 'a runway partially or entirely covered with standing water of more than 1 mm, slush, snow or ice, or a "wet" runway with sand or dust'. Pilot training placed a strong emphasis on landing techniques for wet/contaminated runways.
- Airline D: Used flaps 25 and partial (70% N1) reverse thrust as the normal landing configuration for non-limiting runways. Boeing advisory information for slippery runways was provided to all pilots. JAA definitions for water-affected runways were also provided. Full reverse thrust was required if the runway is 'wet' (and the runway was noted in the company route manual as 'slippery when wet') or worse than 'wet'. No information was obtained on the company's pilot training program.
- Airline E: Used flaps 25/idle reverse as the normal landing configuration for non-limiting runways. Boeing advisory information for slippery runways was provided to all pilots. JAA definitions for water-affected runways were also provided. Full reverse thrust was required when the runway was 'wet' or worse. No information was obtained on the company's pilot training program.
- Airline F: Used flaps 25/idle reverse as the normal landing configuration for non-limiting runways. Flaps 30 was required when runway length was less than 3,000 m and runway surface conditions were worse than 'wet'. Boeing advisory information was provided to all pilots. The JAA definition of contaminated runways was also provided to pilots. There were no simulator exercises which involve contaminated runways.

Observations:

Relative to Qantas, the six operators examined had more comprehensive procedures and processes in place in relation to landing on wet/contaminated runways.

Attachment J: Development and devolution of the Qantas Flight Standards Department

Prior to 1993, the then Civil Aviation Authority (CAA) conducted all the surveillance of CASA flight operations. The surveillance involved 'product audit' activities by Flying Operations Inspectors (FOIs) (see section 4.3).

In 1993, following discussions with the Civil Aviation Authority, Qantas established an internal Flight Standards Department to conduct an internal surveillance program. The Authority referred to the activities of this department as an 'auditable quality control system' and reduced the target amount of its own product surveillance of Qantas by 50%. The Flight Standards Department was to conduct the other 50% of required surveillance tasks.

A 'Flight Standards Manual' was produced on 3 August 1993. The 'forward' section of this manual included the following:

This manual contains the procedures to be followed by Qantas Airways Ltd. In conducting surveillance of Flight Operations and in the approval of Check and Training personnel on behalf of the Civil Aviation Authority.

These procedures are approved by the CAA and will not be changed in any way without the specific approval of the Authority.

Insofar as this manual lays down the minimum levels of surveillance, these levels must be achieved. If for any reason it appears that the required level of surveillance will not be achieved then the Regional Office will be informed. The Authority will then decide whether supplementary inspections will be carried out by the CAA Inspectors, or some other appropriate action taken...

A joint Qantas/CAA Flight Standards Review meeting shall be held at approximately 12-monthly intervals to review the results of inspections and to discuss any trends that may become apparent and to discuss any changes to operational practices that may be warranted as a result thereof.

The manual then outlined the general procedures and amount of surveillance to be conducted by the Qantas Flight Standards Department. Areas to be included in the surveillance were those typically covered by product audits, such as line operations, flight simulator and training sessions, flight crew technical courses, check-and-training personnel, emergency procedures training, flight simulator fidelity, and cabin safety inspections. Procedures were also specified for the approval of check-and-training personnel.

One of the motives for introducing internal surveillance system was to reduce costs to Qantas. In the early 1990s, the CAA was planning to charge operators for the amount of surveillance conducted by the CAA. The proposal was later abandoned by the CAA. No other airline developed the same type of internal surveillance system. As a result, Qantas was paying the same level of regulatory fees as other airlines despite conducting surveillance on behalf of the Authority.

The Qantas Flight Standards Department was composed of an experienced line pilot for each aircraft type in the company's fleet. Each 'bid' period (56 days), Flight Standards submitted a report on their observations to the Chief pilot and other senior Flight Operations Branch management. In addition to conduct the surveillance activities, the Flight Standards also participated in other Flight Operations Branch activities. In particular, the General Manager of the Department was the chairperson of the Flight Standards and Procedures Review Board.

The Flight Standards Manual stated that an annual meeting was to be held each year to review the results of the Qantas inspections. During interviews, CASA personnel reported that these meetings had not occurred in recent years. In addition, the Qantas internal surveillance processes had changed, but there had been no modifications to the manual submitted to the Authority.

In late 1996, a new manager of the CASA Sydney Field Office observed that CASA was not achieving its flying operations' surveillance targets, and had not been doing so for some years. He also noted that the *Flight Standards Manual*, although it had been arranged by the regional CAA office, had no formal authority and the details concerning levels of surveillance had not been included in the Aviation Safety Surveillance Program (ASSP) (see section 4.2). As a result, he developed a Qantas ASSP Surveillance Plan to formalise the existing arrangements. The Qantas Chief pilot ultimately rejected this plan as it would impose additional surveillance costs on the operator.

The CASA Sydney office conducted an audit of Qantas Flight Standards activities for a bid (56-day) period in 1997. This audit only examined the frequency or surveillance of line operations and simulator sessions. Other areas covered by the Flight Standards manual were not considered in this or previous CASA audits. The 1997 audit noted that pilots who were actually commanding the aircraft carried out a large percentage of the internal surveillance. The reviewers believed that this was not an adequate surveillance method. Instead, the auditor should be observing the whole operation and not be conducting it. The report noted that the amount of surveillance being conducted by the Flight Standards Department was below the agreed target levels.

In May 1998, following the March 1998 review of management systems within the Flight Operations Branch, the Qantas Chief pilot decided to abolish the Flight Standards Department as part of a move to introduce a quality assurance program. During the investigation, the Chief pilot and other senior management reported that the Flight Standards Department's surveillance activities rarely detected any significant safety issues, and they also did not detect and report on issues in a timely manner. The QAR program was providing a more complete and up to date picture of their flight operations. It was also noted that the Department's activities overlapped with those of other functional areas.

During the latter part of 1998, the duties of the Flight Standards Department were defined and assigned to other operational areas within the Flight Operations Branch. For example, surveillance of line operations was devolved to fleet management, and surveillance of simulator training sessions was assigned to the Flight Training Department. This devolution plan was completed in March 1999. During interviews, some Qantas personnel noted that there were delays after March 1999 in other parts of the Flight Operations Branch assuming some of their newly assigned functions.

Qantas advised CASA management in Canberra of the proposed devolution of the Flight Standards Department. However, CASA personnel in the Sydney office responsible for surveillance of the operator were not aware that the Flight Standards Department had been devolved until August 1999.

During the investigation, CASA management within the Compliance Branch stated that the manner in which Qantas conducted its internal surveillance was up to the operator. The arrangements that had been made in 1993 with the development of the Flight Standards Manual were no longer relevant, and CASA needed to develop its own new surveillance approach (see section 4.3).

Observations:

There were several deficiencies in the process of developing, operating and then devolving the Qantas Flight Standards Department. Although these deficiencies reduced the amount of product surveillance conducted of Qantas flight operations, they probably had little (if any) influence on the development of the accident.

Attachment K: Survey of Qantas B747-400 flight crew

On 2 February 2000, Qantas Flight Safety Department personnel distributed a questionnaire to the 615 Qantas flight crew of B747-400 aircraft. The purpose of the survey was to collect information from these personnel about their experiences and perceptions of training and line operations. The data was intended to help determine the relevance of various workplace factors to the accident.

Qantas personnel developed the questionnaire and ATSB investigators provided comments on a draft copy. The questionnaire consisted of 42 questions that covered the following types of issues:

- The quality and frequency of company documentation relating to contaminated runways.
- Flight crew experiences with training.
- CRM issues.
- The role of second officers.
- Airmanship practices during approach and landing.

All responses were confidential. Individual questionnaires were only sighted by members of the ATSB and Qantas investigation teams.

A total of 240 questionnaires were returned, indicating a 39% response rate. The Qantas investigation team produced a report which analysed the responses. This analysis led to the following conclusions in relation to company B747-400 operations:

- A general level of dissatisfaction with the quality and accessibility of information about contaminated runways.
- A strong perception that there was less than ideal training for landing on contaminated runways, specifically relating to the lack of training exposure in the use of flaps 30 and full reverse thrust.
- The infrequent use of flaps 30.
- The infrequent briefing and use of full reverse thrust.
- The poor utilisation of the simulator for practising maximum stopping techniques.
- A general level of dissatisfaction with the number of opportunities and current company resources for maintaining effective B747-400 recency/currency.
- A general level of dissatisfaction with the quality and company commitment to CRM training.
- A poorly defined policy in regard to the use of second officers on the B747-400.

The report concluded with a recommendation for the Qantas Flight Operations Branch to consider disseminating a similar safety survey to flight crew operating other aircraft types.

Attachment L: Survey of passengers on board the accident aircraft

In November 1999, the ATSB distributed a questionnaire to the 391 passengers on board the accident aircraft. The purpose of the survey was to collect information on the passengers' recollections and perceptions of the sequence of events, particularly after the aircraft came to a stop.

The questionnaire was developed by the ATSB investigation team, with input from Qantas and CASA personnel. Individual questionnaires were only sighted by ATSB investigators. General comments (de-identified) from the questions were passed on to Qantas and CASA. The questionnaire consisted of 45 questions that covered a variety of issues, as outlined in the following sections.

L.1 Demographics

- The number of responses received was 276 (out of 391), a response rate of 71%.
- Nine respondents were over 75 years old. Eight respondents reported travelling with an infant or child less than 5 years old. One respondent had a 15-week-old baby.
- Eleven respondents advised that they were disabled passengers, four of whom were wheelchair passengers.

L.2 Safety briefing

- Only two passengers said that they did not understand the safety briefing.
- Just over half the respondents (51%) said that they had read the safety-briefing card. Of these passengers, three-quarters read the safety card before takeoff. The remainder either read the card en-route, or did not indicate when they read it.
- Of the passengers who did not read the safety card, three quarters said that they had read it many times before, were familiar with the information, or had read it recently. The remainder said that the information was covered by the safety demonstration, that they were not interested, that they read it after landing, or did not give a reason.
- None of the wheelchair passengers reported receiving an individual pre-flight safety briefing.
- Seventeen passengers said that they did not know where their nearest emergency exits were located prior to landing.

L.3 Events during the landing roll

- Forty-one per cent of respondents said that they were alerted by bumping or shuddering or some other similar aspect.
- Thirty-eight per cent of respondents said that they simply remained seated during the landing while 45% said that they braced or put their head down.
- A number of passengers put their feet up, or arms out in front of them, in a way that exposed them to injury.
- Twenty-two per cent of respondents said that the flight attendants gave instructions or provided information during the landing. Other respondents said that the flight attendants did nothing (40%) or that they could not be seen (36%). (In some sections of the cabin the flight attendants were seated behind the passengers.)

- Almost all passengers who reported that the flight attendants gave instructions or provided information during the landing were seated in zones C or D.
- Seventy per cent of respondents said that they did not hear any instructions from the flight attendants during the landing, 16% said that they heard the instruction 'heads down' or 'stay down' and 12% said that they heard the instruction 'brace'.
- Sixty-two respondents reported overhead lockers opening during the landing, with reports from all zones of the aircraft.
- Nine respondents reported that items fell from the overhead lockers, mostly small items. There were no reports of passengers being hit by these items.
- Four respondents said that their seatbelts were not fastened at the time of landing.
- Two of the four respondents who were nursing an infant without the use of an extension belt reported that they had difficulty in holding the infant during the landing. The respondent nursing an infant with the assistance of an extension belt did not report any difficulty in holding the infant.

L.4 Events after the aircraft stopped

<i>Actions of flight attendants</i>	<i>% of respondents</i>
Gave instructions, provided information	49
Moved around, surveyed scene, checked passengers	20
None	18
General reassurance and calming passengers	18
Sought information (e.g. from flight crew, cabin crew or by other means)	4

- Reports of flight attendants giving instructions or providing information came from all zones of the aircraft.
- Some passengers may have felt that flight attendants standing at their emergency stations were taking no action.
- The majority (63%) of respondents said that the first instructions or information that they received was to stay seated. Almost all said that the cabin crew provided this information.
- The most common instruction that passengers reported receiving from flight attendants was to stay seated. This was reported by respondents from all zones of the aircraft. Reports of instructions to stay calm were also widespread.
- Some respondents from all zones of the aircraft reported being told that there was no fire, or likelihood of fire, after the aircraft came to rest.
- Almost all respondents (89%) reported receiving information or instructions from the flight attendants within five minutes of the aircraft coming to a stop.
- Eighty-two per cent of respondents said that they received some form of other information or instruction before the disembarkation.

- Seventy-nine per cent of respondents made comments about other aspects that they felt were unusual or significant.

<i>Unusual or significant aspect</i>	<i>% of respondents</i>
Fumes or smells, smoke, smell of burning, electrical smell, dusty	20
Aircraft at an angle or low to the ground	19
Hot and stuffy atmosphere in aircraft, lack of air conditioning	8
Disorganised situation, slow for emergency crews to arrive, slow to disembark	7
Cabin damage	6
Aircraft damage	6
Passengers were anxious	5

- Reports of fumes or smells, smoke, the smell of burning, or an electrical smell, were relatively more common from passengers towards the front of the aircraft on the main deck, zones A and B. In contrast, comments about the hot and stuffy atmosphere in the aircraft, and the lack of airconditioning, came from passengers towards the rear of the main deck, zones D and E.
- Reports of sparks and fumes included:
 - *In the ceiling space immediately inside the bulkhead there appeared to be a lot of electric sparks*
 - *Electrical gear sparking dangerously.*
 - *There were sparks and a burning smell.*
- Some passengers said that they mistook camera flashes for electric arcing.
- One respondent, a commercial pilot in zone F (upper deck) stated:
 - *Flight deck door open. Smokey atmosphere inside flight deck. Smell of hot hydraulic oil and hot electrical smell.*
- Other comments included:
 - *We assumed the captain was seriously injured as we heard nothing from the flight deck which was worrying*
 - *No one was standing by the door to open it quickly.*
 - *A few older pax were distressed because of a lack of fresh air.*
 - *All of a sudden we had to get off quickly after sitting there for 25 mins.*

L.5 Arrival of emergency services

- The general consensus of respondents was that emergency services were first visible outside the aircraft between 10 and 15 minutes after the landing.
- Most respondents reported that the time between the aircraft stopping and the start of the disembarkation was between 20 and 30 minutes.

L.6 Instructions regarding precautionary disembarkation

- Seventy per cent of respondents reported that they were instructed not to take their carry-on baggage with them when they disembarked from the aircraft.
- Passengers made a number of comments in relation to what, if any, possessions they could take with them when they left the aircraft.
 - *Asked to clarify (flight attendant) said we could take handbag (passport, wallets etc). Nothing else.*
 - *To take nothing—this was confusing as some staff said to take papers.*
 - *I asked if I could get my shoes out and my passport and money and he said yes as long as the bag was small.*
- There were reports from all zones that passengers were told that the slides would be used, or were given other specific instructions about using the slides.

L.7 Mood just prior to leaving the aircraft

- Most respondents expressed quite negative feelings when describing their mood before leaving the aircraft. Typical terms used to describe their mood were anxious, concerned or scared. Many also said that they were relieved or pleased to leave the aircraft.
- Five per cent said that they felt terrified or some similarly strong feeling. In contrast, 22% of respondents expressed a neutral emotion, saying, for example, that they felt relaxed or calm.
- Numerous respondents made comments about their predicament. In many cases passengers were very concerned about the possibility of fire:
 - *It felt like we were just waiting for this plane to burst into flames and our death.*
 - *Frightened because of obvious risk of fire. I couldn't help thinking about that Saudi Arabian aircraft on which everyone was alive when it landed, yet no-one survived*
 - *It was getting somewhat stuffy and claustrophobic and certainly increasing anxiety levels.*
 - *I just wanted to get off the plane ASAP and felt powerless and helpless just sitting there*
 - *My biggest fears...I experienced immediately after coming to a standstill was that the plane was going to explode due to the impact on landing, as I recall a plane doing at Manchester and people being killed as a result of fire.*
 - *Concerned about leaving via chute. Hip replacement operations in 1998. Would I be able to sit on the top quickly enough not to hold up other passengers.*

L.8 Precautionary disembarkation

The greatest number of respondents (43%) used exit R2. Passengers from all zones used this exit. Exit R5 was used the least (14% of respondents).

<i>Number of respondents exiting</i>				
<i>Zone</i>	<i>Exit</i>			
	<i>R1</i>	<i>R2</i>	<i>R4</i>	<i>R5</i>
A	5	1	-	-
B	-	24	-	-
C	4	46	-	-
D	21	27	19	-
E	12	4	35	37
F	12	10	-	-

- Seventy-four per cent of respondents said that they used the exit they were originally instructed to use. Respondents who used a different exit did so because not all exits were in use, because of shorter queues at the other exits, or because of concerns with using a particular exit. One passenger commented: *Passengers jumped up together, I waited for the majority to leave and then left from the exit with the smallest queue.*

<i>Reasons for using different exit</i>	<i>Number of respondents</i>
No queue or less queue at other slide	19
Original exit not in use, slide not deployed	12
R5 slide too steep	13
New instruction from crew member	9

- Thirteen respondents reported concerns about the steepness of the R5 slide:
 - *It (R5) was too steep because it was too high. More like a rubber cliff.*
 - *The tail of the plane was very high and people were nervous about the slide. There was a queue and so my wife and I went to the front of the plane.*
- Particular concern was expressed by certain passengers, for example the elderly, those with accompanying infants, or passengers with some form of existing injury:
 - *The gradient was so steep, it was difficult to control yourself especially at the bottom of the slide. As I had a 3-year-old to take down, I was told to go up the front of the plane.*
 - *We were instructed to use R5, however this was a particularly steep slide... With unwilling small children, my wife argued with the steward until a passenger or another steward suggested to use the forward exits as they were closer to the ground.*
 - *Couldn't go down slide as it was too steep and as I had a bad knee was worried about doing more damage. On telling staff of fears was instructed to go to first class exit which wasn't steep.*

- Ninety-three per cent of respondents said that they had no difficulty in getting to the exit that they used. Comments about difficulties in getting to an exit were relatively more common from respondents who had been seated on the upper deck (Zone F) or towards the rear of the aircraft (zones D and E)
- Respondents from the upper deck reported that the aisles were crowded and that having to go down the stairs slowed their exit. Some comments by respondents from the rear zones suggested that passengers anxious to disembark moved quickly forward, leading to queues forming at the exits. One passenger commented: *I was sitting near the exit. I would have been about the 20th person off as people panicked and rushed forward.*
- Three of the 19 respondents who said that they did have some difficulty in getting to an exit were passengers over 80 years of age.
- Sixty-two per cent of respondents said that they had received some form of assistance during the disembarkation.
- There were reports from all exits of help by flight attendants during the disembarkation. However relatively more reports were received in relation to the rear exits, as compared to the forward exits. There were also some reports of help by emergency personnel, ground crew, or airport staff from all exits.

L.9 Hand baggage, personal items and disembarkation

- Seventy-one per cent of respondents said that they took some personal items with them when they left the aircraft.

<i>Item(s) taken during disembarkation</i>	<i>% of respondents</i>
Minor items such as passport, medication, mobile phone, or camera	41
None	29
Bag, including handbag or bag of duty free goods	24
Handbag around neck, or with strap diagonally across body	4

- The question of taking hand luggage from the aircraft was one of the most vexed issues for passengers. A number of respondents made comments in this area:
 - *Not being allowed to take small handbag caused enormous problem over the next 40 hours.*
 - *I first ask the flight attendant if could take baby bag, he was reluctant at first but then agreed*
 - *One of the flight attendants suggested it was OK to take a small handbag provided it didn't interfere with exiting.*
 - *Some passengers took their hand luggage. This was unfair.*
 - *Many passengers were very distressed about leaving their hand baggage with passports, medication etc. in them.*

- Forty-two per cent of passengers indicated that they were asked or told not to take personal items with them when they left the aircraft. This was often a contentious issue.

<i>Prevented from taking personal items?</i>	<i>% of respondents</i>
Not prevented from taking items	57
Not physically prevented, but asked not to	22
Yes, told to return bags, or specifically instructed not to take something	20

L.10

Disembarkation

- While the most common direction reported was to simply sit and slide (29% of respondents) passengers were given varied instructions in using the slides.
- Directions to sit and slide were given to passengers who exited via all four slides in use. Directions to cross arms or to jump were also not associated with any particular exit. In comparison, directions to lean forward were predominantly reported by passengers who used exit R5.
- Ninety-six per cent of respondents were able to understand and follow the instructions they were given. While no respondents reported difficulty in understanding instructions, some passengers did report difficulty in carrying out the instructions. For example, they may have been frightened to use the slide, or had difficulty because they were elderly, or were accompanied by an infant.
 - *I was scared and did not want to jump.*
 - *No one ever spoke to me regarding any difficulty, despite being a wheelchair assisted passenger... When we were at the top of the chute we were told to sit and slide down. I was unable to do this due to arthritis, and two attendants lifted me on to the top of the chute.*
 - *A woman with a small child on her knee sat at the top to slide down, but then got up and moved away from the door and exited from another door.*
- Thirty-eight per cent of respondents reported some difficulty in moving down the slide they used. Most problems arose when passengers could not slide easily and needed to push their way down, or get up and walk, because the slope was too shallow or the slide was wet. In comparison, some passengers experienced problems because the slide they used was steep and they travelled too fast. The greatest number of problems was reported in relation to the slides at exits R1 and R2.
- Respondents reported that they were told to place the infant or child on their lap or between their legs, and to hold on to them tightly while using the slide. Two respondents said that they did not receive any instructions on how to use the slide with an infant.
- A respondent travelling with a 4-year old child was asked by a flight attendant if the child could use the evacuation slide on their own. The child was directed to use one side of the slide and was told that they would be assisted at the bottom. The child then exited successfully.

- Respondents reported that they carried the infant or child in front of them, either in their arms, on their lap, or between their legs, depending on the age of the child.
- Two respondents said that they experienced difficulties using the slide with an infant. In both cases they said that it was hard to move themselves down the slide as they could not use their hands to assist themselves.

L.11 Outside the aircraft

- Seventy-six per cent of respondents said that they received some form of assistance at the bottom of the slide. The majority of respondents (67%) did not state who provided the assistance.
- A number of passengers commented on the fact that some people, including some local personnel, were smoking in the vicinity of the aircraft.
- Thirty-eight per cent of respondents said that they received no instructions after leaving the aircraft. The most common directions reported by passengers (31% of respondents) were to go to the other side of the aircraft where buses would be provided.

L.12 Injuries

- Eighty per cent of respondents said that they did not receive any injuries during the landing or disembarkation. Of the 20% that reported some form of injury, five per cent said that they had suffered from psychological trauma.
- Thirty-eight respondents said that they received some form of physical injury. Of these, 22 respondents said that the injury occurred during the landing and 14 respondents said that the injury occurred during the disembarkation.

<i>Type of injury</i>	<i>Number of reports</i>	<i>% of injury reports</i>
Physical injury during landing		
Whiplash, injury to neck	9	24
Bruising, soreness, stiffness	8	21
Hit on head by panel or PSU	3	8
Physical injury during disembarkation		
Wrenching, twisting or jarring	8	21
Hit or bruised	4	11
Other	6	15

- Five passengers (13% of respondents reporting a physical injury) indicated that they received medical treatment at the airport terminal on the night of the occurrence. A further four respondents said that they visited a doctor some time later, either in Bangkok or elsewhere.
- Reports of injury occurring during the landing were relatively less common from zones B and C. Reports of injury during the evacuation were relatively more common from exit R5 compared to the other exits. Indeed, while R5 was reported as being used by the

least number of passengers (37 respondents) it was associated with the greatest number of injuries (7 respondents).

- The most common suggestion, from 24% of respondents, was that there should have been a faster disembarkation of the aircraft. In many cases this response was related to passengers' fear of a subsequent fire. One passenger commented: *At one stage I was going to open the emergency exit myself because of my concern for my daughters and risk of fire.*

INVESTIGATION REPORT 199904538

ISBN 0 642 27472 X

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