AAIB Bulletin No: 2/94 **Ref: EW/C93/9/5** **Category: 1.1**

INCIDENT

Aircraft Type and Registration:	BAC One-Eleven 518FG, G-OBWD	
No & Type of Engines:	2 Rolls-Royce Spey 512-14DW turbofan engines	
Year of Manufacture:	1970	
Date & Time (UTC):	29 September 1993 at 2302 hrs	
Location:	Norwich Airport, Norfolk	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 6	Passengers - 57
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	Approximately 7,500 hours (of which 600 were on type) Last 28 days - 38 hours	
Information Source:	AAIB Field Investigation	

History of the Flight

After the incident, data was available from the Flight Data Recorder (FDR), which covered the whole period of the flight, and from the Cockpit Voice Recorder (CVR), which covered a nominal 30 minute period commencing some 11 minutes prior to landing. This history has been compiled by reference to the recorded data and crew statements, along with flight and aircraft documentation.

The crew reported for duty at Stansted for the series of flights at 0630 hrs on the 28 September (the day before the incident), having had more than 12 hours prior rest period. The crew were transported to Norwich by bus to pick up G-OBWD, for a flight to Deelen (Netherlands) as the outbound leg of a charter. They departed at 1030 hrs from Norwich Runway 09, for an uneventful outbound flight. The aircraft was then positioned empty to Edinburgh, in preparation for the next day's flights. The crew went off duty in Edinburgh at 1415 hrs, and were provided with Hotel accommodation close to the Airport.

The crew's first duty on the 29 September started at 0400 hrs, for a scheduled passenger flight to Amsterdam. The aircraft was then positioned empty to Rotterdam (8 minutes flight time). They were then off duty at 0815 hrs. Hotel accommodation was again provided close to the Airport. The crew returned to duty at 2000 hrs, for a scheduled departure at 2130 hrs to Norwich. In the event, some 12 passengers failed to appear for the flight, so the aircraft left one hour later than planned at 2230 hrs.

Because of the short duration of the flight, the crew completed the approach and landing briefing for Norwich prior to the departure from Rotterdam. The first officer indicated that the runway lighting facilities were discussed as part of that briefing, but the commander could not confirm that this was correct. The crew had not landed on Runway 27 at Norwich by night for a significant time, although they had departed from Runway 09 the previous day in daylight conditions.

The flight time to Norwich was 32 minutes, and the journey was flown at FL180. The routing from Rotterdam was a Standard Instrument Departure from Runway 06, followed by a direct track to Norwich. Eastern Radar monitored the flight's progress until 2254 hrs, when it was handed over to Norwich Approach Control (Radar). During the opening conversation, the Norwich Approach Controller queried whether the aircraft was established on the localiser for Runway 27. Up to this point, the crew were predicting that they would be making an approach to Runway 09, given the forecast conditions and the fact that the Luton weather (obtained while en route from the Volmet broadcast) was also indicating a relatively strong south easterly wind. The Approach Controller instructed the crew to turn left 30° to establish the aircraft on the Runway 27 localiser, to descend to 2,000 feet on QNH 1009, and passed the weather as 160/8 kt, 5,000 metres, rain, scattered cloud at 700 feet, scattered cloud at 1,500 feet, temperature 12°C. The crew were offered an ILS approach to Runway 27 for a straight in landing, or for circling to Runway 09, or a full Surveillance Radar Approach for Runway 09.

The first officer was the handling pilot, but took advice from the commander on the choice of runway. Given the surface wind conditions, and the small tailwind component (calculated by the crew as 2 kt), they elected to conduct the ILS approach for landing on Runway 27. The aircraft was established on the localiser some 14 miles out, the surface wind at this time being given as 160/6 kt. The aircraft commenced its final descent with the glidepath from 1,600 feet amsl (some 5 nm from touchdown). The crew stated that they became visual with the runway some 10 to 12 miles out, and did not enter cloud during the approach. All the appropriate checklist items were carried out, including the selection of the appropriate threshold speed (V_{REF} 122 kt, corresponding to a weight of 37,000 kg) for the calculated landing weight of 36,388 kg.

Control of the aircraft was passed to Norwich Tower at 2300 hrs, with the aircraft approaching the Outer Marker (4 nm from touchdown). The aircraft was cleared to land, and the surface wind was given as 170/12 kt, and a final check as 160/10 kt. The crew noted that the aircraft entered an area of rain in the latter stages of the approach, sufficiently intense for the first officer to have his windscreen wiper operating, although the commander did not consider that he required the left windshield wiper at that time. Full flap (45°) was selected at approximately 150 kt, some 70 seconds before touchdown, when the aircraft was around 900 feet agl and some 3 nm from touchdown. The first officer stated that he was slightly low on the glidepath at 300 feet agl (3 reds plus 1 white showing on the PAPI), at a speed of V_{REF} +15, and was on the glidepath crossing the threshold with 2 reds plus 2 whites on the PAPI, at a speed of V_{REF} +10. The commander's recollection of events was broadly similar.

The commander commented twice on the airspeed during the latter stages of the approach, calling "plus 20" at 28 seconds and again at 17 seconds prior to touchdown. He also made a comment that "it's not an over long runway" approximately 7 seconds before touchdown. Data from the FDR indicated that the airspeeds were 140, 141 and 136 kt respectively at these times. The FDR also indicated that the descent was initially checked 10 seconds prior to touchdown, when the pitch attitude was increased by some 2.5°. The final flare of some 2.2° increase in pitch attitude occurred around 2 seconds prior to touchdown. A gradual reduction of power towards flight idle occurred over some 5 seconds between these times. Touchdown was achieved on the mainwheels at 124 kt, and on the nosewheel two seconds later. The FDR indicated that, during the flare, a heading change of some 5° occurred, indicating that the crosswind component at the time was of the order of 11 kt.

Both ATC Controllers (the Approach and Tower positions are adjacent within the Visual Control Room for an Airport trial) noted that the aircraft touched down further along the runway than normal, and was seen to be at a relatively high speed when passing the Control Tower (abeam a position some two thirds along the runway). They said that they were not unduly worried by the speed, and did not consider that the aircraft would not stop before then end of the runway. A witness living adjacent to the airfield boundary also noted that a late touchdown took place. The crew however did not consider it to be unduly late.

The first officer requested "spoilers" immediately after touchdown, which the commander deployed fully as normal. Reverse thrust was applied by the first officer, and the commander counted down the airspeed from 100 kt to 70 kt. The first officer cancelled reverse at 70 kt, and continued to apply pressure on the toe brakes. The commander's calls during the landing run indicated that the spoilers were deployed, that both reversers were open and both engine speeds were winding up, and he advised "a bit of brake" as reverse thrust was applied, and again to "keep the brake on" as reverse was cancelled at 70 kt. He then joined the first officer pressing on the brake pedals, but both were unable to prevent

the aircraft leaving the end of the paved surface onto the grass stopway area. There were no further calls until the commander realised that the aircraft was about to leave the paved surface. The first officer re-applied reverse thrust momentarily as the aircraft left the paved surface, but it was not effective in preventing the overrun. The sound of reverse thrust was audible on the CVR from just after the commander advising "a bit of brake" until the time of the 100 kt call, a duration of approximately 5 seconds.

In the darkness, neither ATC Controller was certain initially that the aircraft had overrun, as it was in a poorly lit area. As soon as the aircraft had stopped moving, the commander called the Tower to inform them that the aircraft had overrun, that there was no damage, and requested some buses to collect the deplaning passengers. The Tower Controller did not declare an airfield emergency, or aircraft ground incident, but instead contacted the airfield operations section on the UHF radio to request transport. The Airport Chief Fire Officer heard the conversation with the operations section, and decided to proceed to the scene to observe. Another fire vehicle also attended, its crew giving assistance to unload the baggage.

The passengers were deplaned via the rear stairs after a few minutes. The aircraft was shut down and secured, in time for the 30 minute CVR covering the incident period to be preserved. In the post flight cockpit debrief, the commander noted that initially the aircraft was low on the glidepath, but said it had become a little high as it crossed the runway threshold. A comment was also made, some 10 minutes after the incident, that the brake temperatures were indicating 300°C. Both crew members were surprised that the aircraft had not stopped within the available distance.

The FDR did not record parameters for spoiler deployment, or wheel brakes. The thrust settings recorded were from the P7 (jet pipe) pressure of each engine. These transducers are located downstream of the clamshell thrust reverser doors, and it was possible to detect a small drop in P7 pressure whenever the reversers were activated. However, it was not possible to determine the amount of reverse thrust or wheel braking applied by the crew.

Radar Replay

A good replay was obtained from the Cromer secondary radar facility, which covered the period of the flight during the approach, and to a point approximately one third down the landing runway. The sweep rate of the radar head was approximately 1 revolution every 5 seconds. The plot confirmed the correct tracking of the aircraft on the localiser, and the mode C height information confirmed that the aircraft had followed the glidepath. The rate of descent derived from this data showed 740 FPM, which is consistent with that expected for an aircraft following a 3° glideslope at 140 kt groundspeed. The

average groundspeed achieved was calculated for the final half minute of returns, giving a figure of 140 kt. The average air speed recorded by the FDR over the same period was 138 kt, suggesting a 2 kt tailwind component just prior to landing.

Weather Conditions

At the time of the incident, there was a south easterly airstream covering the Norwich area, with a complex frontal system approaching the region from the west.

The surface winds measured at Norwich Airport came from a Vaisala WAD21M digital electronic anemometer system, which had been installed approximately one year previously. The system has three sensor inputs, one located at the Runway 27 threshold, one adjacent to the wind sock, and the third adjacent to the Runway 09 threshold. The Tower Controller stated that the sensor at the Runway 27 threshold was selected for the readings prior to the incident.

The weather passed to the crew prior to the approach was the 2250 hrs Norwich METAR. Light to moderate rain was noted for that observation. In an attempt to quantify the amount of rainfall in the vicinity of the Airport prior to the landing, the previous recorded METARS were checked, and no other rain was noted between 1720 hrs and 2220 hrs. The Meteorological Office rainfall radar plots were also obtained for the period between 1730 hrs and 2330 hrs. These showed that the first rainfall recorded in the vicinity of Norwich Airport during that evening occurred at 2230 hrs. Both the 2230 and 2300 hrs recordings showed rainfall intensities of between 0.03 mm/hr and 1.0 mm/hr in the area of the Airport, both being relatively low rainfall rates.

Runway Data

Runway 27 at Norwich has a landing distance available of 1,842 metres (6,043 feet). It has a threshold elevation of 105 feet and a stop end elevation of 117 feet, giving an overall average upslope of 0.2%. The runway is surfaced with asphalt in the centre section, and has an ungrooved concrete surface at each end. The initial 488 metres (1,601 feet) and final 255 metres (837 feet) are concrete.

In order to increase the emergency distance available, an overrun stopway of 87 metres (285 feet) is provided. This stopway is a level grass area, intended to support the weight of any aircraft suffering an overrun after an abandoned take off.

The runway has high intensity green threshold lights, and high intensity bi-directional runway edge lights with a low intensity omni-directional component. It is also equipped with a row of high intensity red runway end lights, which have a gap (less than 50% of the runway width) on the centreline at the end.

Runway 27 is designated as a precision approach runway (Category 1). The CAA's Civil Aviation Publication 'Licensing of Aerodromes' (CAP 168), recommends as 'operationally desirable' that such a runway should be supplied with centreline lighting. When installed, centreline lights should extend to 900 metres from the upwind runway end, then the following 600 metres should be alternate white and red lights, and the final 300 metres all red lights. Centreline lighting is not installed on Runway 27, however, the edge lighting is arranged such that the last 600 metres of the runway has yellow edge lights. The overrun stopway is also lit, being bounded by low intensity red lights. The ILS Localiser aerial array beyond the Runway 27 stopway is topped by red obstacle lighting.

The runway has a published ILS approach, with a 3° Glideslope, and a Precision Approach Path Indicator (PAPI) system on the south side of the touchdown zone. Both the ILS Glideslope and PAPI facilities were checked after the incident and were found to be within acceptable tolerances. The CAA also carried out a standard aerodrome lighting inspection, during which no anomalies were reported.

During this investigation, there was some suggestion that the crew may have been misled as to the correct location of the end of the paved surface. The aircraft was equipped with Aerad navigation chart publications, but the aerodrome chart for Norwich (plate D1), while noting the presence of a stopway for Runway 27, did not depict its presence pictorially, nor note that it was lighted. The CAA AIP entry for Norwich also does not depict the presence of the stopway pictorially, nor indicates the fact that it is lit with low intensity red lights. The corresponding aerodrome chart produced by Jeppesen does however contain a pictorial representation of the stopway, but omits details of the lighting. None of the charts make reference to the colour coding of the runway edge lighting or to the fact that the stopway surface is grass.

An assessment was made by AAIB Inspectors of the visibility of the runway end by day and night. It was noted that at typical pilot eye height, the runway end is visible from the touchdown zone. However, initial progress down the runway is downslope to approximately half way along. From this position, the runway slopes up and over a crest, thus obscuring the runway end. Visibility of the end is again acquired from a position with approximately 610 metres (2,000 feet) remaining, which virtually coincides with the transition of the edge lighting to yellow colouring. However, the obstacle lighting atop the ILS Localiser aerial array, beyond the stopway, remains visible throughout. The low intensity red lighting of the stopway does not however become significant until close to the end of the paved surface.

Ground Marks

The aircraft had entered the designated stopway area and had come to rest with the mainwheels 20 metres from the end of the paved surface, the nosewheels 33 metres. The aircraft's wheel tracks could clearly be seen in the stopway (Figures 1 and 3). Before the aircraft had come to rest the nose and

mainwheels had penetrated approximately six inches into the surface but sank deeper, up to the axle positions, in the last few feet of travel. The right main gear had sunk deeper in the ground after the coming to rest, such that the right wingtip was reported to have been approximately three feet above ground level before the aircraft was levelled by the use of airbags. During this period it was reported that fuel was spilt from a vent in the right wingtip. It was apparent that the anti-skid system on the four main wheels had been operating over most of the grass surface, alternate skid and wheel rolling marks being evident.

Evidence of wheel marks on the runway from this aircraft could only be positively identified on the concrete surface which formed the last 255 metres of Runway 27. These marks took the form of tyre tracks of a lighter colour than the natural (dirty) surface of the concrete, and were typical of such marks which result from the scouring/cleaning action provoked by water which is abruptly forced out from under the tyre footprint area by high hydrodynamic pressure (Figure 2). Tracks were evident from all four mainwheel tyres and, to a lesser extent, from both nosewheel tyres. There was no evidence from the surface that the tyres had been abraded by, for example, wheel locking. At the time of this examination there was evidence from wet and damp areas on the concrete that water could form shallow puddles on the concrete surface. As the aircraft had passed over the transition line from asphalt to concrete it could be seen that it had been slightly to the right of the centreline but had moved to the left such that the right mainwheels were on the runway centreline by the time the aircraft departed the paved surface.

Aircraft Examination

Before the aircraft was recovered to the paved surface it was established that all tyres were inflated. During the following day, the right outer main gear tyre pressure was measured at 135 psi whilst the other three were at the correct value of 170 psi. The brake packs were all within normal wear limits, and the brakes were free to operate using the hand brake. It was apparent that the tread on two of the tyres, the left outer main and the left nose, were significantly worn and that the surface of the tread of the left outer main was significantly more rough than the other three. Advice from the tyre manufacturer indicates that that wheel had been subjected to heavy braking.

After recovery, all three landing gears were hosed down. The aircraft generally, and the wheels, tyres and brakes in particular, were examined in detail for potential defects. As none were apparent the aircraft operator, in agreement with the AAIB, elected to carry out braking trials prior to conducting a gear down ferry flight to their maintenance base at Southend. Three runs were performed along Runway 27 at up to 100 kt which, apart from establishing the serviceability of the aircraft generally, demonstrated that the anti-skid, spoilers, lift dump and reverse thrust systems were all functioning correctly.

The following day, the aircraft was flown to Southend where it landed in rain without incident on a 1,454 metres (4,770 feet) runway. Over the next few days it underwent a scheduled B1 check, in addition to a special check as a result of the over-run. No specific defects were revealed. The Air Speed Indicator systems were calibrated and found to be accurate to within 1 kt.

In the UK there are at least four airfields with arrester beds engineered at the end of runways deemed to be critical should an aircraft overrun the paved surface. Although stopways are primarily to provide an additional safety feature in the case of a rejected take off, the natural qualities of the Runway 27 stopway at Norwich acted as an almost ideal arrester bed which brought this aircraft to a halt from about 30 kt, with a mean deceleration of around 0.83g, without causing damage. In drier surface conditions though, the aircraft may not have had the benefit of such efficient retardation.

Runway Surface Friction Characteristics

Shortly after the overrun, the Airport Fire Service carried out a surface friction measurement using their calibrated Mk 4 'Mu-Meter' whilst the surface was still wet. An average value of around 0.65 was recorded over the asphalt portion of the runway, but this reduced to around 0.5 over the concrete stop end of Runway 27.

At the request of the AAIB, an independent check was carried out, by the Aircraft Ground Operations Group of Cranfield University, to measure the runway friction and to check the accuracy of the airport equipment, using specialist personnel and equipment.

The results from this check showed the average measured dry coefficient of friction for Runway 27 to be 0.79, within the normally expected values of 0.78 to 0.82. Measurements taken (UK standard method) using the Mu-Meter self-wetting system indicated that this average value dropped to 0.65, which meets the design standard for a new runway as defined in ICAO Annex 14. However, individual values for the concrete and asphalt sections of the runway were very different at 0.47 and 0.72 respectively, the concrete value approaching the ICAO defined maintenance planning level of 0.45.
With surface friction testing machines the values of friction measured do not directly indicate the conditions that exist at the runway/tyre interface of a large aircraft; braking action being a function of the effective braking coefficient of friction, μ eff. A friction measuring device gives a measure of the maximum achievable friction under the specific conditions set up by the device, and from such measured values categorisations of braking action ranging from good through to poor, or unreliable, may be passed to landing aircraft. The relationship between these categories and measured friction values is, however, specific to the particular type of friction measuring device used.

Thus the runway was measured to have been generally within the ICAO definition of good braking action, but from a braking performance point of view, any aircraft requiring maximum use of wheelbrakes on the concrete end of Runway 27 could experience a lower level of braking effectiveness, for a given speed, than when on the asphalt section, together with a sharp adverse transition at the asphalt/concrete boundary.

Aircraft Airspeed Data Analysis

Although not normally intended to be used for the determination of speeds below 60 kt, the FDR airspeed transducer was calibrated after the incident over the lower part of its operating range. The airspeed data recorded during the incident showed a progressive decrease in airspeed during the ground roll down to 30 kt. This parameter was sampled once per second, and there were two further values recorded which showed a rate discontinuity and rapid fall towards zero. It is likely, therefore, that the aircraft left the paved surface at an indicated speed of around 30 kt.

Taking this as the final speed at the end of the paved surface, the data was integrated back for each one second period, and the cumulative total used to indicate the distance travelled along the runway during the landing roll (zero head/tailwind component was also assumed). This indicated that the aircraft mainwheel touchdown was achieved some 2,000 feet in from the threshold end of Runway 27 (ie 1,000 feet in from the normal touchdown aiming point), followed by nosewheel touchdown 500 feet further along. At the time reverse thrust was initially cancelled, at 70 kt, the aircraft was estimated to have been some 1,250 feet from the stop end, and that the boundary between the asphalt and concrete surfaces near the stop end was crossed at approximately 62 kt. If an allowance was included for a 2 kt tailwind component for the entire duration of the landing roll, the touchdown point became 1,905 feet in from the threshold end of Runway 27.

The peak deceleration was achieved with reverse thrust applied, and was calculated at approximately 4.4 kt/sec. This deceleration reduced to some 3.75 kt/sec once reverse had been cancelled. It is estimated that the aircraft's total landing roll on the paved surface took 28 seconds, and the portion of the roll over the end concrete surface took some 10 seconds. There was some indication of a further reduction in deceleration over the last four seconds on that surface, despite the crew applying significant braking effort.

The accelerate-stop that was carried out after the aircraft had been recovered from the overrun area was also recorded. In this case, on the dry asphalt section of Runway 27, the aircraft was stopped from an initial speed of 100 kt. The peak deceleration achieved with spoilers deployed, reverse applied, and wheel braking, was 5.2 kt/sec, albeit that the aircraft was at a very light weight with minimum fuel load.

Data was also available from the FDR for the aircraft's previous (normal) landing on Runway 27 at Norwich. This landing had taken place at 2011 hrs on the 27 September, with a different crew. The weather conditions at that time were a surface wind from 360°/10 kt, 3,000 metres, drizzle, broken cloud base 500 feet, temperature +11°C, QNH 1014 mb. The landing weight of the aircraft at that time was calculated to be 29,200 kg. The peak deceleration in this case, with reverse thrust selected, was 7.3 kt/sec.

Braking Performance

For any given landing speed various factors can affect the stopping distance of an aircraft after touchdown, amongst which are the condition and inflation pressure of the tyres, the type of runway surface and whether it is wet or dry. With a wet runway an increase in stopping distance, compared to a dry runway, is possible for one, or a combination of, three generally accepted phenomena:

(1) Dynamic hydroplaning
(2) Reverted rubber skidding
(3) Lubrication by thin water film.

(1) Neither heavy rain, nor significant standing water on the runway was reported at the time of the incident. Dynamic hydroplaning occurs when the tyre is completely separated from the runway by a thickness of water of between, approximately, 2.5 mm to 10 mm and is influenced by tread pattern, tyre wear and tyre pressure. With tyre pressures of 170 psi, it would not be expected to initiate below a ground speed of approximately 100 kt. Dynamic hydroplaning is characterised by an absence of effective wheel braking action which was not consistent with the rates of deceleration achieved during this landing, as derived from the FDR airspeed data.

(2) Reverted rubber skidding is due to locked wheels on a wet runway. It can occur down to very low speeds and is characterised by a specific patch, or patches, of reverted rubber on the tyre tread. No such patches were seen on the tyres of G-OBWD.

(3) Significant increases in stopping distances on wet runways have also been observed at speeds below the critical hydroplaning speed, particularly in the cases of smooth (non-grooved) surfaces. In these cases the reduction in effective braking coefficient of friction is thought to be due to a lubrication effect of the water viscosity which applies at the tyre/runway interface.

Theoretical and empirical data show that for a wet non-grooved runway this lubrication effect often reduces μ eff. to a value of around 0.2, but this can fall as low as 0.1 for speeds of 80 to 100 kt. Values over 0.25 would be considered good. At lower speeds, μ eff. values generally rise, but remain

significantly below those achievable on a dry runway. Increasing amounts of water on the surface and/or tyre wear degrade braking performance further, but reduced tyre pressures would seem to have little effect on overall braking performance and will exhibit lower critical hydroplaning speeds.

Over the final 255 metres concrete section of Runway 27 the aircraft slowed, using wheelbrakes but without the benefit of reverse thrust or significant aerodynamic drag, from approximately 62 kt to 30 kt. This implies an average deceleration of 3.2 kt/sec. Taking into account the proportion of the aircraft's weight supported by the braked mainwheels and making the assumptions that, a), none of the weight is supported by the wings and, b), that the aircraft's braking capability exceeded that applied through the anti-skid system, calculations show that a mean effective wet braking μ eff. of 0.18 was achieved over this period. This value, although not considered to be particularly good, supports other evidence that the wheelbrakes system was functioning correctly during the landing roll.

Company Operations Manual and Standard Operating Procedures

The maximum allowable tailwind component for the aircraft is normally 20 kt, but this is reduced at airports such as Norwich to 10 kt due to the runway length.

The Company Operations Manual, Flight Management section, details the standard operating procedures for the aircraft. It notes that the indicated airspeed to be maintained on the approach, for normal landings, should be V_{REF} + 20 kt with 26° Flap, reducing to V_{REF} + 10 kt once 45° Flap has been selected, and further reducing in order to cross the runway threshold at V_{REF}. The maximum allowable threshold speed is V_{REF} + 15 kt. The section also notes that *'in strong or gusty wind conditions, crosswind or possible wind shear, the appropriate scheduled* V_{REF} *speed may be factored by the addition of one-third of the reported surface wind speed, up to a maximum addition of 15 kt.'* and *'f the speed at the threshold is in excess of* V_{REF} *+ 15 kt, the attempt to land should normally be abandoned and a missed approach initiated as the risk of exceeding the scheduled landing field length is unacceptably high.'*

It notes that Reverse thrust of 90% HP RPM, 480°C TGT should be used normally, and that reverse should be reduced to idle and cancelled at 70 kt. There is a note that in emergency, the maximum reverse thrust may be used to a standstill.

Advice is also offered that *'if the runway length is LIMITING however FULL REVERSE may be used if necessary until the aircraft stops. Fleet policy is to select 90% HP RPM reverse as soon as possible after the nosewheels are on the runway. At 90 kt the Non Handling pilot calls 90 kt and the Handling pilot commences braking by applying gentle foot braking.*

At 70 kt, the Non Handling pilot calls "cancel reverse" and the Handling pilot selects reverse idle, maintains directional control by use of rudder fine steering until he is ready to turn off the runway. The Handling pilot will steer the aircraft by use of the nose-steering handwheel when the speed has decayed below 60 kt.

At 60 kt, the Handling pilot will select forward idle on the throttles, checking first to ensure the power is at idle as selection of forward idle from reverse idle whilst thrust is still decreasing from 90% reverse will convert that thrust into forward thrust.

N.B. Despite the above, operational reasons may require earlier braking or later cancelling of the reverse thrust.'

Aircraft Flight Manual Performance Data

The following All Engines Operating (Wet Runway) Landing Distance Required data was extracted from the Aircraft Flight Manual Performance Section, for the ambient conditions at the time of landing:

1. All retarding devices operating (basic)	4,800 feet
2. Thrust Reversers Inoperative (basic +10%)	5,280 feet
3. Lift Dumpers Inoperative (basic +6%)	5,088 feet
4. Anti-Skid Inoperative (basic +10%)	5,280 feet
5. Medium Braking Coefficient (basic +20%)	5,760 feet
6. Poor Braking Coefficient (basic +35%)	6,480 feet (with max reverse until stopped)

This data relates to the Landing Distance Required from a screen height of 30 feet, and includes incremental factors of around 1.1 to 1.2 x the actual distances required, under the BCAR Section D 'Reference Landing Distance' scheduled performance calculation system. Implicit in this is the use of the landing technique quoted in the Aircraft Flight Manual. This states that the aircraft should cross the runway threshold as close as possible to the target threshold speed, that reverse thrust levers should be pulled back to the detents (giving around 94 to 96% HP RPM), and that footbrakes are used as required once the aircraft is firmly on the ground.

Figure 1

Aircraft In Relation To Runway End, Stopway And Localiser Aerial

Figure 2

Left Main Tyres Scouring Marks

Figure 3

Left Main Tyre Tracks Across Stopway Arrows Indicate Skid Marks