AVIATION ACCIDENT INVESTIGATION REPORT

RUNWAY OVERRUN ON LANDING

AMERICAN AIRLINES

FLIGHT AA331

BOEING 737-823

UNITED STATES REGISTRATION N977AN

NORMAN MANLEY INTERNATIONAL AIRPORT
KINGSTON, JAMAICA (MKJP)

22 DECEMBER 2009

REPORT NUMBER JA-2009-09

The Jamaica Civil Aviation Authority (JCAA) investigated this occurrence in accordance with Annex 13 to the *Convention on International Civil Aviation.* It is not the purpose of aircraft accident investigation to apportion blame or liability. The sole objective of the investigation and the Final Report is the prevention of accidents and incidents.

Accredited Representative: The National Transportation Safety Board of the United States of America.

Synopsis

American Airlines Flight AA331, a Boeing 737-823 in United States registration N977AN, carrying 148 passengers, including three infants, and a crew of six, was being operated under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121. The aircraft departed Miami (KMIA) at 20:22 Eastern Standard Time (EST) on 22 December 2009 (01:22 Universal Coordinated Time (UTC) on 23 December 2009) on an instrument flight rules (IFR) flight plan, on a scheduled flight to Norman Manley International Airport (NMIA), ICAO identifier: MKJP, Kingston, Jamaica.

The aircraft landed at NMIA on runway 12 in the hours of darkness at 22:22 EST (03:22 UTC) in Instrument Meteorological Conditions (IMC) following an Instrument Landing System (ILS) approach flown using the heads up display (HUD) and becoming visual at approximately two miles from the runway. The aircraft touched down at approximately 4,100 feet on the 8,911 foot long runway in heavy rain and with a 14 knot left quartering tailwind.

The crew was unable to stop the aircraft on the remaining 4,811 feet of runway and it overran the end of the runway at 62 knots ground speed. The aircraft broke through a fence, crossed above a road below the runway level and came to an abrupt stop on the sand dunes and rocks between the road and the waterline of the Caribbean Sea.

There was no post-crash fire. The aircraft was destroyed, its fuselage broken into three sections, while the left landing gear collapsed. The right engine and landing gear were torn off, the left wingtip was badly damaged and the right wing fuel tanks were ruptured, leaking jet fuel onto the beach sand.

One hundred and thirty four (134) passengers suffered minor or no injury, while 14 were seriously injured, though there were no life-threatening injuries. None of the flight crew and cabin crew was seriously injured, and they were able to assist the passengers during the evacuation.

Throughout the text, the male gender refers to both male and female.

Table Of Contents

PHOTOGRAPHS

FIGURES

TABLES

APPENDICES TO SECTION 1, FACTUAL INFORMATION

ABBREVIATIONS

AA	American Airlines
ACARS	Aircraft Communication Addressing and Reporting System
AC	Advisory Circular (FAA)
ACC	Area Control Center
ADIRU	Air Data Inertial Reference Unit
AEP	Airport Entry Pass
agl	above ground level
AIP	Aeronautical Information Publication
ALA	Approach and Landing Accident
ALS	Approach Lighting System
APS	Airport Protection Services
AOC	Airport Operations Centre
AQP	Advanced Qualification Program
ARFF	Airport Rescue and Fire Fighting
asl	above sea level
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATS	Air Traffic Services
AWOS	Automated Weather Observing System
C	centigrade
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DA	Decision altitude
DH	Decision height
DME	Distance Measuring Equipment
EFIS	Electronic Flight Instrument System
EMAS	Engineered Materials Arresting System
EST	Eastern Standard Time
FAA	Federal Aviation Administration (U.S.)
FAR	Federal Aviation Regulations
FCOM	Flight Crew Operations Manual
FDR	Flight Data Recorder
FL	Flight Level
FMS	Flight Management System
ft	feet
fpm	feet per minute
FPV	Flight Path Vector

GAIA	Grantley Adams International Airport (Barbados)
GPS	Global Positioning System
HIRL	High Intensity Runway Lights
HMA	Hot Mix Asphalt
HUD	Heads Up Display
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IFTSA	International Fire Training Association
IMC	Instrument Meteorological Conditions
ILS	Instrument Landing System
JCAA	Jamaica Civil Aviation Authority
JCARs	Jamaica Civil Aviation Regulations
KIAS	Knots indicated airspeed
kts	knots
m	metres
MANOPS	Manual of Operations
mb	millibars
MDA	Minimum Descent Altitude
MEL	Minimum Equipment List
METAR	Meteorological Actual Report (Aviation Routine Weather Report)
MKJP	Kingston Airport (Norman Manley International Airport)
MOU	Memorandum of Understanding
NMIA	Norman Manley International Airport
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board (United States)
NVM	Non Volatile Memory
PA	Public Address System
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIREP	Pilot Report
PM	Pilot Monitoring
PSI	Pounds Per Square Inch
PSU	Passenger Service Unit
QRH	Quick Reference Handbook
RA	Radio Altitude (above ground)
REIL	Runway End Identifier Lights
RESA	Runway End Safety Area
RFF	Rescue and Fire Fighting
RH	Recorded History
RNAV	Area Navigation

RRLL	Required Runway Landing Length
Rwy	Runway
SAFO	Safety Alert For Operators (FAA)
SIAL	Simple Instrument Approach Light System
SOPs	Standard Operating Procedures
SPECI	Special meteorological report
TAF	Terminal Aerodrome Forecast
TDZ	Touchdown zone
UTC	Coordinated Universal Time
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VOR	Very High Frequency Omni Range
VRef	Reference landing speed
Z	Zulu Time (same as UTC)

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SECTION 1

FACTUAL INFORMATION

1.0 Factual Information

1.1 History of the Flight

1.1.1 Departure

American Airlines (AA) Flight AA331, a Boeing 737-823 with United States registration N977AN, carrying 145 passengers and three infants, and operated by a crew of six, departed Miami (KMIA) at 20:22 (Eastern Standard Time (EST), this being local time) on 22 December 2009 (01:22 Co-ordinated Universal Time (UTC) on 23 December 2009) on a scheduled flight to the Norman Manley International Airport (NMIA: ICAO identifier MKJP), Kingston, Jamaica. The flight landed on runway 12 at 22:22 EST, (03:22 UTC on 23 December 2009) following an ILS approach to the runway.

Flight dispatch was provided from the AA main base in Dallas, Texas. The flight crew, who had flown two previous sectors, from Miami to Baltimore and Baltimore to Miami, changed aircraft in Miami for the flight to Kingston.

The captain was designated as the pilot flying (PF) for the sector from Miami to Kingston, and the first officer was designated as pilot monitoring (PM).

The flight crew checked the dispatch documents, which included the enroute and Kingston weather and applicable Notices to Airmen (NOTAM), and proceeded with the preparation for the flight. Forecast weather included turbulence enroute over Cuba and rain in Kingston.

The NOTAMs included notice of the closure of the Sangster International Airport (SIA; ICAO identifier: MKJS) at Montego Bay for maintenance at 22:00 EST (03:00 UTC), close to the original planned arrival time of AA331 at Kingston. Montego Bay was AA331's primary alternate, and AA Dispatch had filed for Owen Roberts International Airport (MWCR), Grand Cayman, as a second alternate airport and so had ordered additional fuel. This brought the calculated landing weight on arrival at Kingston very close to the aircraft's maximum landing weight of 144,000 pounds.

AA Dispatch added MWCR as a second, "nearest next" most suitable alternate to give the AA331 crew more options in case of adverse weather and other contingencies.

The Simple Instrument Approach Light (SIAL) system for runway 12 at Kingston was also NOTAMed as being unserviceable.

The captain briefed the cabin crew regarding the turbulence expected enroute. The first officer stated they did not conduct any special briefing prior to departure other than having a discussion about weather over Cuba for forecast of light turbulence and general weather. They had no detailed discussion about weather issues in Kingston.

The flight was initially delayed by the requirement to remove checked baggage belonging to a passenger who had not boarded. A further short delay was caused during taxi as a result of an air conditioning pack temperature controller fault warning. The crew paused during taxi and discussed this with AA Dispatch and Maintenance, before using the Minimum Equipment List (MEL) to defer the defect. There were no other deferred defects on the aircraft at this time. The aircraft encountered some turbulence during the climb out of Miami.

1.1.2 Enroute

The flight plan was for departure from Miami, climbing initially to Flight Level (FL) 350 (that is, 35,000 feet above mean sea level) direct to reporting point EONNS, A509 to URSUS then by UA301 to MKJP, Kingston.

The aircraft climbed to its first assigned cruising altitude of FL 350 and then to its final cruising altitude of FL 370 and proceeded on to Kingston. While crossing Cuba, it flew into turbulence which the flight crew described as “fairly rough” and “real bumpy”. Throughout the flight there were several suspensions of the in-flight service. The captain ordered the cabin crew to prepare early for landing.

The flight crew reported that the turbulence decreased as they got closer to Kingston. Just prior to descent the flight crew received an Aircraft Communication Addressing and Reporting System (ACARS) message from AA Dispatch advising of the closure of MKJS, the flight's primary alternate airport, thus changing the primary alternate airport to MWCR. Because of the fuel needed to fly to the alternate airport, MWCR, the crew discussed making one approach into Kingston and, if this approach missed, they would proceed directly to their alternate.

The first officer stated that they received updates from MKJP Tower on the runway condition and that it was reported as being “Wet”. He said they did not receive any advisory regarding braking action being less than good and no report of any significant runway contamination. He said, based on his experience flying 4,100 hours in this airplane and over a total of 10,000 hours, the weather was not abnormal and it was “just another day at the office”.

The first officer said he had been to Kingston many times before and had been there the prior week on the same sequence. He had landed there at night and in the rain and had been there a few times over the past year.

The flight crew reported that they briefed for arrival at Kingston prior to commencing descent. During the briefing for the approach they decided that, based on the weather and the minimums for the straight in approach to runway 12, it was a better option to do the straight in and land on 12 with a tailwind, rather than doing a circling approach to runway 30 with a low ceiling, and that this had more likelihood of a successful outcome.

Minimum Descent Altitude (MDA) of 1,150 feet above sea level (asl)/1,140 feet above ground level (agl) and visibility 3.7 kilometers for the circle-to-land procedure for runway 30.[1] The most

[1] See Appendix 4

recent Meteorological Terminal Air Report (METAR) for Kingston was ceiling 1,400 broken agl.

In their interviews, both of the flight crew said there was no instrument approach to runway 30 at Kingston, but they were both aware of the circle-to-land approach to runway 30 from the ILS runway 12 approach.

The first officer said they did not have to calculate landing distance before each landing. They had landing performance data and a tailwind was taken into consideration in that data. He said on a runway like that at Kingston which was 9,000 feet long, with wet conditions, there was no problem with the performance data for landing flaps 30 and they had both done this many times. He also stated that for shorter than 8,000 feet, if wet, there were more factors like wet runway The Jeppesen 11-1 Kingston, Jamaica ILS Runway 12 publication used by the crew indicated a, tailwinds to consider; they were cumulative based on field elevation and landing weight. He said he was very comfortable with the runway data but it was more critical when there was a shorter runway and tailwind.

For the purposes of the investigation, this was taken to mean that the AA331 flight crew believed that if the runway was more than 8,000 feet, and the tailwind was 15 knots or less, on a wet runway it was not necessary to calculate landing distance before each landing. It was also considered possible that the first officer meant a 9,000 foot. This was never determined by the investigation, but the 8,000 foot runway scenario was considered to be most likely.

During the initial interviews with the flight crew immediately after the accident, the first officer described his method of landing distance assessment, later called the "advance analysis", by the AA Flight Safety Programs Manager (See 1.17.1.2.9) described in 1.1.2. No further interviews with the flight crew were conducted, and no more exact details of the flight crew's concept of this landing distance assessment were established, nor were there any details as to its origin and genesis.

The first officer said they sometimes landed at flaps 40 but the captain had briefed flaps 30; which was normal for this situation. He said they had discussed that for these conditions and for the go around, flaps 30 was the better choice. He said that flaps 40 would generally be used for real short runways (*sic*). He said the landing performance charts were based on airplane landing weight and that some airports had a special analysis for tailwind landing, but not Kingston.

The first officer said circle-to-land approaches were not done much anymore, as most airports had improved their facilities, but they did conduct circle-to-land approaches in training.

The first officer said they had both done the ILS runway 12 approach at Kingston many times and were familiar with it, so it seemed more appropriate to fly the ILS runway 12 approach, and land on runway 12. He said the weather in Kingston was rain at the field, and rain was also on the radar, so the runway 12 tailwind was a consideration.

The flight crew also discussed the runway conditions based upon the reported weather, the ceiling and wind. They decided to use Flap 30 and autobrakes 2 (the crew changed this to autobrakes 3 on final approach). The first officer said he had done tailwind landings before in weather.

Regarding the use of autobrake, the first officer said the flight crew had some discretion in its use and, for example, on a long dry runway, they did not need to use it. As conditions deteriorate, he said, one would want to give oneself the additional benefit of autobrake. He said if autobrake did not work you could switch to manual braking but you would generally start with autobrake. He said according to landing distance charts, manual braking provided the maximum braking and shortest stopping distance; however it was not their standard operating procedure to use manual braking.

The first officer said he thought the briefing was particularly thorough because of the conditions. The briefing included the rain, visibility, landing considerations, runway options, circling options, flaps, brakes, missed approach considerations, time and fuel to alternate, and the terrain and minimum sector altitudes.

The briefing was not captured on the Cockpit Voice Recorder (CVR), as it took place more than 30 minutes before the CVR lost power at impact. The CVR only recorded the most recent 30 minutes.

There were no contradictions between the statements of the captain and the first officer.

The captain also stated that he called the Kingston Approach controller and requested the latest conditions at Kingston, and reports from aircraft ahead of them. He said the controller told him that the visibility at Kingston was good, and that other aircraft were landing there and "no one was reporting anything out of the ordinary".

AA331 first made contact with the Kingston Enroute controller at 21:47 EST, while level at FL 370 when the flight was eighty miles north of TOTON, a reporting point along the UA301 airway at the Kingston FIR northern boundary. At that time AA331 was cleared to maintain FL 370, proceed to TOTON, and thence direct to KEYNO, the intermediate fix for the ILS approach runway 12.

The AA dispatcher sent an ACARS message to AA331 about 21:48 EST informing them that the latest METAR for Kingston included thunderstorms and moderate rain shower activity, that is, "SPECI MKJP 230228Z 31009KT 5000 TSRA BKN014 FEW016CB SCT030 BKN100 22/19 Q1013".

De-coded, this is, "MKJP special weather observation at 21:28 EST (02:28 UTC 23 Dec), wind 310 degrees at 9 knots, visibility 5000 metres (m) (approximately 3 statute miles) in thunderstorms and moderate rain, ceiling broken at 1,400 feet, few clouds at 1,600 feet in cumulonimbus clouds, scattered clouds at 3,000 feet, broken at 10,000 feet, temperature 22° C, dew point 19° C, altimeter setting 1013 millibars (mb)".

The ACARS sent to AA331 at 21:28 EST (02:28 UTC) also reminded the captain that the runway at Montego Bay would be closed from 03:00 UTC.

The CVR did not capture the pre-approach briefing, and did not record any Automatic Terminal Information Service (ATIS) message. Also, the AA331 crew did not state whether or not they received the ATIS in their post-accident interviews. The ATC transcripts showed that AA331 contacted the Approach controller before descent and requested the Kingston weather, and did not state to the Approach controller that the flight had received the ATIS, nor did the Approach controller request confirmation of its receipt.

The weather given to AA331 by the Enroute controller at 21:48 EST was, "wind at the station is tree (that is, three) one zero degrees at … seven and a half knots, the visibility is approximately five miles … present weather there's a moderate shower at the station … temperature is two one, dew point two zero, the QNH is one zero one four … understand that there's a broken clouds at one thousand feet …" No runway condition report was included. This information was not the same as that in the official weather reports (see above and 1.7.6).

1.1.3 Descent and Approach

The captain made a public address announcement for everyone to be seated, and for the cabin crew to prepare the cabin early for landing due to the expected turbulence on descent. The forward cabin crew members responsible for operation of cabin door exits L1 and R1[2] and who were seated in the cabin crew seats at L1 during the landing, were able to conduct their pre landing checks. The two aft cabin crew members seated at positions L2 and R2 (left and right aft), who were responsible for cabin doors L2 and R2, were unable to complete their safety checks due to the turbulence experienced in the aft of the aircraft.

At 21:51 EST the Enroute controller cleared AA331 to descend to 15,000 feet, at the pilot's discretion, and again gave the altimeter setting of 1014 Mb. At 21:58 EST, before being officially transferred from Enroute to Approach control, AA331 called ahead and asked the Approach controller if any aircraft had reported turbulence on the approach and was advised that none had been reported. At 21:58 EST AA331 then asked the Approach controller if any aircraft had landed in the last hour and was told that one had arrived, but not from the north, and "didn't have any problems coming in."[3]

When AA331 first contacted the Approach controller at 21:58 EST there was no mention by either party of AA331 having received the current ATIS.

The flight crew described monitoring the fuel quantity and using the speed brakes and going to lower altitudes to burn off sufficient fuel to ensure that the aircraft would be down to its maximum landing weight at Kingston.

[2] Pg. 42, Figure 1

[3] Section 1.1.5

At 22:03:40 EST the Enroute controller transferred control of AA331 to the Approach controller and AA331 reported on contact that the aircraft was descending out of FL 190 for one five thousand feet, and at 22:04:15 EST reported through the transition level of FL 180 for one five thousand feet. The Approach controller responded advising AA331 that they should expect an ILS runway 12 approach, gave the altimeter setting as 1014 mb, and cleared the aircraft to descend to and maintain one five thousand feet. The clearance was read back correctly by AA331.

At 22:04:36 EST the Approach controller told AA331, “be advised the information given to you by the Enroute controller is still the same, visibility five miles and there is moderate rain at the station … wind three two zero at one zero knots …”. The ATC and CVR transcripts did not contain any record indicating that a runway condition report and/or a braking action report were requested by AA331, nor that this information was provided by the Approach controller, as was required by ATS MANOPS.

The Approach controller then advised AA331 that they may have to circle from the ILS runway 12 approach and land on runway 30 as the wind at Kingston was now 320 degrees at one zero knots.

AA331 acknowledged this and advised that they would go ahead and take a straight in on runway 12 with the tailwind. At 22:14 EST the Approach controller cleared AA331 to maintain four thousand feet, and on reaching KEYNO cleared for a straight in ILS approach runway 12, and advised that the wind was now 320 degrees at 15 knots. AA331 acknowledged the clearance and the Approach controller asked AA331 if they had understood that the wind was 320 degrees at one four knots, asking them if they were still able to make a straight in approach for landing on runway 12. AA331 responded that they had received the wind and could make the straight in approach to runway 12.

The first officer said the aircraft had both a predictive and reactive wind shear system, and it was a pictorial indication on the navigation display with an approximate location of the wind shear along with one of several aural warnings. No wind shear warning appeared. He said they had weather selected on the both radar displays.

At 22:17 EST the Approach controller handed control of AA331 to the Manley Tower and AA331 contacted the Tower controller, reporting inbound on the ILS for runway 12, level at 2,800 feet. The Tower controller responded advising them of the wind as 320 at 12 knots, and asked if they were still requesting runway 12. AA331 responded affirmatively and asked for the wind again. The Tower controller responded with the wind at 320 at 14 knots, and AA331 stated “ … that's affirmative … ” and repeated the intention to land on runway 12. The Tower controller then cleared AA331 to land on runway 12, and stated “ … be advised runway wet”. The CVR and ATC transcripts did not include any braking action report, or any other surface condition description.

AA331 thanked the Tower controller. At 22:20 EST, AA331 advised the Tower controller that they were three miles on final and the Tower controller responded that landing clearance was still valid for runway 12. The CVR contained no discussion between the two flight crews about the increased tailwind, the reported rain shower activity, the runway conditions or calculation of landing distance.

The following information regarding the approach was provided by the flight crew during post-accident interviews:

- They encountered heavy rain during approach and noted that the approach was noisy due to the rain.
- During the descent, ATC provided them updates on weather, but none required them to recalculate their landing numbers, and at no time was there a tailwind that exceeded their limitations. AA company limitation for tailwind landing was 15 knots.
- As the aircraft approached Kingston there was light to moderate rain on the weather radar, there were no significant storm cells to fly around, and the radar was indicating a broad area of moderate rain.
- There were some terrain considerations when doing a missed approach. The minimums were high for a circling approach, compared to the straight in ILS runway 12 approach minimums.
- They experienced light to moderate turbulence in the descent. There was terrain they had to cross over on the descent into Kingston, and there was a published missed approach and a single engine departure procedure to the south over the water, and most of the weather was between them and the airfield. They were cleared direct to KEYNO, which was normal, and nothing was rushed, high or fast, and the descent was normal.
- The magnetic track of the localizer, 117 degrees, was offset three degrees from that of runway 12, which was 120 degrees magnetic[4] .
- The first officer could not recall what the weather was on the ATIS but they were receiving the latest weather from the Tower. He said there were no additional messages from dispatch regarding weather changes.
- The first officer did not recall anyone immediately preceding them for landing at Kingston, but the captain asked, and the Tower said, they had an aircraft land 30 minutes prior. He did not specify what type of aircraft, and they did not report anything to the

[4] Appendix (4)

Tower[5]. The captain queried the Tower controller several times to get the most accurate information about the field.

- When they intercepted the ILS runway 12, the weather radar painted light to moderate rain. The weather and rides were smooth, and they did not feel any shifting winds, and not much turbulence on final. The captain had it on speed and on glide path early

- The flight crew started getting ground contact intermittently below 2,000 feet, and consistently below 1,500 feet. The aircraft broke out from the clouds at about 1,000 feet and had the runway in sight, which was well above minimums for that approach, and maintained visual contact with the runway throughout the approach. They were still receiving rain, and the wipers were turned on. There were no lower clouds restricting visibility.

- The aircraft was configured early at 1,000 feet, and was on the ILS glide slope. The first officer was monitoring the tailwind on the navigation display and the tailwind component was dropping as they descended to the final approach fix, where it was about an 8-9 knot tailwind. The first officer said he did not look at it during the flare but he recalled that the last time he saw it, it was showing 8-9 knots tailwind. He saw the visual approach slope indicator (VASI) on final approach and they were “right on it”.

- Because of the weather, he said he gave a few additional call outs, and at 500 feet he called, “On speed, sink 800”.

- The first officer stated that at no point was the aircraft high or above speed, and the captain flew a nice approach.

- At about 550 feet, the captain disconnected the autopilot while leaving the auto throttle engaged, and aligned the aircraft to the runway and at about 50 feet the aircraft was on glide path and on speed. He said the approach was noisy, because of the heavy rain. The windshield wipers were on.

- The aircraft was on speed, on the glide path and localizer and, after transitioning from instrument cues to visual flight cues about three miles back, when the aircraft was turned to line up with the runway, they both said the aircraft had crossed the threshold "right in the slot".

The information from the captain agreed with that of the first officer, as stated above, and also that of the CVR.

5 1.10.4.2

The Flight Data Recorder (FDR) data confirmed that the aircraft crossed the runway threshold at 70 feet radio altitude above ground (RA), that is, main gear height. This would have placed the pilot's eye height at about 85 feet RA, about 14 feet above the PAPI slope, and the aircraft's ILS antenna about 37 feet above the ILS glide slope. Thus, both the visual (PAPI) and ILS indications to the flight crew over the threshold were that the aircraft was high on the approach. The PAPI is a visual aid to the pilot for vertical guidance to the runway.

The localizer of the ILS serving runway 12 was offset three degrees north of the runway track, and hence did not bring landing traffic to the touchdown point[6] , so at Decision Altitude/Height (DA/H) pilots using the ILS had to transition to approach and runway lighting cues and make a very slight left turn to line up with the runway centerline[7]. The aircraft was equipped with a Heads Up Display (HUD) above the left (that is, the captain's) seat.

The captain, who was pilot flying and who was seated in the left seat, stated that this approach was an offset localizer approach and in the HUD it actually gave the pilot too much data. The captain stated in his post-accident interview that the HUD did not have a de-clutter mode. The B737 HUD[8] does have a de-clutter mode switch located on the side of the combiner.

The captain stated that, as the ILS was offset, the HUD indications did not match up with the runway and when the aircraft broke out of the clouds he had the real runway, the Flight Path Vector (FPV) and the aircraft, to get lined up. In this approach, he did not go to visual, but he stayed on the localizer all the way down, so he said he eliminated a few of those issues. He said with the HUD on A-2 mode, having the real runway, fake runway, and FPV was too much information so he stayed on the localizer in A-1 mode until the last point where he thought he could make a smooth turn to the runway and touchdown. The following information from the HUD user guide describes the HUD Approach Modes:

> **AI Approach Mode**
> The AI mode is intended for CAT I ILS approaches. CDS flight director guidance is used to drive the HUD flight director. The HSI symbol is displayed until the localizer course is captured and the localizer deviation is less than 0.25 degrees for seven seconds. At that time there is an automatic switch to the localizer deviation scale. AI mode can be selected at any time, except in TO/GA or on the ground.
> If AI mode is selected prior to capturing the glideslope and localizer, the HUD remains in NP mode with AI mode armed.

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[6] Appendix 4 (4)

[7] Appendix 4

[8] AA B737 HUD Briefing Guide, Page 3

AII Approach Mode
The AII mode is intended for CAT II ILS approaches. It is similar to AI mode except that CDS flight director guidance is used to drive the HUD flight director until the glideslope and localizer are captured. At this time, the HUD switches to HUD computer guidance.

The first officer indicated that, while visual, at about 500 feet, the captain aligned the aircraft with the runway centerline. The FDR indicated that the aircraft made a shallow right turn from the ILS localizer then a left turn to the inbound track to the runway, and continued the approach, crossing the runway threshold at about 70 feet RA.

The FDR indicated that the captain made nose-up control inputs at approximately 70 feet RA and manually disconnected the auto throttle at about 35 feet above the runway and closed the throttles to idle. The auto throttle Flare Mode is designed to retard the power automatically when the aircraft reaches 27 feet RA. Up to the time the auto throttle was manually disconnected by the captain, the auto throttle was in speed mode and was maintaining the aircraft's airspeed at V_{REF30} (reference landing speed with flaps 30) + 5 knots, i.e., at 148 knots, which was a ground speed of 162 knots.

1.1.4 Landing

The FDR data showed the aircraft pitching slightly nose up as it passed the threshold, which reduced the descent rate. The captain turned off the autothrottle manually as the nose pitched up, about 4 seconds after threshold crossing, and the throttle levers were reduced to the flight idle stop about 14 seconds after threshold crossing, which was 3,800 feet down the runway.

The float continued as the aircraft passed the PAPI lights at about 38 feet RA (where it should have been on the ground in a normal landing). The shallow rate of descent was maintained for about ten seconds until touchdown, which occurred at 4,100 feet down the runway, or 1,130 feet beyond the touchdown zone, as defined by AA Flight Manual, Part I.

Both flight crews reported being "on speed and in the slot" as the aircraft crossed the threshold of runway 12. The captain stated it was raining and the windshield wipers were turned on.

There was not much peripheral lighting around the runway because of its location across a peninsula with sea at both ends, and the absence of nearby settlement. A commercial power outage had caused the airport to be operating on its standby power generator. The outage resulted in even less than normal peripheral lighting around the airport.

The aircraft was landed with flaps at 30 degrees.

In his interview, the captain stated that he was not sure what the speed difference was between flaps 30 and flaps 40 for landing. He said there was a different amount of thrust required and that flaps 40 was good for a short or contaminated runway. He thought in this case, he was better off with flaps 30. He said flaps 40 can cause you to float sometimes.

The first officer stated they sometimes landed at flaps 40 but the captain had briefed flaps 30, which was normal for this situation. He said they had discussed that for these conditions and for the go around, flaps 30 was the better choice. He said that flaps 40 would generally be used for really short runways.

At least two pitch-up control wheel inputs were recorded by the FDR during the prolonged flare. The aircraft touched down at 148 knots indicated airspeed (KIAS) and 162 knots ground speed, with a 14 knot tailwind component and a 7 knot crosswind component from the left.

The spoilers deployed at wheel spin up on the first touchdown, the aircraft bounced once and then landed again 200 feet down the runway, then autobrake 3 activated at about 4,600 feet from the threshold. The first officer called the ground spoiler, deployment and reverse thrust engagement, and saw the green lights indicating that reversers were deployed.

The captain stated that the aircraft was not decelerating as expected using autobrake 3 and he overrode the autobrake system, applying maximum manual braking on the brake pedals, and selecting maximum reverse thrust with the thrust levers. He was joined by the first officer simultaneously applying maximum manual braking on the brake pedals.

This commanded full braking pressure of 3,000 pounds per square inch (psi), as indicated by the FDR, while the captain maintained directional control along the centerline. The wheel marks on the runway indicated that the aircraft nose wheel drifted about twenty feet (six metres) left of centerline as the aircraft approached the end of the runway. Both of the flight crew reported an abnormal lack of deceleration during auto-braking and maximum manual braking, and both stated that they soon realized the aircraft would leave the runway. The final radio transmission from AA331 was at 22:22:16 EST.

The following information is from the statements of the flight crew:

- The first officer stated that the visibility at touchdown was adequate in the rain.
- The first officer stated that everything was normal to touchdown, but with a little float on the flare, and a smooth transition to landing and touchdown.
- The captain said he thought they touched down at about 1,500 feet.
- The first officer stated that he felt no yawing on landing, and there were no controllability or directional control problems. He said he pressed the pedals down for braking, and didn't notice any differential or directional issues with the pedals. He said he did not sense any antiskid cycling.
- The first officer stated that he did not recall any abnormal alerts or warnings on landing. He thought the reference speed was about 148 knots and they were close to max gross weight for landing.

- The captain said he brought the reversers back as much as he could, but he felt like he was on ice as there was no deceleration, so he applied full manual braking.

- The first officer said he had landed in heavier rain before with less visibility and had not had any problem with braking. He had never experienced a lack of braking as they experienced in this event.

- The captain said that at touchdown he thought the runway was under water. When he realized the aircraft was not decelerating, he thought about doing a go-around, but did not, as he expected the aircraft would eventually slow down.

- The first officer said he did not recall seeing the runway end lights, and knew there was a road beyond and below the runway. He felt that they crossed the road, and that they hit and the landing gear failed, and that there was a secondary impact.

The flight crew was unable to stop the aircraft on the remaining runway and, according to the FDR data, the aircraft exited the end of the runway at 62 knots ground speed. The aircraft then passed through the chain link airport perimeter fence, crossed above the road located about 12 feet below the embankment at the end of the runway and came to rest on the sandy and rocky shoreline area located there, east of the airport boundary. The FDR showed that forward motion ceased and power was lost at 22:22:21 EST.

There was no warning of the impending impact, and no brace command was given. The flight crew reported that after the aircraft came to a stop the cockpit was dark, and they completed the emergency evacuation checklist.

1.1.5 Information given to AA331 flight crew during approach

The captain's interview summary states: "He called approach control told them who he was, where he was, and asked for what the airport conditions were and any reports from previous airplanes. He said the controller told him the visibility was good and he asked if anyone had given pilot reports for turbulence on the approach, to which the controller replied no one had reported anything out of the ordinary." This call was made at 21:58:47 EST, according to the ATC Transcript, while AA331 was still under Enroute control, before transfer to Approach control.

The available evidence from ATC transcripts and controller interviews indicates the following sequence of events:

1. At 21:47:17 EST, while the aircraft was under Enroute control, AA331 requested Norman Manley International Airport (NMIA) weather from the Enroute controller.
2. The Enroute controller, who was seated nearby and within earshot of the Approach controller, then asked the Approach controller for the NMIA weather.
3. The Approach controller reported that he told the Enroute controller that he had a recent PIREP of ceiling 800 feet.

4. The Enroute controller reported that he gave AA331 the current field condition based on the report on the AWOS as well as a cloud ceiling report from a departing aircraft and tower observation.
5. At 21:48:33 EST the Enroute controller told AA331 *"Wind at the station is tree* (that is, three) *one zero degrees at ... seven and a half knots, the visibility is approximately five miles ah ... there's a moderate shower at station ... the temperature is two one, dew point two zero, the QNH is one zero one four ... understand that there's also a broken clouds at one thousand feet ... "*
6. At 21:51:56 EST the Enroute controller cleared AA331 for the approach, but did not transfer AA331 to Approach control.
7. At 21:55:25 EST AA331 contacted Approach.
8. At 21:58:47 EST AA331 asked Approach if there are any turbulence reports, to which Approach replied, *"None reported".* AA331 then asked if there was any traffic landing in the last hour.
9. At 21:59:15 EST Approach told *AA331, "Affirm, we had one aircraft that landed in the (last hour) ... at zero two zero three and he came in from Montego Bay, came in from the northwest and ah ... he didn't have any problems coming in ... didn't have any body from the north…."*
10. At 21:59:37 EST AA331 contacted Enroute again.
11. At 22:03:43 EST Enroute transferred AA331 to Approach.
12. At 22:03:50 EST, in conversation by landline, Approach controller asked Tower controller *" ... still moderate rain at the station?"*
13. At 22:03:55 EST Tower controller replied *"Affirm ... "*
14. At 22:03:56 EST Approach controller asked *"And what's the visibility on final ... you still can see Portmore?"*
15. At 22:03:59 EST Tower controller replied *"Ah ... hmmm ... well the light dem look dimmer ... so I'm ... I'm I'm ... gonna say less than ten ..."*
16. At 22:04:06 EST Approach controller said *"Alright then ... I'll tell him five ..."*
17. At 22:04:10 EST Tower controller said *"Yes, five is good ..."*
18. At 22:04:36 EST Approach told AA331 *" ... be advised the information given to you by the Enroute controller is still the same, visibility five miles and there is moderate rain at the station."*
19. At 22:04:51 EST Approach reported wind 320 degrees at 10 knots.
20. At 22:14:48 EST Approach reported wind 320 degrees at 15 knots.
21. At 22:15:11 EST Approach reported wind 320 degrees at 14 knots.
22. At 22:17:28 EST Approach transferred AA331 to Tower frequency.
23. At 22:17:42 EST Tower reported wind 320 degrees at 12 knots.
24. At 22:17:52 EST Tower reported wind 320 degrees at 14 knots.
25. At 22:17:57 EST Tower said to AA331, *"American three, three one cleared to land* runway *one two ... be advised runway wet".*

Until the report of "runway wet" by the Tower controller at 22:17:57 EST, less than five minutes before landing, there was no mention of any runway condition report. There was no braking action report given, and there was no mention of the ATIS by either AA331 crew or the Tower controller.

The official METAR at the time of the final approach and landing of AA331, issued at 03:00 UTC (22:00 EST), 22 minutes before the accident, was ceiling 1,400 feet broken, visibility 3,000 meters (about 2 miles)[9]. Visual Flight Rules minima in controlled airspace are ceiling 1,000 feet, visibility 3 statute miles, if reported.[10]

1.2 Injuries To Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	14	-	14
Minor/None	6	134	-	140
Total	6	148	-	154

Table 1: Injuries to Persons

1.3 Damage To Aircraft

The aircraft was substantially damaged during the overrun with the right main gear and right engine torn off, the left main gear and the nose gear collapsed, the main fuselage split into three sections and ruptured and deformed underneath, the wings and flaps damaged, and the fuel tanks in the right wing ruptured.[11]

1.4 Other Damage

The airport boundary fence was damaged when the aircraft went through it. The jet fuel leaked from the right wing tanks into the sandy and rocky area where the aircraft came to rest.

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[9]See 1.7.6

[10] JCARs (2004), Tenth Schedule, sub-paragraph 10.665(a)

[11] Section 1.12, 'Wreckage and Impact Information', details accounts of exterior and interior damage to aircraft

1.5 Personnel Information

1.5.1 ATC Operational Personnel

The records of the Enroute, Approach and Tower controllers involved were examined and it was determined that, at the time of the accident, they all held valid ATC licenses and medical certificates.

1.5.2 Flight Crew – General

Unless otherwise stated, AA personnel information was obtained through the Accredited Representative, the NTSB.

	Captain	First Officer
Pilot License	Airline Transport	Airline Transport
Medical Expiry Date	01 January 2010	01 May 2010
Total Flying Hours	11,147	6,120
Hours on Type	2,727	5,027
Hours Last 24 hours	7	7
Hours Last 7 days	20	26
Hours Last 30 days	66	62
Hours Last 90 days	177	163
Hours on Type last 90 Days	177	163
Hours on Duty Prior to Landing	11:22	11:22
Hours off Duty Prior to Work Period	72+	72+
Proficiency Check	April 2009	April 2009
Last Route Check	14/04/2009	Not required
GPS Approach qualified	Yes	Yes

Table 2: AA Personnel Information

1.5.3 Flight Crew and Cabin Crew – Flight/Duty/Rest Times

The records indicated that the flight/duty/rest history of the crew was within the required limits. At the time of the accident the pilots had been on continuous duty for the eleven and one half hours immediately preceding the accident, and had been awake for more than 14 hours. In their post-accident interviews, both pilots reported having had adequate rest during the three days prior to the day of the accident and neither reported feeling fatigued.

1.5.4 Captain

The captain's Federal Aviation Administration (FAA) medical records contained the following information:

- Last medical: 6/16/09
- First Class
- Weight: 200 lbs.; Height: 74 inches.
- No limitations
- No meds *(sic)*
- Near and intermediate vision: 20/40; distant vision: 20/20.
- Color vision and hearing tests: passed.

The captain stated that he was 49 years old and employed by AA as a Boeing 737-800 captain. He said he had about 13,000 hours total time and did not recall how much of it was as pilot in command (PIC).

The captain said he graduated in 1982 with a degree in Aeronautics. He then worked for a flight school and Part 91 charter company which had twin engine airplanes and six Learjets and ran flights throughout the Bahamas for four years. He went from being a flight instructor to a Learjet captain in a couple of years. He said he became the director of operations and flight training officer for this charter company, and he flew the Lear 25 and 35.

He then joined AA in 1986 as a Boeing 727 flight engineer and followed a typical airline profile of progression to first officer on the Boeing 727, first officer on MD-11, then captain on the Boeing 727. He progressed to check airman on the Boeing 727 where he conducted initial operating experience, line checks and special qualifications training on other flight crew operating into Central and South American cities.

When the Boeing 727 fleet was phased out he was assigned to the Boeing 737 as captain and had flown on the Boeing 737 for several years. He was familiar with Caribbean routes, and had landed at Kingston on runway 12 before during rainy weather.

He said he occasionally drank beer and thought the last time he had one may have been over the last weekend. He was not a heavy drinker and did not use tobacco.

He stated that he had no significant changes to his financial status in the last twelve (12) months and his personal life was great. He normally went to bed around 23:00 EST, and woke up around 08:00 EST. He tried to get one hour of exercise each day. He said he did not have any sleep disorders and liked to take a short 20 minute nap sometimes.

He had gone to bed the normal time on Monday night, about 23:00 EST. On Tuesday, the day of the trip, he said he woke up around 08:00 EST. His first flight was scheduled to leave at about 12:00 EST, so he had some time to walk around the lake at his house to get some exercise.

He left his house about 09:30 EST to get to the Miami airport for the 11:00 EST show. He said he was pilot flying on the first leg of the trip to Baltimore/Washington International Airport. He knew that it had snowed there a lot lately so he was anxious to take a look. He said it was an uneventful flight to Baltimore. They were a little late leaving Miami International Airport due to a deferred auxiliary power unit (APU) problem.

The flight back to Miami International Airport with the first officer as pilot flying was uneventful. While there they swapped airplanes and he said the only MEL item on the airplane was the right air conditioning pack, which they placarded before leaving Miami International Airport.

He said that on any trip the most stressful part seemed to be just trying to get off the gate. He said this particular flight was a little stressful having so many passengers on the flight and it being so rough flying over Cuba – this was not a normal night coming across Cuba. He said they did their best to ask for reports from other flight crews and from the controllers. He said once they got to the Kingston area it was just rain, no turbulence, just heavy rain. He said that heavy rain is noisy and when it is that noisy, it raises your stress level ensuring that you "dot the 'i's and cross the 't's."

He said everything was going the way it should have been and that it was "standard operating procedure".

He said that he had flown with the first officer previously, also on the Boeing 727. He said that the first officer was an excellent pilot and that, based on his experience as a check airman, the first officer went above and beyond the call than most first officers. He said the first officer was very personable and professional, and that they shared mutual interests, so he knew that flying with him would mean that they would have interesting conversations. He said the first officer's greatest strength might be that he was a good communicator, but he did it in a way to not overshadow the captain.

He said the AA Flight Manual, Page 10-7X, included a note about standing water at Kingston, but did not state whether or not he was aware of this before the accident.

1.5.5 First Officer

The first officer's FAA medical record had the following information:

- Last medical: 5/4/09
- First Class
- Weight: 203; Height; 72 inches
- No Limitations
- No meds *(sic)*
- Distant, near and intermediate vision: 20/20
- Color vision and hearing tests: passed

The first officer learned to fly at an aviation college in the United States of America, graduating in 1987 and worked as a flight instructor immediately following graduation. He then flew Part 135 scheduled operations in the Caribbean and Miami on smaller aircrafts, and joined American Eagle in 1994 where he flew ATR aircraft based in Puerto Rico and Miami. He joined AA in

1998 and followed a typical career progression as flight engineer on the Boeing 727 for a year, then first officer on the Boeing 727 for three years, transitioning to international flying on the Boeing 737 as first officer from 2002, based in Miami. He had not flown as a captain and had been a first officer at his previous company.

He said he normally went to bed around 23:00 EST, and, depending on his work schedule, would wake up between 07:00 to 08:30 EST. He said he usually got six to eight hours of sleep to feel rested. He stated he was off on Saturday, Sunday and Monday, and stayed at home within his normal sleep-cycle.

He had gone to bed Monday evening about 23:00 EST, and he woke up on Tuesday around 07:00 EST. Usually it took 20 minutes to get to the Miami International Airport, but on that day it took about 30 minutes and he arrived there at 11:05 EST.

He said his scheduling and workload on the day of the accident was typical and although it was a long day, (this was the longest day of the three day trip) it was not atypical for his schedule. He had breakfast at home, a meal on the flight to Baltimore and a snack on the way back to Miami. The aircraft change in Miami took about one hour, and the first officer stated that he "felt fine" after having flown the Baltimore to Miami leg. He said the weather did not affect his workload significantly on the accident flight, except a few more minutes of talking about the weather over Cuba.

He generally considered his health as excellent, and had no significant changes in his health or financial or personal life in the last twelve months.

He had flown with the captain the first time on the Boeing 727, and once or twice over the last year, but not immediately preceding 22 December, 2009. He considered him to be a very good captain, and was very comfortable flying with him. He was open to input, with excellent flying skills, and his greatest strengths were that he was very professional, had good management skills handling others, was easy going and non-confrontational. He liked working for AA a lot and had no pressures from outside influences to complete flights.

He said he would like to see something in the AA Flight Manual, Page 10-7X regarding standing water at Kingston, to draw more attention to it. He said that in the conditions, they were expecting to land on a wet runway, they had done so many times, but he said they had much less braking than that. He did not recall anyone ever discussing among the pilot group any issues with standing water at this airport.

Regarding the change from ten knots to fifteen knots allowable tailwind he said it was not a runway limit but was a company limit and a 12,000 foot runway would not have made a difference on that limitation. He said generally they did not want to land close to the ten knot limit, even on a dry runway. He said if it was a runway limit it may have made them think of doing something different.

1.5.6 Cabin Crew

The FAA minimum cabin crew for this Boeing 737-800 aircraft, with a configuration of 16 first class seats and 132 economy class seats, was three, but four were assigned for this flight in accordance with AA procedures for international Boeing 737 flights. All of the cabin crew members were trained, certified and qualified for their assigned duties on the aircraft, in accordance with the approved AA training program and FAA regulations.

1.5.7 Crew Pairing

For the flight crew this accident occurred on the third and final leg on day one of a three-day pairing. The four cabin crew members, based in Miami, had been on reserve and were given this flight assignment from Miami to Kingston as their first leg.

1.6 Aircraft Information

1.6.1 General

Manufacturer	The Boeing Company
Type and Model	B737-823
Year of Manufacture	2001
Serial Number	29550
Certificate of Airworthiness	Issued 19 December 2001
Total Airframe Time and Cycles	24,610 hours and 10,402 cycles
Engine Type (Number Of)	CFM 56-7B27 (2)
Maximum Allowable Take Off Weight	174,200 lbs.
Maximum Allowable Landing Weight	144,000 lbs.
Recommended Fuel Type	JET A1
Fuel Type Used	JET A1

Table 3: Aircraft Information

1.6.2 Maintenance

The maintenance records of the aircraft were examined, and it was determined that all required inspections and scheduled maintenance had been performed; that all airworthiness directives had been complied with and that the aircraft major repairs and alterations were satisfactorily documented. The MEL had no open items except for the air-conditioning pack temperature controller fault warning, which was deferred in accordance with the MEL in Miami before departure. On November 17, 2009, the HUD system was placed on MEL due to a “System Inop” display on the HUD. The system was returned to service on November 20, 2009, with no later discrepancies identified. Otherwise, there were no deferred defects.

1.6.3 Weight and Balance

The zero fuel weight of the aircraft was 133,654 lbs. Based on the fuel on-board, approximately 10,000 pounds, the actual landing weight of the aircraft was about 143,654 pounds, which was slightly below the maximum allowable landing weight of 144,000 pounds. The AA dispatch document for Flight AA331 indicated that the aircraft’s centre of gravity was within limits for the duration of the flight.

1.6.4 Landing Speeds

For a landing weight of 144,000 lbs. and Flaps 30 the certified reference landing speed (VRef) was 143 KIAS and the approach speed (VApp or target speed) was 148 KIAS.

1.6.5 Automatic Flight System and HUD

The aircraft was fitted with two separate autopilot systems either of which could be selected to operate individually, one at a time to fly the aircraft, or which could be selected to operate in tandem. It had two independent autothrottle systems to control engine power either of which would be operated individually on its own to control one or both engines. Its navigation systems consisted of VOR DME, Inertial Reference, and air data units which all fed a flight management system computer that processed the data and fed it to the electronic flight instrument displays on the instrument panel. The flight management system could be programmed by the flight crew for flights by entering all required elements of a flight planned route via an input device.

The aircraft had a tactical control panel above the main instrument panel on which manually selected inputs to the FMS and autopilot and auto throttle systems could be made by the pilots, that is, selection of heading or track, speed and altitude and of vertical speed. The electronic flight instruments consisted of displays showing navigation and performance information to the flight crew. Most information displayed on the Electronic Flight Information System (EFIS) displays could also be displayed in the heads up display (HUD). Detailed information on all of this is found in the AA FCOMs and is not duplicated in this report. The HUD system installed on this aircraft was a BAE Systems HUD2020.

1.6.6 Weather Radar

The aircraft was fitted with a Rockwell Collins color digital radar that displayed radar returns on the No.1 and/or No.2 Navigation Display on the left and right forward instrument panels, when so selected by either flight crew member.

AA standard flight operating procedure for the operation of the color digital weather radar fitted in the Boeing 737 aircraft required that flight crew operate it when there was a risk of severe weather or reported thunderstorms in the route of flight. The weather radar was functioning properly during the flight to Kingston, and, according to both flight crew members, the weather radar was used during the flight.

1.6.7 Wind Shear Detection and Prediction

The aircraft was fitted with predictive and reactive wind shear warning devices and there was no evidence from the crew interviews or MEL records that they were not functioning at the time of the accident. The wind shear information was displayed pictorially on either of the navigation displays in front of each flight crew member. Flight crew interviews and the CVR recording indicated that no wind shear alert was activated in the cockpit during the flight or during the approach and landing.

1.6.8 Ground Spoilers

The aircraft was fitted with electro-hydraulically operated ground spoilers, which were armed by the first officer when the landing gear was lowered. The FDR did not record Spoiler Deployment or Wheel Speed. The FDR plot of the Speedbrake Handle and the Air/Ground Switch, and the first officer's comment "Deployed" on the CVR at touchdown, indicated that the spoilers deployed on the first touchdown, as the wheels spun up. The first officer also reported that he manually checked the activation lever position during the landing roll. The evidence indicates that the ground spoiler system was serviceable and operated normally during the landing.

1.6.9 Brake System

The braking system was comprised of four subsystems. The skid control compares the calculated wheel speed with a velocity model to control wheel deceleration. If a wheel slows down too quickly, the skid control releases brake pressure until the wheel speed increases. Skid control does not operate at less than a speed of eight knots. During the normal antiskid operation, the skid control operates for each wheel. During alternate antiskid operation, the skid control operates for both wheels on one main landing gear.

Locked wheel protection compares the wheel speeds of the two outboard wheels to that of the two inboard wheels. If the speed of the slower wheel decreases to less than 30% of the speed of the faster wheel, the locked wheel protection releases brake pressure from the slower wheel. Locked wheel protection does not operate at a speed less than 25 knots.

The touchdown protection releases brake pressure from wheels two and four while the airplane is in the air and remains active until 0.7 seconds after the corresponding wheel spins up to 70 knots, or when the ground mode has been sensed continuously for three seconds.

The number 1 and 3 wheels have similar protection, but it is accomplished via the hydroplane protection logic/algorithm in the Antiskid-Autobrake Control Unit, since the difference between the wheel speeds and the Air Data Inertial Reference Unit (ADIRU) measures when airplane ground speed is greater than 50 knots until wheel spin-up occurs at touchdown.

The touchdown/hydroplane protection compares wheel speed data to ADIRU ground speed data. When the wheel speed decreases to 50 knots less than ground speed, the touchdown/hydroplane protection releases pressure to the brake. The hydroplane function supplies protection to wheels 1 and 3 only.

This is a general description of how the Boeing 737-800 brake system is designed to work, not a description of how the accident aircraft's system worked during the accident sequence.[12]

1.6.10 Engine Controls

The two CFM 56-7B27 engines were controlled by an Electronic Engine Control (EEC) that was inter-connected to the Flight Management System (FMS). The fuel pump controls, engine start controls, and the engine anti-ice controls were located on the forward overhead panel. The auto throttle controls were located on the glare shield panel and on the throttle levers. The auto throttle control could be disengaged by pressing a button on the side of the throttle levers.

1.6.11 Rain Removal System

The aircraft was fitted with variable speed windshield wipers on the captain and first officer windshields. The aircraft was also fitted with a rain repellent system, but this system was not used in the USA due to environmental protection concerns about the toxicity of the repellent fluid.

1.6.12 GPS Navigation Equipment

The aircraft was equipped with GPS navigation equipment Smiths Industries Multi-Sensor FMC, Model No. 171596, Software 549849-006 and 549849-009, and was authorized for the conduct of required navigation performance (RNP) instrument approach procedures (IAP). The Kingston RNAV (GPS) Rwy 30 approach was confirmed to have been in the database of the aircraft's navigational equipment at the time of the accident, and was current.[13]

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[12] Sections 1.12.4 for information about the accident aircraft's brake system.

[13] Section 1.18.9

1.6.13 Aircraft description – Cabin, Seats and Exits

The Boeing 737-823 aircraft, registration N977AN, was a single aisle, passenger transport jet aircraft. The flight deck was equipped with two pilot seats and two observer seats. The aircraft passenger cabin was configured with 148 passenger seats. Passenger seats were placed two on either side of the aisle in First Class (forward cabin) and three on either side of the aisle in Economy (aft cabin). There were 16 seats in the forward cabin (rows 3 to 6) and 132 seats in the aft cabin (rows 7 to 28). Overhead stowage bins were fastened to the cabin sidewalls and ceiling throughout the cabin seating area. The overhead stowage bin doors were designed to latch in the closed and open positions. The doors, once unlatched, would remain in the open position until pulled closed.

The aircraft had four floor-level cabin doors, two forward doors between row three and the cockpit, left and right, designated L1 and R1, and two aft doors in the aft galley, left and right, designated L2 and R2. There were four over wing emergency exits, two on the left and two on the right, at rows 13 and 14.[14] The L1 door was used as the main entry and exit door for the passengers and crew. The remaining floor-level cabin doors were utilized for aircraft service and as emergency exits, and the over wing exits were for emergency use only. The aircraft was equipped with three cabin crew stations at doors L1, L2 and R2.

Doors L1 and R1 are at the forward end of the passenger cabin, with a double, rearward facing cabin crew seat installed on the bulkhead just forward of and adjacent to L1, and the forward galley being adjacent to R1. The cabin attendants assigned to L1 and R1 sit in this seat when they are required to occupy their seats.

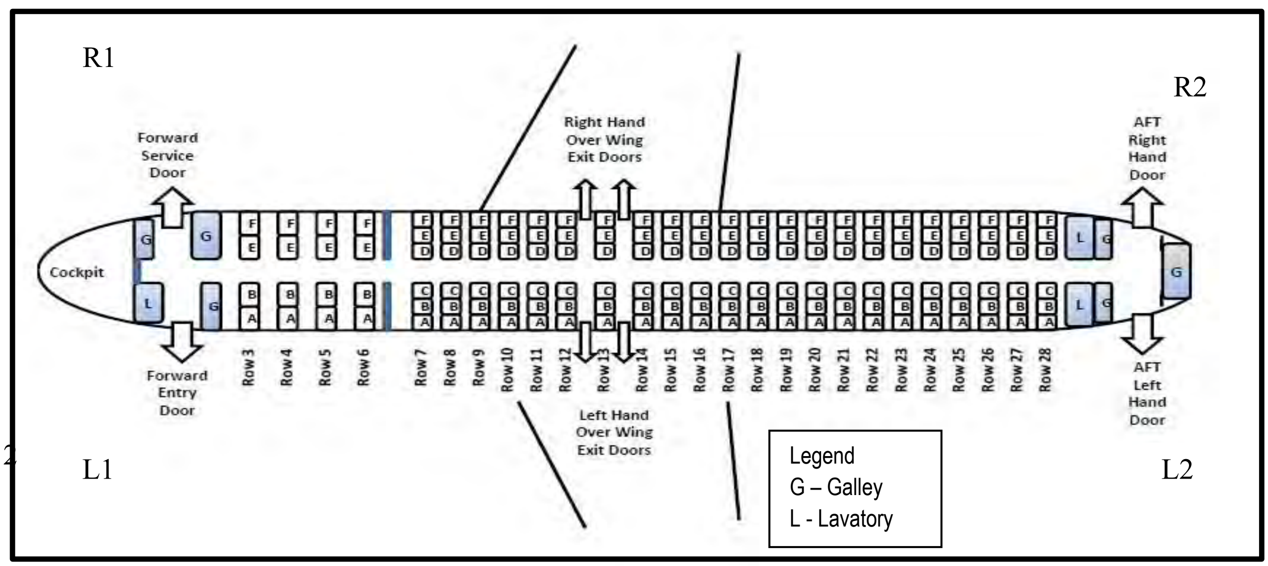

Figure 1: B737-823 Aircraft Cabin and Exits

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[14] See Figure 1

Each cabin crew station was equipped with a double rearward facing cabin crew jump-seat and emergency equipment, including flashlights and life vests, in a compartment below the jump-seat. There were communication handsets for the cabin interphone and public address system at the L1 and L2 stations. There were two megaphones, one at L1 and one at L2.

1.6.14 Aircraft Seats and Restraint Systems

The captain and first officer seats were certified to Title 14 CFR, Part 25, Paragraph 25.785 which includes meeting the requirements of Title 14 CFR, Part 25, Paragraphs 25.561 and 25.562. Part of the requirements of these paragraphs was for the seats to withstand 9g static and 16g dynamic forward decelerations with 10 degree yaw.

The seats of the captain and first officer were mounted on floor tracks. The first observer seat folded to the flight compartment wall when not in use. The second observer seat was attached to the flight compartment wall behind the captain seat. The captain, first officer and first observer seats each had a five-point restraint system, including shoulder harnesses, crotch strap and lap belt, with a rotary buckle release mechanism. The second observer seat had a shoulder harness and lap belt.

The cabin crew seats and passenger seats were certified to Title 14 CFR, Part 25, Paragraph 25.785, which includes meeting the requirements of Title 14 CFR, Part 25, Paragraphs 25.561 and 25.562. Part of the requirements of these paragraphs is for the seats to withstand 9g static and 16g dynamic forward decelerations with 10 degree yaw. The cabin crew seats were equipped with shoulder harnesses and seat belt restraint system. Each passenger seat was equipped with a lift-latch style lap belt.

1.6.15 Emergency Exits – Flight Deck

The flight deck had two emergency escape windows, one on each side by the captain and first officer positions. There were two escape lanyards, one over each pilot seat, to enable the flight crew to escape through the cockpit windows and lower themselves to the ground.

Due to floor deformation in the forward galley area, the members of the flight crew were unable to open the enhanced (that is, bullet-proof) flight deck door. However, the flight deck door had an upper and a lower panel, both of which were designed to be removed from within the flight deck, to provide emergency egress.

1.6.16 Emergency Exits - Cabin

There were four automatic over-wing emergency exits, two on the left side and two on the right side, located adjacent to seats 13A, 13F, 14A and 14F (Fig. 1). Each over-wing exit door was hinged at the top and opened outward and upward. There were two over-wing escape straps in stowage tubes above each aft emergency exit. The emergency exit had to be deployed to gain access to the over-wing escape strap. In an emergency, the hook end of the escape strap was attached to a fitting on the wing enabling the passengers to move safely and maintain stability on the wing in a ditching situation.

1.6.17 Evacuation Escape Slides

The aircraft was equipped with four single-lane slides at the L1, L2, R1 and R2 exit doors to facilitate rapid evacuation in the event of an emergency (Fig.3). Each escape slide was packed in a valise which was stowed inside the escape slide compartment on the lower half of the inside of each exit door (Figs. 2 and 3). The slides were manufactured by the Goodrich Corporation.

The deployment and inflation of each escape slide was designed to be automatically initiated when the door was opened in the armed mode. The door was armed by removing the girt bar from the stowage hooks located on the bottom of the slide compartment and securing it into the floor brackets. There was a chain connecting the girt bar to the slide release latch on the slide compartment.

When the door was opened about 60 degrees, tension on the chain would release the latch and the hinged shelf holding the slide pack in the slide compartment would fall down. This allowed the escape slide pack to fall out of the escape slide compartment.

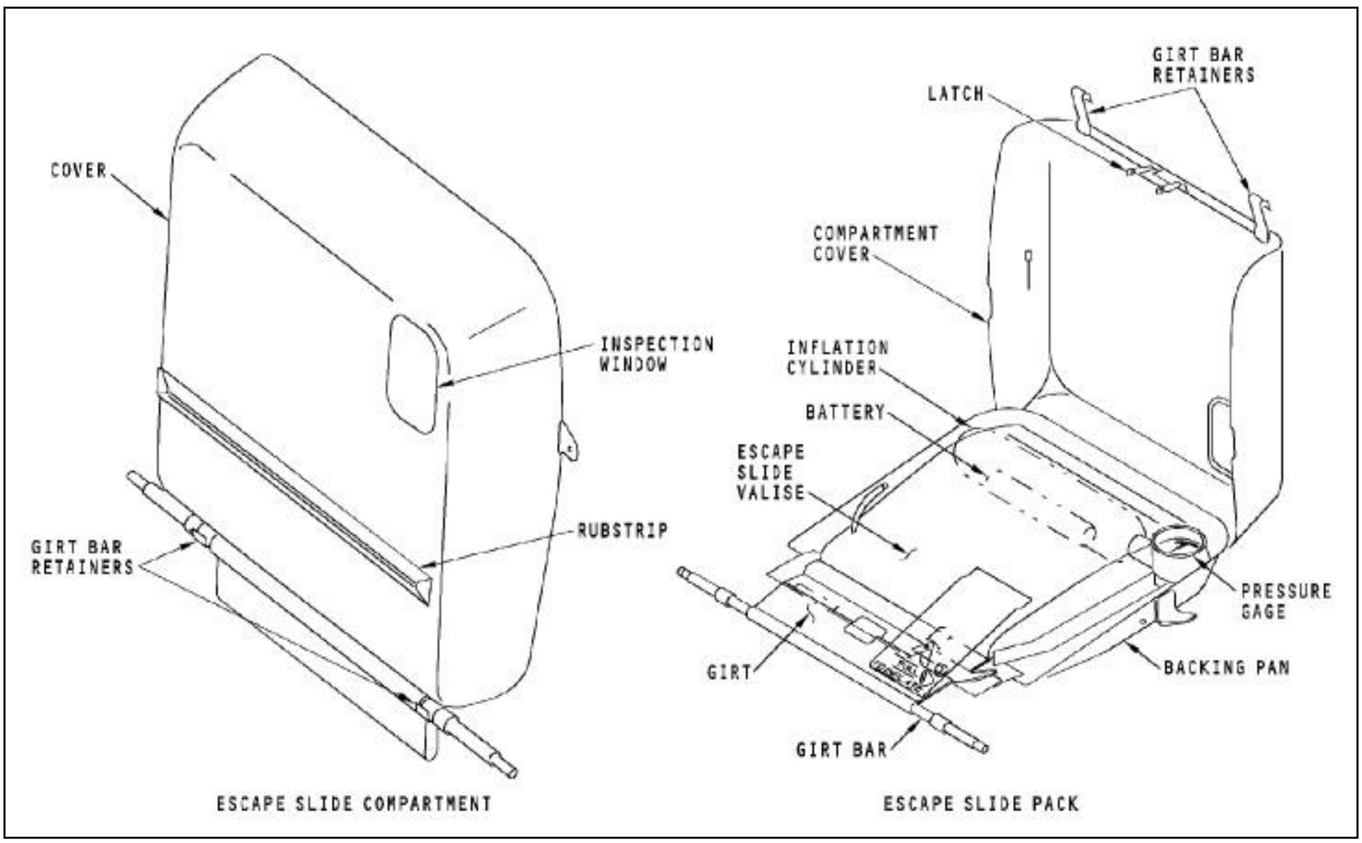

Figure 2. Escape Slide Pack

Illustrates the escape slide compartment, and the escape slide pack that it contains.

An inflation cable attached the girt to the inflation valve. The outward movement of the door would cause the slide pack to fall out of the escape slide compartment as described above.
As it fell, tension on the inflation cable would open the inflation valve of the inflation cylinder. High pressure gas in the inflation cylinder would then be released to the escape slide and it would begin to inflate. The escape slide would take approximately six seconds to fully inflate. In the event that inflation did not start automatically, the slide could be inflated with a manual inflation handle.

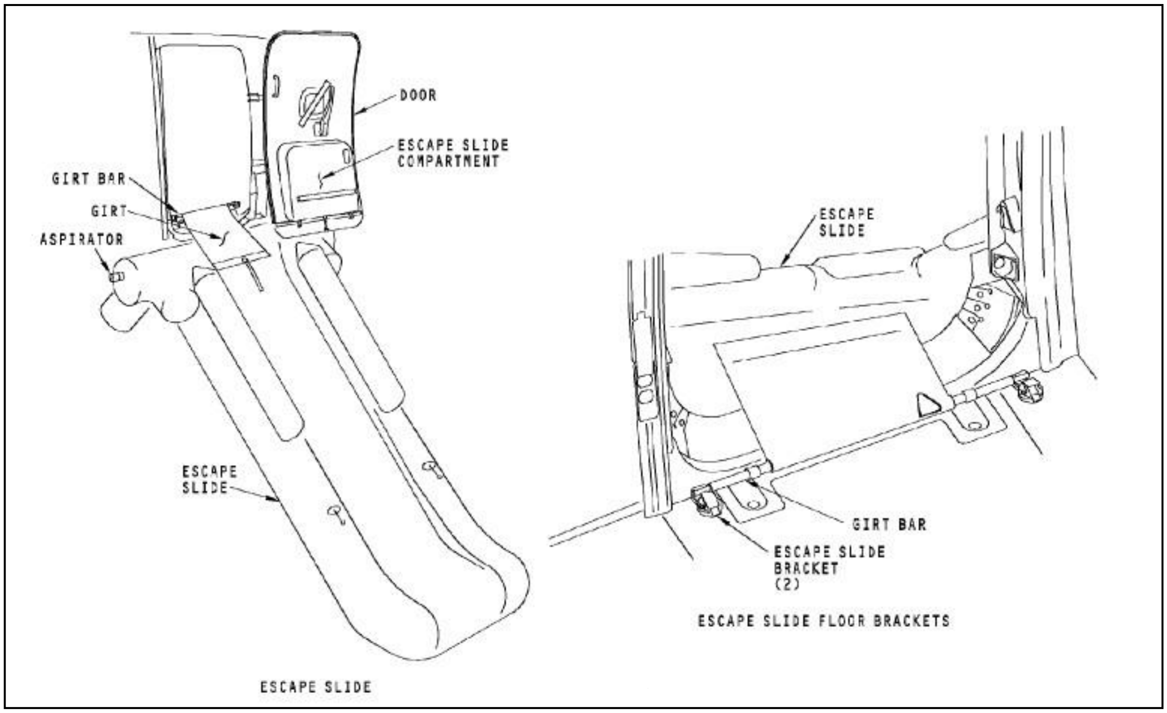

Figure 3. Escape Slide Deployment

The escape slide compartment, which contained the escape slide pack, was attached to the aircraft's door by inserting the lower centre support pin on the back of the escape slide compartment into the bottom support bracket in the aircraft door, then rotating the top of the escape slide compartment upwards flush to the aircraft door, and securing it with screws.

There were no escape slides at the over-wing exits, as the distance to the ground from the wings, when the flaps were extended to Flap 1, which was the highest setting that was certified for the Boeing 737-800 for take-off or landing, was such that FAA regulations did not require slides at the over-wing exits.

1.6.18 Emergency Lighting

1.6.18.1 Emergency Lighting - General

The emergency lighting system was composed of nine independent systems, each one powered by a battery pack, each one of which was continuously charged from the aircraft's Number 1 DC bus-bar. These packs were installed in the ceiling panels at the forward and aft entry areas and on the side structure near the floor. If electrical power to Number 1 DC bus-bar failed, or if AC power was turned off, the emergency exit lights illuminated automatically.

Exit lights were located throughout the passenger cabin to indicate the approved emergency exit routes. The system was controlled by a switch on the cockpit overhead panel. The switch had three positions, OFF, ARMED and ON and was guarded to the ARMED position.

The emergency exit lights could also be illuminated by a switch on the aft flight attendant control panel. Lifting the guard and pressing the switch ON overrode the flight deck control and illuminated the emergency exit lights. Control from this panel was available in the event of failure of the automatic control. The flight deck aft dome light contained a separate bulb that was powered by the emergency lighting system to provide for flight deck evacuation.

1.6.18.2 Interior Emergency Lighting

Interior emergency exit lights were located:

- In the lower inboard corner of stowage bins, to illuminate the sidewalls.
- Over the entry/service and over-wing emergency hatches to indicate the door and hatch exits.
- In the ceiling to locate the exits and provide general illumination in the area of the exits.
- On the inboard leg of each aisle seat.

Self-illuminating exit locator signs were installed at the forward, middle, and aft end of the passenger cabin, and on the bulkheads between cabin classes.

Floor proximity emergency escape path lighting consisted of locator lights spaced at regular intervals down one side of the aisle. Lighted arrows pointed to over-wing exits and a lighted EXIT indicator was near the floor by each door and over-wing exit. Escape path markings were provided for visual guidance for emergency cabin evacuation when other sources of cabin lighting were obscured. Colored lighting was located on the aisle side of the inboard passenger seats at the over-wing emergency evacuation exit rows of seats 13C and 13D, and 14C and 14D.

1.6.18.3 Exterior Emergency Lighting

Exterior emergency lights illuminated the escape slides. The fuselage installed escape slide lights were adjacent to the forward and aft service and entry doors. Lights were also installed on the fuselage to illuminate the over-wing escape routes and ground contact area.

1.6.19 Public Address and Communication System

The aircraft was equipped with a public address system. Under normal circumstances, the flight crew could make announcements to the passengers and communicate with the cabin crew from the cockpit to the L1 and L2 cabin crew stations, and the cabin crew could also make announcements to the passengers and communicate with the flight crew using the handsets at the L1 and L2 cabin crew stations. There was also a megaphone at the L1 and L2 cabin crew stations.

1.6.20 Emergency Equipment

The cabin was equipped with portable emergency equipment in accordance with the applicable regulatory requirements.

1.7 Meteorological Information

1.7.1 METARS on AA331 Dispatch Document

The following information was on the finalized AA Dispatch document for AA331, given to the investigation, and was marked “RH”, meaning recorded history.

This is a record of the Kingston METARS throughout the history of the flight, from the starting of the dispatch document to the last ACARS message to the aircraft.

KIN
230317 230300Z 32008KT 3000 PLUSSHRA BKN014 FEW016CB SCT03
230317 230300Z 32008KT 33000 ?SHRA BKN014 FEW016CB SCT030 B
230315 230300Z 32008KT 3000 ?SHRA BKN014 FEW016CB SCT030 BK
230238 230228Z 31009KT 55000 TSRA BKN014 FEW016CB SCT030 BK
230235 230228Z 31009KT 5000 TSRA BKN014 FEW016CB SCT030 BKN
230217 230200Z 300122KT 5000 SHRA BKN014 SCT030 BKN100 22/2
230214 230200Z 30012KT 5000 SHRA BKN014 SCT030 BKN100 22/20
230213 230200Z 300122KT 5000 SHRA BKN014 SCT030 BKN100 22/2
230212 230200Z 30012KT 5000 SHRA BKN014 SCT030 BKN100 22/20
230116 230100Z 040033KT 5000 SHRA BKN016 SCT030 BKN100 23/2
230113 230100Z 04003KT 5000 SHRA BKN016 SCT030 BKN100 23/20
230113 230100Z 040033KT 5000 SHRA BKN016 SCT030 BKN100 23/2
230008 230000Z 32004KT 9999 FEW016 BKN030 BKN100 24/19 Q101
222316 222300Z 00000KT 9999 VCSH SCT016 SCT030 BKN100 24/20
222226 222200Z 35008KT 9999 FEW015 BKN032 BKN100 24/19 Q1
222116 222100Z 33005KT 9999 FEW015 BKN032 BKN100 23/19 Q1
222007 222000Z 31005KT 9999 -RA FEW012 SCT032 OVC100 23/19
221929 221900Z 10012KT 9000 -RA SCT012 OVC100 22/19

1.7.2 Graphic Area Forecasts

Graphic area forecasts were not included in the dispatch document given to AA331 flight crew, nor were they required.

1.7.3 Weather over Jamaica

Weather information received after the accident from the Meteorological Service of Jamaica for the period in which the accident happened was as follows:

"Weather data shows an area of convective activity moving northward over the island at the time of the accident. Thunderstorm and rain showers reported immediately within the hour of the accident with heavy rain showers at the time of the accident in cumulonimbus clouds."

and,

"Synoptic conditions indicated a stalled stationary front over the Caribbean Sea in the vicinity of Jamaica. GOES-12 infrared satellite imagery surrounding the period indicated an enhanced area of clouds associated with convective activity moving northward across the island of Jamaica and over Kingston at the time of the accident. The radiative cloud top temperatures over Kingston at Satellite imagery from GOES-12 depicted at 0232Z, 0245Z, and 0315Z temperatures of 235.4°, 235.6°, and 247.1° Kelvin, or -37° to -26° Centigrade (C) during the period, which corresponded to cloud tops from 30,000 to 34,100 feet."

1.7.4 En route Weather

From the AA331 Dispatch document, indicating the wind and temperature at various flight levels:

```
ENRT WX FL 240 FL 300 FL 340 FL 390
I TD WIND WCP I TD WIND WCP I TD WIND WCP I TD WIND WCP
URS 0P09/22070M022 2P10/21103M060 2P09/21116M064 0P00/21118M061
UCA 0P10/21061M048 2P10/21093M081 2P08/21107M093 0P00/21111M094
```

1.7.5 Thunderstorms and Lightning

Recent thunderstorm was reported in the METAR for Kingston at 22:00 EST and in the special report at 22:25 EST; however, the flight crew reported that on approach the aircraft radar returns showed a broad area of light to moderate rain. The Doppler radar of the Meteorological Service of Jamaica did not indicate the presence of severe weather, beyond a lot of rain activity.

Lightning was not reported by ground observers, nor by the control tower staff, nor was it mentioned by the flight crew of AA331. The presence of thunderstorms typically results in the observation or detection of lightning; however, lightning was not reported by ground observers, nor by the control tower staff while the flight was on approach and at touchdown.

1.7.6 Hourly Weather Observations

The following official weather reports were based on observations recorded by the Meteorological Service of Jamaica weather observer at the Norman Manley International Airport.

METAR MKJP 230200Z 30012KT 5000 SHRA BKN014 SCT030 BKN100 22/20 Q1013 RERA

SPECI MKJP 230228Z 31009KT 5000 TSRA BKN014 FEW016CB SCT030 BKN100 22/19 Q1013

METAR MKJP 230300Z 32008KT 3000 +SHRA BKN014 FEW016CB SCT030 BKN100 21/20 Q1014 RETSRA

(Accident occurred at 22:22 EST (03:22 UTC, 23 Dec)

SPECI MKJP 230325Z 32011KT 2200 +SHRA BKN014 FEW016CB SCT030 BKN100 21/19 Q1014 RETSRA

METAR MKJP 230400Z 32014KT 1500 +SHRA BKN014 FEW016CB SCT028 BKN090 21/18 Q1013 RERA

Visibilities are in metres (converted to statute miles), cloud layers heights in feet above ground level).

These are interpreted as follows:

Kingston (MKJP) weather observation at 21:00 EST (02:00 UTC, 23 Dec), wind 300 degrees at 12 knots, visibility 5,000 m (approximately 3 miles) in rain showers, ceiling broken at 1,400 feet, scattered clouds at 3,000 feet, broken at 10,000 feet, temperature 22° C, dew point 20° C, altimeter setting 1013 mb, recent rain.

Kingston (MKJP) special weather observation at 21:28 EST (02:28 UTC, 23 Dec), wind 310 degrees at 9 knots, visibility 5,000 m (approximately 3 miles) in thunderstorms and moderate rain, ceiling broken at 1,400 feet, few cumulonimbus clouds based at 1,600 feet, scattered clouds at 3,000 feet, broken at 10,000 feet, temperature 22° C, dew point 19° C, altimeter setting 1013 mb.

Kingston (MKJP) weather observation at 22:00 EST (03:00 UTC, 23 Dec), wind 320 degrees at 8 knots, visibility 3,000 m (approximately 2 miles) in heavy rain showers, ceiling broken at 1,400 feet, few cumulonimbus clouds at 1,600 feet scattered clouds at 3,000 feet, broken at 10,000 feet, temperature 21° C, dew point 20° C, altimeter setting 1014 mb, recent thunderstorm and rain.

(Accident occurred at 22:22 EST (03:22 UTC, 23 Dec.)

Kingston (MKJP) special weather observation at 22:25 EST (03:25 UTC, 23 Dec), wind 320 degrees at 11 knots, visibility 2,200 metres (approximately 1 1/2 miles) in heavy rain showers, ceiling broken at 1,400 feet, few cumulonimbus clouds at 1,600 feet, scattered clouds at 3,000 feet, broken at 10,000 feet, temperature 21° C, dew point 19° C, altimeter setting 1014 mb, recent thunderstorm and rain.

This observation was taken three minutes after the accident.

Kingston (MKJP) weather observation at 23:00 EST (04:00 UTC, 23 Dec), wind 320 degrees at 14 knots, visibility 1,500 metres (approximately 1 mile) in heavy rain showers, ceiling broken at 1,400 feet, few cumulonimbus clouds at 1,600 feet in, scattered clouds at 2,800 feet, broken at 9,000 feet, temperature 21° C, dew point 18° C, altimeter setting 1013 mb, recent rain.

1.7.7 Aerodrome Forecasts

1.7.7.1 Kingston/Norman Manley International Airport (NMIA)

A Terminal Aerodrome Forecast (TAF) was issued for MKJP at 16:00 EST (21:00 UTC) for the period 00:00 UTC on 23 December to 24:00 UTC on 23 December (19:00 EST, 22 December to 19:00 EST 23 December). The TAF forecasted wind from 340° at 8 knots, visibility 10 kilometers or more (better than 6 miles), a few clouds at 1,800 feet, scattered clouds at 3,200 feet, and a ceiling at 9,000 feet with temporary conditions between 18:00 EST, 22 December and 09:00 EST, 23 December of visibility 8,000 metres (5 miles) in moderate rain showers, ceiling broken at 1,600 feet, few clouds at 1,800 feet in cumulonimbus clouds, and scattered clouds at 3,200 feet. The rest of this forecast is not relevant to the investigation.

TAF MKJP 222100Z 2300/2324 34008KT 9999 FEW018 SCT032 BKN090
TEMPO 2300/2314 8000 SHRA BKN016 FEW018CB SCT032
BECMG 2314/2316 20010KT
TEMPO 2318/2324 8000 SHRA SCT018 SCT080

The next scheduled TAF for MKJP was issued at 22:00 EST (03:00 UTC, 23 Dec), immediately prior to the landing, and forecast a wind from 330 degrees at 9 knots, visibility 10 kilometers or more (better than 6 miles), ceilings at 1,600 feet agl, with temporary conditions of visibility 5,000 metres (3 miles) in moderate rain showers. The rest of this forecast is not relevant to the investigation. It should be noted that neither of these forecasts predicted IFR conditions or heavy rain at the time of the accident.

TAF MKJP 230300Z 2306/2406 33009KT 9999 BKN016 FEW018CB BKN070
TEMPO 2306/2324 5000 SHRA
BCMG 2315/2317 16010KT
BECMG 2401/2403 VRB03KT SCT018 BKN032

1.7.7.2 Montego Bay - Sangster International Airport

The following forecast for Montego Bay was provided to the flight crew by AA flight dispatch prior to the departure from Miami.

MKJS 222100Z 2300/2324 14005KT 9999 BKN016 BKN070
BECMG 2308/2310 VRB03KT PROB40
TEMPO 2309/2314 8000 SHRA BKN016 BKN030

BECMG 2314/2316 04010KT FEW022 SCT032

1.7.7.3 Grand Cayman - Owen Roberts International Airport - MWCR

The following forecast was provided to the flight crew by AA Dispatch prior to departure from Miami.

GCM TAF MWCR 222100Z 2300/2324 07018KT 8000 -SHRA SCT018 BKN080
TEMPO 2300/2306 4000 SHRA BKN018
BECMG 2313/2315 05013KT 9999 FEW020 SCT200
TEMPO 2318/2324 SHRA SCT018

1.7.8 Area Forecast and Flash Flood Warning

At 20:21 EST, the U.S. National Weather Service in San Juan, Puerto Rico, issued the following Area Forecast:

FXCA62 TJSJ 230121
AFDSJU
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE SAN JUAN PR
921 PM AST TUE DEC 22 2009

UPDATE...DEEP LAYER TROUGH WITH INTENSIFYING SURFACE FEATURE TRACKING NORTHEASTWARD OVER THE CENTRAL CARIBBEAN WILL BE MAIN PLAYER OVER THE NEXT FEW DAYS. SATELLITE IMAGERY SHOWS IMPRESSIVE DEEP CONVECTION NEAR THE SURFACE CENTER CURRENTLY JUST SOUTHEAST OF JAMAICA AND RAPIDLY LIFTING NORTHEAST. ACCOMPANYING U/L TROUGH AND RIGHT REAR QUAD OF IMPRESSIVE 250 POLAR/SUBTROPICAL JET PROVIDING STRONG SHEAR AND DYNAMICS MORE TYPICAL OF A PROGRESSIVE MID LATITUDE PATTERN THAN THE AVERAGE TROPICAL SURFACE LOW. AS THIS PATTERN PROGRESSES NORTHEASTWARD...IT WILL ENCOUNTER SOME DEGREE OF WEAKENING AND NORTHWARD DEFLECTION AROUND THE PERIPHERY OF THE RESIDENT LOW MID TO MID LAYER RIDGE OVER THE E CARIBBEAN. THIS SEEMS TO BE THE NUMBER ONE FACTOR PREVENTING A MORE WIDESPREAD CONVECTIVE EVENT.

At 11:30 EST on December 22, the Meteorological Service of Jamaica released the following flash flood warning to the general public of Jamaica. Note: this warning was not an official aviation product and was not reflected in the TAFs, nor was it required to be included in the dispatch release for AA331, nor required to be reviewed by flight crews.

> *A FLASH FLOOD WARNING means flooding has been reported or will occur shortly. Motorists and pedestrians should not attempt to cross flooded roadways or other low-lying areas as strong currents are likely. Residents in low-lying areas should be on the alert for rising waters and be ready to move quickly to higher ground.*
> *A Frontal System and a Trough in the vicinity of Jamaica are expected to continue to influence the weather across the island until Wednesday. Radar reports indicate that light to moderate showers are affecting most parishes.*
> *The forecast is for periods of showers, along with isolated thunderstorms to continue across the island today and tomorrow. Cool conditions are also expected especially over northern parishes.*

1.7.9 Kingston/Norman Manley International Airport, Wind Information

The weather system over Jamaica on December 22nd, 2009 was a system known locally as a "Norther", in which the wind blows from the northwest down-slope from the hills and mountains that form the central ridge along the east-west axis of Jamaica. The northwest winds that have a several mile reach from the mountains, blow across the Kingston Harbour toward the airport and runway. The runway starts at the shoreline of the harbour and for about half its length is bordered by its parallel taxiway with the open harbour just to the north side of the taxiway. Typically the diurnal effect reverses at night causing an increase in these winds.

The runway wind direction and speed was measured by a remote anemometer located adjacent to taxiway Alpha, about the midpoint of runway 12-30. Data was transmitted to the weather observer office and to the airport control tower and relayed to the Approach controller. The anemometer's service record showed no evidence of erroneous readings. Wind data from the anemometer was reported in hourly and special weather observations and was also provided by voice radio to aircraft by the air traffic controllers working in the approach control and aerodrome control units.

1.7.10 Weather Information From Radar

The flight crew used the aircraft weather radar to navigate around some weather build ups over Cuba and the first officer reported checking the weather radar returns in the Kingston area, noting that he saw a wide area of green with some yellow, indicating moderate rainfall, but saw no red to indicate convective cloud buildups with heavy rain. This interpretation was corroborated by the returns from the Jamaica Meteorological Service Doppler Radar recording provided by the Jamaica Meteorological Service, which indicated much the same type of weather. The aircraft weather radar returns were not recorded by the FDR, nor was there a regulatory requirement for the FDR to record that data.

1.7.11 Recorded Rainfall Rates At MKJP Norman Manley International Airport

The Meteorological Watch Office at MKJP recorded 20.4 millimeters/0.804 inches of precipitation in the one hour and 55 minutes preceding the accident, consistent with heavy rain (See 1.7.11.2), falling even-spaced during this period. This station also recorded a total of 62 millimeters/2.44 inches of precipitation between 1900 EST on 22 Dec 2009, and 0100 EST on 23 December 2009. While heavy rain continued to be reported at the time of the accident, an increase in the rainfall was noted between 21:26 EST and 21:59 EST, prior to the accident.

1.7.11.1 Recorded Rainfall at MKJP Norman Manley International Airport

Date	Time (EST)	mm	inch
22/12/2009	09:52:00	0.2	0.00788
22/12/2009	09:53:00	0.2	0.00788
22/12/2009	09:54:00	0.4	0.01576
22/12/2009	09:55:00	0.4	0.01576
22/12/2009	09:56:00	0.6	0.02364
22/12/2009	09:57:00	0.4	0.01576
22/12/2009	09:58:00	0.2	0.00788
22/12/2009	09:59:00	0.4	0.01576
22/12/2009	10:00:00	0.2	0.00788
22/12/2009	10:02:00	0.2	0.00788
22/12/2009	10:04:00	0.2	0.00788
22/12/2009	10:06:00	0.2	0.00788
22/12/2009	10:07:00	0.2	0.00788
22/12/2009	10:09:00	0.2	0.00788
22/12/2009	10:10:00	0.2	0.00788
22/12/2009	10:11:00	0.2	0.00788
22/12/2009	10:12:00	0.2	0.00788
22/12/2009	10:13:00	0.2	0.00788
22/12/2009	10:15:00	0.2	0.00788
22/12/2009	10:16:00	0.2	0.00788
22/12/2009	10:17:00	0.2	0.00788
22/12/2009	10:18:00	0.2	0.00788
22/12/2009	10:19:00	0.2	0.00788
22/12/2009	10:20:00	0.2	0.00788
22/12/2009	10:22:00	0.2	0.00788
22/12/2009	10:23:00	0.2	0.00788

Table 4 : Recorded Rainfall at MKJP

1.7.11.2 Definitions of Rainfall

Light - up to 0.10 inch/hour; maximum 0.01 inch in 6 minutes.
Moderate - 0.11 to 0.30 inch/hour; more than 0.01 to 0.03 inch in 6 minutes.
Heavy - more than 0.30 inch/hour; more than 0.03 inch in 6 minutes.

The rainfall rate in 1.17.11.1 above, where conversion from millimeters to inches, by a conversion factor of 0.0394, averaged 0.049 inches per 6 minutes in the 30 minutes preceding the accident. Therefore the rainfall rate at MKJP in the 30 minutes preceding the accident meets the definition of "Heavy".[15]

1.7.12 Weather Conditions on the Ground at Kingston

Rain had been falling steadily most of the day and moderate to heavy shower activity was frequent. Visibility in rain was reported as three to five miles and the ceiling was around 1,000 feet, with wind from the northwest at 12 to 15 knots.

1.7.13 AA Field Condition Report for Kingston

The following field condition report for MKJP Norman Manley International Airport was included in the AA331 dispatch release:

```
* KIN FIELD REPORT *
*******************************************************
* REPORT LAST UPDATED AT 1520 LOCAL TIME *
*******************************************************
---------------------------------------------------------------
DATE 22DEC09 TIME 1853 LOCAL
---------------------------------------------------------------
EXISTING TAA DRP(((((((
---------------------------------------------------------------
RUNWAY STATUS CONDITIONS BRAKING ACTION/RMKS
12 OPEN WET 0.10 IN WATER
30 OPEN WET 0.10 IN WATER
RAMP/TXWY SURFACE WET 0.10 IN WATER
---------------------------------------------------------------* KIN FIELD
```

This report stated that it was last updated 15:20 Local Time (EST), i.e. 5 hours before AA331 departed Miami. No other Field Condition Reports for NMIA were found to have been generated by AA or any other agency before the accident.

[15] Definitions from the (US) Federal Meteorological Handbook, No. 1, Page 8-3, Table 8-1.

1.7.14 Weather Information Provided by Air Traffic Control

At 21:48 EST the Enroute controller told AA331 that the weather was approximately 5 miles visibility in moderate rain (see 1.1.5). The current official weather at this time was the SPECI at 21:28 EST of 5,000 meters (that is, about 3 miles) in thunderstorms and moderate rain.[16]

At 22:04 EST on the Direct Line the Approach controller was informed by the Tower controller that the weather was 5 miles visibility, and he then advised AA331 that the weather was the same as given by the Enroute controller, that is, 5 miles visibility in moderate rain (see 1.1.5). The current official weather at this time was the METAR at 22:00 EST of 3,000 metres, (about 2 miles) in heavy rain.

ATC passed the surface wind to the aircraft, as follows:

Surface Wind Reports from ATC

Time (UTC)	Direction/Speed	Source
02:48:33	From 310 degrees at 7.5 knots	Enroute
03:04:51	From 320 degrees at 10 knots	Approach
03:14:48	From 330 degrees at 15 knots	Approach
03:15:11	From 320 degrees at 14 knots	Approach
03:17:42	From 320 degrees at 12 knots	Tower
03:17:52	From 320 degrees at 14 knots	Tower
03:22:22	IMPACT	

Table 5: ATC Surface Wind Reports

The flight crew acknowledged the wind information, and said they would continue for runway12. The Enroute, Approach and Tower controllers were providing real time anemometer readings from the anemometer positioned just north of the parallel taxiway adjacent to the midpoint of runway 12.

At the time of the accident there was no runway Visual Range (RVR) and Ceilometer equipment at NMIA, hence visibility information had to be provided by means of estimates and reliance on official hourly METAR observations.

[16] Section 1.7.6

1.7.15 Rain Reports During Approach from Flight Crew

In his interview, the captain stated:

- The first officer gave him extra call-outs "because the rain was so heavy".
- When they got into the Kingston area there was heavy rain, making the approach noisy.
- When he touched down, he thought the runway was under water.
- After he got out of the aircraft "he had never been in rain that heavy: it was like a monsoon".

In his interview, the first officer stated:

- That there was rain, and the wipers were on.
- The radar was painting light to moderate rain.

1.8 Aids To Navigation

1.8.1 General

The Kingston Very High Frequency Omni-directional Range (VOR)/Distance Measuring Equipment (DME) and the Kingston runway 12 ILS/DME systems were functioning normally at the time of the accident. The runway 12 ILS and DME were flight tested by an FAA calibration aircraft on 29th December 2009, shortly after the accident, and found to be within normal performance limits, as per ICAO Annex 10. The PAPI lights were not checked by this calibration aircraft.

1.8.2 Instrument Approaches at MKJP, Norman Manley International Airport

See approach charts at Appendix 4, "Jeppesen Approach Plates for Kingston MKJP/KIN". These approach plates were published by Jeppesen, and issued to, and used by, the AA331 flight crew.

1.8.2.1 Runway 12 Instrument Approaches

Runway 12 was served by a VOR/DME approach, an ILS approach and an RNAV Global Positioning System (GPS) approach.

MKJP ILS 12 approach included a localizer and a glide path for lateral and vertical electronic approach path guidance. ICAO Annex 10, Volume 1, Sixth edition (2006), permitted installation of a laterally offset localizer antenna where there was insufficient land off the departure end of the runway to site the antenna in the optimal location. There were limits as to the lateral offset effect on the final approach course provided by that installation and the MKJP localizer 12 fell within the limits contained in ICAO Doc 8168, Vol II PANS-OPS.

In practical terms it meant that the final approach course was offset to the right by 3 degrees from the extended course of the runway centerline. It therefore intercepted the extended course of the runway centerline approximately 0.75 NM from the threshold of the runway at a glide path height of 280 feet above the runway 12 touchdown zone elevation.

The ILS localizer was on a magnetic track of 120 degrees, offset 3 degrees right of the runway magnetic track, which was 117 degrees (See Appendix 4). The ILS glideslope intersected with the runway surface 1,000 feet beyond the runway threshold.

The ILS was classified as an ILS Category One precision approach.

There was a PAPI system for runway 12, the glide slope of which intersected with the runway surface 1,400 feet beyond the runway threshold.

The ILS runway 12 approach was designed based on International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services Operations (PANS OPS), based on criteria contained in ICAO Doc 8168.

For the approach, the flight crew of AA331 used the Kingston, Jamaica ILS runway 12 Jeppesen approach chart (22 AUG 08 (11-1)) (See Appendix 4), issued to them by American Airlines. This chart stated “PANS OPS” in the lower left hand corner, indicating that these were the design specifications used.

The ILS approach minima in an approach based on “PANS OPS” was established by specific obstacle clearance criteria for the category of the ILS serving that particular runway, and was not predicated on the availability of an Approach Lighting System (ALS).

The ILS runway 12 approach chart stated that 278 feet above sea level (asl) /270 feet above ground level (agl) was the Decision Altitude/Height (DA/H).

The ILS runway 12 approach chart stated further, that the visibility of 1.9 kilometers was for “FULL” *and* “ALS OUT” conditions.

ICAO Doc 8168, Vol. 2, Fifth Edition, amendment 4, did not contain any visibility requirements as a basis of procedure design for straight-in ILS approaches. However, suggested (advisory) visibility requirements were promulgated for approaches that involved visual maneuvering (circling). ICAO Doc 8168, Part - I, Section 4, Chapter 7, 7.2.4 stated: “ … This information is not required for the development of the procedure, but is included as a basis for the development of operating minima.”

1.8.2.2 Runway 30 Instrument Approaches

Runway 30 was served by an RNAV (GPS) approach, with a PAPI system and a REIL (Runway End Identification Light) system. The MDA was 390 feet asl /373 feet agl. Also, there was a published circle-to-land approach for runway 30 from the ILS Runway 12 approach; the MDA for Boeing 737 (Category C aircraft) was 1,150 feet asl/1,140 feet agl, with a visibility of 3.7 kilometers.

1.9 Communications

No malfunctions of ground or aircraft radio communications systems were reported between the time AA331 first made contact with the Kingston Air Traffic Services, and the time the aircraft lost power.
Communications in the aircraft during the flight were reasonable and effective. En route, the captain advised the cabin crew and passengers about the weather and related turbulence. According to the cabin crew interviews, the captain instructed the cabin crew to suspend the cabin service, stow service items and take their seats due to the turbulence. Before commencing descent, the captain requested that everyone remain seated due to the anticipated turbulence on the approach into Kingston and for the cabin crew to prepare early for the landing.

No brace command was given prior to the accident by either the flight crew or cabin crew.

As soon as the aircraft came to a stop, the captain called out “Easy Victor” to notify the cabin crew to evacuate the aircraft, but he was not sure that the PA system was working.

The flight attendant at R2 inboard reported that she thought she heard the captain yelling “Easy Victor”.

The forward flight attendant used the megaphone to yell her commands.

1.10 Airport Information

Photo 1 Aerial Photograph of Accident Site

1.10.1 General

The accident occurred at Norman Manley International Airport (NMIA), Kingston, Jamaica, ICAO identifier MKJP, position North 17 degrees 56.1 minutes, West 076 degrees 47.3 minutes, magnetic variation 5.7 degrees west, elevation 10 feet asl.

MKJP was two miles south of the city of Kingston on the southeast coast of the island of Jamaica, situated on a long spit of land leading to Port Royal, and oriented east/west.

MKJP was operated by the NMIA Airports Limited, and the Airports Authority of Jamaica. The Jamaica Civil Aviation Authority (JCAA) had regulatory oversight. At the time of the accident MKJP was not certified by the JCAA, however the certification of the airport was in progress.

MKJP was governed by the Civil Aviation Act of Jamaica and the Civil Aviation Regulations of Jamaica (JCARs) 2004, as amended, Part XIII *Aerodromes*. As such, NMIA Airports Limited was required to operate in compliance with these regulations. The regulations empowered the use of the Aerodrome Standards and Recommended Practices contained in ICAO Annex 14 and related documents.

MKJP operated 24 hours a day and was open for traffic operating under visual flight rules and instrument flight rules (VFR and IFR).

Runways 12 and 30 were closed immediately after the accident, and reopened on the morning following the accident with modified Declared Distances to compensate for the protrusion of the wreckage of AA331 into the airspace at the end of runway 12.

MKJP had a maintenance program. This maintenance program was not approved as required by Regulation 108 and the Twenty First Schedule, paragraph 21.135,

An inspection of the aerodrome was made subsequent to the accident, by the Airports Group investigators. The resulting report is in Appendix 10.

1.10.2 Runway Description

1.10.2.1 Runway 12

The Aeronautical Information Publication, Jamaica, Amendment 01/07, valid at time of the occurrence, stated the following information regarding MKJP runway 12:

- Runway 12 was 8,911 feet long by 151 feet wide (2,716 metres by 46 metres). The orientation of runway 12 was 112 degrees True/117 degrees Magnetic.
- The take-off run available (TORA) of runway 12 was 8,911 feet (2,716 metres), take-off distance available (TODA) was 13,367 feet (4,073 metres), accelerate stop distance available (ASDA) was 8,911 feet (2,716 metres), the landing distance available (LDA) was 8,911 feet (2,716 metres).
- The slope of runway 12 was 0.02/0.0.

There was a short up-slope starting at about 6,911 feet from the runway threshold. The gradient of the up slope at the departure end of the runway did not fall within the recommendations of ICAO Annex 14. [17]

The elevation change down the centerline of the runway was 9 feet.

1.10.2.2 Runway 30

The Aeronautical Information Publication, Jamaica, Amendment 01/07, valid at time of the occurrence, stated the following information regarding MKJP runway 30:

- Runway 30 was 8,911 feet long by 151 feet wide (2,716 metres by 46 metres). The orientation of runway 30 was 292 degrees True/297 degrees Magnetic.

[17] Section 1.10.3

- The take-off run available (TORA) of runway 30 was 8,911 feet (2,716 metres), take-off distance available (TODA) was 13,367 feet (4,073 metres), accelerate stop distance available (ASDA) was 8,911 feet (2,716 metres), the landing distance available (LDA) was 8,911 feet (2,716 metres).
- The slope of runway 30 was 0.02/0.0

The elevation change down the centerline of the runway was 9 feet.

1.10.2.3 Runway 12/30, Transverse and Longitudinal Slopes

The drawings from an engineering survey commissioned for this investigation indicated that a transverse slope of 0.9% away from the centerline on both sides was typical along the full length of the runway. Runway construction also included drainage. A survey of the transverse slope did not identify any deviations from engineering drawings.

The meaning of the slope information for both runways in the AIP, which stated “The slope of runway 12 (and 30) was 0.02/0.0”, was not clear, and no explanation for this was found.

A longitudinal survey of runway 12/30, prepared by EDM Consultants, dated February 1997, titled: “Rehabilitation of Runway, Taxiway and Pavement Works, Runway Profile” was provided to the investigation by the Airports Authority of Jamaica. This provided the following information:

1. The slope for runway 30 from 0 m to 260 m (853 ft) was -1.233%
2. For the portion of runway 30 from 0 m to 260 m (853 ft) it stated “This portion of runway longitudinal slope exceeds 0.8%”.
3. The slope for runway 30 from 260 m (853 ft) to 790 m (2,592 ft) was -0.098%.
4. The slope for runway 30 from 790 m (2,592 ft) to 1,200 m (3937 ft) was -0.052%.
5. The slope for runway 30 from 1,200 m (3,937 ft) to 2,335 m (7,661 ft) was 0.004%.
6. The slope for runway 30 from 2335 m (7,661 ft) to 2,720 m (8,924 ft), was -0.034%.

ICAO Annex 14, Vol 1, Fifth Edition – Aerodromes, 1.7.4, Table 1-1, states that an aerodrome with a field length of
1,800 m and over is a Code number 4 Aerodrome reference code.

NMIA is a Code number 4 aerodrome.

ICAO Annex 14, Vol 1 states: “Longitudinal slopes, Recommendation – the slope computed by dividing the difference between the maximum and minimum elevation along the runway centre line by the runway length should not exceed … 1 per cent where the code number is … 4.” [18]

[18] ICAO Annex 14 – Aerodromes, 3.1.13

On the subject runway survey the elevation above sea level at the west end (threshold of runway 12) was 2.476 m, and the elevation at the east end (threshold of runway 30) was 5.676 m, (difference is 3.2 m), and the runway length was 2,720 m, giving a slope of 1.18%.

ICAO Annex 14 – Aerodromes states: "Longitudinal slopes, Recommendation – Along no portion of a runway should the longitudinal slope exceed … 1.25 per cent where the code number is 4, except that for the first and last quarter of the length of the runway the longitudinal slope should not exceed 0.8 %." [19]

Along no portion of the runway did the longitudinal slope exceed 1.25%.

The longitudinal slope of the first 260 m (853 ft) of the first quarter of runway 30 exceeded 0.8%.

ICAO Annex 14 – Aerodromes, states: Declared distances.

a) *Take-off run available (TORA).* The length of runway declared available and suitable for the ground run of an aeroplane taking off.

b) *Take-off distance available (TODA).* The length of the take-off run available plus the length of the clearway, if provided,

and recommends: "The length of the clearway should not exceed half the length of the runway."

Both runway 12 and runway 30 ended at the ocean, which provided an unobstructed clearway, therefore the clearway for both runway 12 and runway 30 was declared to be half the length of the runway, that is, the TODA was 8,911 feet x 1.5 = 13,367 feet.

1.10.2.4 Runway Survey

A visual survey of the runway was conducted. This showed:

1. There was evidence of edge damming on both sides of the runway.
2. There was evidence of water flowing off both sides of the runway, then soaking away.
3. Maintenance of drainage system was poor.
4. There were obstacles on runway strip. (rocks, old concrete blocks and uncovered drainage cisterns).
5. Runway surface had polishing in touchdown zone of runway 12.
6. Surface was not deformed, and had positive transverse slopes along entire length.

[19] ICAO Annex 14 – Aerodromes, 3.1.14

7. There was no cracking, apart from longitudinal joint cracks on entire length, and lateral cracks associated with construction, plus some block cracking in touchdown zone of runway 12.
8. Runway was in good condition overall.[20]

1.10.2.5 Runway Drainage System

The runway drainage was achieved by the transverse slope on either side of the runway so that the water would flow away to the sandy areas to the south and the centerfield to the north and then enter into the drainage system and then soak away into the drainage ducts.

Examination of the surveyor's drawings showed no evidence of the drainage system in the runway strip being linked to the main drainage system or drainage ducts routed under the apron.

1.10.2.6 Runway 12 Lighting and Markings

The following information was gathered from the Aeronautical Information Publication, Jamaica, Amendment 01/07, valid at the time of the accident, and from the operator, NMIA Airports Limited:

- The approach lighting for runway 12 was an SIAL system, with lead-in lights.
- Runway 12 was equipped with a PAPI**.** The design angle of the beam projection was 3º and was required to conform as closely as possible to the angle of the ILS glide path. The PAPI consisted of four light units on each side of the runway, each being in the form of a horizontal bar. These were located 1,400 feet from the runway threshold. The aircraft was on slope if the two units furthest from the runway showed white, too high if all units showed white and too low if all units showed red.
- Runway 12 was equipped with high-intensity runway edge lights (HIRL), uniformly spaced at 60 m (196 feet) intervals. There were five variable intensity settings. At the time of the occurrence, the runway edge lights were on setting 5, the maximum setting.
- The HIRL lights were white for the first 5,911 feet of runway, alternate red and white for the next 2,000 feet, and red for the last 1,000 feet. Runway 12 was also equipped with high speed exit taxiway lights.

Runway 12 was not equipped with touchdown zone (TDZ) lighting, nor was this required or recommended by ICAO Annex 14 for Category 1 systems.

Runway 12 was not equipped with distance remaining markers nor was it required to be by Jamaica Civil Aviation Regulations, 2004, as amended, nor was this recommended by ICAO, Annex 14.

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[20] Appendix 10, Airports Group Report

At the time of the accident there was an active NOTAM for the SIAL system for Runway 12 that indicated that the system was not operational - see NOTAM in section 1.18.3 informing aircraft operators of this. This NOTAM had been in effect since 30 November 2009. This did not affect the use of the runway for the landing of AA331.[21]

All other parts of the lighting system for runway 12 were serviceable. Runway 12 had white runway markings consisting of the following:

- Threshold markings - a series of vertical bars marking the threshold;
- Runway designation markings, consisting of the runway number;
- Touchdown zone markings, consisting of repeating series of vertical bars either side of the centreline, every 500 feet within the first 3,000 feet of the runway;
- Aiming point markings at 1,500 feet from the threshold, and
- Centreline markings - a dashed line indicating the centreline of the runway.

There was no lighting embedded in the runway surface, and the runway markings did not contain any reflective material.

ICAO Annex 14 (valid at the time of the accident) recommended that, "At aerodromes where operations take place at night, pavement markings ***should*** be made with reflective materials designed to enhance the visibility of the markings." [22] (bolding added).

All markings and lighting on runway 12 met the standards for runway lighting and markings of ICAO Annex 14.[23] Though the Norman Manley International Airport was not certified in accordance with Part XIII of the JCARs 2004, NMIA Airports Ltd., as an applicant for an aerodrome certificate, was required by Schedule 21, 21.135 to detail the particulars of the procedures for the inspection and maintenance of aeronautical lights (including obstacle lighting), signs, markers and aerodrome electrical systems.

Jamaica Civil Aviation Regulations, 2004, as amended, stated:

113. An aerodrome operator shall ensure that his aerodrome is operated and maintained with a reasonable degree of care and diligence and compliance with the standards and practices specified in Regulation 91(2).

118. - (1) Subject to any directions issued under maintenance of paragraph (2), an aerodrome operator shall operate an aerodrome. and maintain an aerodrome in accordance with the procedures set out in the approved Aerodrome Operator's Manual.

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[21] Section 1.8.2.1

[22] ICAO Annex 14, 5.2.1.7, Doc. 9157 Part 4, "Aerodrome Design"

[23] ICAO Annex 14, Aerodromes Design and Operations, Volume 1, Chapter 3

The NMIA had a draft manual, but did not have any approved manual at the time of the accident. In the absence of any approved manual and in the absence of an Aerodrome Certificate, the aerodrome operators of the NMIA were being held to the standards contained in ICAO annex 14, Volume 1, Fifth Edition.

Annex 14 stated:

> *"The system of preventive maintenance employed for a precision approach* runway *category I shall have as its objective that, during any period of category I operations, all approach and runway lights are serviceable and that, in any event, at least 85 per cent of the lights are serviceable ..."* [24]

1.10.2.7 Runway 30 Lighting and Markings

The following information was gathered from the Aeronautical Information Publication, Jamaica, Amendment 01/07 (valid at the time of the accident), and the NMIA operator:

- The approach lighting for runway 30 was a Simple Instrument Approach Light (SIAL) system. This did not have lead-in lights.
- Runway 30 was equipped with a precision approach path indicator (PAPI). The design angle of the beam projection was 3º. The PAPI was located 1,400 feet from the runway threshold, and consisted of four light units on the each side of the runway in the form of a horizontal bar. The aircraft was on slope if the two units nearest the runway showed red and the two units furthest from the runway showed white; the aircraft was too high if all units showed white, and too low if all units showed red.
- Runway 30 was equipped with high-intensity runway edge lights (HIRL), uniformly spaced at 60 m (196 feet) intervals. There were five variable intensity settings.
- Runway 30 was equipped with runway End Identification Lights (REIL), which were white strobe lights identifying the threshold of the runway.
- Runway 30 was not equipped with touchdown zone (TDZ) lighting, nor was this recommended by ICAO standards or required by JCARs.

At the time of the accident, all parts of the lighting system of runway 30 were operational.

Runway 30 had white runway markings consisting of the following:

- Threshold markings - a series of vertical bars marking the threshold;
- Runway indication markings, consisting of the runway number;
- Touchdown zone markings, consisting of repeating series of vertical bars either side of the centreline, every 500 feet within the first 3,000 feet of the runway;
- Aiming point markings at 1,500 feet from the threshold; and

[24] ICAO Annex 14, Chapter 10, 10.4.10

• Centreline markings - a dashed line indicating the centreline of the runway. The centreline was not lighted.

The runway was not equipped with distance remaining markers nor was it required to be by Jamaica Civil Aviation Regulations 2004, as amended, nor was this recommended by ICAO, Annex14.

There was no lighting embedded in the runway surface, and the runway markings did not contain any reflective material.

ICAO Annex 14 states: "At aerodromes where operations take place at night, pavement markings ***should*** be made with reflective materials designed to enhance the visibility of the markings" (bolding added).[25]

Apart from the lack of reflective material in the runway markings, all the relevant markings and lighting on runway 30 met the recommendations for runway lighting and markings of ICAO Annex 14, Aerodromes Design and Operations, Volume 1.

There was a maintenance program for the PAPIs, as per NMIA Maintenance Manual, 5.7.

The PAPIs for both runway 12 and runway 30 were examined and found to meet the requirements of ICAO Annex 14 (5.3.5.1). All units were operational and appeared to be well maintained.

As determined by the maintenance records the previous calibration/maintenance was performed on 08 August 2008. The systems were found to be within calibration standards when checked on 26 December 2009. Periodicity of maintenance was not specified in ICAO Annex 14 and was normally subject to the manufacturer's specifications.

The Aerodrome Group Report recommended that MKJP institute a specific maintenance/calibration periodicity and a periodic maintenance schedule to service the PAPIs.

1.10.2.8 Runway End Safety Area (RESA)

Neither runway 12 nor runway 30 had a RESA. Runway 12 ended with a drop of about 12 feet to a road running north/south, then a rocky berm which rose to the shore of the Caribbean Sea. Runway 30 ended in the waters of Kingston Harbour. There were no obstructions at either end of the runway.

[25] ICAO Annex 14, 5.2.1.7, Doc. 9157 part 4, "Aerodrome Design"

1.10.3 Runway Surface Friction Measurement

The runway surface was hot mix asphalt (HMA), hard paved and was not grooved. The maintenance department of NMIA Airports Limited had a program in place to remove rubber deposits and take runway friction measurements. NMIA Airports Limited did not have its own friction measuring equipment but rented it when measurements were to be taken.

The previous friction test was conducted five years before the accident. ICAO Annex 14 states:

"Measurements of the friction characteristics of a runway surface shall be made periodically with a continuous friction measuring device using self-wetting features." [26]

Thus, as the ICAO recommendation did not specify a maximum period between tests, the frequency of friction testing did meet the ICAO recommendation. The relatively long period between tests, in this case five years, was due to the NMIA not being in possession of the testing equipment.

For runway 12, the most recent runway friction measurement before the accident was performed on 17 July 2004 by technical personnel from Grantley Adams International Airport (GAIA), Barbados, using a Findley Irving Mark 2 Grip Tester, Serial Number GT 289, registered to the GAIA.

The results of this measurement indicated that, for runway 12, the average reading for the first third of the runway was 0.65, the second third was 0.62, and the last third was 0.58**.** The friction levels measured by the Grip Tester exceeded the values listed in Table A-1 of Section 7.9 of ICAO Annex 14 volume 1 for maintenance planning level and the minimum friction level. The friction levels given were absolute and were intended to be applied without any tolerance when the average coefficient of friction for the entire runway fell below 0.43 at a speed of 65 Km. There were recommendations for rubber removal in the touchdown areas from 275 to 650 metres along the runway three metres south of the centreline, and this work was subsequently done.

As part of the accident investigation, a similar friction measurement procedure for runway 12 was performed by GAIA technical personnel, using the same equipment, on 05 January 2010, fourteen days after the accident. Standard measurements were made in the wheel path area of the runway, approximately three metres left and right of centreline. Additional full-length friction measurement tests were conducted at 6 metres left and right of centreline to further define the surface characteristics of the runway.

The results indicated that, at three metres left and right of centreline, the average reading for the first third of the runway was 0.66, the second third was 0.60, and the last third was 0.54. In

[26] ICAO Annex 14, Vol. 1, Ch. 10, Paragraph 10.2.3

the first third, the lowest reading for 100 metres was 0.51, and in the last third, there were two readings of 0.48. These readings were above levels requiring maintenance action.

The report from GIAI stated "All of the frictional averages obtained are well over the recommended ICAO minimum friction value of 0.42".

The runway macro texture was measured and calculated for Runway 12 using the Langley Technique for Measuring Surface Roughness, also known as the "Grease Test".

Five separate areas of the runway were examined. The texture measurements were not taken in areas where the wheel braking occurred. Qualitative observation indicated the area where the main gear wheel braking occurred had less texture or was more "polished" than the locations where the Grease Test was performed.

The runway was observed following rain activity in February 2010. The whole runway was wet, with about 20% of the surface covered with shallow water patches.

1.10.4 Runway Surface Condition Reports

1.10.4.1. AIP Jamaica

The Aeronautical Information Publication (AIP) states:

> "*Information on standing water at Kingston/Norman Manley and Montego Bay/Sangster is transmitted by Air Traffic Services (ATS) to landing and departing aircraft. Drainage of the runways at these aerodromes is generally good, however standing water occurs during heavy rains and runways at times become slippery during these periods. No facilities exist for the measurement of standing water at these aerodromes*". [27]

The JCAA staff responsible for the AIP stated that the subject statement has been in the Jamaica AIP since 01 January 2000, and was in the Jamaica AIP at the time of the accident, as AIP Amendment 02/07. No documented history of, or background to, this statement was available from the JCAA or from any other source.

1.10.4.2 Air Traffic Control (ATC)

There was no braking action report requested from, or given by, the arriving aircraft preceding AA331, an Airbus 320, which landed at 21:07 EST, approximately one hour and 15 minutes prior to AA331 landing.

The only runway condition report given to AA331 was given by the Tower controller at 03:17:57

[27] AIP for Jamaica, AD 1.1-1, 30 Sep 07, "3. Dissemination of information of runways affected by water"

UTC, less than 5 minutes before impact, was, “Be advised runway wet”. ATC did not inform AA331 that no braking action report was available. [28]

Heavy precipitation was recorded prior to and during the landing of AA331 by the Meteorological Watch Office [29] and reported in the 03:00 UTC METAR and the 03:25 UTC SPECI (See 1.7.6). The evidence indicated that the 03:00 UTC METAR was transmitted to the aircraft by ACARS [30] at 22:15 EST and 22:17 EST. ATC did not inform the AA331 flight crew of “heavy” rain.

In a post-accident interview the Tower controller stated that the wet runway condition report was based on the controller’s observation that it was raining.

The ATS Manual of Operations (MANOPS) stated that the Approach controller, on initial contact, should give the current runway condition, and the latest braking action report, or state that none had been received. The Approach controller did not do this.

The Meteorological Services of Jamaica provides aeronautical weather services in Jamaica through an aeronautical meteorological watch office at NMIA and an aeronautical meteorological station at MBJ.

1.10.4.3 AA Flight Manual Part II Jeppesen Page 10-7X

The AA Flight Manual Part II Jeppesen Page 10-7X for Kingston, Jamaica, dated 11 JUL 08, stated “Runway is uneven and subject to pools of standing water after heavy rain.” [31]

1.10.4.4 American Airlines Field Condition Reports

The AA Dispatch Procedures Manual, states:

> “Field Condition Reports are updated by station personnel at the station opening, every three hours after, when conditions have changed or when pilot braking action reports are received.” [32]

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[28] Section 1.1.3

[29] Section1.7.11

[30] Section 1.7.1

[31] Appendix 5 to Section 1

[32] AA Dispatch Procedures Manual, Section 10, Page 14, 8/4/08, Paragraph 5. Field Condition Reports, 5.1

Also, the AA Station Manual for Kingston, 11.2 A stated:

> "Airport Inspections will be conducted at least weekly by each General Manager or a designated representative. Inspections will increase in frequency during periods of inclement weather. Inspections should provide detailed information concerning … condition of runways … amount of standing water on runways … "

Also, in 11.4, it stated:

> "During periods of severe or inclement weather, local station management is responsible for keeping Dispatch informed and for updating the local field condition report."

The following runway condition report was in the AA331 dispatch document:

```
* KIN FIELD REPORT *
*******************************************************
* REPORT LAST UPDATED AT 1520 LOCAL TIME *
*******************************************************
---------------------------------------------------------------
DATE 22DEC09 TIME 1853 LOCAL
---------------------------------------------------------------
EXISTING TAA DRP(((((((
---------------------------------------------------------------
RUNWAY STATUS CONDITIONS BRAKING ACTION/RMKS
12 OPEN WET 0.10 IN WATER
30 OPEN WET 0.10 IN WATER
RAMP/TXWY SURFACE WET 0.10 IN WATER
---------------------------------------------------------------
```

(bolding added)

This report stated it was last updated at 15:20 Local Time (EST), that is, 5 hours before AA331 departed Miami.

When the AA NMIA Station Manager was asked if AA procedures required the obtaining of a runway Condition Report when the weather was inclement, it was stated that weather reports go from Meteorological Services to AA dispatch in Dallas and that the AA station staff would have to get that information from Meteorological Services or the Control Tower.

It was also stated that the AA station staff do not have airside passes for the maneuvering area and do not do runway condition reports. When asked if extremely heavy rainfall would prompt a runway inspection by AA, the response was "No, NMIA does that."

AA dispatch was asked where this runway condition report came from, and responded: "The AA operations agent in Kingston entered the information into the KIN field report. The ops agent had put this in their field condition report since they could see water on the tarmac after many hours of torrential rain on that date. It was not an accurate measurement as it was not obtained from an airport or government source. The operations agents in KIN, at that time, thought if they called the field "wet" they needed to add a numerical value to the description." AA also stated, "The numerical value was based on standard practices, and not a measurement that was obtained from an airport or government source." There was no evidence that any such field condition reports were conducted at NMIA in the period before the accident by any agency, or disseminated to AA personnel.

There was no evidence that the AA331 flight crew was aware that this field report was not based on any observation or measurement.

It should be noted that it is impossible to accurately measure the water depth over an entire runway, and qualitative reports from visual inspections are the best that can be done. ICAO does have a format or standard to describe such a process at this time. [33]

1.10.4.5 Runway Condition Reports – ICAO Requirements

ICAO Document 4444 PANS-ATM, stated:

> *Information that water is present on* a runway *shall be transmitted to each aircraft concerned, on the initiative of the controller, using the following terms:*
>
> *DAMP — the surface shows a change of colour due to moisture.*
> *WET — the surface is soaked but there is no standing water.*
> *WATER PATCHES — patches of standing water are visible.*
> *FLOODED — extensive standing water is visible.* [34]

ICAO Document 9137, stated:

> *"Standing water checks should be carried out on request from air traffic control or airport operations. A verbal assessment for the centre half of the width of the runway is required (see Annex 14, Chapter 2). On completion of the check the results should be passed to air traffic control and recorded for reference purposes."* [35]

ICAO Annex 14, describes the obligation of the aerodrome operator:

> *"Information on the condition of the movement area and the operational status of related facilities shall be provided to the appropriate aeronautical information services units, and similar information of operational significance to the air traffic services units, to enable those units to provide the necessary information to arriving and*

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[33] Section 1.10.4..5

[34] ICAO Document 4444 PANS-ATM, fifteenth edition (2007), Chapter 11, "Air Traffic Services Messages," 11.4.3.4.2

[35] ICAO Document 9137, Part 8, Chapter 6 "Rain," 6.5.2

departing aircraft. The information shall be kept up to date and changes in conditions reported without delay." [36]

"Airport Operational Services", the ICAO "Airport Services Manual" stated:

> *"During adverse weather, airport operations will advise air traffic control of relevant surface conditions and should carry out such various checks that the weather may dictate."* [37]

Such surface conditions, as stated in Section 6.2.2, include 'rain – giving reduced runway friction'.

There was no provision in Part 8 for a methodology to be used by which an airport operator could provide quantifiable data related to standing water on the landing surface of the runway.

1.10.4.6 Runway Condition Reports at Kingston

The JCAA ATS MANOPs, Second Edition, Effective September 1992, included phraseologies which made use of the term "Wet", however, the conditions under which a runway was reported as being "Wet" were not defined in the JCAA ATS MANOPs.

ICAO Annex 11, "*Information on aerodrome conditions and the operational status of associated facilities"* stated:

> *Aerodrome control towers and units providing approach control service shall be kept currently informed of the operationally significant conditions of the movement area, including the existence of temporary hazards, and the operational status of any associated facilities at the aerodrome(s) with which they are concerned.* [38]

There were no ATS Unit Specific instructions that required aerodrome controllers to obtain runway reports from NMIA during periods of inclement weather, nor was there evidence of any Memorandum of Understanding (MOU) between KIN Tower and MKJP regarding such a process. In the absence of a formal agreement between the parties, there was no standardized, mutually agreed-upon procedure to obtain and report runway surface conditions.

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[36] ICAO Annex 14, Volume 1, Fifth Edition, Chapter 2, 2.9.1

[37] Part 8 "Airport Operational Services", Section 6.2 of the ICAO "Airport Services Manual"

[38] ICAO Annex 11, 7.2

Part 8 “Airport Operational Services”, Section 6.2 of the ICAO “Airport Services Manual”, stated:

> *“During adverse weather, airport operations will advise air traffic control of relevant surface conditions and should carry out such various checks that the weather may dictate.”*

NMIA was not in compliance with this.

The NMIA Operations Manual, which had not been approved by the JCAA, did not indicate any changes to the pavement inspection frequency if inclement weather was being experienced at the aerodrome. “Operating Procedures and Safety Measures,” indicated the following:

1. The pavement of the maneuvering area, (movement area, excluding the apron), was inspected every morning at daybreak by the Airport Protection Services.
2. An airside surface inspection was conducted by the Operations Coordinator at the beginning of every shift. [39]

The manual did not appear to indicate the number of shifts available or when they began, therefore it was not possible to determine the frequency with which airside inspections were conducted.

The management of NMIA Airports Ltd. was questioned as to the runway inspections that were conducted during 22 December 2009. Two completed “Daily Airside Inspection Report” forms for that date were produced, one indicating that Airport Protection Services (APS) did an inspection at 06:20 Local, and the other that APS did an inspection at 06:35 Local. It was stated that each Operations Coordinator conducts two inspections, one around the beginning of his/her 8-hour shift, and the other around the end of the shift, and that only if there was a noteworthy finding was it reported to Airport Operations Centre (AOC) and recorded in the AOC log.

It was stated that inspections were done on that day, but there were no adverse findings, so no report was made. Apart from this statement, there was no other evidence, documented or otherwise, available to confirm that these inspections were done.

There was no evidence that the runway was examined by the personnel of AA, ATC, NMIA or any other organization at the NMIA airport during the heavy precipitation in the period preceding the time of this accident. There was no indication that any runway condition reports were generated, or disseminated to AA personnel from ATC, NMIA or any other organization in the period before the accident.

[39] NMIA Operations Manual, Original Issue (September 2008), Chapter 4 “Operating Procedures and Safety Measures,” Paragraph 4.5, sub-paragraph 4.5.5.

1.10.5 Airport Rescue and Fire Fighting (ARFF)

In accordance with the Civil Aviation Regulations of Jamaica, as amended 2004, Paragraph 134, NMIA Airports Limited, the operator of MKJP, provided Airport Rescue and Fire Fighting Services Category 8 ARFF, as specified by ICAO Annex 14, Section 9.2.

The airport was a single runway with a parallel taxiway and four connecting taxiways. The fire station was located on the north side of the taxiway at approximately two thirds of the distance of the total runway length from the threshold of runway 12.

According to ICAO Annex 14 the operational objective of the rescue and fire-fighting services shall be to achieve a response time not exceeding three minutes to any point of each operational runway, in optimum visibility and surface conditions. There was no direct access from the fire station to the runway; however the routes utilizing the taxiway to either threshold allowed the services to meet the required response time to either threshold.

The aircraft left the runway at 22:22:21 EST. One ARFF fire tender was at that time deployed on the main ramp providing standby fire protection during the refueling of a Boeing 747 aircraft which was about to depart. The driver of the fire tender on seeing the aircraft departing the end of the runway, went immediately to the end of runway 12, across from the crash site, reaching it in a position from which it could project foam fire suppressant over the entire accident site, at 22:25 EST.

The crew of this fire tender gave a situation report to the other two ARFF fire tenders and advised them that they would have to access the site by driving off airport and by the Port Royal road around to the accident site. These two fire tenders reached the crash site at 22:31 EST.

As there was no fire, the ARFF fire-fighting capability was not needed, but they remained in attendance due to the continued risk from the spilt fuel and electrical hazards. The investigation found that the ARFF services at MKJP met the regulatory requirements, and that the response was adequate.

1.10.6 Meteorological Services and ATIS weather information

The Jamaica Meteorological Services (JMS) provided weather observations and forecasts at MKJP throughout the 24 hour period. Landing Trends could be provided with the landing forecast upon request.

The JMS also provided weather data for the Airport ATIS system. This was achieved by an Automated Weather Observing System (AWOS) located 1,333 metres from the threshold of runway 12 and 208 metres from the centerline of the runway, on the north side. This site contained the equipment to provide certain elements of the ATIS information, that is, a wind vane anemometer and tipping bucket rain gauge. Elements such as visibility were not obtained by automated readings since NMIA did not have a transmissometer.

1.10.7 Airport Lighting

The ambient lighting around the buildings at the airport was less than usual, as there had been a power cut, and the airport was powered by standby generators.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder (CVR)

Recorder Manufacturer/Model: L-3 Communications FA 2100-1010
Recorder Serial Number: 000142599

For the purposes of the investigation of this occurrence, a CVR Group was formed, whose members represented the JCAA, National Transportation Safety Board (NTSB), FAA, Allied Pilots Association, AA and the Boeing Company,

The CVR Group meeting convened on 28 December 2009, at the premises of the NTSB, Washington DC. The CVR was examined at the CVR laboratory of the NTSB, and a complete transcript of the 30-minute, 38-second digital recording was prepared.

This model CVR recorded 30 minutes of digital audio stored in solid-state memory modules. Four channels of audio information were retained: one channel for each flight crew, one channel for the cockpit area microphone (CAM) and one channel for the flight observer/third crewmember. The CVR had not sustained any heat or structural damage. The audio information was extracted from the recorder without difficulty and was of good quality.

The CVR data was correlated to local time using the air traffic control transcript provided by the JCAA. The recording and transcript began at 21:51:44 EST as the aircraft was descending toward Kingston. The recording contained events from the descent, approach, and accident sequence. The recording ended immediately following the accident at 22:22:21 EST.

The flight crew was invited to review the CVR transcript and suggest corrections or additions. The suggested technical corrections were made to the transcript with the concurrence of the CVR group. Information from the CVR is included in Section 1.1 of this report. The complete CVR transcript appears in Appendix 2.

1.11.2 Flight Data Recorder (FDR)

1.11.2.1 Flight Data Recorder

Recorder Manufacturer/Model: L-3 Communications FA 2100
Recorder Serial Number: 00788

This recorded 1,176 individual parameters, and could record a minimum of 25 hours of flight data.

The Flight Data Recorder (FDR) was retrieved from the aircraft at the accident site and forwarded to the NTSB laboratory, where data was download and transcription was completed. The FDR was received in an undamaged state. The FDR was serviceable at the time of the accident, performed as required and contained data relevant to the accident. The relevant data was of good quality, and was analyzed by the NTSB, Boeing flight safety personnel and the accident investigation FDR and Performance groups.

The Flight Data was plotted by the NTSB and by the Boeing Aircraft Company.

The FDR was correlated to local time using the air traffic control transcript provided by the JCAA. Appendix 1 contains a copy of the Boeing FDR plot.

1.11.2.2 Information from Flight Data Recorder

Examination of the FDR revealed the following:

Note 1: " - " , as in " - 1,000 feet" means 1,000 feet *before* the threshold of runway 12. " + ", as in " + 1,000 feet" means 1,000 feet *after* the runway threshold. Distances and times are approximations.

Note 2: The electronic approach guidance on runway 12 was from an ILS transmitter with a 3 degree slope which intersected with the runway 1,000 feet from the threshold. The visual approach guidance on runway 12 was from a PAPI which had a 3 degree slope and intersected with the runway 1,400 feet from the threshold.

Note 3: The distance between the glideslopes of the ILS and the PAPI was designed so that a Boeing 747, the largest aircraft using the runway at the time of the installation of the PAPI and ILS, could be flown with the aircraft on both glideslopes. As the Boeing 737-800 had a shorter pilot eye/ILS antenna distance than the Boeing 747, the Boeing 737-800 could not be on both glideslopes at the same time.

Note 4: Information from the Boeing 737 NG Flight Crew Training Manual, 5.28 and 6.5, indicated that if the pilot of a Boeing 737-800 aircraft flew a 3 degree PAPI glideslope that met the ground at 1,400 feet from the threshold, the main gear would meet with the runway (no flare) at about 1,044 feet from the runway threshold. Also, that if the pilot of a Boeing 737-800 aircraft flew a 3 degree ILS glideslope that met the ground at 1,000 feet from the threshold, the main gear would meet with the runway (no flare) at about 471 feet from the runway threshold.

Note 5: Localizer track was offset 3 degrees north of the runway track (117 degrees Vs. 120 degrees). [40]

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[40] Appendix 4 (4)

- At three miles from the threshold the aircraft was on an ILS coupled approach, gear down, flaps 30 degrees, with autopilot and auto-throttle engaged, and with glideslope and localizer captured.

- Autopilot was disengaged 41 seconds before threshold crossing, at about 1.8 miles from the threshold.

- ILS glideslope deviation started 10 seconds before threshold crossing, at -3,000 feet, to 1 dot high at -1,000 feet, about 4 seconds before reaching the threshold.

- Pitch was increasing from +2 degrees (up) to +3 degrees as the aircraft crossed the runway threshold at about 70 feet RA.

- Pitch increased from +2 degrees to +4 degrees in 9 seconds, from -400 feet to +2,300 feet.

- The aircraft crossed the runway threshold at 70 feet RA (that is, main gear height), which placed the pilot's eye height at about 85 feet RA, about 14 feet above the PAPI slope, and the aircraft's ILS antenna about 37 feet above the ILS glide slope. Thus both the visual (PAPI) and instrument (ILS) indications to the flight crew when over the threshold were that the aircraft was high on the approach.

- Vertical speed decreased from about 660 feet per minute (fpm) down at the threshold, to 0 fpm at +2,600 feet, in 10 seconds.

- Auto throttle was disengaged 4 seconds after threshold crossing, at +1,200 feet, at about 40 feet RA.

- At +1,400 feet, about where the PAPI glide path met the ground, the aircraft was well above the PAPI glide path, descending through 38 feet RA, at a vertical speed of about 3 feet per second down, and at an airspeed of 148 KIAS.

- The Throttle Resolver Angles were reduced from about 56 degrees, where they had been during the latter stages of the approach, at +2,000 feet, and were at the flight idle stop at +3,700 feet.

- N1 (engine speed, both engines) was at 60% until +2,000 feet, 9 seconds after threshold crossing, then fell to about 30% (idle) at +4,300 feet.

- 15 seconds elapsed between threshold crossing and first touchdown at +4,100 feet.

- At touchdown, airspeed was 148 KIAS, and ground speed was 162 knots.

- The first touchdown was at +4,100 feet, followed by a bounce, and the second touchdown was at +4,300 feet.

- Brake pressure was at zero until +4,600 feet.

- Brake pressure was at 500 psi from +4,800 to +6,300 feet. (autobrake 3 design deceleration was achieved)

- The Throttle Resolver Angles were at Max Reverse Thrust at +4,800 feet.

- N1, for reverse thrust, started to increase at +4,500 feet.

- N1, for reverse thrust, was at 82% (maximum) at +5,500 feet.

- Brake pressure reached 3,000 psi (maximum manual brake pressure) at +6,900 feet, and remained there until runway departure.

- Boeing FDR graphs showed aircraft ground speed at end of runway was 62 knots, in accordance with runway condition between Wet Smooth and Standing Water.

- Boeing FDR graphs showed actual rate of deceleration from braking on the wet runway to be less than defined by FAR 25.109 for a Wet-Smooth runway, but more than defined by the NASA Standing Water Runway model.

All of the information from the FDR, the CVR, ATC transcripts, radar tapes and the flight crew interviews was compatible, and showed that the aircraft flew a stabilized final approach, on course, on glide slope and on target air speed until 600 feet agl. It recorded that the captain disengaged the autopilot at about -11,200 feet (1.8 Nautical miles) prior to the runway threshold, and turned the aircraft slightly to the right at about 600 feet above ground level, then turned left and flew the visual approach to runway 12. This resulted in the aircraft being slightly above the ILS electronic glideslope at the end of the turn, at about 1,500 feet from the threshold. The aircraft then continued the approach in a stable configuration and crossed the threshold of runway 12 at about 70 feet RA. At this point the aircraft was very slightly to the right of the extended runway centerline, on speed, more than one dot above the ILS glideslope and with the autothrottle still engaged**.**

The FDR indicated that the aircraft had started to deviate above the ILS glideslope about 3,000 feet before the threshold, and exceeded one dot above the glideslope at 1,000 feet before the threshold. The FDR showed at this point a slight upward elevator deflection, and the aircraft's pitch attitude increasing from 2 degrees nose up to 4 degrees nose up, and the downward vertical speed decreasing, at threshold crossing. This manual pitch up control input was followed by several more until touchdown at 4,100 feet down the runway about 15 seconds later. Some aileron and rudder control inputs were also recorded.

The FDR recorded the manual disconnection of the auto-throttle at 35 feet RA, and the N1 being reduced coincident with the throttles being retarded manually to the forward idle stop at 27 feet RA. The aircraft was maintained at the target airspeed of Vref plus 5 = 148 KIAS, giving a ground speed of 162 knots, until touchdown. The aircraft bounced on the first touchdown, touched down 200 feet down the runway, the speed brakes deployed, and on wheel spin up the autobrake engaged to the autobrake 3 setting, with a brake system pressure of approximately 500 psi. The FDR revealed that the aircraft achieved a deceleration rate of 0.22g, which is consistent with the designed deceleration rate for an autobrake 3 setting.

Throttles were initially set manually to idle and then the N1s of both engines were recorded as advancing quickly to full reverse at +5,500 feet. Full manual braking, as reported by the flight crew, was recorded by the FDR indicating maximum brake system pressure of 3,000 psi at +6,900 feet. Full reverse and full manual braking were maintained until impact.

The aircraft remained close to centre-line, however the rate of deceleration remained fairly constant, that is, did not increase, and was not what the flight crew expected from full manual braking. The aircraft went off the end of the runway at a ground speed of 62 knots, with the FDR recording ceasing at impact.

The FDR indicated that at 3 miles from landing the wind was from 358 degrees at 8 knots, and at touchdown increased to 323 degrees at 16 knots. At touchdown the calculated tailwind component was 14 knots, and the calculated crosswind component was 7 knots from the left.

The "typical landing flare time" is described in the Boeing 737NG Flight Crew Training Manual, [41] as four to eight seconds, and is a function of approach speed. The FDR of AA331 indicated that the flare time was about ten seconds. Flap 30 was used for the landing, and the aircraft was landed on speed plus five knots, however, the landing was at about 4,100 feet from the runway threshold, 1,130 feet past the touchdown zone limits.

The touchdown zone is defined in AA Flight Manual (FM) [42] as the "first 3,000 feet of the runway beginning at the threshold", or the first third of the runway, in this case 8,911/3 = 2,970 feet. The AA Flight Manual (FM), [43] defines the desired touchdown point as the first 800 to 1,500 feet beyond the threshold.

The AA B737 Wind Component and Landing Data Card [44] stated that the Required Runway Landing Length for Dry or Wet/Good Runway Conditions was based, and included,

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[41] Boeing 737NG Flight Crew Training Manual, Page 6.10 See 1.17.2.2

[42] AA Flight Manual (FM), Part I, Section 10, paragraph 7.2, page 32

[43] AA Flight Manual (FM), Part I, Section 10, paragraph 7.3, page 32

[44] Appendix 7

“demonstrated ‘air distance’ from runway threshold to touchdown”, and for Medium/Fair or Poor runway Conditions “includes 1,000 feet ‘air distance’ from threshold to touchdown”. AA was asked to define “demonstrated ‘air distance’”, but they were not able to provide this information.

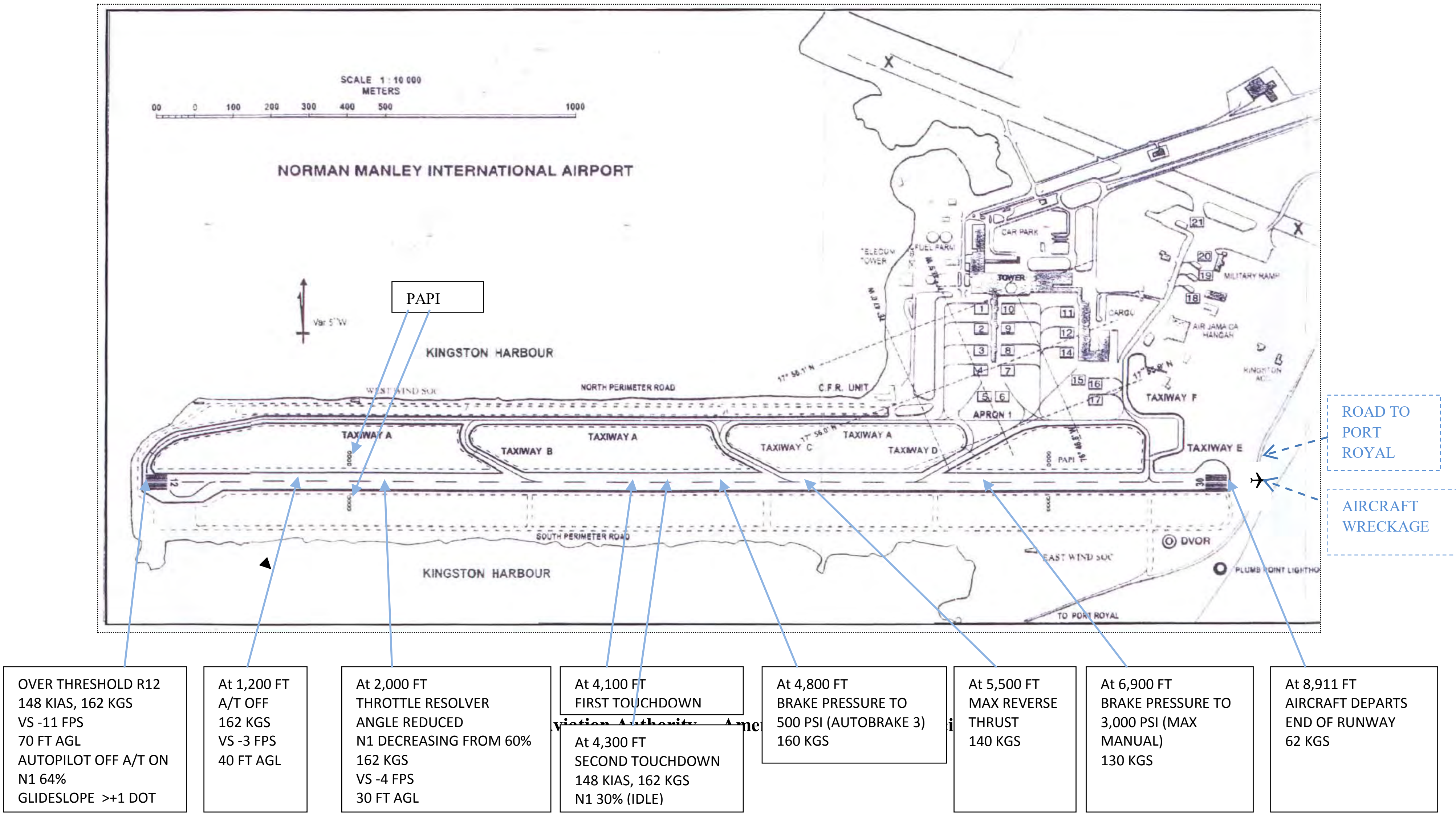
The length of runway 12 was 8,911 feet.

Figure 4: Landing Sequence Key Events

Not To Scale

KIAS KNOTS INDICATED AIRSPEED
KGS KNOTS GROUND SPEED
VS VERTICAL SPEED
FT FEET
FPS FEET PER SECOND

AGL ABOVE GROUND LEVEL
PSI POUNDS PER SQUARE INCH
A/T AUTOTHROTTLE



1.12 Wreckage And Impact Information

1.12.1 Debris Path and Other Damage

After leaving the runway the airplane impacted the airport perimeter fence about 12 feet beyond the threshold, and three runway fence posts were broken. It then travelled airborne about 74 feet horizontally and dropped about 9.5 feet vertically before its initial impact with the sand berm. The initial impact point was characterized by disturbed sand, rocks, and vegetation consistent with the locations of the engines and landing gear. After impacting the berm, the airplane travelled about 100 feet along the up-sloping berm before coming to rest on the beach, a short distance from the water line, and narrowly missed colliding with the concrete pedestals for the approach lights for runway 30.

During the accident there was some slight pavement lip damage at the end of the runway, two threshold end lights were damaged, the airport boundary fence was broken, and some contamination resulted on the beach sand area due to the rupture of the fuel tank in the right wing.

The only markings on the runway conclusively identified as being from the accident airplane were some scrub marks on the white threshold markings and some light tire marks adjacent to the threshold. The scrub marks were relatively cleaner areas of paint with dimensions and tread patterns consistent with the tires of the nose landing gear and those of both main landing gears.

There was a noticeable upslope at the end of runway 12 that began about 670 feet before the end of the runway.

The scrub marks were centred about 27 feet, 10 inches to the left of the runway centreline at the west end of the runway 30 threshold marks. The light tire marks exited the runway threshold about 39 feet, 3 inches left of the runway centreline.

The 4^{th} runway end light from the left side was broken from its mount and the 5^{th} runway end light was turned clockwise. The 6^{th} runway end light was missing from its mount and the runway mount was severely corroded.

The forward section of the aircraft came to rest on a track of 088 degrees magnetic and the centre and aft sections were on a track of 128 degrees magnetic.

Photo 2 Aircraft Wreckage

1.12.2 Damage to Aircraft - General

The aircraft was substantially damaged during the overrun with the right main gear and right engine torn off, the left main gear and the nose gear collapsed, the fuselage split into three sections and ruptured and deformed underneath, and the wings and flaps were damaged. The fuel tanks in the right wing were ruptured, and the fuel had leaked out.

Of the three sections into which the aircraft broke, the forward section consisted of the flight deck, the forward cabin crew seats, and passenger seats from rows three through six. The centre section contained passenger seat rows 7 through 22, including the four over wing emergency exits. The aft section consisted of the aft fuselage of the aircraft from passenger seat row 23 through to the tail of the aircraft.

There was no evidence of pre-impact damage to, or pre-impact failure of, any part of the aircraft's fuselage, wings or control surfaces.

Photo 3 Forward Fuselage

Photo 4 Centre Fuselage

Photo 5 Aft Fuselage

Photo 6 Left Wing

Photo 7 Right Wing

1.12.3. Damage to Engines

The two CFM 56-7B27 engines were examined on site. Both had suffered extensive impact damage. Both had the thrust reverser actuators extended, and the translating cowls of both were in the aft position, indicating that the thrust reversers were extended at impact. This information agreed with the FDR data. There was no evidence of pre-impact malfunction of, damage to, or pre-impact failure of, any part of either engine or associated systems.

1.12.4 Damage to Landing Gear

1.12.4.1 Nose Gear

The nose gear was folded back by impact forces, but the FDR indicated that it was down and locked before impact. The wear on the tires was typical of in-service tires. The left tire pressure was 200 psi, and the right was 0 psi.

Photo 8 Nose Landing Gear

1.12.4.2 Main Landing Gear

1.12.4.2.1 General

As the sequence of events brought into question the functioning of the aircraft's braking system, a detailed examination of the left and right main landing gears was conducted.

1.12.4.2.2 Right Main Landing Gear

The right main landing gear was separated from the wing and came to rest about 30 feet aft of the right wing. The damage was consistent with the impact pattern. The FDR indicated that the right main landing gear was down and locked before impact.

The brakes were intact and appeared to be undamaged. No leaks were observed at the brake pistons. The inboard brake wear pin protrusion beyond the guide was approximately $1^3/_8$ inches. The outboard brake wear pin protrusion beyond the guide was approximately 9/16 inch. The wheels were intact and appeared to be undamaged.

The inboard tire had retread level R1 dated 10/2009. The remaining tread depth was measured from the base of the groove to the rib. From the outside to the inside of the tire the tread depth of each groove measured 3/32 inch, 6/32 inch, 7/32 inch and 1/32 inch, respectively. The measured tire pressure was 215 psi. Both side shoulder ribs had heavy abrasion and large amounts of melted rubber balls 360° around the tire. The centre tread rib exhibited typical abrasion for a rolling tire. Both shoulders exhibited abrasion wear with some heavy abrasion similar to that identified on the shoulder ribs, but with very little evidence of melted rubber balls.

The outboard tire had retread level R4 dated 9/2009. The following measurements of the remaining tread depths were recorded (measured outboard to inboard): 9/32 inch, 12/32 inch, 13/32 inch and 7/32 inch, respectively. The measured tire pressure was 210 psi. The serial side shoulder rib had heavy abrasion and melted rubber balls 360° around the tire. The non-serial side shoulder rib also exhibited heavy abrasion and melted rubber balls 360° around the tire, however, there was not as much abrasion as on the serial side shoulder rib. The centre tread rib demonstrated typical abrasion wear for a rolling tire. There was some heavy abrasion on the shoulders similar to that identified on the shoulder ribs but very little evidence of melted rubber balls.

There was no evidence of pre-impact damage to, or pre-impact failure of, any part of the right main landing gear system, including the tires and the brakes.

Photo 9 Right Main Landing Gear

1.12.4.2.3 Left Main Landing Gear

The left main landing gear was folded aft under the left wing and impacted the left inboard flap. The damage was consistent with the impact pattern. The FDR indicated that the left main landing gear was down and locked before impact.

The brakes were intact and appeared to be undamaged. No leaks were observed at the brake pistons. The inboard brake wear pin protrusion beyond the guide was about 7/8 inch.

The outboard wear pin protrusion beyond the guide was about ¾ inch. The wheels were intact and appeared to be undamaged.

The in-board tire had retread level R1 dated 9/2009. The following measurements of the remaining tread depths were recorded (measured outboard to inboard): 4/32 inch, 6/32 inch, 5/32 inch and 2/32 inch. The measured tire pressure was 199 psi. Both side shoulder ribs exhibited some abrasive wear damage 360° around the tire. There was no evidence of melted rubber balls. The centre tread rib exhibited typical abrasion wear for a rolling tire.

The outboard tire had retread level R2 dated 9/2009. The following measurements of the remaining tread depths were recorded (measured outboard to inboard): 6/32 inch, 12/32 inch, 12/32 inch and 2/32 inch. The measured tire pressure was 204 psi. Both side shoulder ribs had heavy abrasion 360° around the tire, but there was no evidence of melted rubber. The centre tread rib exhibited typical abrasion wear for a rolling tire.

There was no evidence of pre-impact damage to, or pre-impact failure of, any part of the left main landing gear system, including the tires and the brakes.

Photo 10 Left Hand Main Landing Gear

1.12.4.2.4 Evidence of Hydroplaning

The tires were examined at the accident site and it was observed that the tires on the right main landing gear had melted rubber balls and the tires on the left main landing gear did not.

The rubber balls on the right main tires could possibly be an indication that the tires were turning and the brakes were working to slow them, but there was reduced friction such that the rubber balls were not removed during the braking process. With good friction, the rubber balls would normally be scrubbed off by the runway during braking. There was no ready explanation why the tires on the right gear should have melted rubber balls, and the tires on the left gear did not.

There was no evidence that the wheels locked up during the landing roll, or of any hydroplaning on any of the tires, as there were no signs of rubber reversion on the tires or marks on the runway.

1.12.5 Damage to Exits

1.12.5.1 Forward Left Door (L1) and Escape Slide

The forward left door, designated L1, was found in a partially open position, with the door handle in the “open” position. The caution strap was found snapped in position above the viewing window.

The escape slide pack was jammed into the doorway on the aft corner of the escape slide and was not able to fall free from the door sill [45]. Once the escape slide pack had been removed, the door was tested for operation. It was found to operate to the open position, but could not be fully closed in the locked position

[45] Photo 11

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Photo 11 Forward Left Door (L1)

1.12.5.2 Forward Right Door (R1) and Escape Slide

The forward right door, designated R1, was found opened and the door handle in the "open" position. The caution strap was found snapped across the viewing window. The door was tested for operation and found to be difficult to close due to the buckled galley floor, but could be fully closed in the locked position.

The escape slide pack had been released from the escape slide compartment. The escape slide was found deflated, but there was evidence that the slide had been inflated post impact. [46]

[46] See Photo 12

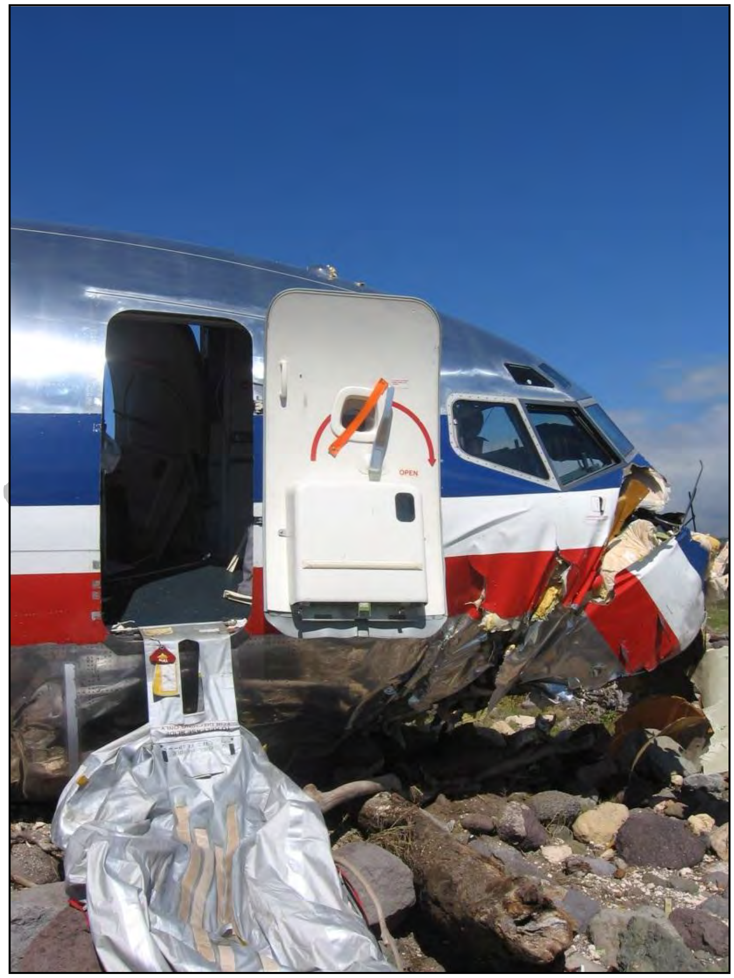

Photo 12 Forward Right Door (R1)

1.12.5.3 Aft Left Door (L2)

The L2 door was found in the fully open position. The door handle was positioned between the open and locked positions. The caution strap was found snapped across the viewing area. The operation of the door was checked and found to open normally.

The L2 escape slide pack was found on the ground, released from the slide pack compartment, but the slide was not inflated.

After the accident the aft fuselage of the airplane was too close to the ground for the slide to fall far enough to activate the inflation mechanism.

Photo 13 Aft Left Door (L2)

1.12.5.4 Aft Right Door (R2)

The R2 door was found in the fully open position with the handle positioned between the open and locked positions. The caution strap was found snapped across the viewing area. The operation of the door was checked and was found to open normally.

The R2 escape slide pack was found on the ground, released from the slide pack compartment, but the slide was not inflated. After the accident the aft fuselage of the airplane was too close to the ground for the slide to fall far enough to activate the inflation mechanism.

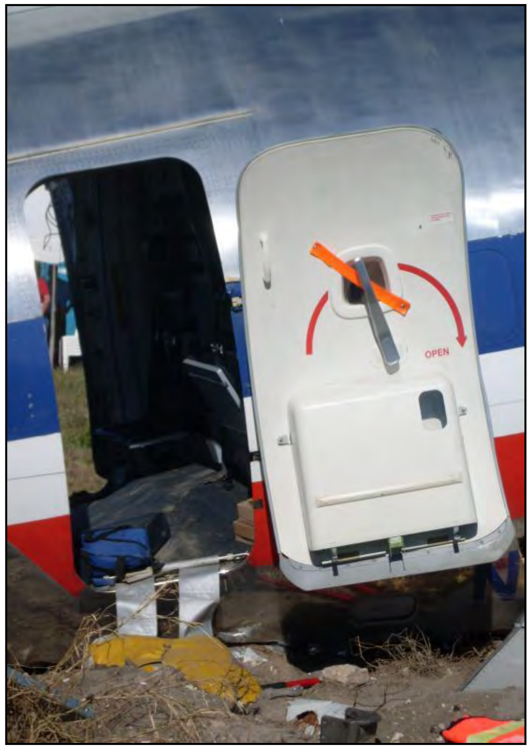

Photo 14 Aft Right Door (R2)

1.12.5.5 Automatic Over-wing Exits

All four automatic over-wing exits were found open and all four operated normally when tested. The escape straps for the aft left and aft right hand over-wing exits were found in their stowed positions.

1.12.6 Damage to Flight Deck

1.12.6.1 General

The forward section, which included the flight deck, came to rest in a longitudinal direction about 40 degrees left of that of the centre section.

1.12.6.2 Flight Deck Seats

Both the captain and first officer's seats were subjected to high horizontal forces during the impact. A mathematical calculation was conducted by IPECO, manufacturer of the flight deck seats, and it was estimated that the G-loads during the impact sequence were between 10 and 12.7 G for a forward deceleration.

The captain's seat crotch belt was found broken loose from the seat structure because the captain's crotch belt bracket was broken. [47] Both the crotch belt and the outboard shoulder harness were found buckled. The captain's outboard shoulder harness was locked in the extended position and the inboard shoulder harness retracted normally.

Photo 15 View into Flight Deck

[47] Photo 16

Both the captain and first officer's seats translated freely in the tracks, but had restricted travel in the forward most position due to contact with the damaged side wall panels. The first observer's seat was found jammed in the stowed position. The second observer's seat floor structure fittings were found sheared.

The Cabin Safety Investigator's Factual Report indicated that the bottom seat cushion of the captain's seat was not an approved part for that seat. It had the wrong part number, and was not a certified seat bottom cushion. This seat cushion invalidated the dynamic qualification of the seat to TSO C127a and in particular the occupant injury criteria for spinal compression load.

1.12.6.3 Flight Deck Floor

The flight deck floor forward of the flight deck door was buckled upwards. The floor under both pilot seats was continuous up to the rudder pedals. Forward of the rudder pedals, the floor was articulated forward and downward away from the captain and first officer positions.

1.12.6.4 Flight Deck Sidewalls

Both of the sidewalls adjacent to the captain and first officer seats were pushed inward towards the seats. The sidewalls came in as far as the outboard rudder pedal on each side.

1.12.6.5 Flight Deck Windows

All flight deck windows remained intact. The two emergency egress flight deck windows were found closed. Investigators unlatched the actuation handles on site and attempted to open the windows, however, damage to the window tracks prevented the windows from opening.

1.12.6.6 Flight Deck Instrument Panel

The instrument panels separated from the fuselage just below the windscreen and articulated forward, away from the pilots. The whole instrument panel was rotated forward (outboard) and downward.

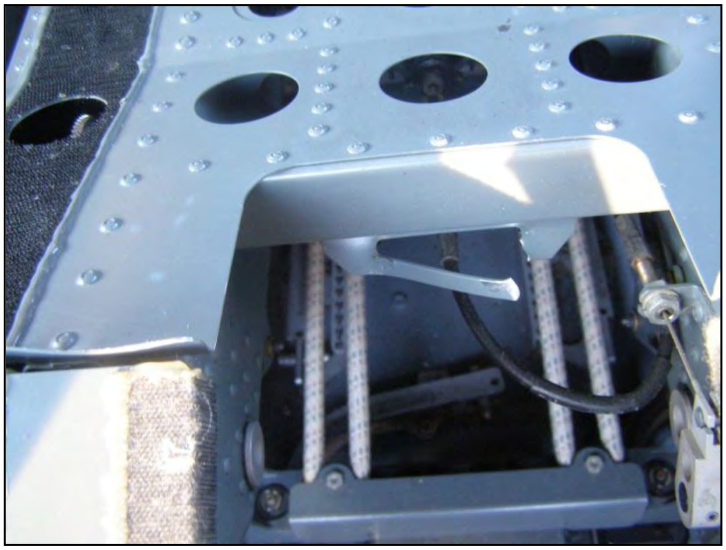

Photo 16 The captain's crotch belt bracket

1.12.6.7 Flight Deck Door

The floor both inside and outside the flight deck had buckled and the flight deck door could only be opened 2 inches at the top and 1.5 inches at the middle and floor levels. The upper and lower blowout panels were not in the door. The lower panel was found, and was undamaged. The upper panel was not found.

1.12.6.8 Forward Entry, Cabin Crew Seats and Forward Galley Area

The forward entry area floor buckled laterally about midway through the R1 doorway. The buckling continued clear across the cabin flooring from left to right. Most of the buckling was in the R1 entry area and in the aisle to the flight deck door.

In the galley area, forward of R1, it was evident that the structure was buckled, causing some items to be jammed in position. Both of the cabin crew members seated at L1 reported that they were unable to retrieve their flashlights because the doors to the emergency equipment compartments under their jump seats were jammed due to the buckling of the floor.

Photo 17 Flight Deck Door

1.12.7 Main Cabin

1.12.7.1 Forward Section - First Class Cabin – Row 3 through Row 6

The interior of the forward section sustained the heaviest damage compared to the centre and aft sections. This section of the aircraft was angled about 40 degrees to the left of the centre section, leaving an opening on the right side about 6 feet wide, and no opening on the left side. The ceiling panels, overhead stowage bins, passenger service units (PSUs), and spacer panels were found displaced. The forward video monitor was stowed. The aft ceiling mounted video monitor remained attached to the stringer and the monitor shroud was displaced downward. The life raft was found in its stowage compartment in the ceiling above Rows 3 and 4. The attachments on the left side of the life raft compartment remained attached to the stringers, but the right side was detached from the stringers.

The majority of the seats in this area were in good condition, with exceptions throughout the section.

Photo 18 First Class Cabin

1.12.7.2 Centre Section – Economy Class Cabin – Row 7 through Row 22

The damage to this section was the least of the three sections. The majority of the seats in this area were in good condition, with exceptions throughout the section. The overhead stowage bins remained in place, with the exception of the bins located at the fuselage breaks. All of the PSUs were dislodged from under the overhead stowage bins and were found either hanging in the seat rows, lying on passenger seats or on the floor.

1.12.7.3 Aft Section - Economy Class Cabin – Row 23 through Row 28

In the aft section, row 23 overhead stowage bins were dislodged on both the ABC and DEF sides of the aisle, and resting on the seats. All PSUs had become dislodged from under the overhead bins and were found either hanging in the seat rows, lying on passenger seats or on the floor.

Photo 19 Centre Section

The aft-most portion of floor between the lavatories had buckled exposing a gap between cabin floor panels and the aft galley floor. The majority of the seats in this area were in good condition, with exceptions throughout the section.

1.12.7.4 Aft Entry, Cabin Crew Seats and Aft Galley Area

The aft galley complex compartments were all closed and locked. All cart compartments were stowed, latched, locked, operable, and intact. The work light was set to "DIM".

Photo 20 Aft Section

The handset was found stowed. The entry light switch was in the "DIM" position, ceiling lights switch in "DIM" position, work light switch in "ON" position, emergency light switch in "OFF" position, and window lights switch in the "OFF" position.

The cabin crew member seated at L2 and the one seated at R2 reported that they were unable to retrieve their flashlights because the doors to the emergency equipment compartments under their jump seats were jammed due to the buckling of the floor.

1.13 Medical and Pathological Information

1.13.1 Captain

The captain was examined by a medical doctor at the University of the West Indies, Kingston a few hours after the accident. Drug tests for Cocaine, Cannabis and Ethanol were conducted, and were negative. Chest and abdominal examination revealed transverse abrasions to the anterior aspect abdomen consistent with his seat restraint. There was mild abdominal tenderness in this region, and some mild tenderness over cervical spine. The resulting report stated that he had sustained some trauma to head, chest and abdomen, and abdominal abrasions consistent with seat restraint, but was otherwise essentially normal. There was no medical finding that could have contributed to causing this accident.

1.13.2 First Officer

The first officer was examined by a medical doctor at the University of the West Indies, Kingston a few hours after the accident. Drug tests for Cocaine, Cannabis and Ethanol were conducted, and were negative. The resulting report stated that he had sustained some trauma to chest and upper abdomen consistent with seat restraint; also right knee and left hand had pain and swelling. Otherwise he was essentially normal. There was no medical finding that could have contributed to causing this accident.

1.14 Fire

Although the conditions were ideal for combustion, that is, electrical sparks, spilt fuel, fuel fumes, hot mechanical parts etc., there was no evidence of any fire. The presence of heavy rain probably impeded the chance of fire. The first ARFF unit arrived within 3 minutes, and remained on standby in case of fire.

1.15 Survival Aspects

1.15.1 Notification of Accident

ATC was immediately aware of the accident, and informed the NMIA emergency services. ARFF had one unit already deployed on the main ramp providing standby fire protection during the refueling of a Virgin Atlantic aircraft about to depart, and that unit went immediately to the end of runway 12, across from the crash site, reaching it in a position from which it could project foam fire suppressant over the entire site, at 22:25 EST, according to interview information from ARFF personnel. The ARFF crew advised other ARFF personnel by radio that they would have to access the crash site by driving off-airport to the Port Royal road, which they did, at the east end of runway 12. They arrived at the aircraft at about 22:31 EST

1.15.2 Emergency Lighting in aircraft

Please refer to 1.16.2 of this report.

1.15.3 Communications

Because of the sudden and unexpected nature of the accident, there was no opportunity for the flight crew to alert the cabin crew and passengers to the impending impact.

The cabin crew interviews indicated that the inter-phone/public address system was not functioning after the accident. It was not determined as to whether or not the flight crew's public address system was functioning after the accident, but there were no reports that any message from it was audible in the passenger cabin. It was reported that the forward flight attendant used the megaphone to yell her commands. In all other respects, communications, both normal and emergency, worked as planned and without interruption.

1.15.4 Evacuation

The following information is from the statements of the flight crew and the cabin crew:

- As the aircraft went over the lip at the end of the runway, the captain hit his head on the cockpit ceiling, then his face hit the HUD, causing him to be dazed.
- No brace command was given prior to the accident by either the flight crew or cabin crew. As soon as the aircraft came to a stop, the captain called out "Easy Victor" to notify the cabin crew to evacuate the aircraft.
- The captain was not sure that the PA system had worked. One of the cabin crew at the aft of the aircraft thought she heard the captain calling "Easy Victor",
- After the impact, when the aircraft came to a rest, it was quiet and dark, and the flight crew tried to open the cockpit window exits but they were jammed closed.

- The captain saw sparks, and knew they had to get out of the aircraft quickly. He had difficulty in getting out of his seat. It was obvious at that point that the aircraft was damaged, and they could see the water on the rocks through the broken cockpit.

- The captain called for the emergency evacuation checklist, and the flight crew completed the items on the checklist, not knowing if the aircraft had power, and even though the engines were probably not on the aircraft.

- The first officer said he didn't remember seeing the instrument panel in front of him, and could see the emergency light on.

- The cabin crew ordered evacuation almost immediately after the aircraft stopped.

- The cabin crew could not open door L1, and had difficulty opening door R1.

- The flight crew lost track of time, but believed they were in the cockpit for about five to ten minutes before they exited.

There was a large hole in the front of the aircraft and the first officer reported seeing the sea water in front of the aircraft, smelling fuel and seeing some sparks and said he considered exiting via the hole. The first officer tried to open the cockpit door, but it was jammed, however he was able to unlatch and remove the upper escape panel in the flight deck door and he left the flight deck through there, followed immediately by the captain.

Some emergency vehicles were already there when the flight crew exited, arriving promptly. They tried to organize the passengers, but it was very chaotic. They noticed other people coming up to the airplane as the passengers scattered. The cabin crew all acted in a timely and appropriate manner, helping to reduce passenger injuries or possible loss of life.

Passengers evacuated from L2, R1, R2, the left and right over-wing exits and the right side of the forward break in the aircraft. The L1 door was jammed and could not be opened fully. The slide at the R1 door was the only slide to deploy. The captain stated that the slide was lying on the rocks, and people jumped out into it and hit the rocks. The L2 and R2 slides were attached to the airplane, but, due to the close proximity of the door sills to the ground, they did not deploy and each was lying on the ground outside of its respective door.

The cabin crew had already got everyone off the airplane when the captain told the first officer to go out and assemble the passengers. Some of the passengers alighted the aircraft within seconds, while others took several minutes. Some passengers helped each other, while some stepped over others in their efforts to get out of the aircraft.

The captain tried to go through first class, but saw that it was completely blocked by collapsed overhead bins, and the damage from the break in the fuselage. He saw one of the cabin crew carrying a large woman who didn't want to leave, and he believed she was the last passenger to leave. The captain told the first officer to verify that the passengers were off, and he went into the back of the airplane. He said it was chaos, with rain and jet fuel on the ground. He said he had never seen rain that heavy and described it as being "like a monsoon".

The flight crew exited the aircraft at R1, and entered the rear section of the aircraft through R2. They then rechecked the front of the aircraft and ensured there was no one remaining inside. They then proceeded to the road behind the aircraft to try to consolidate the passengers.

The captain said he thought the response was prompt, but once all passengers were finally gathered it was very chaotic. He said there were sirens and people around, and he thought there was a delay in getting the area secure. There was no one from ARFF securing the area or working on getting access to the airplane. He was the only one going into the airplane and he said he felt like he needed some help searching the airplane.

There was no post-crash fire**.** The 148 passengers, and the six crew members evacuated the aircraft with some passengers being assisted by the cabin crew or other passengers. Fourteen passengers received serious injuries.

A passing Jamaica Urban Transit Corporation bus, travelling from Port Royal to Kingston on its last run of the evening, stopped at the crash site. The driver had witnessed the crash, and she picked up most of the passengers and drove them to the NMIA Arrivals area, then returned to the crash site for another load of people.

The passengers were ferried to the main terminal in various vehicles and some of them departed with those meeting them, in their own vehicles or by taxi. Transportation to the hospital was arranged for the injured. The evidence indicated that the flight crew and the cabin crew performed as trained in response to the emergency circumstances.

1.15.5 Emergency Exits

The damage to the emergency exits and evacuation slides is described in Section 1.12.5 of this report.

1.16 Tests And Research

1.16.1 Escape Slide Tests

It was apparent that the L1 escape slide pack had fallen prematurely from the escape slide compartment, and tests were conducted to determine the reason. During testing, it was found that when the escape slide compartment was installed on the door the lower center support pin on the back of the slide compartment was not properly inserted into the bottom support bracket in the aircraft door. No other problems were identified with the L1 slide or slide compartments. Although the improper installation of the slide compartment may have contributed to the premature slide release, the exact cause of the slide release jamming could not be determined.

The Boeing Company has since produced a proposed revision to the Boeing 737 maintenance manual to further clarify proper installation procedures. [48]

1.16.2 Emergency Lighting in aircraft

The Emergency Lighting system was tested, and the following was found:

The right forward emergency lighting battery pack was found to be charged. The right forward pack connector was found to be damaged. On-aircraft testing showed that the wiring to the R1 door lights (internal and external) and exit signs was intact. The wiring to the centre, overhead bin and seat lights did not have continuity and was not connected to the lights.

The left forward emergency lighting battery pack was found to be charged. The left forward pack connector did not have any visible damage. On-aircraft testing showed that wiring to the overhead bin and L1 door lights did not have continuity and was not connected to any of the lights, because the wiring was severed between all the lights and the battery pack.

The five centre section emergency lighting battery packs were all found to be at very low voltage and, according to Boeing, would be considered to be depleted of charge. On-aircraft testing showed that wiring to the left and right over-wing emergency exit lights and exit signs, including the over-wing exterior lights, was intact. The left forward wing exit light was missing and the right forward over-wing light and centre over-head exit light did not illuminate. The wiring to all of the seat lights was intact and illuminated the lights when voltage was applied to the connector wiring, except for the last row of main cabin lights. This was due to the severed wiring at the right fuselage break at rows 22 and 23. The bin lights at the left over-wing exits located at rows 13 and 14, did illuminate when voltage was applied for the specific light. The rest of the overhead bin lights did not have proper continuity at the pack connectors.

The right aft emergency lighting battery pack was found to be at very low voltage. However, on-aircraft testing showed that wiring to the R2 door lights (internal and external) and exit signs was intact and illuminated the lights when voltage was applied for the specific light. The wiring to the centre overhead bin and seat lights did not have continuity and was not connected to the lights. As a result of the break in the sidewall and cabin floor on the right side in this section the seat light wiring was severed and was only visibly connected to the last two seat rows, but was not connected to the battery pack connector.

The left aft emergency lighting battery pack was found to be at very low voltage and, according to Boeing, would be considered to be depleted of charge. On aircraft testing showed that wiring to the L2 door lights (internal and external) and exit signs was intact and the lights illuminated when voltage was applied to the lights. The wiring to the overhead bin lights did not have continuity and was not connected to the lights.

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[48] Section 4.1.5

The emergency light switch in the aft flight attendant control panel was in the off position.

Three of the four cabin crew members, according to their interviews, and 15 of the 17 passengers who answered questionnaires, reported seeing no lights. However, as detailed above, testing showed that some of the overhead bin and floor lighting was operational; and all but the two forward exit and door lights and possibly the forward over wing exits, displayed signs of having been illuminated. One passenger reported that he saw the exterior lights illuminated.

1.16.3 Simulator Trials

Full replication of the flight in a flight simulator using the actual flight data was not considered to be necessary, since sufficient data existed for the investigation team to complete the required analysis.

Members of the operations investigation team observed several instrument approaches flown in an AA B737-800 full flight simulator at the AA Dallas training center. These flights were set up to simulate the Kingston ILS runway 12 approach using wind and weather conditions set to simulate those on the accident flight, as well as introducing wet runway and flooded runway simulated deceleration effects. It was observed that whenever the runway condition was set to that of a flooded runway the aircraft did not stop on the runway.

This was not considered to be relevant for the investigation as the simulator did not replicate the actual runway, or the actual braking conditions and this was for demonstration purposes only. It was also noticed that on almost all simulator transitions to visual cues from the offset localizer to line up with the runway for landing, the aircraft climbed a little, going slightly high during the left turn, placing it about ¼ dot above the ILS glide-path. On all approaches the autothrottle was left on after the autopilot was disconnected.

1.16.4 Display Guidance Computer

The Display Guidance Computer was tested at the BAE Systems facility in Redmond WA in the presence of JCAA and NTSB investigators.

The Non Volatile Memory (NVM) was downloaded from the unit prior to testing. There were multiple primary glideslope deviation flagged invalid and secondary glideslope deviation flagged invalid events recorded just prior to landing for the accident flight. All of these events were recorded at an altitude of 60 ft, or below while the HUD was in mode “A1”. There was also one Pitch Angle #1 and #2 Miscompare event recorded for the accident flight. This event occurred after the aircraft had touched down, at an airspeed indication of 47 knots.

The unit was tested in the presence of NTSB and JCAA investigators, in accordance with BAE Systems Test Procedures Document 560/62745 Rev. P dated February 2002.

The results were as follows:

1. Bonding Resistance Check – Seven of the nine pins were within limits; however the resistance checks for pins 2 & 3 of connector J1b were not within limits (300 milli-Ohms, test limit 30 milli-Ohms).

2. Isolation Resistance Check – All checks for this process were within the prescribed parameters.

3. Initialization – The unit successfully completed this function.

4. HUD Test Mode Check – All tests and displays for this process were as designed.

5. Configuration Check – All hardware and software configurations were per specifications for the dash number of the unit.

6. Overhead Data Check – The data and status displayed were as designed.

7. Discrete Input Tests – All tests and displays for this process were as designed.

8. Cockpit Discrete Input Tests – All status shown were as designed.

9. Static HUD Display – Ten of the thirteen displays for this process were as designed.

   A. The second HUD Display was incorrect; it revealed 'No AIII Miscompare'. The 'AIII' did not illuminate but 'No AIII' did illuminate on the Annunciator panel.

   B. The decluttered HUD display was incorrect; it revealed a 'No AIII Miscompare'.

   C. The Aeronautical Radio, Inc. (Specification) Input status did not receive an input from FMC Bus#1 as indicated on the Multipurpose Control and Display Unit (MCDU).

The NVM was downloaded from the unit after testing. The same events from the accident flight were displayed on this download as on the previous download. As supported by these test results and analysis of the NVM, and the fact that no malfunction was reported by the captain, the HUD was believed to be functioning correctly at the time of the accident.

1.16.5 Tests on Braking System

1.16.5.1 Antiskid/Autobrake Control Unit

The Antiskid/Autobrake Control Unit was tested at the Crane Aerospace and Electronics facility in Burbank, CA, observed by investigators from the JCAA and the NTSB. The manufacturer's Test Procedure TP-42-935-2 Rev. C dated October 20, 1999 was run on the unit. The unit passed the automated and manual tests with no failures noted. The unit was considered to have been serviceable at the time of the accident.

1.16.5.2 Antiskid Valves

The four antiskid valves were tested at the Crane Aerospace and Electronics facility in Burbank, CA in the presence of JCAA and NTSB investigators, in accordance with Crane Test Procedures TP 39-353 Rev. G dated August 12, 1991.

All units passed the electrical continuity test.

All the units passed the internal leak test except for one, which had a negligible leakage rate.

All units passed the step response tests and the signal tracking response tests.

All units passed the hysteresis tests.

The proof test portion of the acceptance test procedure was performed last and all units passed.

The gear retraction test was found to be acceptable for all units.

A graph of brake pressure versus current was created for each unit and compared to gated parameters. All units were slightly outside of the required envelope for a new or overhauled unit. The antiskid units were considered to have been serviceable at the time of the accident.

1.16.5.3 Wheel Speed Transducers

The Wheel Speed Transducers were tested at the Crane Aerospace and Electronics facility in Burbank, CA in the presence of JCAA and NTSB investigators.

The adaptor and canon plugs were removed from the transducers and all units were tested in accordance with Crane Test Procedure TP 140-025 Rev. J dated May 15, 1995, used to test new and overhauled units.

All Wheel Speed Transducer units successfully passed all aspects of the test, and were considered to have been serviceable at the time of the accident.

1.16.5.4 Autobrake Valve Module

The Autobrake Valve Module was tested at the Woodward HRT facility in Santa Clarita, CA in the presence of JCAA and NTSB investigators, in accordance with the manufacturer's test procedure Document No. HR 72700405 Rev. F, dated June 18, 1997.

The unit tested within the Autobrake Production Steady State Pressure Gain Envelope and the Autobrake Production Steady State Pressure Gain Expanded Scale Envelope. The threshold, step off and hysteresis were within limits.

The Brake Pressure Variation Test and the Pressure Threshold Tests were within limits.

The Proof Pressure Test with + 8mA applied and the low pressure test were successful, and there was no leakage.

The Flow Test @ 1000 psi & 3000 psi was successful.

The Return Flow Test @ 1800 psi was within limits.

The Leakage Test @ 1000 psi and the de-energized Leakage tests were within limits.

The status light for the pressure switch (solenoid) did not illuminate within the specified pressure band of 900 to 1100 psi on the pressure supply increase or the minimum pressure value of over 750 psi on the pressure supply reduction as expected. An impulse test of this pressure switch was accomplished and the unit performed as expected. This test simulated the on-airplane response when autobrakes were activated. The Autobrake Valve Module was considered to have been serviceable at the time of the accident.

1.17 Organization and Management Information

At the time of the accident, American Airlines, Inc., operating as American Airlines (AA), was a major U.S. airline and a subsidiary of AMR Corporation. It was headquartered in Fort Worth, Texas, adjacent to its largest hub at Dallas/Fort Worth International Airport. American Airlines operated an extensive international and domestic network, with scheduled flights throughout North America, the Caribbean, South America, Europe, and Asia/Pacific.

1.17.1 AA Manuals, Policies and Procedures

1.17.1.1 AA Procedures for Approach and Landing, and go-around

1.17.1.1.1 Stabilized Approach Requirement

The requirements for a stabilized approach are described in AA B737 Operating Manual, [49] as follows:

> *Significant speed and configuration changes during an approach can complicate aircraft control, increase the difficulty of evaluating an approach as it progresses, and complicate the decision at the decision point; i.e., DA, DH, MDA. A pilot must assess the probable success of an approach before reaching the decision point. This requires the pilot to determine that requirements for a stabilized approach have been met and maintained.*
> *To limit configuration changes at low altitude, the airplane must be in landing configuration by 1,000 feet agl (gear down and landing flaps). A stabilized approach must be established before descending below the following minimum stabilized approach heights:*
> - *IMC – 1000 feet agl*
> - *VMC – 500 feet agl*

[49] AAB737 Operating Manual, Vol 1, Section "Approach – Landing – Go-Around", Page 15.8

A stabilized approach means the airplane must be:
• At Approach Speed (VREF + additives),
• On the proper flight path, and at the proper sink rate,
• At stabilized thrust.
These requirements must be maintained throughout the rest of the approach for it to be considered a stabilized approach.
If the stabilized approach requirements cannot be satisfied by the minimum stabilized approach heights or maintained throughout the rest of the approach, a go-around is required.

1.17.1.1.2 CAT I ILS Approach Procedures

Included in the normal procedures for an ILS approach, as described for flight crews in the AA 737 Operating Manual: [50]

Wind

• Tailwind: Max 10 knots (may be further modified by Performance section requirements)

At Decision Height
■ If requirements for descent below DA are satisfied:
Disengage autopilot no later than 50 feet agl and maintain stabilized approach to touchdown.
■ If requirements for descent below DA are not satisfied:
Execute missed approach

Conditions Requiring a Go-Around:
• Anytime:
Localizer deviation of two and one half dots (magenta localizer diamond goes hollow at two and one half dots).
• Prior to DA:
Any of the required airplane or ground equipment fails.
• At DA:
Requirements to continue approach below DA (FAR 121.651) have not been met.
• Below DA:
A reduction in visual references occurs which prevents the PF from safely continuing the approach and landing.
• The Captain determines that a landing cannot be safely accomplished within the touchdown zone.

[50] AA 737 Operating Manual, Vol. 1, Section "Approach – Landing - Go- Around", Page 25.3

1.17.1.1.3 Landing on a Slippery Runway/Hydroplaning

AA B737 Operating Manual, provides the following information to its flight crews for landing on slippery runways:

> *Landing is a lot more complicated on a runway with very little or no friction with the tires. This reduction in friction (braking action) is usually caused by either ice or water (hydroplaning).*
>
> *On short or slippery runways, braking may be least effective at the departure end because of rubber deposits, snow or ice. In these conditions, since the middle of the runway offers the best friction for wheel braking, brakes should be aggressively applied by the use of MAX autobrakes or manual braking immediately after.*
>
> *Icy runway: Icy runways are treated with sand, salt and/or chemical deicers to provide adequate traction. Use your best judgment and factors such as the extent of the runway contamination, runway length and braking action reports to decide if a landing should be attempted at all.*
>
> *Hydroplaning: Hydroplaning occurs when the tire(s) ride on a film of water and don't touch the runway. The speed at which a tire is prone to hydroplane is primarily a function of tire pressure. To complicate matters, if the water is contaminated by ice, dust, oil, or grease, it makes the water more viscous and more difficult for the tires to displace. In this case the tire hydroplanes more readily and at slower speeds. For example, an aircraft landing on a thin layer of slush may hydroplane more easily than on a thicker layer of standing water.* [51]
>
> *If a tire hydroplanes long enough to stop spinning, then all braking action is lost. The*
>
> *effects of contamination on braking action / landing distance can be:*
>
> • *Snow: Twice as slippery as dry pavement*
>
> • *Ice: 4-16 times as slippery as dry pavement*
>
> • *Wet runway: 60% increase in landing distance without hydroplaning*
>
> • *Hydroplaning: Double or triple the landing distance without reverse thrust.*
>
> *Rubber Reversion: Rubber reversion is a form of hydroplaning where heat under the tire produces high pressure, superheated steam. The extreme heat causes the rubber to revert to its uncured state and form a seal around the footprint area, trapping the high-pressure steam*

[51] AA 737 Operating Manual, Vol. 1, Section "Approach - Landing - Go- Around", page 35.10

and causing the tire to "float". Rubber reversion can occur if the runway touchdown zone is damp and the wheels don't spin-up.

Factors Affecting Hydroplaning:

Standing Water Depth.

Landing on a runway during or immediately after heavy rain is the condition most favorable for hydroplaning. Even with no wind, most crowned runways have adequate drainage even in heavy rain. Drainage can be seriously affected in crosswinds above 10 knots. When landing on a wet runway with a crosswind, the Upwind side of the runway may have more water on it than the downwind side. A 15 to 20 minute waiting period after a heavy downpour is usually sufficient for water to drain.

Tire Condition

If the tire tread depth is greater than the depth of the water on the runway, then hydroplaning usually won't occur. Knowing the general condition of the tires is helpful when landing on a contaminated runway.

Tire Pressure

Hydroplaning can occur at speeds above 9 times the square root of the tire pressure. Once started, however, hydroplaning can persist down to 8.1 times the square root of the tire pressure. So, the range of speeds most conducive for hydroplaning at 200 psi is 127 to 115 knots.

Runway Condition

Grooved runways reduce the effective water depth compared to un-grooved runways. Also, heavy rubber deposits in the touchdown zone can adversely affect the runways landing characteristics.

Aircraft Touchdown

Cross the threshold at VREF (plus wind additives). Touchdown should be firm and at the desired aim-point – don't float. Eliminate any side drift prior to touchdown and ensure spoilers deploy (manually if necessary).

1.17.1.1.4 Factors Affecting Landing Distance

Advisory information for normal and non-normal configuration landing distances is contained in the PI Section of the AA Quick Reference Handbook (QRH).

Actual stopping distances for a maximum effort stop are approximately 60% of the dry runway field length requirement. Factors that affect stopping distance include: height and speed over the threshold, glide slope angle, landing flare, lowering the nose to the runway, use of reverse thrust, speed-brakes, wheel brakes and surface conditions of the runway.

Note: Reverse thrust and speed-brake drag are most effective during the high speed portion of the landing. Deploy the speed-brake lever and activate reverse thrust with as little time delay as possible.

Speed-brakes fully deployed, in conjunction with maximum reverse thrust and maximum manual antiskid braking, provides the minimum stopping distance.

Floating above the runway before touchdown must be avoided because it uses a large portion of the available runway. The airplane should be landed as near the normal touchdown point as possible. Deceleration rate on the runway is approximately three times greater than in the air.

1.17.1.1.5 AA Approach Preparation/Calculation of Landing Distance

The AA B737 Aircraft Operating Manual Vol. 1, Section "Climb – Cruise – Descent", Page 15.7 states the following for approach preparation: (51)

Considerations Prior to Descent
To optimize situation awareness, the Captain should ensure that significant terrain and obstacles affecting arrival or approach are identified. Review charted MSA, Grid MORA, MEA, contour or spot elevation, EGPWS, and TRR indicated on the flight plan (highest actual terrain height 5 left and right of course between route waypoints on the planned route).

Both flight crew should review field conditions and special procedures for the arrival airport, including Ops Advisory pages. When the ATIS indicates that SMGCS (Surface Movement Guidance Control System) procedures are in effect, brief the SMGCS page."

Approach Briefing
To optimize situational awareness, planning for the approach and landing should begin before departure. The arrival weather forecast, NOTAMS, field conditions, and MEL items should be considered during preflight planning.
The approach briefing is completed prior to top of descent, to the extent possible, to minimize distractions in high-density operations at lower altitudes. The Captain will conduct whatever briefing is appropriate to the situation (e.g., poor weather, inexperienced crewmember, special qualification airports, etc.). The Captain may delegate the briefing to the F/O.

Each pilot is responsible for reviewing the applicable approach chart. Set-up for the instrument approach, if available. Crosscheck the Jeppesen page against the FMS data for the arrival, approach and missed approach. [52]

This contains no specific reference to the circumstances under which a Required Runway Landing Length calculation should be made. [53]

However, AA Performance Manual, Section R14, Bulletin 737-07, dated 11-26-06 (see Section 1, Appendix 6) stated:

"The new FAA recommendation is to confirm landing performance limits just prior to landing, using the actual runway conditions at time of landing. If the landing conditions, from the time of dispatch do not change, there is no need to do this assessment, because the requirements for dispatch are sufficient to assure adequate performance at time of landing.

"However, if conditions change, or deteriorate, the flight crew should use the charts on the revised Wind Component and Landing Data Card (attached to this bulletin) to confirm adequate runway length for landing."

The "new FAA recommendation" referred to was Safety Alert For Operators (SAFO) 06012.

1.17.1.1.6 AA Policy on the use of reverse thrust on landing

AA B737 Operating Manual, states:

Apply reverse thrust as soon as possible after nose wheel touchdown.
• When reversing, if directional control is lost, reduce reverse until control is regained. Use forward idle thrust if necessary.
• Do not come out of reverse at a high RPM. Sudden transition of reversers before engines spool down will cause a forward acceleration.
• Use as much of the runway for roll-out as needed to slow airplane to a safe taxi speed before turning off a wet/slippery runway.
CAUTION
In an emergency, use maximum reverse thrust, if required, to stop in the remaining runway. [54]

This information is found in the Cold Weather Operations portion of the AA 737 Operating Manual.

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[52] AAB737 Aircraft Operating Manual Vol 1, Section "Climb – Cruise – Descent", Page 15.7

[53] Section 2.20

[54] AA737 Operating Manual, Vol. 1, Section "General", page 30.27

1.17.1.1.7 AA Procedures for Landing with Tailwinds

AA B737 Operating Manual, states:

Landing Flaps
• Flaps 15, 30 or 40 are the normal landing flap settings.
• Use of flaps 40 is recommended when landing with:
– Braking action reported less than good,
– Tailwind,
– Wet / contaminated runway, or
– When deemed prudent by the Captain.
• Flaps 15 may be required at high density altitude airports when climb limited maximum landing weight is exceeded for landing flaps 30 or 40. Refer to the Performance Manual – LANDING. [55]

The fight dispatch document for the accident flight contained the following "Special Message" to flight crew members and was applicable to AA331:

```
SPC MSG NBR 9482
SUBJECT-  15  KNOT  TAILWIND  AUTHORIZATION
REFERENCE- 737 OPERATING MANUAL VOLUME 1
EFFECTIVE IMMEDIATELY, AMERICAN AIRLINES 737 AIRCRAFT ARE AUTHORIZED TAKEOFFS
AND LANDINGS WITH UP TO AND INCLUDING 15 KNOTS OF TAILWIND
COMPONENT  FOR  VISUAL,  CIRCLING,  NON-ILS,  AND  CAT  I  ILS
APPROACHES ONLY. THE RESTRICTION OF 10 KNOTS TAILWIND MAXIMUM
STILL APPLIES FOR HUD LOW VISIBILITY TAKEOFFS AND CAT II OR III
APPROACHES. RESTRICTED CAPTAINS EXERCISING AMERICAN AIRLINES EXEMPTION 5549
MUST  COMPLY  WITH  THE  WIND  LIMITATIONS  IN  FM  I,  SECTION  10,
PARAGRAPH 2.2. AS ALWAYS, FLIGHT CREW MUST ENSURE THE REPORTED
TAILWIND   COMPONENT   COMPLIES   WITH   AIRPLANE   PERFORMANCE
REQUIREMENTS FOR THE RUNWAY IN USE.
```

AA confirmed to the investigation by e-mail on 02 December 2011 that the intention of this message was to make it mandatory for AA B737 flight crews to perform a Landing Performance Assessment before landing with a tailwind. With relation to this authorization, the captain was not restricted.

Neither of the flight crew of AA331 had received specific training from AA on landing with tailwinds of up to 15 knots, nor did AA conduct specific training in simulators on tailwind landings. The captain said he had had some training on tail wind landings, but did not specify when or on which type of aircraft. When interviewed for this investigation, some AA B737 training captains said they did not train pilots for tailwind landings.

The AA Aircraft Operating Manual and the Flight Crew Training Manual for the B737-800 did not contain any information regarding landing with tailwinds other than in the Operating Manual

[55] AA737 Operating Manual, Vol 1, Section "Approach - Landing - Go-Around", page 15.2

excerpts quoted in Section 1 of this report, and the Limitations section, where the maximum tailwind component is stated to be 15 knots.

1.17.1.1.8 AA Normal Procedures for Landing from ILS

The AA Boeing 737-800 Flight Manual Part 1, Section 10, "Approach and Landing", page 32 defines the desired touchdown point as the first 800 to 1,500 feet beyond the threshold, and the touchdown zone as the first 3,000 feet of the runway, beginning at the threshold.

The AAB737 Operating Manual recommended the following procedures for landing on slippery runways:

> *Landing*
>
> *Obtain current runway condition reports for both destination and alternate.*
> *Request runway surface friction information from Approach Control or tower (refer to Flight Manual Part I and II).*
> *Flaps 40 is recommended for landing on slippery runways (refer to "Landing on a Slippery runway" in the APPROACH – LANDING – GO-AROUND section).*
> *Falling or blowing snow can create visual illusions or depth perception problems. When flying the HUD, the Taxi Light may be left off if it causes visual illusions.*
> *If landing on a wet / slippery runway, the recommended technique is:*
> *• Land on speed.*
> *• Touchdown at the planned point. A firm landing is better than a "grease job".*
> *• Keep nose wheel firmly on runway with elevator.*
> *CAUTION*
> *An excessive amount of down elevator will download the main gear and reduce braking efficiency.*
> *• Use maximum autobrakes or aggressive manual braking and auto spoilers.*
> *• Maintaining directional control is the highest priority.*
> *• Apply reverse thrust as soon as possible after nose wheel touchdown.*
> *• When reversing, if directional control is lost, reduce reverse until control is regained. Use forward idle thrust if necessary.*
> *• Do not come out of reverse at a high RPM. Sudden transition of reversers before engines spool down will cause a forward acceleration.*
> *• Use as much of the runway for roll-out as needed to slow airplane to a safe taxi speed before turning off a wet/slippery runway.* [56]
> *CAUTION*
> *In an emergency, use maximum reverse thrust, if required, to stop in the remaining runway.*

[56] AA737 Operating Manual, Vol. 1, Section "General", page 30.27

This information is found in the Cold Weather Operations portion of the AA 737 Operating Manual and is located in the Boeing FCOM. AA crews are required to use the guidance in the FAA approved AA Operating Manual. – Vol. 1.

1.17.1.1.9 AA Information on Baulked Landings (Go Around)

AA did not practice rejected landings following touchdown as a regular simulator training procedure, although go-around procedures were practiced on a regular basis as well as baulked landings.

The captain reported that he had been trained in the simulator on go-around procedures after touchdown.

There was no statement in the AAB737 Operating Manual to the effect that a first officer who was the pilot monitoring could call for a go-around, with the pilot flying (that is, the captain) being obliged to follow through with this. It was not possible to determine exactly what was the company's procedure regarding this.

The AA Flight Manual, stated the following:

> *Missed-approach decision: The Captain has full control and authority in the operation of the aircraft (FAR 121.533, 121.535), however the Captain should give every consideration to a recommendation by another cockpit crewmember that a missed approach be executed.* [57]

AA noted a need for clarification on go-arounds in their Flight Operations Information Bulletin Number 2010-06, dated April 2010 (post-accident) when they said:

> *Feedback from our pilots and an analysis of our current stable approach and go-around guidance indicates that there are several key areas which require attention or need clarification in order to reduce and perhaps eliminate the reluctance of pilots to execute a go-around when an approach is unstable:*
>
> *• Specific go-around flight parameters are not very clearly defined in the Operating Manual which makes it nebulous and left to wide interpretation as to when a go-around is mandatory.....*

[57] AA Flight Manual, Section 10, Page 2

AA has subsequently revised the AA Boeing 737 Operating Manual, with the following language:

> ***Go-Around Requirements***
>
> *On final, the Pilot-Flying is responsible for executing a go-around if any of the parameters listed below are exceeded without Pilot-Flying correction. If the Pilot-Monitoring observes that the Pilot-Flying is not executing a go-around, he or she is responsible for directing a go-around by calling – "GO-AROUND". The directed go-around will be executed unless an emergency situation overrides this requirement.* [58]

1.17.1.1.10 AA No Fault Go-Around Policy and Missed Approach decision

AA Flight Manual states:

> *American Airlines has a no-fault go-around policy, recognizing that a successful approach can end in a missed approach. If the stabilized approach requirements cannot be satisfied by the minimum stabilized approach height or maintained throughout the rest of the approach, a go-around is required.* ***If in the pilot's judgment a safe landing cannot be accomplished within the touchdown zone, or the aircraft cannot be stopped within the confines of the runway, a go-around is also required*** (bolding added)**.** [59]

AA Flight Manual states:

> *A. American Airlines has a no-fault go-around policy. Pilots should execute every approach with the presumption that a missed approach is a successful outcome. Plan each approach through the missed-approach procedure and make the decision to land only when all criteria are safely satisfied.*
>
> *B. Missed-approach decision: The Captain has full control and authority in the operation of the aircraft (FAR 121.533, 121.535), however the Captain should give every consideration to a recommendation by another cockpit crewmember that a missed approach be executed.* [60]

AA Flight Manual states:

> *The First Officer is required to immediately advise the Captain of any deviation, from applicable regulations, policies or procedures, or any unsafe condition which may place the aircraft, passengers or crewmembers in jeopardy. The Captain may choose to disregard this advice, but regardless of the degree of*

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[58] AA Boeing 737 Operating Manual, page 15.8

[59] AA Flight Manual Part I, Section 10, Paragraph 6.0, "Missed approach"

[60] AA Flight Manual Part I, Section 10, Paragraph 1.2, "Missed Approach Decision Making

frequency with which advice may go unheeded, flight crewmembers will be held responsible for continuing to offer advice for the Captain's consideration. [61]

1.17.1.1.11 AA Bulletin 737-07

AA Bulletin 737-07, dated 11-27-06, [62] was concerned with expanding runway surface condition reports, and stated flight crews must use *"the most adverse, reliable and appropriate braking action report, or the most adverse expected conditions ... when assessing the required landing distance prior to landing."* It includes a Braking Action Chart which states that Standing Water depth of 1/8 inches or less is "Good", and Standing Water depth of 1/8 inches or more is "Poor".

It should be noted that AA Bulletin 737-07 stated "… if conditions change, or deteriorate, the flight crew should use the charts on the revised Wind Component and Landing Data Card (attached to this bulletin) to confirm adequate runway length for landing". For Dry and Wet/Good conditions these charts provided more than the minimum recommended 15% safety margin and provided a 15% buffer for Fair/Medium and Poor braking action.

The investigation determined that the flight crew had this information on board, but was unable to determine exactly how the information was used in the cockpit prior to landing, in conjunction with the Required Runway Landing Length table on the Landing Data Card. [63]

1.17.1.1.12 AA HUD Usage Policy and Briefing Guide

The AA737 Operating Manual, "HUD Usage Policy" states:

HUD use is mandatory for all take-offs and all approaches and landings to assist in tail-strike prevention, unless it is placarded. ... On approach, the HUD must be used no later than 1,000 feet AFL. HUD will be used regardless as to whether the captain is pilot flying or pilot monitoring. The HUD provides multiple tools to enhance situational awareness and safety, including tail-strike prevention for both take-off and landing ... [64]

According to the AA B737 HUD Briefing Guide [65] the HUD will provide a flare cue below approximately 90 feet agl. In A1 mode, the flare cue provides pitch guidance only; aim point and

[61] AA Flight Manual Part 1, Chapter "Crew Qualification and Responsibility", Section 3, page 5, part 1.8, "First Officer Responsibility"

[62] Appendix 6

[63] Appendix 7

[64] AA737 Operating Manual, Section "General", Page 15.1 "HUD Usage Policy"

[65] AA B737 HUD Briefing Guide (Section XI, Flare Cue, Page 5

lateral placement is the Captain's responsibility (e.g. – flare cue will not attempt to land the aircraft in the touchdown zone.)

The artificial runway is not displayed in A1 mode. [66] The flight director is removed 50 ft. below minimums but reappears at 90 feet as the flare cue. [67] Final Runway alignment would be via visual reference to the runway centerline, and glide path aligned to the PAPI.

1.17.1.1.13 AA B737 RRLL Tables, Wind Component and Landing Data Card

Estimated Wet and Contaminated Runway Landing Distance tables. These are in Appendices 7 and 8.

1.17.1.2 AA – Other Information

1.17.1.2.1. AA Crew Resource Management (CRM) Training

AA had an approved CRM training program which all flight crew attended. In interviews with training personnel, they stated that CRM training was part of the initial, upgrade and new-hire training, and in the Advanced Qualification Training program (AQP), every nine months. The training included how the crew interacts, and they used examples of good and poor interactions, with incidents being recreated by crews in a video made by the human factors department. Also, during check rides, the tone of the cockpit was evaluated to ensure it was conducive to efficient flight safety, and to ensure all pilots were willing to speak up.

1.17.1.2.2 AA Flight Manual Page 10-7X.

This included information about standing water at MKJP Kingston. It stated *"Runway is uneven and subject to pools of standing water after heavy rain."* See Appendix 5.

1.17.1.2.3 AA Boeing 737 Training

AA followed a standard program of pilot training for the Boeing 737 that was approved by the FAA as meeting FAR part 121 standards, and, for recurrent training, used an annual qualification program of ground school, simulator training and checks, and an annual line check. Both flight crews were current on the aircraft for 90 day landings, both had valid proficiency checks and line checks, and no issues were noted from their training records.

Neither had been specifically trained in landing with tailwinds, nor in the use of HUD with an offset ILS. The B737 Training Manager advised that this was not normally done in flight

[66] AA HUD Briefing Guide, Section II, HUD Symbols and Display Overview, page 1

[67] AA HUD Briefing Guide, Section VIII, NP Mode, page 3

simulators and that crosswind landings and landing on a short runway (Orange County) and at high altitude runways were all practiced in the simulator training. The captain reported that he had received training regarding go-around after touchdown.

1.17.1.2.4 AA Dispatch Information

In accordance with AA procedures, Flight AA331 was dispatched by the AA Dispatch in Dallas, Texas, by a qualified flight dispatcher.

The AA Dispatcher who dispatched this flight was interviewed, and he made the following statements:

1. The AA station manager was responsible for providing field condition reports.
2. The captain would know he was legal to fly to Kingston because a dispatch release was sent.
3. Zero winds were considered for the release.
4. The captain was expected to select the best runway for landing.
5. Dispatch did not play any part in runway selection.
6. Flights were dispatched either dry or wet.
7. The captain could not tell whether the flight was dispatched wet or dry – there was no place on the flight plan to indicate that.
8. As long as the braking action was better than Nil, the flight would be released.
9. The captain was responsible for determining the braking action on arrival.
10. He sent AA331 an updated METAR about 21:48 EST, which included weather going from rain showers to thunderstorms.
11. He did not know of any Caribbean airport being other than good/wet, and had never received a report of standing water at Kingston.

The METAR mentioned in item 10 was:
SPECI MKJP 230228Z 31009KT 5000 TSRA BKN014 FEW016CB SCT030 BKN100 22/19 Q1013

"Kingston (MKJP) special weather observation at 21:28 EST (02:28 UTC, 23 Dec), wind 310 degrees at 9 knots, visibility 5,000 m (approximately 3 miles) in thunderstorms and moderate rain, ceiling broken at 1,400 feet, few clouds at 1,600 feet in cumulonimbus clouds, scattered clouds at 3,000 feet, broken cloud at 10,000 feet, temperature 22° C, dew point 19° C, altimeter setting 1013 mb." AA331 was dispatched "Wet".

METARS on AA331 Dispatch Document

The following information was on the finalized American Airlines dispatch document for AA331, given to the investigation, and was marked RH, meaning recorded history.

```
KIN
230317 230300Z 32008KT 3000 PLUSSHRA BKN014 FEW016CB SCT03
230317 230300Z 32008KT 33000 ?SHRA BKN014 FEW016CB SCT030 B
230315 230300Z 32008KT 3000 ?SHRA BKN014 FEW016CB SCT030 BK
230238 230228Z 31009KT 55000 TSRA BKN014 FEW016CB SCT030 BK
230235 230228Z 31009KT 5000 TSRA BKN014 FEW016CB SCT030 BKN
230217 230200Z 300122KT 5000 SHRA BKN014 SCT030 BKN100 22/2
230214 230200Z 30012KT 5000 SHRA BKN014 SCT030 BKN100 22/20
230213 230200Z 300122KT 5000 SHRA BKN014 SCT030 BKN100 22/2
230212 230200Z 30012KT 5000 SHRA BKN014 SCT030 BKN100 22/20
230116 230100Z 040033KT 5000 SHRA BKN016 SCT030 BKN100 23/2
230113 230100Z 04003KT 5000 SHRA BKN016 SCT030 BKN100 23/20
230113 230100Z 040033KT 5000 SHRA BKN016 SCT030 BKN100 23/2
230008 230000Z 32004KT 9999 FEW016 BKN030 BKN100 24/19 Q101
222316 222300Z 00000KT 9999 VCSH SCT016 SCT030 BKN100 24/20
222226 222200Z 35008KT 9999 FEW015 BKN032 BKN100 24/19 Q1
222116 222100Z 33005KT 9999 FEW015 BKN032 BKN100 23/19 Q1
222007 222000Z 31005KT 9999 -RA FEW012 SCT032 OVC100 23/19
221929 221900Z 10012KT 9000 -RA SCT012 OVC100 22/19
```

The latest field condition reports for KIN were included in the AA331 dispatch release and showed the following:

```
* KIN FIELD REPORT *
*******************************************************
* REPORT LAST UPDATED AT 1520 LOCAL TIME *
*******************************************************
--------------------------------------------------------------
DATE 22DEC09 TIME 1853 LOCAL
--------------------------------------------------------------
EXISTING TAA DRP((((((( 
--------------------------------------------------------------
RUNWAY STATUS CONDITIONS BRAKING ACTION/RMKS
12 OPEN WET 0.10 IN WATER
30 OPEN WET 0.10 IN WATER
RAMP/TXWY SURFACE WET 0.10 IN WATER
--------------------------------------------------------------* KIN FIELD
```

This report was last updated 15:20 Local Time, i.e. five hours before the flight departed Miami.

By FAA regulation, the “Field Report” was not required for dispatch purposes. However, AA Bulletin 737-07, “Landing Performance Check”, stated “If the landing conditions from the time of dispatch do not change, there is no need to do this assessment … ”

Therefore it would be necessary for the flight crew to have the “Field Report”, that is, “ … the landing conditions from the time of dispatch” to compare them with the “ … actual runway conditions at the time of landing…” and then decide whether or not it was necessary to do a landing performance confirmation.

The following forecasts were used for planning for the AA331 flight:

```
*** FORECAST USED FOR PLANNING ***

MIA TAF/
TAF KMIA 222103Z 2221/2321 06008KT P6SM SCT040 SCT150 OVC250
FM230100 04006KT P6SM SCT030 BKN250
FM231400 07012KT P6SM SCT025 SCT250
FM231800 08015G22KT P6SM SCT030 BKN050
WSI/JB
```

KIN 221500Z 2218/2318 12016KT 9999 -RA FEW016 BKN032 TEMPO 2218/2302 6000 TSRA BKN016 SCT018CB BECMG 2302/2304 35008KT TEMPO 2304/2312 8000 SHRA BKN016 FEW018CB SCT032 BECMG 2314/2316 20006KT

Relevant part decoded is: Kingston, issued on 22 December at 15:00 UTC for period 18:00 UTC on 22 December to 18:00 UTC on 23 December, wind 120 at 16 knots, visibility more than 10 kilometers (6 miles), light rain showers, few clouds at 1,600 feet, broken cloud at 3,200 feet. Temporarily, between 18:00 UTC on 22 December and 02:00 UTC on 23 December, visibility 6,000 meters, thunderstorms and rain showers, broken cloud at 1,600 feet, scattered cloud at 1,800 feet with cumulonimbus cloud, becoming, from 02:00 to 04:00 UTC on 23 December wind 350 at 8 knots. (Estimated time of arrival was about 03:21 UTC, so the balance of forecast is not relevant).

```
MBJ 221500Z 2218/2318 09012KT 9999 -RA FEW018 BKN030 OVC080
TEMPO 2218/2302 7000 SHRA BKN017 FEW020CB BKN030 BECMG
2302/2304
15005KT BECMG 2308/2310 24010KT SCT020 BKN030 BECMG
2316/2318
32010KT FEW020 SCT034
```

The following forecast information for Kingston was provided to the flight crew by AA flight dispatch prior to departure from Miami.

TAF MKJP 222100Z 2300/2324 34008KT 9999 FEW018 SCT032 BKN090
TEMPO 2300/2314 8000 SHRA BKN016 FEW018CB SCT032
BECMG 2314/2316 20010KT
TEMPO 2318/2324 8000 SHRA SCT018 SCT080

De-coded, this is: a Terminal Aerodrome Forecast (TAF) was issued for MKJP at 16:00 EST (21:00 UTC) for the period 00:00 UTC on 23 December to 24:00 UTC on 23 December (19:00 EST, 22 December to 19:00 EST 23 December).

The TAF forecasted wind from 340 degrees at eight knots, visibility 10 kilometers or more (better than six miles), a few clouds at 1,800 feet, scattered clouds at 3,200 feet, and a ceiling at 9,000 feet with temporary conditions between 18:00 EST, 22 December and 09:00 EST, 23 December of visibility 8,000 metres (five miles) in moderate rain showers, ceiling broken at 1,600 feet, few clouds at 1,800 feet in cumulonimbus clouds, and scattered clouds at 3,200 feet. (Balance not relevant to the investigation).

The graphic area forecast was not included in the dispatch document given to AA331 flight crew, nor was it required to be.

The NOTAM referred to in 1.18.4 was included in the dispatch document received by the AA331 flight crew.

The following Special Message was included in the dispatch document:

```
/// SPECIAL INFO MESSAGES ///
SPC MSG NBR 9482
SUBJECT- 15 KNOT TAILWIND AUTHORIZATION
REFERENCE- 737 OPERATING MANUAL VOLUME 1
EFFECTIVE IMMEDIATELY, AA 737 AIRCRAFT ARE AUTHORIZED TAKEOFFS
AND LANDINGS WITH UP TO AND INCLUDING 15 KNOTS OF TAILWIND
COMPONENT FOR VISUAL, CIRCLING, NON-ILS, AND CAT I ILS
APPROACHES ONLY. THE RESTRICTION OF 10 KNOTS TAILWIND MAXIMUM
STILL APPLIES FOR HUD LOW VISIBILITY TAKEOFFS AND CAT II OR III
APPROACHES. RESTRICTED CAPTAINS EXERCISING FAA EXEMPTION 5549
MUST COMPLY WITH THE WIND LIMITATIONS IN FM I, SECTION 10,
PARAGRAPH 2.2. AS ALWAYS, PILOTS MUST ENSURE THE REPORTED
TAILWIND COMPONENT COMPLIES WITH AIRPLANE PERFORMANCE
REQUIREMENTS FOR THE RUNWAY IN USE.
```

The last sentence of this, “AS ALWAYS, PILOTS MUST ENSURE THE REPORTED TAILWIND COMPONENT COMPLIES WITH AIRPLANE PERFORMANCE REQUIREMENTS FOR THE RUNWAY IN USE” meant that it was mandatory for flight crew to complete a landing performance assessment before landing**.** This was confirmed by AA Quality Assurance Management in an Email to the NTSB on 01 December 2011.

Based upon the weather forecasts prior to departure and the available runway length at Kingston, AA331 was a legally dispatched flight. [68]

1.17.1.2.5 AA Required Runway Landing Length (RRLL) table, and Landing Data Card.

The AA B737 Wind Component and Landing Data Card [69], which stated that the Required Runway Landing Length for Dry or Wet/Good runway Conditions was based, and included, “demonstrated ‘air distance’” from runway threshold to touchdown”, and for Medium/Fair or Poor Runway Conditions “includes 1,000 feet ‘air distance’ from threshold to touchdown, contrasts with other AA information, as follows: The touchdown zone is defined in AA Flight Crew Operations Manual (FCOM) [70], as the “first 3,000 feet of the runway beginning at the threshold”, or the first third of the runway, in this case 8,911/3 = 2,970 feet. The Flight Crew Operations Manual (FCOM) [71], defines the desired touchdown point as the first 800 to 1,500 feet beyond the threshold.

---

[68] Section 1.17.4.1

[69] Appendix 7

[70] AA Flight Crew Operations Manual (FCOM), Part I, Section 10, paragraph 7.2, page 32

[71] Flight Crew Operations Manual (FCOM), Part I, Section 10, paragraphm7.3, page 32,

AA was asked to define “demonstrated ‘air distance’”, and responded:

> *The manufacturer has never listed the “air distance” used in the certified landing distances. The AFM only contains the total distance. The Fair/Medium and Poor columns, comes from the manufacturer, but is not certified. In this case, the manufacturer specifies that 1,000 feet is used for the “air distance”.*

The investigation assumed that the “air distance” for the Wet/Good landing figures was about 1,000 feet.

1.17.1.2.6 AA Landing Distance Calculations

1.17.1.2.6.1 Landing Data Card

The following Required Runway Landing Length table, from the AAB737-800 Aircraft Operating Manual, Appendix 4 for Landing Performance, Landing Data Card, is for a Flap 30, sea level landing. [72]

Aircraft Gross weight 1000's pounds	**Runway condition: DRY**	**Runway condition/ reported braking action: WET/GOOD**	**Reported braking action: FAIR/MED**	**Reported braking Action: POOR**
100	4,122	4,740	5,360	6,790
110	4,431	5,096	5,770	7,350
120	4,787	5,505	6,180	7,910
130	5,175	5,952	6,590	8,480
140	5,566	6,401	7,010	9,070
144	5,714	6,571	7,180	9,300
150	5,937	6,827	7,430	9,660
160	6,293	7,237	7,850	10,250
170	6,647	7,644	8,270	10,840
174.2	6,795	7,814	8,440	11,090
Headwind per knot	-21 feet	-21 feet	-33 feet	-49 feet
Tailwind per knot	+101 feet	+103 feet	+121 feet	+191 feet
No Reverse Thrust	0	0	+1,633 feet	+3,766 feet

Table 6: Landing Data Card

[72] Appendix 7

WET/GOOD braking action

Given:

Runway Elevation	10 Ft asl
Runway condition	Less than 1/8 inch (3mm) water.
Landing Weight	144,000 LB
Flap setting	30°
Touchdown point	1,000 Ft
Reverse Thrust	None
Braking	Maximum Manual
With tail wind 0, Required Runway Landing Length	6,571 Ft
With tail wind 8KT, Required Runway Landing Length	7,395 Ft (6,571 Ft + 824 Ft)
With tail wind 14KT, Required Runway Landing Length	8,013 Ft (6,571 Ft + 1,442 Ft)

Note, these figures are based on the 14 Code of Federal Regulations (CFR) Part 25.125 demonstrated landing distance on a dry runway, and include a 92% safety margin.

FAIR/MEDIUM braking action

Given:

Runway Elevation	10 Ft asl
Runway condition	More than 1/8 inch (3mm) water.
Landing Weight	144,000 LB
Flap setting	30°
Touchdown point	1,000 FT
Reverse Thrust	Normal
Braking	Max autobrakes
With tail wind 0, Required Runway Landing Length	7,180 Ft
With tail wind 8 KT, Required Runway Landing Length	8,148 Ft (7,180 Ft + 968 Ft)
With tail wind 14 KT, Required Runway Landing Length	8,874 Ft (7,180 Ft + 1,694 Ft)

Note: these figures are the manufacturer's estimated landing distance, and include a 15% safety margin.

For both WET/GOOD and FAIR/MEDIUM the calculated required runway landing lengths are based on crossing the runway threshold at 50 Ft agl, at the normal reference landing speed, VRef, with the aircraft in the correct landing configuration and no system malfunction that would affect the landing distance.

1.17.1.2.6.2 AA Performance – Landing Table

The information in the AA 737 Operating Manual, 16 Performance – Landing, "Estimated Wet and Contaminated Runway Landing Distances" [73], gives the following information for landing at 144,000 pounds, sea level, flap 40, maximum manual braking, maximum reverse thrust, landing 1,000 feet from threshold with 14 knot tail wind, braking action FAIR, no additional margin. In this case the absolute distance for stopping was 7,240 feet. This distance plus 15% margin equals 8,326 feet.

1.17.1.2.7 Advisory Circular No: 91-79

FAA Advisory Circular (AC) 91-79, Appendix 4, stated:

> *"For example, if there is no clear report of runway condition but if the pilot knows rain has been in the area, that pilot should assume that the runway is at least wet. If there is rain actively falling on the runway, standing water should be assumed"*,

That is, the runway condition should be considered as contaminated. AC 91-79 was provided to the AA Safety Officer by the FAA and the Safety Officer in turn provided AC 91-79 to the various fleet captains. It was not tracked by the Safety Officer to see if any action was taken in relation to its recommendations, nor was the material in AC 91-79 considered to be mandatory in the way that the material in SAFO 06012 was put into Bulletin 737-07, and expected to be followed by AA crews. It should be noted that AC91-79 did not carry regulatory force, and was only advisory.

1.17.1.2.8 Crew Flight/Duty/Rest System

AA had a comprehensive system of flight and duty time limitations and maintained good records of flight crew flight/duty/rest times. It had a scheduling alert system to prevent assignment of crew members to flights when they had not had the minimum required rest periods prior to those flights. The system was documented in the Company Operations Manual.

1.17.1.2.9 AA Interviews with Staff

Evidence from interviews with AA training and operational staff indicated that flights were dispatched either Dry or Wet/Good. In the Kingston Field Report the measurement "0.10 IN WATER" was not the result of an actual measurement, but was more of a term used to describe wet, as opposed to dry, runways.

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[73] Appendix 8

When one of the senior captains was asked whether crews should re-evaluate runway conditions from Wet/Good as stated by a controller to Medium or Poor when flying an approach in heavy rain, he responded that people on the ground have better information than pilots in the air.

Interviews with AA training management and training staff indicated the following:

1. Since 2001 AA had operated B737 with a 15 knot landing tailwind limit to four destinations, otherwise the limit was 10 knots.
2. Problems with operating into San Jose airport had resulted in the increase of the tailwind landing limit for the whole AA B737 fleet from 10 to 15 knots.
3. No simulator or other training on tailwind landing was in place or was introduced when the AA B737 tailwind landing limit was increased from 10 to 15 knots.
4. No changes in landing procedures were made when the AA B737 tailwind landing limit was increased from 10 to 15 knots.
5. The AA flight crews were informed of the B737 tailwind landing limit increase from 10 to 15 knots by company bulletin.
6. The decision making process to increase the B737 tailwind landing limit from 10 to 15 knots included Ops Engineering, Flight Ops and Boeing.
7. The decision making process to increase the B737 tailwind landing limit from 10 to 15 knots did not include the AA B737 Lead Check Airman, the Managing Director of Flight Training or the Manager, Flight Safety.
8. AA's B737 AQP did not include tailwind landing.
9. An AA B737 Check Airman stated he did not use tailwind landings in checks.

Also, the following statements were made:

1. Tailwind has no effect on touchdown point.
2. Emphasis was placed on landing in the touch down zone.
3. Landing ground speed with a headwind at high altitude is similar to, and may be faster than, landing at another airport with a tailwind.
4. There is little difference between a tailwind landing and a high altitude landing.
5. There is no benefit to training tailwind landing.
6. There is no difference between a 10 knot and a 15 knot tailwind landing.

1.17.1.2.10 AA– information regarding Bulletin 737-07 and AC 91-79

The following information was given to the investigation by the AA Flight Safety Programs Manager:

1. Re: AA flight crew training regarding Bulletin 737-07:

> *AA flight crews are provided comprehensive training on 737 Aircraft Performance during their initial training on the airplane and are subsequently required to complete a Performance Manual review with a Ground School instructor during recurrent training. In addition, the 737 Check Airmen review performance issues during the initial and recurrent training simulator sessions when we simulate landing on contaminated runways.*

2. Re: statement in Bulletin 737-07 “to comply with new FAA recommendations”:

   This (wording) is taken directly from an AMR Certificates Management Office letter dated September 8, 2006 requesting AA assure their office we would comply with the recommended actions of SAFO 06-012. Bulletin 737-07 was issued to the 737 fleet in response to this SAFO and CMO letter. Other fleets issued similar Bulletins to their Operating Manual Performance Sections as well.

3. Re: question as to why compliance with Bulletin 737-07 by AA flight crews not made mandatory by AA (that is, AA used “should”, which means “recommended”, therefore it was not mandatory):

   AA used the same language as the FAA Advisory Circulars and Safety Alerts for Operators on which the Bulletin was based.

4. Re: question “Did AA management expect AA flight crews to follow the instructions (“recommendations”) in Bulletin 737-07, or assume that they would?”

   AA management both expects and assumes flight crews will follow the instructions (recommendations) in Bulletin 737-07.

5. Re: question as to why AA put Bulletin 737-07 in the Performance Section, when it was an issue relating to operational procedures:

   The Performance Section is issued as part of Operating Manual Volume 1 which is the flight crew’s operational procedures manual. The Performance Section is what the pilots refer to, if needed, in order to determine aircraft performance for different phases of flight. The Performance Section is also where the FAR Part 25 performance requirements are presented. Also, as an attachment to Bulletin 737-07, a Landing Data Card was provided for the pilots’ reference prior to landing. This additional card is typically carried by the pilots in their “trip book”, a small binder used to contain documents for ready reference by the pilots.

6. Re: question “What would a runway condition report of “Wet” from a controller at Kingston airport (Jamaica) mean to an AA pilot?”

   A simple report of a runway condition of “Wet” would normally indicate Good braking action to an AA pilot. We would expect the tower to provide any amplifying information, e.g. braking action reports from other flights or standing water on the runway such as required by the Jamaica AIP.

7. Re: question “Why did the AA331 flight crew use an assumption that if the runway was more than 8,000 feet, was “wet”, the tailwind was less than 15 knots, aircraft at max landing weight, then it was safe to land? Is this method approved by AA, taught by AA, commonly used by AA flight crews?”

A runway condition report of "Wet" with no other modifying information, e.g. "braking action Poor", would indicate braking action Good. An acceptable technique for a flight crew who flies into a certain airport frequently is to conduct an "advance analysis" of the worst case scenario for the landing runway, that is, for a known landing length, braking action, wind component, landing weight, etc. the crew could determine in advance that as long as they landed below the maximum weight for these worst case conditions the runway length was acceptable. A review of this "advance analysis" prior to landing using the actual conditions at time of landing is acceptable.

American Airlines stated that no AA documents or training materials specifically define the "advance analysis" concept that the JCAA cites in the draft report. AA flight crews are not trained to use, required to use, or discouraged from using this method.

8. Re: question "Did AA management make SAFO 06012 and AC 91-79 available to AA flight crews?"

   AA typically produces their own revisions, Operating Manual Bulletins, Info Bulletins, etc. after receiving relevant documents from outside sources, e.g. Bulletin 737-07 is based on information contained in SAFOs and Advisory Circulars. Our documents are succinct representations of the FAA/NTSB documentation. AA also has a link on their AAPILOTS website to the FAA and NTSB web sites where pilots can download and read any safety documents they desire.

9. Re: question "Does AA have some system to verify that AA flight crews have read and understood Bulletins such as 737-07?"

   Flight Manual Part One instructs the crews to read and insert Operating Manual revisions and bulletins as soon as possible after receipt. AA maintains a list in our flight planning system software that provides the pilots with the latest status of manual revisions, bulletins, etc. AA pilots are required to ensure they have all the current manual revisions, etc. before flying. The current list of manual status is also available on the AAPILOTS web site.

1.17.1.2.11 AA Safety Initiatives Re: AA331 Landing Accident

See Section 4.0, Safety Action, Paragraph 4.1.1.

1.17.2 Boeing Information

1.17.2.1 Glide path, slippery runway, friction measurement

Boeing 737-800 Flight Crew Training Manual, states:

Height of the airplane over the runway threshold also has a significant effect on total landing distance. For example, on a 3° glide path, passing over the runway threshold at 100 feet altitude rather than 50 feet could increase the total landing distance by approximately 950 feet. This is due to the length of runway used up before the airplane actually touches down.

Glide path angle also affects total landing distance. As the approach path becomes flatter, even while maintaining proper height over the end of the runway, total landing distance is increased.

Slippery Runway Landing Performance
Appendix A.2.7

When landing on slippery runways contaminated with ice, snow, slush or standing water, the reported braking action must be considered. Advisory information for reported braking actions of good, medium and poor is contained in the PI section of the QRH. The performance level associated with good is representative of a wet runway. The performance level associated with poor is representative of a wet ice covered runway. Also provided in the QRH are stopping distances for the various autobrake settings and for non-normal configurations. Flight crew should use extreme caution to ensure adequate runway length is available when poor braking action is reported.

Pilots should keep in mind slippery/contaminated runway advisory information is based on an assumption of uniform conditions over the entire runway. This means a uniform depth for slush/standing water for a contaminated runway or a fixed braking coefficient for a slippery runway. The data cannot cover all possible slippery/contaminated runway combinations and does not consider factors such as rubber deposits or heavily painted surfaces near the end of most runways.

One of the commonly used runway descriptors is coefficient of friction. Ground friction measuring vehicles typically measure this coefficient of friction. Much work has been done in the aviation industry to correlate the friction reading from these ground friction measuring vehicles to airplane performance. Use of ground friction vehicles raises the following concerns:

- *the measured coefficient of friction depends on the type of ground friction measuring vehicle used. There is not a method, accepted worldwide, for correlating the friction measurements from the different friction measuring vehicles to each other, or to the airplane's braking capability.*

• most testing to date, which compares ground friction vehicle performance to airplane performance, has been done at relatively low speeds (100 knots or less). The critical part of the airplane's deceleration characteristics is typically at higher speeds (120 to 150 knots).October 31, 2008

Boeing 737 NG Flight Crew Training Manual

Landing
FCT 737 NG (TM) 6.33
• ground friction vehicles often provide unreliable readings when measurements are taken with standing water, slush or snow on the runway. Ground friction vehicles might not hydroplane (aquaplane) when taking a measurement while the airplane may hydroplane (aquaplane). In this case, the ground friction vehicles would provide an optimistic reading of the runway's friction capability. The other possibility is the ground friction vehicles might hydroplane (aquaplane) when the airplane would not, this would provide an overly pessimistic reading of the runway's friction capability. Accordingly, friction readings from the ground friction vehicles may not be representative of the airplane's capability in hydroplaning conditions.
• ground friction vehicles measure the friction of the runway at a specific time and location. The actual runway coefficient of friction may change with changing atmospheric conditions such as temperature variations, precipitation etc. Also, the runway condition changes as more operations are performed.
*The friction readings from ground friction measuring vehicles do supply an additional piece of information for the pilot to evaluate when considering runway conditions for landing. Crews should evaluate these readings in conjunction with the PIREPS (pilot reports) and the physical description of the runway (snow, slush, ice etc.) when planning the landing. Special care should be taken in evaluating all the information available when braking action is reported as POOR or if slush/**standing water** is present on the runway (bolding added). October 31, 2008.* [74]

1.17.2.2 Boeing Flight Crew Operations and Training Manuals, B737, Landing

The Boeing 737-823 Flight Crew Operations Manual, provides the following normal procedure for landing from an ILS approach, with regard to autopilot and auto throttle handling:

> *If suitable visual reference is established at DA(H), MDA(H) or the missed approach point,* ***disengage the autopilot and autothrottle*** (bolding added). *Maintain the glide path to landing.* [75]

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[74] Boeing 737-800 Flight Crew Training Manual, Revision 8, Page 6.32 "Factors Affecting Landing Distance."

[75] The Boeing 737-823 Flight Crew Operations Manual, AA Inc., Section “Normal Procedures – Amplified Procedures”, page NP.21.55

The Boeing Flight Crew Training Manual, Page 6.9, contains the following instructions for landing the B737:

Flare and Touchdown

The techniques discussed here are applicable to all landings including one engine inoperative landings, crosswind landings and landings on slippery runways. Unless an unexpected or sudden event occurs, such as wind shear or collision avoidance situation, it is not appropriate to use sudden, violent or abrupt control inputs during landing. Begin with a stabilized approach on speed, in trim and on glide path.

When the threshold passes under the airplane nose and out of sight, shift the visual sighting point to the far end of the runway. Shifting the visual sighting point assists in controlling the pitch attitude during the flare. Maintaining a constant airspeed and descent rate assists in determining the flare point. Initiate the flare when the main gear is approximately 20 feet above the runway by increasing pitch attitude approximately 2° - 3°. This slows the rate of descent.

After the flare is initiated, smoothly retard the thrust levers to idle, and make small pitch attitude adjustments to maintain the desired descent rate to the runway.

Ideally, main gear touchdown should occur simultaneously with thrust levers reaching idle. A smooth thrust reduction to idle also assists in controlling the natural nose-down pitch change associated with thrust reduction.

Hold sufficient back pressure on the control column to keep the pitch attitude constant. A touchdown attitude as depicted in the figure below is normal with an airspeed of approximately VREF plus any gust correction.

Note: Do not trim during the flare or after touchdown. Trimming in the flare increases the possibility of a tail strike.

For airplanes equipped with HUD, flare guidance is provided in the AIII mode. Follow the guidance cue and perform the flare and landing using HUD guidance and visual cues. Monitor the roll out annunciation (as installed) and transition to rollout guidance. Use normal procedures to decelerate to taxi speed.

The Boeing Flight Crew Training Manual, contains the following information regarding the flare profile:

- *3° approach glide path*
- *flare distance is approximately 1,000 to 2,000 feet beyond the threshold*
- *typical landing flare times range from 4 to 8 seconds and are a function of approach speed*

• airplane body attitudes are based upon typical landing weights, flaps 30, VREF 30 + 5 (approach) and VREF 30 + 0 (landing), and should be reduced by 1° for each 5 knots above this speed.

Typically, the pitch attitude increases slightly during the actual landing, but avoid over-rotating. Do not increase the pitch attitude after touchdown; this could lead to a tail strike.

Shifting the visual sighting point down the runway assists in controlling the pitch attitude during the flare. A smooth thrust reduction to idle also assists in controlling the natural nose down pitch change associated with thrust reduction.

Hold sufficient back pressure on the control column to keep the pitch attitude constant. Avoid rapid control column movements during the flare. If the flare is too abrupt and thrust is excessive near touchdown, the airplane tends to float in ground effect.

Do not allow the airplane to float; fly the airplane onto the runway. Do not extend the flare by increasing pitch attitude in an attempt to achieve a perfectly smooth touchdown. Do not attempt to hold the nose wheels off the runway. [76]

1.17.2.3 Boeing Information on Rejected/Baulked Landings

The Boeing 737 NG Flight Crew Training Manual describes the referenced procedure for rejected (baulked) landings as follows:

Rejected Landing

A rejected landing maneuver is trained and evaluated by some operators and regulatory agencies. Although the FCOM/QRH does not contain a procedure or maneuver titled Rejected Landing, the requirements of this maneuver can be accomplished by doing the Go-Around Procedure if it is initiated prior to touchdown. (Refer to Chapter 5, Go- Around after Touchdown, for more information on this subject.)

The Boeing B737 Flight Crew Training Manual, Section "Approach and Missed Approach", Page 5.76, provides the following instructions regarding a go around after touchdown:

Go-Around after Touchdown:

If a go-around is initiated before touchdown and touchdown occurs, continue with normal go-around procedures. The F/D go-around mode will continue to provide go- around guidance commands throughout the maneuver.
If a go-around is initiated after touchdown but before thrust reverser selection, auto speed-brakes retract and autobrakes disarm as thrust levers are advanced. The F/D go-

[76] Boeing Flight Crew Training Manual, Page 6.10

around mode will not be available until go-around is selected after becoming airborne. Once reverse thrust is initiated following touchdown, a full stop landing must be made. If an engine stays in reverse, safe flight is not possible.

1.17.2.4 Autopilot/Autothrottle Use During Approach

In an article by Bill McKenzie of Flight Crew Operations, Boeing Commercial Airplanes, May 2004, entitled "Auto throttle Use with Autopilot Off" and used for B757 training, it is stated that the following are some disadvantages of auto throttle use with autopilot off:

- Excessive airspeed landing in gusts and turbulence,
- Potential pitch coupling close to the ground,
- Additional MCP coordination,
- Excessive unexpected throttle movement,
- Less thrust awareness, and
- Airspeed crosscheck skills not exercised.

The writer recommended:

- Use Of Manual Thrust Control In Manual Flight,
- Auto Throttle Is Disconnected No Lower Than 300 Feet,
- Operator Establishes A Clear Policy.

It is stated in the Boeing 737 NG Flight Crew Training Manual:

Autothrottle Use:
Auto throttle use is recommended during takeoff and climb in either automatic or manual flight. During all other phases of flight, auto throttle use is recommended only when the autopilot is engaged in CMD. [77]

This is not an FAA approved AA manual; it is the manufacturer's guidance. This information was not contained in the FAA approved manuals for AA B737 operations, and was not presented to AA crews in AA publications. AA flight crews are required to use the guidance in the FAA approved AA Operating Manual.

[77] Boeing 737 NG Flight Crew Training Manual, page 1.34

1.17.3 Air Traffic Control Procedures

1.17.3.1 Assignment of Active Runway

The JCAA Air Traffic Services Manual of Operations (ATS MANOPS), Amendment No. 15 to Part 7, sub-paragraph 710.1 A., valid at the time of the accident, stated:

> *"(The controller shall) Assign the operationally suitable runway most nearly aligned into the wind if the wind speed is 5 knots or more."*

The Tower controller on duty at the time of the accident reported being aware of this procedure, but that frequently pilots chose to land with a tailwind. The Tower controller reported having coordinated with the Approach controller for AA331 to use runway 12, and that the ATIS was stating that runway 12 was the active runway.

1.17.3.2 Weather Standby

The JCAA Air Traffic Services Manual of Operations (ATS MANOPS), Amendment No. 15 to Part 7, sub-paragraph 703.5 states:

> *"(The controller shall) Place the local Airport Emergency Services on WEATHER STANDBY if conditions are of such that landings are difficult, or difficult to observe."*

The Airport Emergency Services were not placed on Weather Standby during the period of AA331's approach and landing.

1.17.3.3 Information for arriving aircraft

JCAA ATS MANOPS, Amendment 25, sub-paragraph 807.1 C stated that, in addition to meteorological information, Approach Control shall transmit to the arriving aircraft "Current runway surface conditions, in case of precipitants or other temporary hazards."

Sub-paragraph 1102.2 of this MANOPS stated "If no report has been received for the runway of intended use, issue an advisory to that effect", and that the phraseology to be used is "Runway is wet, no braking action reports received." No such runway surface condition or braking action reports were transmitted by ATC to AA331, except for the Tower controller saying " … be advised runway wet." when giving landing clearance less than 5 minutes before the aircraft landed.

1.17.4 FAA Information

1.17.4.1 FAA Regulatory Requirements Regarding Landing Distance Calculation

14 *Code of Federal Regulations* (CFR) part 121, section 121.195(b), part 135 section 135.385(b), and part 91, section 91.1037(b) and (c) require operators to comply with certain landing distance requirements at the time of takeoff. These requirements limit the allowable takeoff weight to that which would allow the airplane to land within a specified percentage of the landing distance available on: (1) the most favorable runway at the destination airport under still air conditions; and (2) the most suitable runway in the expected wind conditions. The performance effects of a tailwind on landing are not necessarily taken into account for dispatch purposes, depending on the airplane dispatch basis.

Dispatch, or factored, landing distance calculations are used during flight planning to ensure that dispatched airplanes will be able to land safely at the intended destination airport or a planned alternate and are based on estimated landing weights and forecast conditions. Factored landing distances, including preflight landing safety margins, are required and standardized by U.S. and international aviation authorities. Specifically, in accordance with 14 CFR 121.195, "Airplanes: Turbine Engine Powered: Landing Limitations: Destination Airport," "no person operating a turbine engine powered large transport category airplane may take off unless the weight of the airplane on arrival…would allow a full stop landing at the intended destination airport within 60 percent of the effective length of each runway."

The effective runway length (factored) is further extended by 15% if "the runways at the destination airport may be wet or slippery at the estimated time of arrival.

1.17.4.2 History of SAFO 06012, OpSpec/MSpec C082 and AA Bulletin 737-07

The June 7, 2006 Federal Register publication provided advance notice of the FAA intent to issue mandatory Operation Specification/Management Specification (OpSpec/MSpec) C082, N 8400.C082. This would have required all turbojet operators under Title 14 of the Code of Federal Regulations (14 CFR) parts 121, 135, 125, and 91 subpart K to conduct landing performance assessments (not necessarily a specific calculation) before every arrival based, in part, on planned touchdown point, procedures and data at least as conservative as the manufacturer's, updated wind and runway conditions, and an additional 15 percent safety margin. However, the FAA subsequently decided not to issue the mandatory OpSpec/MSpec C082 at that time and, in August 2006, published Safety Alert For Operators (SAFO) 06012 as an interim guidance measure. SAFO 06012 addressed similar issues to the proposed mandatory OpSpec/MSpec, but operator compliance with the SAFO was, by definition, voluntary.

It is significant to note that the summary of this publication states:

> *"The following advance notice of policy and information would provide clarification and guidance for all operators of turbojet aircraft for establishing operators' methods of ensuring that sufficient landing distance exists for safely making a full stop landing with an*

acceptable safety margin, on the runway to be used, in the conditions existing at the time of arrival, and ***with the deceleration means and airplane configuration to be used." (***bolding added)

This publication stated that one example of a means of compliance would be:

"Establishment of a minimum runway length required under the worst case meteorological and runway conditions for operator's total fleet or fleet type that will provide runway lengths that comply with this notice and OpSpec/MSpec C082."

The FAA did provide a mechanism for operators to formally document full "compliance" with the FAA recommendations in SAFO 06012. See SAFO 06012, page 1, item 2, Discussion, which states that SAFO 06012 is based on the FAA's policy statement published in the Federal Register on June 7, 2006, and incorporates revisions based on public comments received by the FAA. It also states that operators may use Operation/Management specification paragraph C382 to record their voluntary commitment to this practice, pending rulemaking.

There was evidence that AA issued Bulletin 737-07 to comply with SAFO 06012, in response to a request from the FAA AMR Certificates Office, dated 08 September 2006. There was no evidence of AA using OpSpec/MSpec C382 to record their voluntary commitment to this practice.

There was no evidence presented to the investigation that the "advance analysis" used by the AA331 flight crew on the accident flight had received any such "coordination" with the FAA.

Furthermore, there was no evidence as to whether or not the "advance analysis" used by the AA331 flight crew had been modified to account for the increased landing distance that resulted when the AA B737 tailwind landing limit was increased from 10 knots to 15 knots.

1.17.4.3 FAA Recommendations Regarding Landing Distance Calculation

FAA SAFO 06012, 8/31/06, and AC No: 91-79, 11/06/07, were sent to, and were received by, American Airlines.

The expressed purpose of SAFO 06012 was as follows:

"This SAFO urgently recommends that operators of turbojet airplanes develop procedures for flight crews to assess landing performance based on conditions actually existing at time of arrival, as distinct from conditions presumed at time of dispatch. Those conditions include weather, runway conditions, the airplane's weight, and braking systems to be used. Once the actual landing distance is determined an additional safety margin of at least 15% should be added to that distance."

The expressed purpose of AC 91-79 was:

"This AC provides ways for pilots and operators of turbine-powered airplanes to identify, understand, and mitigate risks associated with runway overruns during the

landing phase of flight. It also provides operators with detailed information that may be used to develop company standard operating procedures to mitigate those risks."

AC 91-79, [78] states that: *"If there is rain actively falling on the runway, standing water should be assumed"*, and SAFO 06012 states that standing water constitutes a runway condition that should be considered as contaminated.

1.17.4.4 FAA Advisory Circular AC 91-79

The following is taken from FAA Advisory Circular 91-79, 11/06/07, Appendix 4.

10. Water on the runway is the most common contaminant dealt with by the pilot, but it still provides several challenges. Is the runway wet? Is there standing water on the runway? For that matter, how wet is "wet"? These are questions for which no clear answers are available. Some manufacturer's wet and contaminated supplemental data provide the following or similar definitions (taken from European standards) for wet and contaminated runways:
a. Wet Runway. A runway is considered as wet when there is sufficient moisture on the surface to cause it to appear reflective, but without significant areas of standing water.
b. Runway Contaminated by Standing Water, Slush, Dry Snow, or Wet Snow.
(1) A runway is considered to be contaminated when more than 25 percent of the runway surface area (whether in isolated areas or not) within the required length and width being used, is covered by surface water more than 3 mm (0.125 inch) deep, or by slush or loose snow equivalent to more than 3 mm (0.125 inch) of water.
(2) The "reflective surface" in the wet runway definition and the 3-millimeter depth over 25 percent of the runway require that the pilot be able to see the runway, since these types of conditions are rarely reported to flight crew.

NOTE: The FAA has taken the position that a runway does not need to be reflective to be considered wet. ***If a runway is contaminated or not dry, that runway is considered wet*** (bolding added).

11. If there is any sort of restriction to visibility at the field, or even just low clouds, the pilot will not have sufficient time, once the runway is in view, to ascertain the runway condition and select the appropriate landing distance chart. This requires that the pilot gather the available information prior to approach and make a conservative choice. For example, if there is no clear report of runway condition, but the pilot knows rain has been in the area, that pilot should assume the runway is at least wet. If there is rain actively falling on the runway, standing water should be assumed. If there is any doubt, assume the most conservative condition that requires the longest landing distance.

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[78] Section 1.17.1.2.7

12. Once committed to an operation on a wet or contaminated runway, the pilot should expect a lower level of deceleration than routinely experienced on a dry runway. As an example, consider the landing distances for wet and contaminated surfaces, assuming zero wind and a zero runway gradient. The wind and runway gradient conditions do not require additional corrections. Under these conditions, for the example airplane, a wet runway increases the landing distance over a dry runway by approximately 26 percent. If standing water is present, the landing distance increases approximately 52 percent. Remember that the contaminant only affects the ground roll and braking. It has no impact on the air distance from 50 feet to touchdown, which is included in the landing distance. For this example, the air distance is almost half of the total dry runway landing distance. In the presence of standing water, for the total landing distance to increase 52 percent, the ground braking distance increases 100 percent. This situation might surprise a pilot the first time it is encountered because the deceleration rate on this surface will be only one-half of what the pilot might be accustomed to. For any contaminant, the pilot should expect a relatively low deceleration rate in the initial phase of braking. A wet runway may be less severe than other contaminants, but the pilot must remember that any increase in total landing distance will occur entirely in the landing ground roll braking segment."

The investigation found no evidence that any of the related information in AC91-79 was incorporated in AA Manuals.

It should be noted that AC91-79, Appendix 4, 10 b. (2), as above, stated "*If a runway is contaminated or not dry, that runway is considered wet",* and that SAFO 06012, item 4. Definitions, stated *"i. A wet runway is one that is neither dry nor contaminated"*.

1.17.4.5 SAFO 10005

SAFO 10005 was published by the FAA 3/1/10 (shortly post-accident).

The stated purpose of the SAFO was: "To recommend that all operators should provide written policy to flight crews emphasizing that either pilot may make a go-around callout and that the response to a go-around callout is an immediate missed approach".

The Recommended Action was that operators should publish or reinforce existing written policy emphasizing that:

1. Either the pilot flying or the pilot monitoring may make a go-around callout, and
2. The flying pilot's immediate response to a go-around callout by the non-flying pilot is execution of a missed approach.

1.17.5 NTSB Recommendations to FAA

1.17.5.1 NTSB Recommendations, General

The NTSB has an extended history of recommendations to the FAA regarding the question of requiring flight crews to calculate landing distance for actual conditions at time of arrival, but to the date of the publication of this report no such requirement has been put in place by the FAA. [79]

1.17.5.2 NTSB Safety Recommendation, in reply to A-07-58 through -64

NTSB Safety Recommendation to the FAA, in reply to A-07-58 through -64, dated 16 October 2007, stated:

> *Because the FAA has not required actions to address the Board's urgent safety recommendation, flight crews of transport-category airplanes may still be permitted to land in wet, slippery, or contaminated runway conditions, without performing arrival landing distance assessments that incorporate adequate safety margins.* ***As another winter season approaches, the urgent need for such margins becomes more critical.*** *The Safety Board concludes that because landing conditions may change during a flight, preflight landing assessments alone may not be sufficient to ensure safe stopping margins at the time of arrival; arrival landing distance assessments would provide pilots with more accurate information regarding the safety of landings under arrival conditions.* ***Further, the Safety Board concludes that although landing distance assessments incorporating a landing distance safety margin are not required by regulation, they are critical to safe operation of transport-category airplanes on contaminated runways. Therefore, the Safety Board believes that the FAA should require all 14 CFR Part 121, 135, and 91 subpart K operators to accomplish arrival landing distance assessments before every landing based on a standardized methodology involving approved performance data, actual arrival conditions, a means of correlating the airplane's braking ability with runway surface conditions using the most conservative interpretation available, and including a minimum safety margin of 15 percent.*** (bolding added).

[79] Section 2.21

1.18 Additional Information

1.18.1 Air Traffic Control

1.18.1.1 Enroute Radar Service

Enroute and Approach control services were co-located in the Kingston Air Traffic Control Centre (KATCC). The evidence indicated that all of the Enroute radar and communication equipment was serviceable at the time of the accident.

The Enroute controller was a graduate of the CAA Training Institute (CAATI) and held an ATC license with an Area Radar Control rating. Controllers are required to complete the ATC basic and advanced courses at the CAATI to qualify for the ATC license and then to undergo on the-job-training for rating validation. This had been done in accordance with the JCARS Eighth Schedule.

The Enroute controller held a valid air traffic controller license, medical certificate and a valid radar rating. The controller's work schedule did not reveal a pattern of fatigue.

1.18.1.2 Approach Radar Control Service

The Approach radar and the communication equipment were serviceable. The Approach controller held a valid air traffic controller license, medical certificate and a valid Approach Radar rating. The controller's work schedule did not reveal a pattern of fatigue.

Runway assignment for IFR traffic required coordination between the Approach controller and the Aerodrome controller. Runway 12 was often used by incoming traffic in light tailwinds due to its having an ILS approach, and when AA331 was assigned to runway 12 the wind was from the north at seven knots.

There was a letter of agreement between Approach and Aerodrome control units for operational co-ordination and the exchange of information. This agreement also required the Aerodrome controller to keep Approach units informed of aerodrome conditions.

1.18.1.3 Aerodrome Control Service

The evidence indicates that all control tower equipment was serviceable including the communication and runway lighting controls. The Tower controller held a valid air traffic controller license, medical certificate and a valid Tower controller rating. The controller's work schedule did not reveal a pattern of fatigue.

None of the controllers issued a runway surface condition report or braking action report to AA331. There were no reports available to the controllers to pass since none had been reported to ATC. However, the Tower controller did advise AA331 at 21:17 EST, "Be advised runway wet".

On initial contact with an aircraft the Enroute controller and/or the Tower controller was required to pass information to arriving aircraft concerning runway surface condition reports and braking action reports or had to advise the aircraft that none are available. No reports existed and the controllers did not advise AA331 that no reports were available.

1.18.2 JCAA ATS QA Audits, and Controller Training and Checking

At the time of the accident JCAA ATS had no consistent system of QA audits, no proficiency checks and no recurrent training for controllers.

1.18.3 JCAA Automatic Terminal Information Service (ATIS)

There was no record to show that the computer in the tower that disseminated the ATIS message was unserviceable. There was no record that an ATIS message was generated or broadcast. The CVR of AA331 also did not capture an ATIS broadcast. The ATIS message was not recorded by ATS.

There was no requirement in ICAO Annex 11, Chapter 6, 6.2.2 "*Communications between air traffic services units and other units,*" for ATIS messages to be recorded, nor was there any requirement in the Jamaican Civil Aviation Regulations (JCARs) nor any mention of this in the Air Traffic Services Planning Manual (Doc 9426).

The first officer in his interview reported that he did not recall what the weather was on the ATIS. The captain stated that he did not only rely on ATIS reports, and for this flight he called the Approach controller for the airport conditions. The flight crew did not make any other mention of the ATIS in their interviews, and there was no mention of the ATIS in the recordings of the CVR and the ATC transmissions.

The Tower controller, when interviewed, stated that the ATIS broadcast in effect at the time of the accident was announcing that runway 12 was active.

1.18.4 JCAA Notices To Airmen (NOTAMS)

The following information was included in NOTAMS which were in effect for the Norman Manley International Airport at Kingston, and the Sangster International Airport at Montego Bay on 22 December 2009, at the time of the accident.

Norman Manley International Airport

- - RUNWAY -
- -- APCH LIGHTS RUNWAY 12 U/S. CAUTION ADZ.
- 30NOV09/1201 31JAN10/1200 MKJP A0176/09
- - FACILITIES -
- -- WORKMEN AND EQPT WILL OPR AT A DISTANCE OF 60M FROM THR RUNWAY
- 12,TO A DISTANCE OF 420M IN THE KINGSTON HARBOUR. CTN ADZ.
- 01DEC09/1201 31JAN10/1200 MKJP A0184/09
- MBJ NO/

This indicated that the approach lighting system serving runway 12 at Kingston was unserviceable, and that work was being carried out on the system.

Sangster International Airport

1. The NOTAM announcing the planned runway closure at Montego Bay was as follows:

(A0208/09 NOTAMN
Q)MKJK/QMRLC/IV/NBO/AE/000/999/182956.21N0775527.3W
A)MKJS
B)0912230300
C)0912231100
E)RUNWAY 07/25 CLSD TO FACILITATE REPAIRS.)
Sent: Dec. 19, 2009

This announced the runway was to be closed from 03:00 UTC to 1100 UTC on 23 December 2009 (Accident occurred at 03:22 UTC, on 23 December 2009).

This NOTAM was sent to Aeronautical Fixed Telecommunication Network (AFTN) at 23:42 UTC on 19 December 2009, and received at 2358 UTC.

2. The NOTAM cancelling the planned runway closure was as follows:

(A0215/09 NOTAMC A0208/09
Q)MKJK/QMRXX//////
A)MKJS
E)SCHEDULED RUNWAY REPAIRS CANCELLED.)
Sent: Dec. 22, 2009

This announced that the scheduled runway repairs were cancelled.

This NOTAM was sent to AFTN at 21:23 UTC on 22 December 2009, and received at 21:30 UTC. The evidence collected during the investigation indicates that the NOTAM "AO208/09 NOTAMN", which announced the planned closure of runway 07/25 at Montego Bay, was received by AA Dispatch.

The evidence also indicated that the NOTAM "AO215/09 NOTAMC AO208/09", announcing the cancellation of this runway closure, was never delivered to the flight crew of AA331, even though it was issued several hours before the flight's departure.

AA researched the matter, and reported that it was highly likely that NOTAM AO215/09 successfully reached AA Dispatch, and that this would have resulted in the original NOTAM AO208/09 being removed from the system at approximately 21:41 UTC on 12/22/09.

AA stated,

> *"Note - The AA NOTAM system 'NIMS" does not alert on NOTAM cancellations. It just removed the NOTAM from the flight planning system in response to a cancellation message. Thus there would not be an easy way for the dispatcher to alert the pilot that a NOTAM has been removed."*

1.18.5 JCAA Air Traffic Control Radar

The evidence indicated that the Kingston air traffic Area (Enroute) and Approach control radars were functioning normally during the approach and landing of AA331.

1.18.6 Estimated Water Depth and Braking Action

The Performance section of the investigation determined that the depth of water on MKJP runway 12 during the flight 331 ground roll can be reliably estimated using the following independent methods:

1. Empirically-based models for pavement water drainage rates that rely on factual data documented by the investigation, including MKJP precipitation rates and runway 12/30 pavement properties.

2. Existing B737NG wet runway flight test data.

3. Available AA flight 331 FDR data, B737-800 aerodynamics and engine simulation models, and models for airplane/ runway braking action or runway surface contamination required to match the event stopping performance during the ground roll segment on an improved surface.

The depth of water on MKJP runway 12 during the flight 331 ground roll can be estimated using empirically-based models to calculate water depth as a function of rainfall intensity and the runway 12/30 width, transverse slope, and pavement macro-texture characteristics. Based on the NASA rainfall rate/flooding exposure model and the Texas Transportation Institute (TTI) accumulated water depth model data presented to the JCAA at the Aircraft Performance Group Briefing in August 2010, no evidence supports a runway 12/30 water depth accumulation close to 3 millimeters (mm) of water.

These models indicate that, depending on the pavement macro-texture and airplane lateral position, there was at most a 0.5 to 1.0 mm water depth in the calculated main gear braked wheel path. A similar conclusion holds (at most 0.75 to 1.5 mm water depth) for all possible pavement macro-textures, even if the measured rainfall rate at the time of the accident is doubled to 1.0 inch/hour and the calculated airplane lateral position is artificially and significantly biased toward the runway shoulder.

An independent Boeing analysis of the existing rainfall precipitation and runway 12/30 factual data is consistent with the TTI model results described here.

The NASA, TTI, and Boeing pavement drainage model results do not incorporate potential runway edge water damming, surface wind influence on water drainage, and/or airport infield water-ponding effects. However, based on the qualitative FAA inspection of runway 12/30 (during the runway 12/30 visit in August 2010 in light rain conditions) and the absence (to date) of compelling JCAA or U.S. Team data to the contrary, runway edge water damming and/or airport infield water ponding effects on water depth in the main gear braked wheel paths for a B737- 800 are believed to be negligible The runway 12/30 transverse slope data indicate that the outboard runway edge lines and the runway shoulder edges lie, on average, about 8 inches and at least 11 inches below the runway centerline elevation, respectively.

The estimated depth of water in the airplane braked wheel paths during the runway 12 ground roll was less than 3 mm (less than .125 in.), which corresponds to an equivalent stopping performance level better than that expected for either a runway covered with standing water or a flooded runway. From an aircraft performance perspective, standing water and flooded are synonymous terms used to describe surface water depth greater than 3 mm (.125 in) on more than 25 percent of the runway surface area (whether in isolated areas or not) within the required runway length and width being used.

Independent of the above models for estimating water depth, the airplane deceleration observed during the flight 331 ground roll is consistent with B 737NG (-700/900) flight test data on an artificially wet (no active rainfall; water applied to pavement prior to airplane touchdown using a fleet of tanker trucks), un-grooved runway with pavement macro-texture characteristics similar to or better than MKJP runway 12. These Boeing flight test data benefit from explicit knowledge that less than 25 percent of the runway surface was subject to standing water 1/8 inch deep or greater. In other words, the AA 331 braking performance level has been achieved on a wet, un-grooved runway with no active rainfall and less than 1/8 inch depth of water.

Analysis of the AA flight 331 event indicates the achieved airplane braking coefficient value was less than that traditionally considered to be associated with a wet runway (0.2), but better than what Boeing associates with a flooded runway (0.05). The factual evidence indicates that the airplane/ runway stopping performance interaction for AA flight 331 was essentially consistent with AA Fair/Medium braking action.

In other words, the AA flight 331 stopping performance level is inconsistent with the Boeing model for standing water or flooded runway.

Quoted performance is based on Wet/Good braking action, maximum manual braking, without reverse thrust and landing at about 1,000 feet from the threshold.

1.18.7 NTSB Review of Fatigue in Major U.S. Accidents

The following information was obtained from the NTSB Accident Report NTSB/AAR-08/02, PB2008-910402, Runway Overrun During Landing, Pinnacle Airlines Flight 4712, Traverse City, Michigan, April 12, 2007:

> *"Research has shown that long duty days can be associated with pilot fatigue and degraded performance. Aviation accident data show that human-performance-related airline accidents are more likely to happen when pilots work long days.*
>
> *The Board's 1994 study of flight-crew-related major aviation accidents found that captains who had been awake for more than about 12 hours made significantly more errors than those who had been awake for fewer than 12 hours. Such errors included failing to recognize and discontinue a flawed approach; pilots often exhibited a tendency to continue the approach despite increasing evidence that it should be discontinued ... Research and accident history also show that fatigue can cause pilots to make risky, impulsive decisions; become fixated on one aspect of a situation; and react slowly to warnings or signs—any of which can result in an approach being continued despite evidence that it should be discontinued.*
>
> *Additionally, research shows that people who are fatigued become less able to consider options and are more likely to become fixated on a course of action or a desired outcome."*

1.18.8 AA use of FAA Safety Recommendations in AC No: 91-79

The investigation was advised that FAA Advisory Circular AC No: 91-79, dated 11/06/07 was provided to the AA Safety Officer by the FAA, who, in turn, provided the AC to the various AA fleet captains. The investigation was unable to determine to what degree the guidance in the AC had been incorporated into AA manuals.

1.18.9 GPS Approach Requirements and Information

AA held Operations Specifications C300 and C384, which authorized the conduct of required navigation performance (RNP) instrument approach procedures (IAP). Both flight crew were qualified to conduct RNAV approaches. The Jeppesen chart (12-2) for MKJP/KIN, Kingston, Jamaica, RNAV (GPS) Rwy 30, dated 22 August 08, was in the possession of the AA331 flight crew during the flight.

The AA331 flight plan indicated that the aircraft was RNAV capable. The dispatch paperwork showed no MEL restrictions on the aircraft's RNAV capability. The Kingston RNAV (GPS) Rwy 30 approach was in the database of the aircraft's navigation equipment. [80]

---

[80] See also Section 1.6.12

1.18.10 Stopping Performance Information

During type certification of the 737-800, Boeing demonstrated landing and stopping performance tests on dry runways in tailwind conditions up to 31 knots, using maximum wheel braking and no reverse thrust. No data was demonstrated for wet or contaminated runways, and the FAR 25 safety factor method (121.195) was used to certify the aircraft flight manual performance for wet and contaminated runways.

The wet or slippery runway landing distance requirements of 14 CFR 121.195(d) are based on applying a safety factor to demonstrated dry runway distances rather than demonstrating wet runway landing distances. Stopping performance data for the AA Boeing 737-800 was issued on a "Landing Data Card" [81] for Dry, Wet/Good, Fair/Medium and Poor runways, with corrections for aircraft weight, flap setting, airport elevation, headwinds and tailwinds, and reverse thrust.

The Boeing 737-800 aircraft was certificated per AC 25-7A Change 1 (FAA Flight Test Guide) for 15 knot tailwind landings and a bulletin (SPC MSG NBR 9482, see 1.17.1.2.4) had been issued by AA to all flight crews removing the company's previous 10 knot tailwind limitation and increasing it to 15 knots for all aerodromes.

1.18.11 Runway Water Depth Measurement

The following information was obtained from the ICAO Airport Services Manual (Doc 9137), Part 2, Pavement Surface Conditions:-

> *2.1.10 There has been some speculation on whether measuring water depth could perhaps replace measuring runway friction. To this end, a study was undertaken to ascertain a list of requirements to be met by such measuring devices. [. . .] Although possible [to design], it would not be practical to develop a device that could meet all of the [. . .] requirements; it is preferable to develop programmes aimed at improving the surface texture and drainage of runway rather than measuring the water depth. [. . .] Even assuming that a device meeting [all of the] requirements [was to be] developed, another big difficulty appears to be the number and location of devices needed for a runway. [At the time of writing], it has been concluded that standardization of water depth measuring devices with the object of measuring runway friction is not practical. Work continues in this area."*

[81] Appendix 7

1.18.12 Hazards associated with tailwind landings.

A paper entitled "Safety aspects of tailwind landings" was published by G.W.H van Es and A.K. Karwal, National Aerospace Laboratory of the Netherlands, in January 2001.

This study discussed the hazards associated with tailwind landings, as follows:

1. On glide slope, excessive rates of descent (that is, more than 1,000 fpm) can be required when conducting a descent in a strong tailwind. Flap speed limits may be exceeded.
2. Increased ground speed may result in approach becoming de-stabilized or rushed, and increases pilot workload.
3. On glide-slope, low engine power settings resulting from high rates of descent increase spool-up time if go-around is necessary.
4. Increased landing groundspeed results in pilots tending to bleed off speed by floating the aircraft before touchdown, thus using up runway available.
5. Close to ground, tailwind tends to decrease causing increase in True Air Speed (inertial effect), thus amplifying floating.
6. FMS is unreliable indicator of tailwind, has 2 – 3 second delay, and is measured only where aircraft actually is.
7. Combination of tailwind and wet runway results in high risk of runway over run.
8. Wake vortices patterns from a tailwind landing differ from those in calm or headwind conditions.

1.18.13 Hazards Associated With Go-Around After Touchdown

Although go around after landing was a hazardous procedure, the option for the flight crew to do so was open until such time as reverse thrust was selected, and the captain reported that he considered this when the aircraft was on the runway.

The hazards associated with go-around after touch-down are:

1. Asymmetric engine spool-up,
2. Speed bleed-off,
3. Time for re-set of flap and trim,
4. Possible insufficient runway remaining,
5. Loss of directional control.

See also 1.17.4.5, SAFO 10005, regarding go-around call out procedures.

1.18.14 Flight Safety International Approach and Landing Accident Reduction Report

Approach and landing accident reduction (ALAR) has long been among the primary goals of the Flight Safety Foundation (FSF). When the international FSF ALAR Task Force published its report in 1998, it cited data showing that an average of 17 fatal ALAs had occurred each year from 1980 through 1998 in passenger and cargo operations involving aircraft weighing 5,700 kg/12,500 lb. or more.

The task force's work, and the subsequent safety products and international workshops on the subject, have helped reduce the risk of ALAs, but the accidents still occur. In 2009, of 17 major accidents, nine were ALAs, compared with 19 and eight the previous year.

Since the ALAR campaign began, members of the FSF Controlled Flight Into Terrain and Approach and Landing Action Group (CAAG) have conducted numerous ALAR workshops around the world, and the Foundation has distributed more than 40,000 copies of the FSF *ALAR Tool Kit* — a unique set of pilot briefing notes, videos, presentations, risk-awareness checklists and other products designed to prevent approach and landing accidents.

A major update of the FSF *ALAR Tool Kit* — featuring the findings of analyses of recent accident data, as well as the data-driven findings of the FSF Runway Safety Initiative — was issued in 2010. It is the Foundation's intention to periodically update the *ALAR Tool Kit* to include new information aimed at reducing the risk of approach and landing accidents.

1.18.15 Boeing 737-800 Tailwind Certification Process

The FAA certified the Boeing 737-800 series aircraft for operations in tailwinds of 10 knots or less, and 15 knots or less, and operators could purchase the aircraft with a performance package for either a 10 or 15 knot tailwind limitation. AC 25-7A, Change 1, which was active guidance material at the time of the certification described an acceptable method for the manufacturer to comply with the requirements, including flight testing. U.S. operators wishing to use either package had to be approved by the FAA.

1.18.16 Definition of Black Hole Approach

In the article by A. Howard Hasbrook, "The Black Hole Approach: Don't Get Sucked In!", published in Business and Commercial Aviation Magazine, August 1971, there is the following definition:

> *" … a black hole approach is a long, straight-in approach at night to a brightly lit runway over featureless and unlit terrain".*

APPENDICES TO FACTUAL INFORMATION

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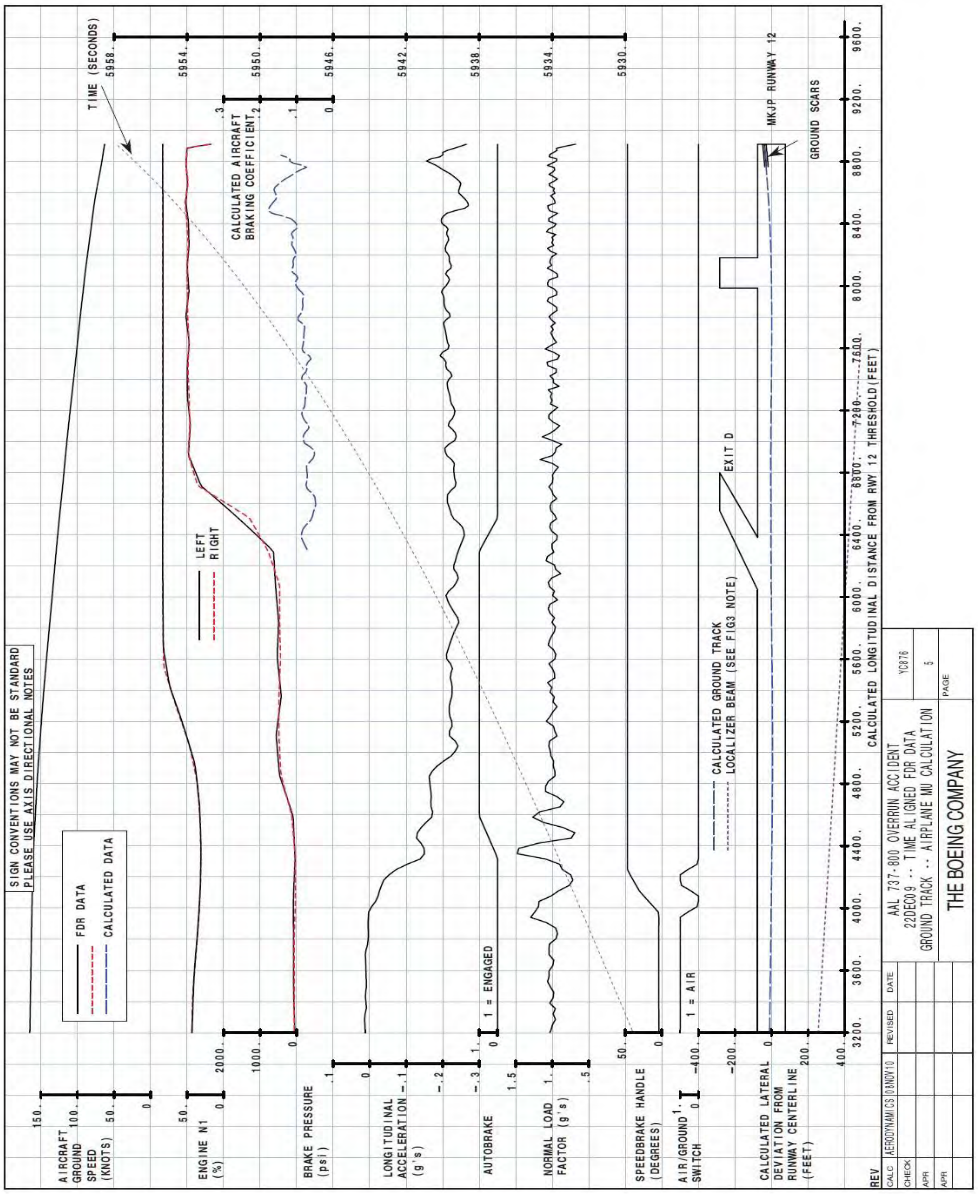
APPENDIX 1

AA331 Flight Data Recorder Plot by The Boeing Company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TIME (SECONDS)
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LEFT
RIGHT
AIRCRAFT GROUND SPEED (KNOTS)
ENGINE N1 (%)
BRAKE PRESSURE (psi)
LONGITUDINAL ACCELERATION (g's)
AUTOBRAKE
1 = ENGAGED
NORMAL LOAD FACTOR (g's)
SPEEDBRAKE HANDLE (DEGREES)
AIR/GROUND SWITCH
1 = AIR
CALCULATED LATERAL DEVIATION FROM RUNWAY CENTERLINE (FEET)
CALCULATED GROUND TRACK
LOCALIZER BEAM (SEE FIG3 NOTE)
EXIT D
MKJP RUNWAY 12
GROUND SCARS
CALCULATED LONGITUDINAL DISTANCE FROM RWY 12 THRESHOLD (FEET)
AAL 737-800 OVERRUN ACCIDENT
22DEC09 -- TIME ALIGNED FDR DATA
GROUND TRACK -- AIRPLANE MU CALCULATION
YC876
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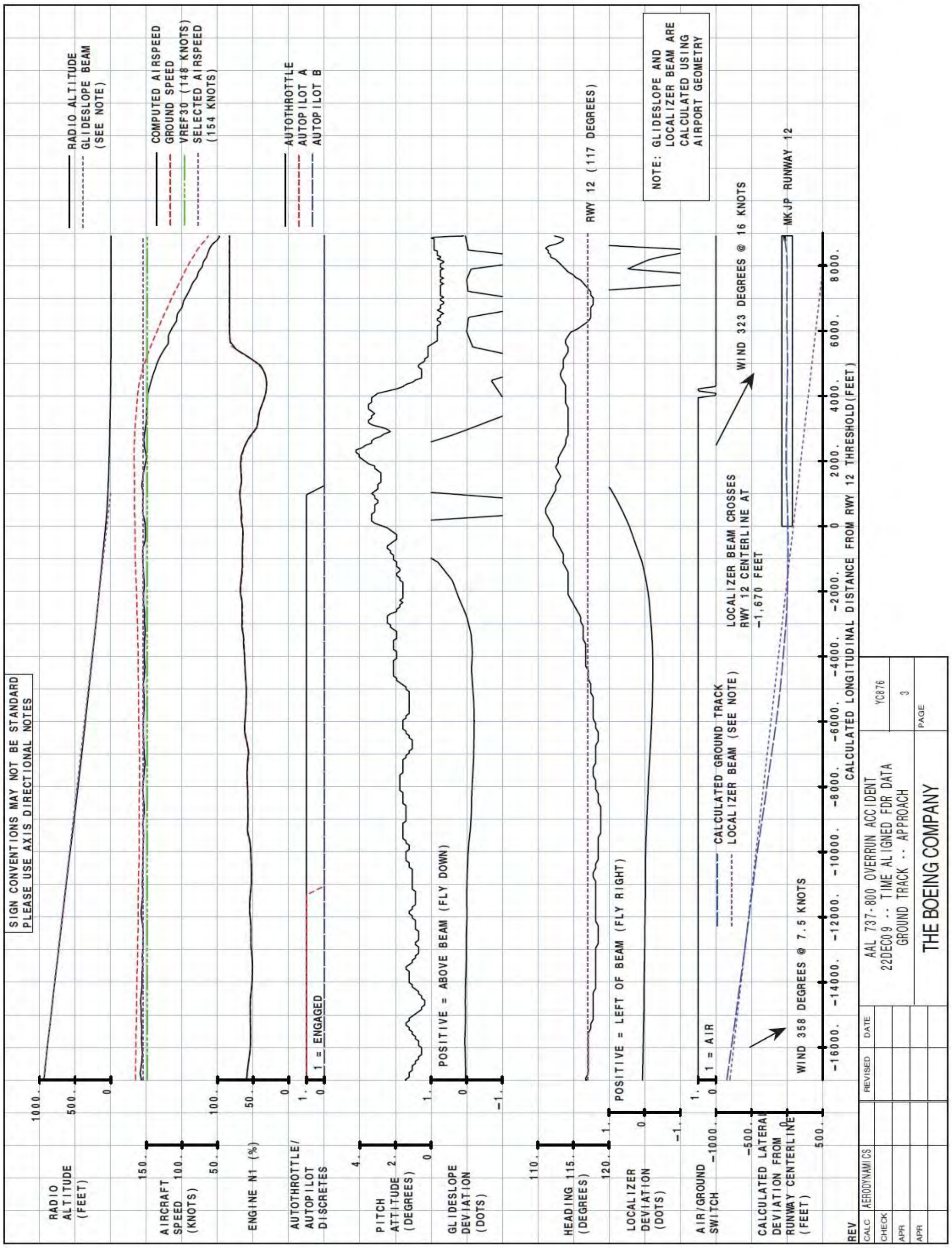
THE BOEING COMPANY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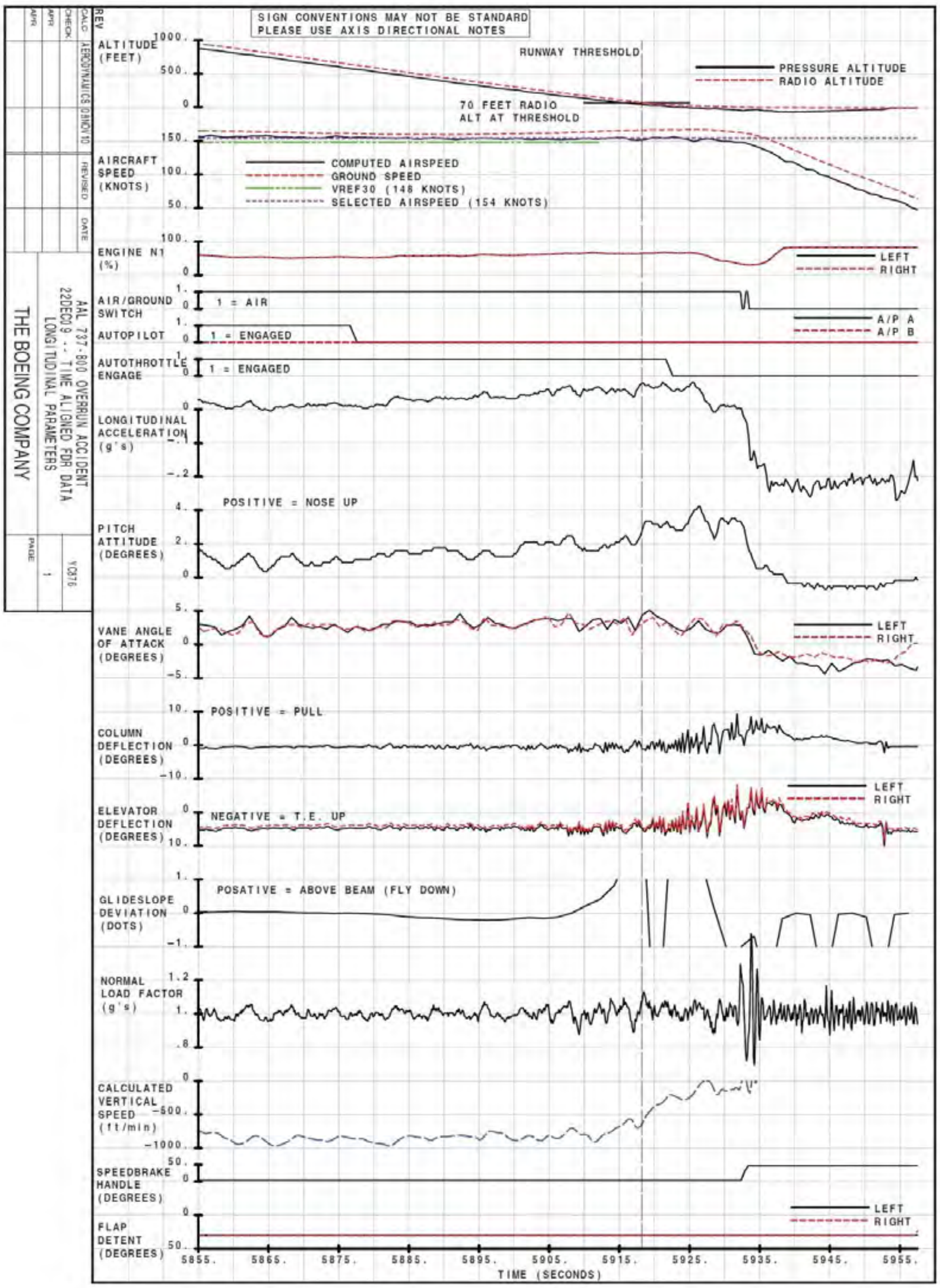
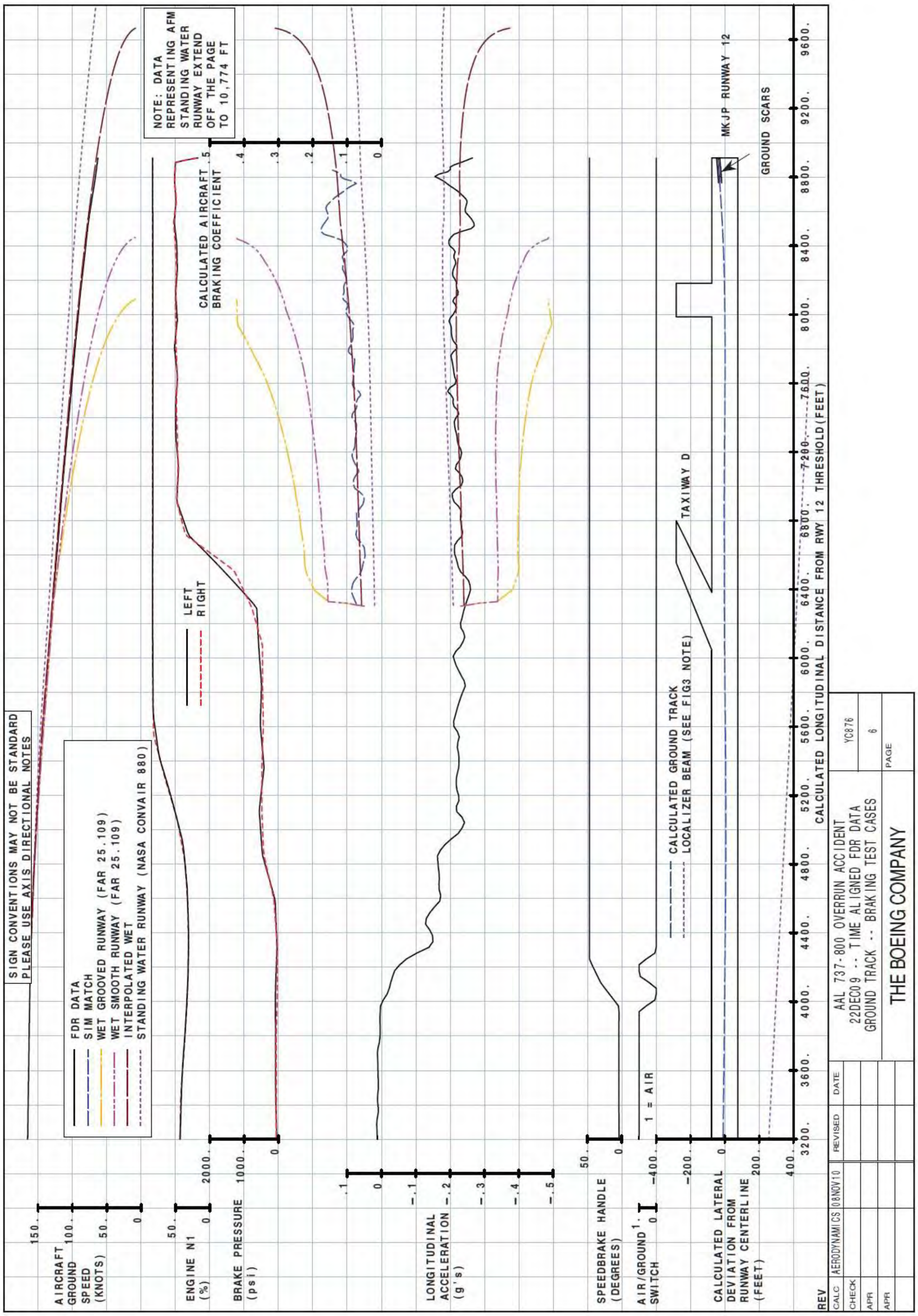
PLEASE USE AXIS DIRECTIONAL NOTES
RADIO ALTITUDE (FEET)
AIRCRAFT SPEED (KNOTS)
ENGINE N1 (%)
AUTOTHROTTLE/ AUTOPILOT DISCRETES
PITCH ATTITUDE (DEGREES)
GLIDESLOPE DEVIATION (DOTS)
HEADING (DEGREES)
LOCALIZER DEVIATION (DOTS)
AIR/GROUND SWITCH
CALCULATED LATERAL DEVIATION FROM RUNWAY CENTERLINE (FEET)
RADIO ALTITUDE
GLIDESLOPE BEAM (SEE NOTE)
COMPUTED AIRSPEED
GROUND SPEED
VREF30 (148 KNOTS)
SELECTED AIRSPEED (154 KNOTS)
AUTOTHROTTLE
AUTOPILOT A
AUTOPILOT B
1 = ENGAGED
POSITIVE = ABOVE BEAM (FLY DOWN)
RWY 12 (117 DEGREES)
POSITIVE = LEFT OF BEAM (FLY RIGHT)
1 = AIR
NOTE: GLIDESLOPE AND LOCALIZER BEAM ARE CALCULATED USING AIRPORT GEOMETRY
CALCULATED GROUND TRACK
LOCALIZER BEAM (SEE NOTE)
LOCALIZER BEAM CROSSES RWY 12 CENTERLINE AT -1,670 FEET
WIND 358 DEGREES @ 7.5 KNOTS
WIND 323 DEGREES @ 16 KNOTS
MKJP RUNWAY 12
CALCULATED LONGITUDINAL DISTANCE FROM RWY 12 THRESHOLD (FEET)
AAL 737-800 OVERRUN ACCIDENT
22DEC09 -- TIME ALIGNED FDR DATA
GROUND TRACK -- APPROACH
YC876
PAGE 3
THE BOEING COMPANY


SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
ALTITUDE (FEET)
RUNWAY THRESHOLD
PRESSURE ALTITUDE
RADIO ALTITUDE
70 FEET RADIO ALT AT THRESHOLD
AIRCRAFT SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
VREF30 (148 KNOTS)
SELECTED AIRSPEED (154 KNOTS)
ENGINE N1 (%)
LEFT
RIGHT
AIR/GROUND SWITCH
1 = AIR
AUTOPILOT
1 = ENGAGED
A/P A
A/P B
AUTOTHROTTLE ENGAGE
1 = ENGAGED
LONGITUDINAL ACCELERATION (g's)
PITCH ATTITUDE (DEGREES)
POSITIVE = NOSE UP
VANE ANGLE OF ATTACK (DEGREES)
COLUMN DEFLECTION (DEGREES)
POSITIVE = PULL
ELEVATOR DEFLECTION (DEGREES)
NEGATIVE = T.E. UP
GLIDESLOPE DEVIATION (DOTS)
POSATIVE = ABOVE BEAM (FLY DOWN)
NORMAL LOAD FACTOR (g's)
CALCULATED VERTICAL SPEED (ft/min)
SPEEDBRAKE HANDLE (DEGREES)
FLAP DETENT (DEGREES)
TIME (SECONDS)
THE BOEING COMPANY
AAL 737-800 OVERRUN ACCIDENT
22DEC09 - TIME ALIGNED FDR DATA
LONGITUDINAL PARAMETERS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PLEASE USE AXIS DIRECTIONAL NOTES
FDR DATA
SIM MATCH
WET GROOVED RUNWAY (FAR 25.109)
WET SMOOTH RUNWAY (FAR 25.109)
INTERPOLATED WET
STANDING WATER RUNWAY (NASA CONVAIR 880)
NOTE: DATA REPRESENTING AFM STANDING WATER RUNWAY EXTEND OFF THE PAGE TO 10,774 FT
CALCULATED AIRCRAFT BRAKING COEFFICIENT
LEFT
RIGHT
AIRCRAFT GROUND SPEED (KNOTS)
ENGINE N1 (%)
BRAKE PRESSURE (psi)
LONGITUDINAL ACCELERATION (g's)
SPEEDBRAKE HANDLE (DEGREES)
AIR/GROUND SWITCH
1 = AIR
CALCULATED LATERAL DEVIATION FROM RUNWAY CENTERLINE (FEET)
CALCULATED GROUND TRACK
LOCALIZER BEAM (SEE FIG3 NOTE)
TAXIWAY D
MKJP RUNWAY 12
GROUND SCARS
CALCULATED LONGITUDINAL DISTANCE FROM RWY 12 THRESHOLD(FEET)
3200. 3600. 4000. 4400. 4800. 5200. 5600. 6000. 6400. 6800. 7200. 7600. 8000. 8400. 8800. 9200. 9600.
AAL 737-800 OVERRUN ACCIDENT
22DEC09 -- TIME ALIGNED FDR DATA
GROUND TRACK -- BRAKING TEST CASES
THE BOEING COMPANY
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CALC AERODYNAMICS 08NOV10
CHECK
APR
APR
REV
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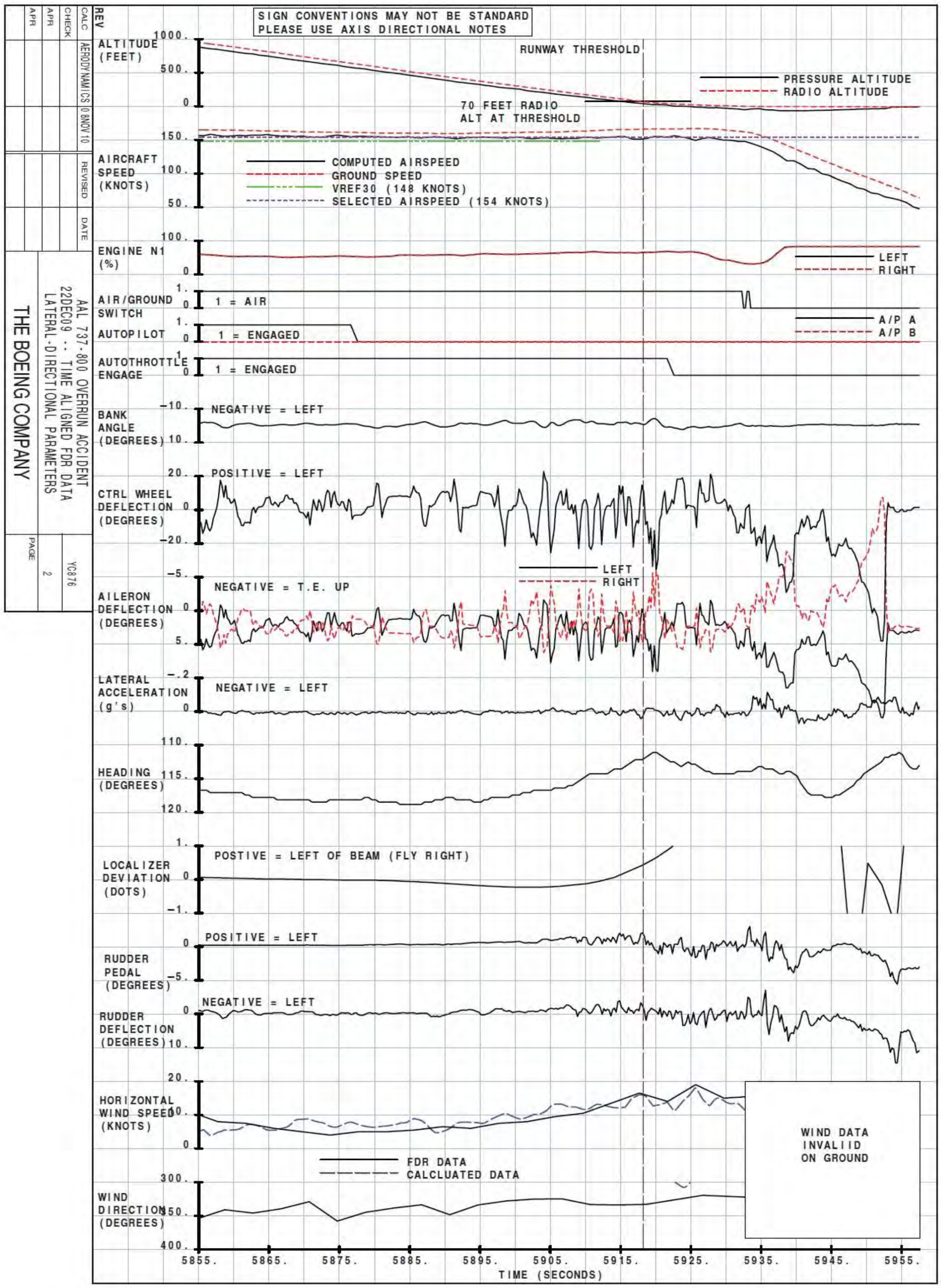
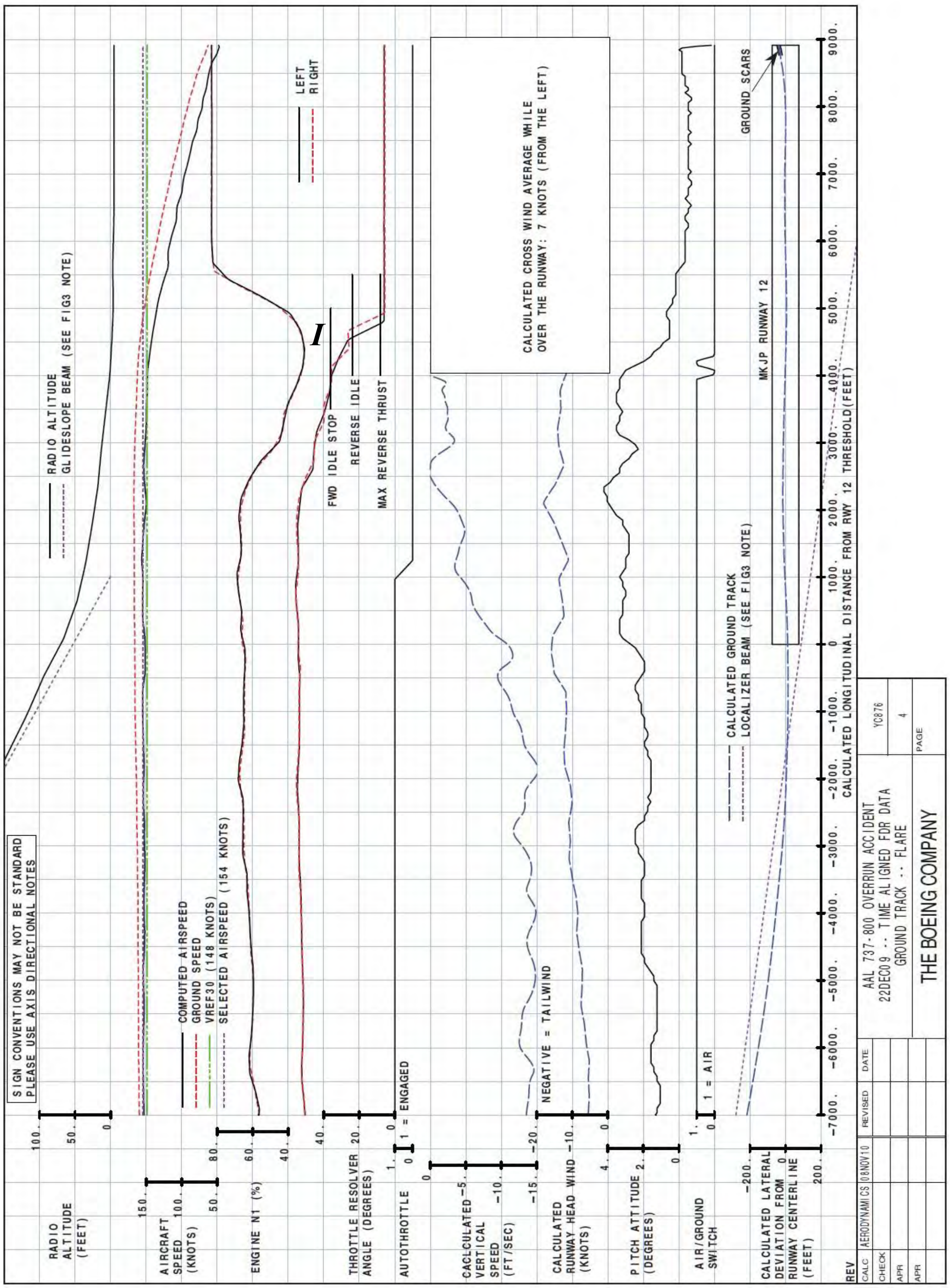
DATE


SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
RUNWAY THRESHOLD
ALTITUDE (FEET)
PRESSURE ALTITUDE
RADIO ALTITUDE
70 FEET RADIO ALT AT THRESHOLD
AIRCRAFT SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
VREF30 (148 KNOTS)
SELECTED AIRSPEED (154 KNOTS)
ENGINE N1 (%)
LEFT
RIGHT
AIR/GROUND SWITCH
1 = AIR
AUTOPILOT
1 = ENGAGED
A/P A
A/P B
AUTOTHROTTLE ENGAGE
1 = ENGAGED
BANK ANGLE (DEGREES)
NEGATIVE = LEFT
CTRL WHEEL DEFLECTION (DEGREES)
POSITIVE = LEFT
AILERON DEFLECTION (DEGREES)
NEGATIVE = T.E. UP
LEFT
RIGHT
LATERAL ACCELERATION (g's)
NEGATIVE = LEFT
HEADING (DEGREES)
LOCALIZER DEVIATION (DOTS)
POSTIVE = LEFT OF BEAM (FLY RIGHT)
RUDDER PEDAL (DEGREES)
POSITIVE = LEFT
RUDDER DEFLECTION (DEGREES)
NEGATIVE = LEFT
HORIZONTAL WIND SPEED (KNOTS)
FDR DATA
CALCLUATED DATA
WIND DATA INVALIID ON GROUND
WIND DIRECTION (DEGREES)
TIME (SECONDS)
5855. 5865. 5875. 5885. 5895. 5905. 5915. 5925. 5935. 5945. 5955.
REV
CALC AERODYNAMICS 08NOV10
CHECK
APR
APR
REVISED
DATE
AAL 737-800 OVERRUN ACCIDENT
22DEC09 :: TIME ALIGNED FDR DATA
LATERAL-DIRECTIONAL PARAMETERS
THE BOEING COMPANY
YC876
PAGE 2


SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
RADIO ALTITUDE (FEET)
RADIO ALTITUDE
GLIDESLOPE BEAM (SEE FIG3 NOTE)
AIRCRAFT SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
VREF30 (148 KNOTS)
SELECTED AIRSPEED (154 KNOTS)
ENGINE N1 (%)
LEFT
RIGHT
THROTTLE RESOLVER ANGLE (DEGREES)
FWD IDLE STOP
REVERSE IDLE
MAX REVERSE THRUST
AUTOTHROTTLE
1 = ENGAGED
CALCULATED VERTICAL SPEED (FT/SEC)
CALCULATED CROSS WIND AVERAGE WHILE OVER THE RUNWAY: 7 KNOTS (FROM THE LEFT)
CALCULATED RUNWAY HEAD WIND (KNOTS)
NEGATIVE = TAILWIND
PITCH ATTITUDE (DEGREES)
AIR/GROUND SWITCH
1 = AIR
CALCULATED LATERAL DEVIATION FROM RUNWAY CENTERLINE (FEET)
CALCULATED GROUND TRACK
LOCALIZER BEAM (SEE FIG3 NOTE)
GROUND SCARS
MKJP RUNWAY 12
CALCULATED LONGITUDINAL DISTANCE FROM RWY 12 THRESHOLD (FEET)
AAL 737-800 OVERRUN ACCIDENT
22DEC09 -- TIME ALIGNED FDR DATA
GROUND TRACK -- FLARE
THE BOEING COMPANY
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APPENDIX 2

Cockpit Voice Recorder Transcript

The following is a transcript of the L-3 Communications FA 2100-1010 solid-state cockpit voice recorder (CVR), serial number 000142599, installed on an American Airlines Boeing 737-800 (N977AN), which overran runway 12 at Norman Manley International Airport in Kingston, Jamaica, on 22 December 2009.

CAM	Cockpit area microphone voice or sound source
HOT	Flight crew audio panel voice or sound source
RDO	Radio transmissions from N977AN
APR	Radio transmission from the Kingston approach controller
TWR	Radio transmission from the Manley airport tower controller
TAWS	Terrain avoidance and warning system sound source
PA	Aircraft public address system sound source
-1	Voice identified as the captain
-2	Voice identified as the first officer
-3	Voice identified as the flight attendant
-?	Voice unidentified
-A	Identified as first Kingston approach frequency
-B	Identified as second Kingston approach frequency
*	Unintelligible word
#	Expletive
@	Non-pertinent word
( )	Questionable insertion
[ ]	Editorial insertion

Note 1: Times are expressed in local EST

Note 2: Generally, only radio transmissions to and from the accident aircraft were transcribed.

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

21:51:44.0
START OF RECORDING
START OF TRANSCRIPT

21:51:54.5
HOT-1 so now uh if we have to go to an alternate it's going to be Grand Cayman instead of Montego Bay. if we go to Montego Bay...

21:52:10.6
CAM-2 Grand Cayman it's gonna be a little bit less. it's gonna be lot more fuel.

21:52:11.2
HOT-1 ...yeah to go to Grand Cayman it's gonna be a lot more gas. we need to do that at ten thousand two hundred pounds. so missed approach right to Grand Cayman.

21:52:22.3
HOT-2 alright.

21:52:24.1
HOT-1 here we go. startin' on down.

21:52:36.1
HOT-1 be off for just a second.

21:52:40.5
PA-1 well ladies and gentlemen we've started our initial descent into the Kingston area. uh it's gonna be quite a bumpy ride on the descent here. other aircraft up ahead of us have been telling us they've been uh shouldn't be much worse than this but it's gonna be a little bit too hard for the flight attendant's to continue their service so I've asked them to take their seats and buckle in for the remainder of the flight. we are gonna touch down about twenty past the hour. and the current weather they're having uh rain shower activity at the airport at this time. and uh it's still uh the temperature's right around uh seventy three degrees. like to take this time once again and thank you for choosing American and we hope to see you again on future American flights.

21:53:23.5
HOT-1 anytime that # window's open and you hit that it goes right for speed.

21:53:36.4
CAM-2 here goes the recall. watch your eyes there.

21:53:38.7
HOT-1 alright.

21:53:40.7
CAM-2 still working fine.

21:53:47.4
CAM-2 oh we talked about the approach. approach brief.

21:53:50.4
HOT-1 complete for now?

21:53:52.1
CAM-2 complete for now.

21:54:17.0
HOT-1 why don't you pull up the Grand Cayman weather.

21:54:19.2
CAM-2 check on that.

21:54:36.4
HOT-1 it's probably going to go by the identifier which is...

21:54:39.6
CAM-2 I've got it up here somewhere...M-W-C-R.

21:55:11.3
RDO-1 Kingston Approach American three three one.

21:55:27.3
RDO-1 Kingston Approach American three three one.

21:55:38.0
HOT-1 and I heard after TOTON direct KEYNO correct?

21:55:40.2
CAM-2 that's correct.

21:55:52.4
HOT-1 alright there's TOTON direct KEYNO.

21:55:55.8
CAM-2 that looks good.

21:56:06.8
HOT-2 unlimited visibility scattered at one thousand six hundred scattered at nine thousand no sig one twenty at nine. weather there looks nice.

21:56:22.1
HOT-1 alright.

21:56:28.2
HOT-1 grid MORA's coming in here. are five thousand to the uh west and ninety eight hundred to the east.

21:56:40.8
HOT-2 alright

21:56:41.5
HOT-1 if we have to deviate for weather. so anything to the east ten thousand feet is good.

21:56:48.3
HOT-2 sounds good.

21:57:03.3
HOT-1 bring the heat on for me.

21:57:14.6
HOT-1 # been doing this # for the last three trips man.

21:57:23.0
HOT-1 kill those strobes.

21:57:25.6
CAM-2 say again?

21:57:27.0
HOT-1 kill the strobes. just put it on steady or something.

21:58:14.8
HOT-1 trying to get a hold of approach to see uh if they're having any trouble on the approach but there might not be anybody in there.

21:58:23.1
RDO-1 Kingston Approach this is American three three one. check

21:58:30.8
APP-A American three three one Manley Radar.

21:58:33.2
RDO-1 yes sir we're still presently one hundred and twelve nautical miles from the airport understand that you have moderate rain shower on the approach. just wondering if any aircraft have been uh experiencing turbulence on the approach.

21:58:44.3
APP-A American three three one none reported.

21:58:47.5
RDO-1 none reported. have you had anybody land in the last hour?

21:58:52.3
APP-A okay stand by. let me just tell you the last aircraft that landed at the time...affirm we had one aircraft that landed in the la— at uh zero two zero three and he came in from Montego Bay. he came in from the the northwest and uh he didn't have any problems coming in. didn't have anybody from the north.

21:59:18.0
RDO-1 okay thank you and uh we'll talk to you in a few minutes. we're about a hundred uh and ten miles from the airport.

21:59:22.4
APP-A uh roger.

21:59:25.5
HOT-1 heh. he said none reported but then I said 'have you had any airplanes land in the last hour' and he goes 'uh let me check.' [sound of laughter]

21:59:33.8
HOT-1 [sound of laughter]

21:59:35.8
HOT-1 no wonder there's none reported. they had one airplane landed at thirty past. came in from Montego Bay.

21:59:44.5
HOT-2 so we got that going for us.

21:59:45.8
HOT-2 yeah.

21:59:48.3
HOT-1 one night I was doing— I was doing three approaches over top of Managua. Taca's up ahead of me you know. he— Taca finally lands. I'm coming in I say 'Taca when did you break out' and the guy goes 'ooy the weather's no good it— it's okay though it's no good oh it's okay.' I went 'no what altitude you break out at?' he goes 'oh it's okay.' [sound of laughter] [sound of gutteral noise] third go around you know.

22:00:12.8
HOT-2 I uh had the same thing on my I-O-E on the seven two going into uh San Pedro Sula with one of these Dallas guys he had no idea what was going on out there.

22:00:22.4
HOT-1 yeah he was—.

22:00:24.0
HOT-2 he was lost.

22:00:24.4
HOT-1 working hard.

22:00:25.6
HOT-2 so we were like— I was like you know I saw there was like a low pressure system moving into the area before we left Miami. figured we'd get there ahead of it. so I asked the guy. said 'you know what uh find out what the field condition. we're getting bounced all over the place.'

22:00:43.9
HOT-1 yeah.

22:00:44.5
HOT-2 you know it's one of those things where you got to do a teardrop entry alignment pattern.

22:00:48.7
HOT-1 oh yeah you got to come back all around. nasty.

22:00:53.0
HOT-2 yeah bounced around in the seven two and it was like uh so he says 'what are your field conditions?' he says 'well it's some rain. it's some clouds. it's okay.' [sound of laughter]

22:01:01.0
HOT-1 [sound of laughter] some rain. [sound of laughter] weather's okay.

22:01:08.0
HOT-2 so we did two approaches in there and ended up in San Salvador.

22:01:12.8
HOT-1 nice.

22:01:14.0
PA-3 ladies and gentlemen please remain in your—.

22:02:24.3
HOT-1 that's some good rain shower man sitting down here.

22:02:30.4
HOT-2 yeah go figure.

22:02:42.6
INT-1 hey I just want to make sure everybody stays seated for the rest of the flight okay...okay thank you...alrighty alrighty...bye.

22:03:26.1
APP-A American three three one call approach one twenty point six.

22:03:29.8
RDO-2 good day American three three one.

22:03:33.2
HOT-1 I'm gonna keep it slow as we get into this stuff.

22:03:35.0
HOT-2 yeah.

22:03:41.4
RDO-2 uh Kingston good evening American three three one. we're out of one niner zero for one five thousand.

22:03:59.0
APP-B American three three one Manley Radar.

22:04:01.9
RDO-2 Manley American three three one one eight zero for one five thousand.

22:04:06.5
APP-B American three three one Manley Radar. expect I-L-S approach runway one two. Q-N-H one zero one four descend and maintain five thousand.

22:04:17.5
RDO-2 descend and maintain uh five thousand American uh three three one.

22:04:21.1
HOT-1 down to five thousand.

22:04:21.6
APP-B American three three one affirm. be advised the information that was given to you by the onward controller is still the same. visibility five miles and there is moderate rain at the station.

22:04:34.0
RDO-2 five miles with rain American uh three three one.

22:04:37.7
APP-B American three three one you may have to circle to land. the wind uh three two zero degrees at one zero knots.

22:04:44.2
HOT-1 that's still good. we'll still land straight in.

22:04:47.4
RDO-2 understand that uh that— we can uh go ahead and uh take a straight in with that American three three one.

22:04:53.5
APP-B American three three one roger copy.

22:05:07.9
HOT-1 alright once you get above ten you can secure the heat.

22:05:13.3
HOT-2 alrighty.

22:05:14.1
HOT-1 and down to five thousand feet now.

22:05:18.0
HOT-2 five thousand set...got twelve degrees engine heat is off.

22:05:23.5
HOT-1 thank you.

22:05:32.7
HOT-2 and I don't know if we said this. transition level altimetres?

22:05:35.7
HOT-1 yes sir I got ten fourteen ten fourteen ten fourteen and lights are on.

22:05:39.3
HOT-2 alright.

22:05:41.3
PA-1 flight attendants prepare for landing.

22:05:44.2
HOT-2 P-A?

22:05:45.4
HOT-1 is complete.

22:05:46.7
HOT-2 before landing checklist.

22:05:47.9
HOT-? *.

22:06:02.5
HOT-1 okay I see yellow but I don't see any red.

22:06:04.9
HOT-1 how's that temperature look? I mean the uh one forty forty four?

22:06:08.1
HOT-2 okay we're looking good.

22:08:05.3
HOT-2 how about radios and displays?

22:08:08.9
HOT-1 I-M-L-Y one two zero inbound got uh one forty eight for ref. keep an eye on that...seven hundred pounds here. we should be alright. two seventy eight and ten fourteen.

22:08:21.4
HOT-2 very close.

22:08:24.8
HOT-2 alright set and checked.

22:08:26.1
HOT-1 reset and crosschecked.

22:08:28.8
HOT-2 set and crosschecked.

22:08:41.4
HOT-1 a little more drag.

22:09:40.6
HOT-1 having fun Peter?

22:09:43.2
HOT-2 enjoying it. it's been— like you said it's been one of those um— figure they paid for an airplane ride.

22:09:52.5
HOT-1 well they're gettin' one tonight.

22:09:52.9
HOT-2 they're complaining about all this stuff before. when they get there they'll be happy now.

22:09:57.2
HOT-1 yeah.

22:09:58.1
HOT-2 out of ten.

22:10:00.4
HOT-1 I just wish I was making about two hundred and fifty thousand dollars a year to do this every time I come to work you know.

22:10:05.1
HOT-2 exactly.

22:10:44.0
HOT-2 HUD?

22:10:45.6
HOT-1 HUD is set...think it is.

22:11:22.0
HOT-1 when we get down here to five thousand we're gonna be limited on our—.

22:11:26.0
HOT-2 I'm sorry?

22:11:26.3
HOT-1 when we get down here to five thousand we're gonna be limited on our turns.

22:11:27.7
HOT-2 yeah...right.

22:11:30.7
HOT-1 gonna have to keep it nice and slow.

22:12:08.9
HOT-1 that thing's gonna come— bring us in offset and I'm gonna have to fly the instruments all the way down. so when we break out the runway's gonna be to the left.

22:12:18.6
HOT-2 okay.

22:12:25.5
HOT-1 one to go.

22:12:27.9
HOT [sound of altitude alert]

22:12:30.6
HOT-2 six for five.

22:13:08.8
HOT-1 looks like it's just on the other end of it. on the other side of it it's clear.

22:13:11.6
HOT-2 yeah...exactly.

22:13:14.1
HOT-1 that's # up.

22:13:50.7
HOT-1 how are we looking on that weight?

22:13:56.0
HOT-1 *.

22:13:56.1
HOT-2 five hundred pounds to go.

22:14:00.1
HOT-2 looks like you're gonna— you're gonna make it but uh showing we're gonna burn uh six hundred so we're not going to make it by much.

22:14:10.3
HOT-1 yeah.

22:14:16.6
HOT-1 wanna ask this guy after KEYNO if we're cleared for the approach. he's never said anything to us.

22:14:22.5
HOT-2 alright.

22:14:34.7
APP-B American three three one descend and maintain four thousand. at KEYNO cleared straight in I-L-S approach runway one two. be advised wind now three two zero degrees at one five knots.

22:14:44.8
HOT-1 okay.

22:14:47.4
RDO-2 okay after uh— descend down to four thousand now and uh after KEYNO cleared for the I-L-S runway one two American three three one.

22:14:56.7
APP-B American three three one uh affirm and uh did you copy the wind three two zero degrees at one four knots. are you able to still land uh make a straight in approach runway one two?

22:15:07.0
HOT-1 yes sir. flaps one.

22:15:07.7
RDO-2 we copy the wind and we can go straight in to one two.

22:15:11.4
HOT [sound of altitude alert]

22:15:12.5
APP-B roger.

22:15:13.6
HOT-2 below two forty flaps one. let me uh—.

22:15:18.5
CAM [sound similar to trim-in-motion]

22:15:22.7
HOT-1 let's bring it flaps five.

22:15:26.0
HOT-2 still below two forty going to flaps five.

22:15:26.7
CAM [sound similar to flap handle movement]

22:15:28.3
CAM [sound similar to trim-in-motion]

22:15:35.9
HOT-1 can't even see # with that— all that radar in there.

22:15:37.7
CAM [sound similar to trim-in-motion]

22:15:58.8
CAM [sound similar to trim-in-motion]

22:16:10.3
HOT-2 four thousand feet set uh...two thousand if you want to do a V-NAV now.

22:16:17.2
HOT-1 yeah you can set two thousand in there

22:16:33.4
CAM [sound similar to trim-in-motion]

22:16:41.5
HOT-1 go flaps ten.

22:16:44.2
HOT-2 below two ten flaps ten. CIBUG at twenty eight— above twenty eight hundred.

22:16:45.4
CAM [sound similar to flap handle movement]

22:16:48.9
HOT-1 twenty eight hundred?

22:16:49.9
HOT-2 yeah.

22:16:50.1
HOT-1 uh get on em.

22:16:50.4
HOT-2 uh af— if you want to go L-NAV I—.

22:16:52.1
HOT-1 let's go twenty eight hundred until I get to it.

22:16:54.0
HOT-2 yeah.

22:16:56.8
HOT-2 alright.

22:16:56.8
HOT-1 it's not gonna pick up the approach just yet.

22:16:57.7
HOT [sound of altitude alert]

22:17:14.5
APP-B American three three one contact the tower one one eight decimal six five good day.

22:17:14.8
CAM [sound similar to trim-in-motion]

22:17:19.2
RDO-2 eighteen sixty five good night American three three one.

22:17:25.0
TAWS twenty five hundred.

22:17:31.6
RDO-2 Manley Tower good evening American three three one's with you. we are level inbound on the ILS runway one two. level twenty eight hundred.

22:17:41.6
TWR American three three one wind three two zero degrees one two knots. confirm still requesting runway one two.

22:17:42.7
CAM [sound similar to trim-in-motion]

22:17:47.0
HOT-1 yes ma'am.

22:17:48.0
RDO-2 uh that's affirmative. uh say again the wind.

22:17:48.2
HOT [sound of altitude alert]

22:17:50.8
HOT-1 what'd she say this last time?

22:17:52.0
TWR three two zero now at one four knots.

22:17:54.3
HOT-1 that's good.

22:17:55.2
RDO-2 that's affirmative uh runway one two.

22:17:57.5
TWR American three three one clear to land runway one two. be advised runway wet.

22:18:01.2
RDO-2 thank you.

22:18:03.2
HOT-2 runway's wet you want to go to brakes three perhaps?

22:18:06.2
HOT-1 yeah let's do that. brakes three.

22:18:07.4
HOT-2 little tailwind.

22:18:09.1
HOT-1 yup localizer capture.

22:18:25.8
HOT-2 alright we're two hundred pounds above— one hundred pounds above the uh landing weight. so we're looking not too bad.

22:18:32.5
HOT-1 s'go gear down. flaps fifteen.

22:18:35.3
CAM [sound similar to trim-in-motion]

22:18:36.4
CAM [sound similar to landing gear deployment]

22:18:37.5
CAM [sound similar to flap handle movement]

22:18:43.4
HOT-2 below two hundred knots flaps fifteen. speedbrakes?

22:18:46.3
HOT-1 speedbrake is armed with a green light.

22:18:47.5
HOT-2 armed green light.

22:18:48.9
CAM [sound similar to trim-in-motion]

22:18:54.0
TAWS twenty five hundred.

22:18:55.4
HOT-1 let's go flaps twenty five.

22:18:57.0
CAM [sound similar to trim-in-motion]

22:18:58.1
HOT-1 trying to burn up a little bit of it.

22:18:58.4
CAM [sound similar to flap handle movement]

22:18:58.9
HOT-2 below one ninety flaps twenty five.

22:19:02.6
HOT-1 and flaps thirty.

22:19:04.5
HOT-2 below one seventy five.

22:19:04.8
HOT-1 set missed approach altitude.

22:19:06.0
CAM [sound similar to flap handle movement]

22:19:07.9
HOT-2 missed approach altitude is set three thousand.

22:19:11.9
CAM [sound similar to trim-in-motion]

22:19:12.6
HOT-1 landing gear down and green.

22:19:15.8
HOT-2 down and green. flaps?

22:19:20.0
HOT-1 thirty thirty and green light.

22:19:21.8
HOT-2 thirty thirty green light.

22:19:32.8
HOT-2 alright...before landing checklist is complete.

22:19:40.5
HOT-2 I can give you the wipers if you like.

22:19:50.1
HOT-2 I've got ground contact.

22:19:53.6
HOT-1 no runway though.

22:19:54.9
HOT-2 no runway yet.

22:19:56.5
CAM [sound similar to trim-in-motion]

22:20:00.6
CAM [sound similar to windscreen wipers]

22:20:26.4
CAM [sound similar to trim-in-motion]

22:20:32.1
TAWS one thousand.

22:20:32.8
HOT-1 let me know when you see it Pedro.

22:20:34.0
HOT-2 alright um before landing checklist is complete.

22:20:37.6
HOT-1 alright.

22:20:39.8
RDO-2 and American uh three three one we're on a three mile final.

22:20:46.0
TWR American three three one landing clearance still valid. cleared to land runway one two.

22:20:49.9
RDO-2 thank you.

22:20:50.5
HOT-2 just wanted to check. cleared to land she says.

22:20:55.5
HOT-2 runway's in sight.

22:20:56.7
HOT-1 alright.

22:21:00.2
HOT-1 autopilot's comin' off.

22:21:00.8
HOT [sound similar to autopilot disconnect warning]

22:21:07.5
TAWS five hundred.

22:21:08.3
HOT-2 you're on speed sinking eight.

22:21:16.4
TAWS plus hundred.

22:21:24.8
TAWS minimums.

22:21:26.6
HOT-2 on speed sinking eight.

22:21:27.1
CAM [sound similar to trim-in-motion]

22:21:38.8
TAWS one hundred.

22:21:43.0
TAWS fifty.

22:21:44.6
TAWS forty.

22:21:46.0
CAM [sound of click]

22:21:46.5
TAWS thirty.

22:21:48.9
TAWS twenty.

22:21:52.4
TAWS ten.

22:21:56.0
CAM [sound similar to speedbrake motor]

22:21:56.1
CAM [sound of three clicks]

22:21:57.2
HOT-2 deployed.

22:21:58.2
CAM [sound similar to nose gear touchdown]

22:22:00.4
CAM [sound similar to thrust reversers]

22:22:06.8
HOT-2 autobrakes are off.

22:22:11.7
HOT-1 we're not stopping man.

22:22:15.3
HOT-1 come on baby.

22:22:17.7
HOT-1 aw #.

22:22:18.3
HOT-2 #.

22:22:19.3
HOT-? [sound of grunt]

22:22:20.4
HOT-? # no.

22:22:21.1
CAM [sounds of impact]

22:22:22.0
END OF TRANSCRIPT
END OF RECORDING

APPENDIX 3

Kingston ATC Transcripts: En route, Approach and Tower
Kingston Air Traffic Control Centre

Transcript of Voice Recordings
Accident AA331, 23 December 2009

Part 1 Of 3 En route Control

TIME	CHANNEL	STATION	TRANSMISSON
02:47:00	128.1	AAL331	Ah….Kingston Control, good evening American Tree Tree One..
:03	"	Kingston Enr	American Tree Tree One Kingston Radar….
:05	"	AAL331	Kingston American Tree Tree One we're level tree seven zero, we are eight zero miles north of position TOTON…..
:13	"	Kingston Enr	American Tree Tree One Kingston Radar, radar contact maintain flight level tree seven zero proceed TOTON Direct to KEYNO….
:19	"	AAL331	TOTON direct KEYNO, American Tree Tree One and ah… it…is it possible for you to give us the aah…weather at Kings…. Manley….
:27	"	Kingston Enr	Roger sir, give me one minute, okay…
:30	"	AAL331	Thank you….
02:48:28	"	Kingston Enr	American Tree Tree One…copy aah.. Manley's field conditions…
:32	"	AAL331	Go ahead please……

TIME	CHANNEL	STATION	TRANSMISSON
02:48:33	128.1	Kingston Enr	Wind at the station is tree one zero degrees at aah..seven and a half knots the visibility is approximately five miles ah….present weather there's a moderate shower at station… the temperature is two one, dew point two zero the QNH is one zero one four… understand that there's also a broken clouds at one thousand feet…..
02:49:03	“	AAL331	Okay, understand that ..understand the wind you say was aah.. Tree one zero seven.. Thank you….
:08	“	Kingston Enr	And aah.. Tree Tree One affirm…
02:51:13			And Kingston American Tree Tree One we're back with you tree seven zero aah.. Havana has aah..authorized lower, we would like to start our descent now if it's okay with you…..
			Station calling Kingston say again aah… your request…..
:31	“	AAL331	Aah….Kingston it's American aah…Tree Tree One we're level tree seven zero aah… Havana's ... switched us over to you and aah... they've authorized lower and we'd like to request aah… start to descend now….
:36		Kingston Enr	American Tree Tree One descend your discretion one five thousand QNH at Manley One Zero One Four…

KATCC Transcript of Voice Recordings – Accident AAL331 Part 1- Enroute Control Page 2 of 3

TIME	CHANNEL	STATION	TRANSMISSON
02:51:56	128.1	AA331	Okay one…aah…pilot's discretion one five thousand, American aah.. Tree Tree One…..
02:52:01	"	Kingston Enr	American Tree Tree One affirm…
03:03:40	"	Kingston Enr	American Tree Tree One call Approach One Twenty point six…
:43	"	AA331	Good day, American Tree Tree One…

KATCC Transcript of Voice Recordings – Accident AAL331 Part 1- En route Control
Page 3 of 3

Kingston Air Traffic Control Centre Transcript Of Voice Recordings Accident Aal331, December 23, 2009 (UTC)

Part 2 Of 3 Approach Control

TIME	CHAN NEL	STATION	TRANSMISSON
02:55:25	“	AAL331	Kingston Approach, American Three Three One….
:41		AAL331	Kingston Approach, American Three Three One.
		AAL331	Kingston Approach, this is American Three Three One….
		Manley APP	American Three Three One, Manley Radar…..
		AAL331	Yes Sir, we're still presently a hundred and twelve nautical miles from the airport. Understand, that you have moderate rain showers on the approach Just wondering if any aircraft have been experiencing turbulence on the approach….
		Kingston Enr	American Tree Tree One, none reported. None reported. Have you had anybody land in the last hour?
			Ok, standby, let me just tell you the last aircraft that landed and the time ..
			Affirm we had one aircraft that landed in the la.. at zero two zero three and he came in from Montego Bay, came in from the the northwest and ah.. he didn't have any problems coming in .. didn't have any body from the north….

KATCC Transcript of Voice Recordings – Accident AAL331 Part 2 – Approach Control

TIME	CHANNEL	STATION	TRANSMISSON
02:59:31	120.6	AAL331	OK thank you and ah we'll talk to you in few minutes. We're about a hundred ah and ten miles from the airport ….
:37	“	Manley APP	Ah roger…..
03:03:55	“	AAL331	Kingston good evening American Tree Tree One we're out of one niner zero for one five thousand…
03:04:13	“	Manley APP	American Tree Tree One Manley
:15		AAL331	Radar... Manley, American Three
:20	“	Manley APP	Three One One eight zero for one five thousand…
:31		AAL331	American Tree Tree One..aah..Manley Radar expect ILS Approach runway one two QNH one zero one four descend and maintain five thousand…
:36	“	Manley APP	Descend maintain ah…five thousand American ah… Tree Tree One…
:48	“	AAL331	American Tree Tree One affirm be advised the information that was given to you by the enroute controller is still the same visibility five miles and there is moderate rain at the station…
:51		Manley APP	Five miles of rain…American ah… Tree Tree One
03:05:01		AAL331	American Tree Tree One you may have to circle to land the wind is tree two zero degrees at one zero knots…
			Understand that, aah… that we can ah… go ahead and ah… take a straight-in with that American Tree Tree One…

TIME	CHANNEL	STATION	TRANSMISSON
03:05:07	120.6	Manley APP	American Tree Tree One roger copied…
03:14:48	“	Manley APP	American Tree Tree One descend and maintain four thousand at KEYNO cleared straight-in ILS Approach runway one two…be advised the wind’s now tree two zero degrees at one five knots..
03:15:01	“	AAL331	Okay after ah… descend down to four thousand now and ah...after KEYNO cleared for the ILS runway one two… American…. Three Three One…
:11	“	Manley APP	American Tree Tree One…affirm and ah.. did you copy the wind tree two zero degrees at one four knots. Are you able to still land ah.. to make a straight-in approach runway one two?....
:21	“	AAL331	Er….we copied the wind and we can go straight-in to one two…
:26	“	Manley APP	Roger…..
03:17:28	“	Manley APP	American Tree Tree One contact the Tower one one eight decimal six five good day…
:33		AAL331	Eighteen sixty five good night…American Tree Tree One…..

TRANSCRIPT: 118.65 MHZ (Manley Tower Frequency)

Record Playback: Start Time – 12/23/09 02:38:24Z & Stop Time – 12/23/09 03:48:14Z

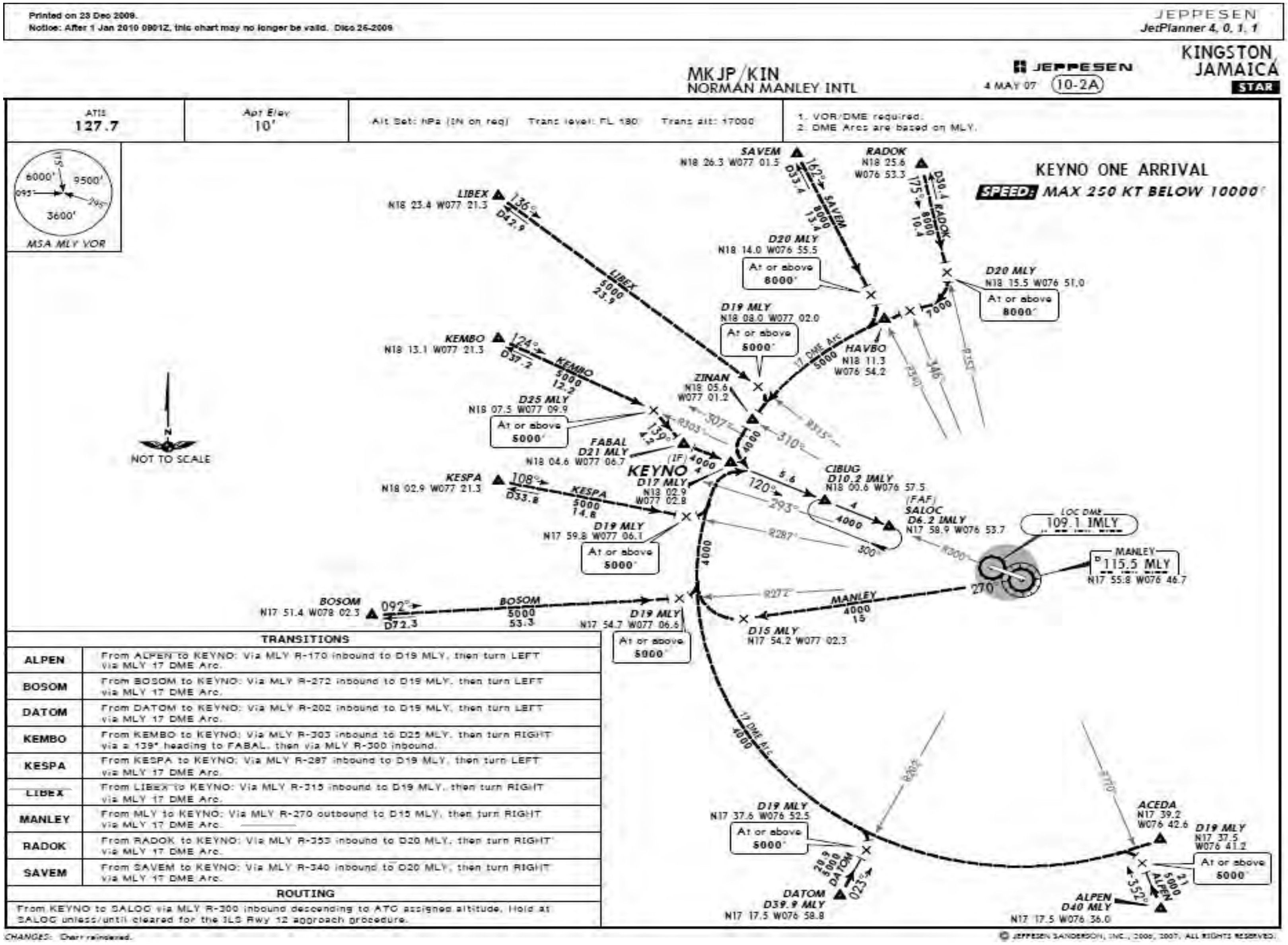
RE: ACCIDENT: AAL 331 – DECEMBER 23, 2009

TIME	FREQUENCY	STATION	TRANSMISSON
03:17:32	**118.65**	AAL331	Manley Tower good evening American three three one is with you… we are… level… inbound on the ILS runway one two….level twenty eight hundred feet.
:42	"	MLY TWR	American three three one wind three two zero degrees at one two (*fades out*) confirm still requesting runway one two (*fades out*
:48	"	**AAL331**	That's affirmative; ah… say again the wind?
:52	"	MLY TWR	Three two zero…now at one four knots.
:54	"	**AAL 331**	That's affirmative… ahh runway one two.
:57	"	MLY TWR	American three three one cleared to land runway One two… be advised runway wet.
03:18:00	"	**AAL331**	Thank you
03:20:40	"	"	And American three three one… we are on three mile final.
:46	"	MLY TWR	American three three one landing clearance still valid, cleared to land runway one two.
03:22:16	"	**AAL 331**	(*Noise in background*) (expletive) nnnnoo… (expletive)…aah… (expletive) nnn
:40	"	ACFT 628	Manley Tower aircraft six two eight
03:23:01	"	ACFT 628	Manley Tower aircraft six two eight?
:04	"	MLY TWR	Six two eight standby

APPENDIX 4

Jeppesen Approach Plates for Kingston MKJP/KIN

1. **MKJP: KEYNO ONE ARRIVAL.**
2. **MKJP: Airport Information.**
3. **MKJP: Page 10-9 Runway Information.**
4. **MKJP: Page 11-1 ILS Runway 12.**
5. **MKJP: Page 12-2 RNAV (GPS) Runway 30.**


Printed on 23 Dec 2009.
Notice: After 1 Jan 2010 0901Z, this chart may no longer be valid. Disc 26-2009
JEPPESEN
JetPlanner 4, 0, 1, 1
MKJP/KIN
NORMAN MANLEY INTL
JEPPESEN
4 MAY 07
10-2A
KINGSTON, JAMAICA
STAR
ATIS 127.7
Apt Elev 10'
Alt Set: hPa (IN on req) Trans level: FL 180 Trans alt: 17000
1. VOR/DME required.
2. DME Arcs are based on MLY.
MSA MLY VOR
6000'
9500'
3600'
KEYNO ONE ARRIVAL
SPEED: MAX 250 KT BELOW 10000'
NOT TO SCALE
SAVEM N18 26.3 W077 01.5
RADOK N18 25.6 W076 53.3
LIBEX N18 23.4 W077 21.3
KEMBO N18 13.1 W077 21.3
KESPA N18 02.9 W077 21.3
BOSOM N17 51.4 W078 02.3
D20 MLY N18 14.0 W076 55.5
D20 MLY N18 15.5 W076 51.0
D19 MLY N18 08.0 W077 02.0
HAVBO N18 11.3 W076 54.2
ZINAN N18 05.6 W077 01.2
D25 MLY N18 07.5 W077 09.9
FABAL D21 MLY N18 04.6 W077 06.7
KEYNO D17 MLY N18 02.9 W077 02.8
CIBUG D10.2 IMLY N18 00.6 W076 57.5
(FAF) SALOC D6.2 IMLY N17 58.9 W076 53.7
LOC DME 109.1 IMLY
MANLEY 115.5 MLY N17 55.8 W076 46.7
D19 MLY N17 59.8 W077 06.1
D19 MLY N17 54.7 W077 06.6
D15 MLY N17 54.2 W077 02.3
D19 MLY N17 37.6 W076 52.5
DATOM D39.9 MLY N17 17.5 W076 58.8
ACEDA N17 39.2 W076 42.6
D19 MLY N17 37.5 W076 41.2
ALPEN D40 MLY N17 17.5 W076 36.0
At or above 8000'
At or above 5000'
TRANSITIONS
ALPEN From ALPEN to KEYNO: Via MLY R-170 inbound to D19 MLY, then turn LEFT via MLY 17 DME Arc.
BOSOM From BOSOM to KEYNO: Via MLY R-272 inbound to D19 MLY, then turn LEFT via MLY 17 DME Arc.
DATOM From DATOM to KEYNO: Via MLY R-202 inbound to D19 MLY, then turn LEFT via MLY 17 DME Arc.
KEMBO From KEMBO to KEYNO: Via MLY R-303 inbound to D25 MLY, then turn RIGHT via a 139° heading to FABAL, then via MLY R-300 inbound.
KESPA From KESPA to KEYNO: Via MLY R-287 inbound to D19 MLY, then turn LEFT via MLY 17 DME Arc.
LIBEX From LIBEX to KEYNO: Via MLY R-315 inbound to D19 MLY, then turn RIGHT via MLY 17 DME Arc.
MANLEY From MLY to KEYNO: Via MLY R-270 outbound to D15 MLY, then turn RIGHT via MLY 17 DME Arc.
RADOK From RADOK to KEYNO: Via MLY R-353 inbound to D20 MLY, then turn RIGHT via MLY 17 DME Arc.
SAVEM From SAVEM to KEYNO: Via MLY R-340 inbound to D20 MLY, then turn RIGHT via MLY 17 DME Arc.
ROUTING
From KEYNO to SALOC via MLY R-300 inbound descending to ATC assigned altitude. Hold at SALOC unless/until cleared for the ILS Rwy 12 approach procedure.
CHANGES: Chart reindexed.
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REVISION LETTER For Disc 25-2009
Printed on 23 Dec 2009.

JEPPESEN
JetPlanner 4, 0, 1, 1

Page 1
Changed chart(s) since Disc 24-2009
ADD = Added chart, REV = Revised chart, DEL = Deleted chart.

ACT	PROCEDURE IDENT	INDEX	REV DATE	EFF DATE

No revision activity since Disc 24-2009

Airport Information
MKJP (Norman Manley Intl)

JEPPESEN
JetPlanner 4, 0, 1, 1

General Info

, JAM
N 17° 56.13' W 76° 47.25' Mag Var: 5.7°W
Elevation: 10'

Public, Control Tower, IFR, No Fee, Rotating Beacon, Customs
Fuel: 100-130, Jet A-1
Repairs: Minor Airframe, Minor Engine

Time Zone Info: Bogota, Lima, Quito Time GMT-5:00 no DST

Runway Info

Runway 12-30 8911' x 151' asphalt

Runway 12 (117.0°M) TDZE 8'
Lights: Edge, ALS
Right Traffic
Runway 30 (297.0°M) TDZE 17'
Lights: Edge, ALS

Communications Info

ATIS **127.7**
Manley Tower Tower **118.65**
Manley Ground Ground Control **121.7**
Manley Approach Approach Control **120.6** Arrival Service
Kingston TMA **128.1**
Kingston TMA **125.4**

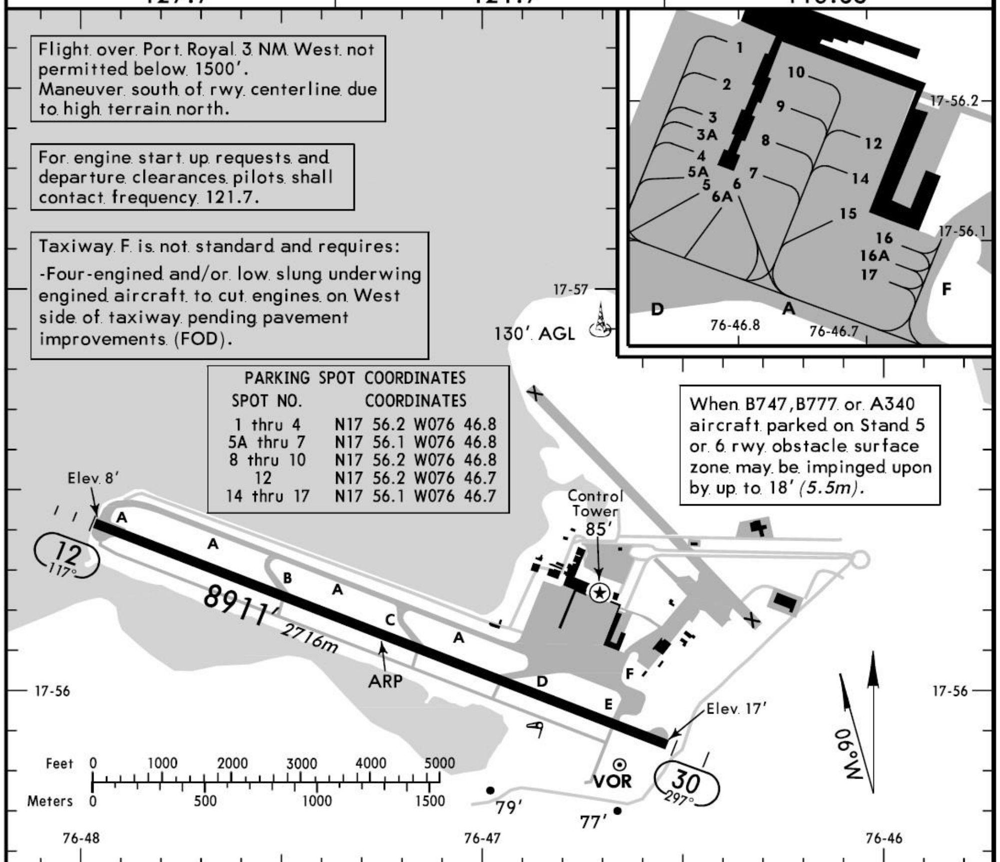
Notebook Info

MKJP/KIN — *Apt Elev* **10′** — N17 56.1 W076 47.3

JEPPESEN — 22 AUG 08 — (10-9)

KINGSTON, JAMAICA
NORMAN MANLEY INTL

ATIS	*MANLEY Ground	Tower
127.7	121.7	118.65



RWY	ADDITIONAL RUNWAY INFORMATION	USABLE LENGTHS — LANDING BEYOND — Threshold	Glide Slope	TAKE-OFF	WIDTH
12 / 30	HIRL SALS REIL PAPI (angle 3.0°)		7884′ *2403m*		150′ *46m*

TAKE-OFF & DEPARTURE PROCEDURE

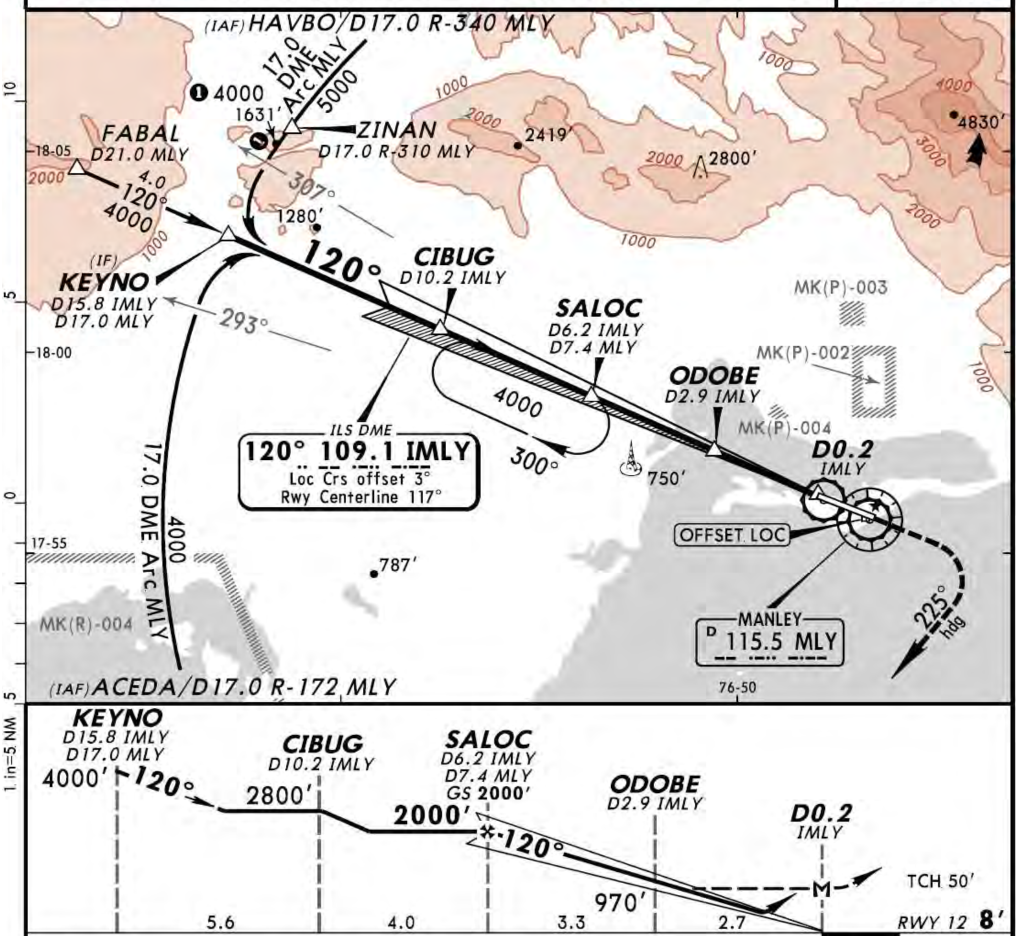
	All Rwys
1 & 2 Eng	*1.9 km*
3 & 4 Eng	*930m*

FOR FILING AS ALTERNATE

A B	1100 -*3.2 km*
C D	1100 -*5.6 km*

DEPARTURE PROCEDURE: Rwy 12, climb on runway heading to minimum 200′ then make a climbing RIGHT turn and proceed in accordance with ATC instructions.
Rwy 30, proceed in accordance with ATC instructions.

CHANGES: Tower frequency.



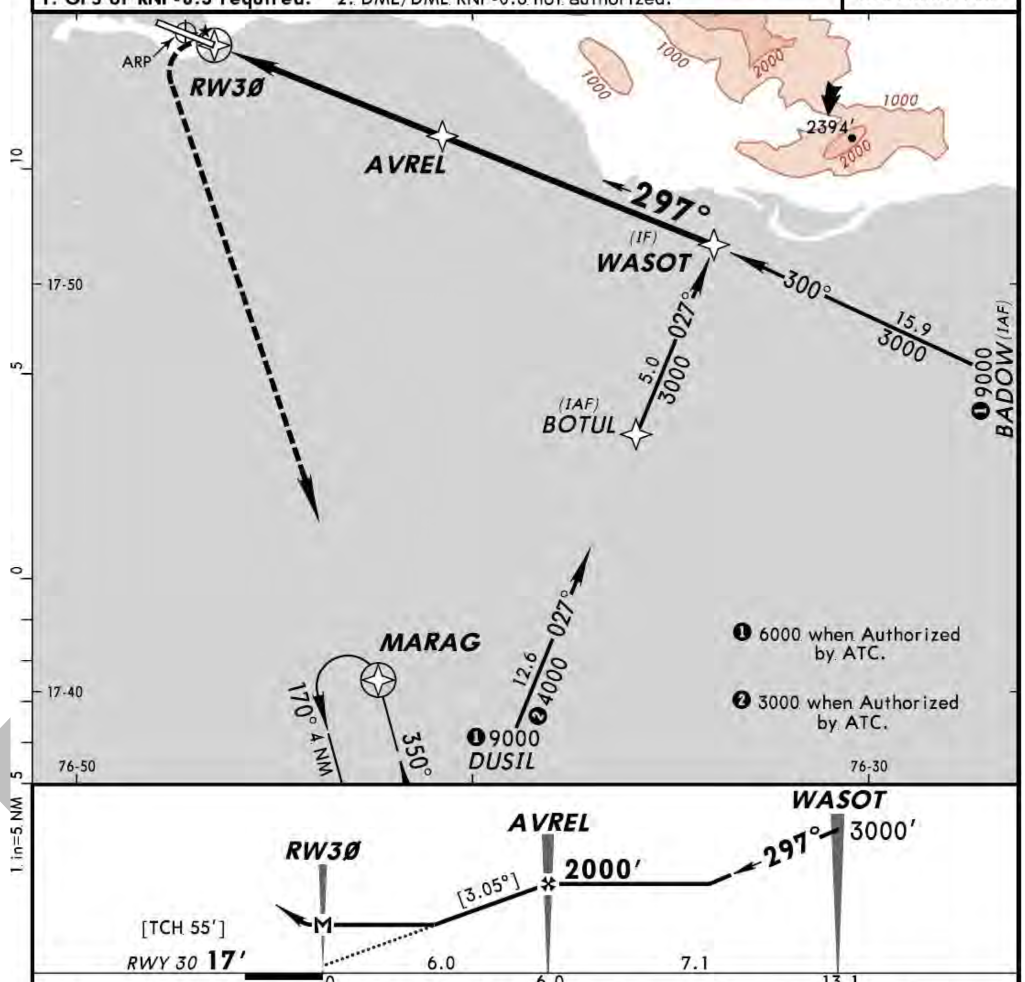
Gnd speed-Kts		70	90	100	120	140	160
GS	3.00°	377	484	538	646	753	861
MAP at D0.2 IMLY or SALOC to MAP	6.0	5:09	4:00	3:36	3:00	2:34	2:15

SALS
REIL
PAPI — PAPI
1000′

	STRAIGHT-IN LANDING RWY 12 ILS DA(H) 278′(270′) FULL	ALS out	LOC (GS out) MDA(H) 328′(320′)	ALS out	Max Kts	CIRCLE-TO-LAND Not Authorized North of Extended Rwy Centerline MDA(H)
A	1.9 Km		1.9 Km		100	1050′(1040′)-1.9 Km
B			2.3 Km		135	1050′(1040′)-2.8 Km
C			2.8 Km		180	1150′(1140′)-3.7 Km
D			3.2 Km		205	1150′(1140′)-4.6 Km

PANS OPS

CHANGES: Tower frequency.



Gnd speed-Kts	70	90	100	120	140	160
Descent angle [3.05°]	378	486	540	648	755	863
MAP at RW3Ø						

SALS, REIL, PAPI__PAPI — 3000' LT — MARAG

	STRAIGHT-IN LANDING RWY 30 LNAV MDA(H) 390'(373')	Max Kts	CIRCLE-TO-LAND Not Authorized North of Extended Rwy Centerline MDA(H)
A	1.9 Km	100	1050'(1040')-2.3 Km
B	1.9 Km	135	1050'(1040')-2.8 Km
C	2.3 Km	180	1150'(1140')-5.6 Km
D	2.3 Km	205	1150'(1140')-5.6 Km

ALS out

PANS OPS

CHANGES: Tower frequency.

APPENDIX 5

AA Flight Manual Part II, Kingston MKJP Page 10-7X

AMERICAN AIRLINES

KINGSTON, JAMAICA
NORMAN MANLEY INTL
(ICAO) MKJP (ATA) KIN

10-7X 11 JUL 08

FLIGHT MANUAL PART II
SO AM/CARIBBEAN COVERAGE

GENERAL

NOTES

KIN is a one runway airport. Tropical weather, possible navigational aid unreliability, and distance to alternate airports makes careful review of fuel requirements mandatory.

Pilots are required to wear a reflective vest while performing walk-around. The security lead agent who meets the aircraft will provide the vest at the jetbridge or aircraft stairs and collect it when walk-around is complete.

Frequencies - Operations 131.4

ARRIVAL

CAUTIONS

All aircraft maneuvering, if required, must be done south of airport due to high terrain / obstacles northwest, north and northeast of field.

VFR training areas west and south of airport below 5000'.

Runway is uneven and subject to pools of standing water after heavy rain.

NOTES

Due to localizer offset, the HUD runway outline is not coincident with the actual runway.

Requests for weather / route deviations greater than 4 NM from published routes inbound to KIN may require additional time for ATC to coordinate. Plan ahead. Exercise caution.

Prevailing winds are southeast. Runway 12 landings in the afternoon can expect windshear approaching the threshold.

Ceilings and visibility from ATC are "estimated" values.

Ramp area is dark and when wet, objects / personnel difficult to see.

Alternate Airports	ICAO	ATA	NM
Montego Bay, Jamaica	MKJS	MBJ	73
Port-Au-Prince, Haiti	MTPP	PAP	259
Grand Cayman	MWCR	GCM	284

Change: Arrival notes

Imaged by Jeppesen.

APPENDIX 6

American Airlines 737 Operating Manual – Performance Section

Bulletin No. 737-07, Date 11-27-06
Landing Performance Check

AA737 Operating Manual

AA

737 Operating Manual - Performance Section

BULLETIN

Subject: Landing Performance Check	**No.** 737-07
	Date 11-27-06

File: Replace Performance Section Bulletin 737-06 with this bulletin filed at PERFORMANCE - LANDING in front of page 1

This bulletin replaces Performance Section Bulletin 737-06, the only changes are the crosswind limits on the attached Wind Component and Landing Data Card.

Introduction

This bulletin expands the landing distance data and issues a new Braking Action definitions chart. This data and information is issued to comply with new FAA recommendations to check runway length before landing, using the actual reported conditions.

This bulletin includes a revised Wind Component and Landing Data Card to replace the current card in the appendix, and a revised Braking Action chart.

Landing Performance

The new FAA recommendation is to confirm landing performance limits just prior to landing, using the actual runway conditions at time of landing.

If the landing conditions, from the time of dispatch do not change, there is no need to do this assessment, because the requirements for dispatch are sufficient to assure adequate performance at time of landing.

However if conditions change, or deteriorate, the flight crew should use the charts on the revised Wind Component and Landing Data Card (attached to this bulletin) to confirm adequate runway length for landing. This assessment must take into account the meteorological conditions affecting landing performance (airport pressure altitude, wind velocity, wind direction, etc.), surface condition of the runway to be used for landing, approach speed, airplane weight and configuration, and planned use of airplane ground deceleration devices.

Runway Surface Conditions

This new landing data is expanded with runway surface condition. The conditions are expressed as reported braking action; Dry, Wet/Good, Medium/Fair, and Poor. Braking action "Nil" is not shown because landing is prohibited in this case.

Runway surface conditions may be reported using several types of descriptive terms including; type and depth of contamination, a reading from a runway friction measuring device, an airplane braking action report, or an airport vehicle braking condition report.

Distribution: List 654 and all 737 Captains and F/Os

AA737 Operating Manual

Bulletin 737-07
Page 2
11-27-06

Because friction measurements have not been found consistently reliable by the FAA, flight crews cannot base the calculation of landing distance solely on runway friction meter readings. If Mu is the only information provided, attempt to ascertain the depth and type of runway contaminants to make a better assessment of actual conditions.

Likewise, because pilot braking action reports are subjective, flight crews must use good judgment in using them to predict the stopping capability of their airplane.

Also, runway conditions can degrade or improve significantly in very short periods of time dependent on precipitation, temperature, usage, and runway treatment and could be significantly different than indicated by the last report. **Flight crews must consider all available information, including runway surface condition reports, braking action reports, and friction measurements.**

The flight crew must use the **most adverse reliable and appropriate braking action report or the most adverse expected conditions** for the runway, or portion of the runway, that will be used for landing when assessing the required landing distance prior to landing.

For example, if the braking action is reported as “medium to poor”, then “poor” braking action must be used in computing required landing distance, because it is the most adverse reported braking action. However, one must consider the following factors in assessing runway condition reports:

- Age of the report,
- Meteorological conditions present since the report was issued,
- Type of airplane or device used to obtain the report,
- Whether the runway surface was treated since the report, and
- The methods used for that treatment.

Flight crews are expected to use good judgment in determining the applicability of this information to their airplane's landing performance.

Landing Data

The landing data on the revised Wind Component and Landing Data Card uses the FAR dispatch required runway length, for runway conditions Dry and Wet/Good, without credit for reverse thrust. However for Medium/Fair and Poor runway conditions, the data on the card is only based on expected landing distance, with reverse thrust, and a 15% margin. **It is imperative to understand the criteria used in calculating these tables to effectively use them in conjunction with good pilot judgment.**

To summarize, the data on the Wind Component and Landing Data Card is based on:

- Dry or Wet/Good runway conditions
  - FAR demonstrated landing distance on dry runway plus 67% (92% wet) margin.
  - Maximum Manual braking without reverse thrust.
  - Includes demonstrated “air distance” from runway threshold to touchdown.

AA737 Operating Manual

Bulletin 737-07
Page 3
11-27-06

- Medium/Fair or Poor runway conditions
  - Manufacturer's estimated landing distance plus 15% margin.
  - Maximum manual braking (or Max autobrakes, whichever is longer) **with** normal reverse thrust.
  - Includes 1000 feet "air distance" from threshold to touchdown

Chart Use

Enter the chart for the Landing Flap setting with Pressure Altitude (Field Elevation) and anticipated Landing Gross Weight. Interpolate for Pressure Altitude and Landing Gross Weight if necessary. Determine the Required Runway Landing Length for the runway surface condition.

If the visibility is less than ¾ mile (RVR 4000), use the Wet/Good braking action column, unless the Medium/Fair or Poor braking action apply.

Apply any applicable corrections.

Braking Action Chart

This bulletin introduces a revised Braking Action chart. It not only defines the various levels of braking action, but also shows the correlation with various runway surface conditions. This chart was developed by the airline industry to standardize definitions.

To harmonize phraseology with terms used outside of the U.S., it was decided to replace "Fair" with "Medium". The FAA will phase in this change over the winter. During this period, both terms may be used.

Pireps

When braking action conditions less than "Good" are encountered, pilots are expected to provide a PIREP based on the definitions provided in the table. Until FAA guidance materials are revised to replace the term "Fair" with "Medium", these two terms may be used interchangeably. The terms "Good to Medium" and "Medium to Poor" represent an intermediate level of braking action, not a braking action that varies along the runway length. If braking action varies along the runway length, such as the first half of the runway is "Medium" and the second half is "Poor", clearly report that in the PIREP (e.g., "first half Medium, last half Poor").

Correlating Expected Runway Conditions

The correlation between different sources of runway conditions (e.g., PIREPs, runway surface conditions and Mu values) are estimates. Under extremely cold temperatures or for runways that have been chemically treated, the braking capabilities may be better than the runway surface conditions estimated below. When multiple sources are provided (e.g., braking action medium, runway covered with ice and runway Mu is 27/30/28) conflicts are possible. If such conflicts occur, consider all factors including data currency and the type of airplane a PIREP was given from. A valid PIREP or runway surface condition report are more reliable indicators of what to expect than reported runway Mu values.

AA737 Operating Manual

Bulletin 737-07
Page 4
11-27-06

Runway Friction Mu (μ) Reports

Mu values in the U.S. are typically shown as whole numbers (40) and are equivalent to the ICAO standard decimal values (.40). Zero is the lowest friction and 100 is the highest Mu friction. When the Mu value for any one-third zone of an active runway is 40 or less, a report should be given to ATC by airport management for dissemination to pilots. The report will identify the runway, the time of measurement, the type of friction measuring device used, Mu values for each zone and the contaminant conditions (e.g., wet snow, dry snow, slush, deicing chemicals).

While the table includes information published by ICAO correlating runway friction measurements to estimated braking actions, the FAA cautions that **no reliable correlation exists**. Runway Mu values **can vary significantly** for the same contaminant condition due to measuring techniques, equipment calibration, the effects of contamination on the friction measuring device and the time passage since the measurement. **Do not** base landing distance assessments solely on runway Mu friction reports. If Mu is the only information provided, attempt to ascertain the depth and type of runway contaminants to make a better assessment of actual conditions.

Braking Action Chart

Braking Action		Estimated Correlations		
			ICAO	
Term	Definition	Runway Surface Condition	Code	Mu (μ)
Good	Braking deceleration is normal for the wheel braking effort applied. Directional control is normal.	• Standing Water depth of 1/8" or less • Dry snow less than 3/4" in depth • Compacted snow with OAT at or colder than -15°C	5	40 & above
Medium (Fair)	Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be slightly reduced.	• Dry snow 3/4" or greater in depth • Sanded snow • Sanded ice • Compacted snow with OAT warmer than -15°C	3	30 - 39
Poor	Braking deceleration is significantly reduced for the wheel braking effort applied. Potential for hydroplaning exists. Directional control may be significantly reduced.	• Wet snow • Slush • Standing Water depth more than 1/8" • Ice (not melting)	1	21 - 29
Nil	Braking deceleration is minimal to non-existent for the wheel braking effort applied. Directional control may be uncertain. ***Note: Taxi, takeoff, and landing operations in Nil conditions are prohibited.***	• Ice (melting) • Wet Ice	-	20 & below

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APPENDIX 7

American Airlines Boeing 737-800 Required Runway Landing Length Tables

American Airlines Boeing 737-800 Wind Component and Landing Data Card

Flaps 15 Required Runway Landing Length - Feet

Gross Weight 1000 Lbs	Pressure Altitude (Field Elevation) - 1000 Feet																			
	Sea Level				2000				4000				6000				8500			
	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR
100	4334	4984	5690	7220	4532	5211	6090	7810	4743	5455	6490	8400	4969	5715	6890	8980	5277	6069	7400	9710
110	4698	5403	6130	7840	4915	5652	6530	8430	5148	5920	6930	9020	5396	6205	7340	9600	5733	6593	7840	10340
120	5112	5878	6570	8460	5351	6153	6970	9050	5608	6450	7380	9640	5882	6764	7780	10220	6255	7193	8280	10960
130	5528	6357	7020	9090	5790	6658	7420	9670	6072	6983	7820	10260	6372	7327	8220	10840	6779	7795	8730	11580
140	5946	6838	7480	9730	6231	7165	7880	10320	6539	7519	8280	10910	6864	7894	8680	11490	7307	8403	9190	12230
144	**6105**	**7021**	**7660**	**9990**	**6399**	**7358**	**8060**	**10580**	**6716**	**7723**	**8460**	**11170**	**7052**	**8109**	**8870**	**11750**	**7508**	**8634**	**9370**	**12490**
150	6343	7295	7940	10380	6650	7647	8340	10970	6982	8029	8740	11560	7333	8432	9140	12140	7810	8981	9650	12880
160	6724	7733	8400	11030	7052	8110	8800	11620	7407	8518	9200	12210	7782	8949	9600	12790	8292	9535	10110	13530
170	7219	8301	8860	11680	7574	8710	9260	12270	7961	9154	9660	12860	8368	9623	10060	13440	9315	10712	10712	14180
174.2	7455	8573	9050	11960	7824	8997	9450	12540	8226	9459	9850	13130	8843	10168	10260	13720	9947	11439	11439	14450
Headwind	- 22	- 22	- 34	- 52	- 23	- 23	- 34	- 52	- 23	- 23	- 34	- 52	- 24	- 24	- 34	- 52	- 24	- 24	- 34	- 52
Tailwind	+ 120	+ 125	+ 125	+ 196	+ 140	+ 145	+ 125	+ 196	+ 160	+ 165	+ 125	+ 196	+ 180	+ 185	+ 125	+ 196	+ 210	+ 215	+ 125	+ 196
No Rev	0	0	+1886	+4468	0	0	+1886	+4468	0	0	+1886	+4468	0	0	+1886	+4468	0	0	+1886	+4468

Add 700 Feet if landing Flaps 15 and any of the following apply:

- Engine Anti-ice will be used for landing.
- Wing Anti-ice has been used any time during the flight.
- Icing conditions were encountered during the flight and the landing temperature is colder than 10°C.

Flaps 30 Required Runway Landing Length - Feet

Gross Weight 1000 Lbs	Pressure Altitude (Field Elevation) - 1000 Feet																			
	Sea Level				2000				4000				6000				8500			
	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR
100	4122	4740	5360	6790	4309	4956	5740	7310	4510	5187	6120	7840	4725	5433	6500	8370	5017	5770	6980	9030
110	4431	5096	5770	7350	4635	5330	6150	7880	4854	5581	6530	8410	5086	5849	6910	8940	5404	6214	7390	9600
120	4787	5505	6180	7910	5010	5761	6560	8440	5249	6036	6940	8970	5504	6329	7320	9500	5851	6728	7790	10160
130	5175	5952	6590	8480	5419	6232	6970	9000	5682	6534	7350	9530	5960	6854	7730	10060	6340	7291	8200	10720
140	5566	6401	7010	9070	5831	6705	7390	9600	6117	7034	7770	10130	6420	7383	8150	10650	6833	7858	8620	11320
144	**5714**	**6571**	**7180**	**9300**	**5987**	**6885**	**7560**	**9830**	**6283**	**7224**	**7940**	**10360**	**6595**	**7584**	**8320**	**10890**	**7020**	**8074**	**8790**	**11550**
150	5937	6827	7430	9660	6222	7155	7810	10190	6531	7510	8190	10720	6857	7886	8570	11250	7301	8397	9040	11910
160	6293	7237	7850	10250	6598	7588	8230	10780	6928	7967	8610	11310	7278	8369	8990	11840	7753	8916	9460	12500
170	6647	7644	8270	10840	6971	8017	8650	11370	7323	8421	9030	11900	7695	8849	9410	12430	8200	9430	9880	13090
174.2	6795	7814	8440	11090	7127	8196	8820	11620	7488	8611	9200	12150	7869	9049	9580	12680	8387	9645	10060	13340
Headwind	- 21	- 21	- 33	- 49	- 22	- 22	- 33	- 49	- 22	- 22	- 33	- 49	- 23	- 23	- 33	- 49	- 24	- 24	- 33	- 49
Tailwind	+ 101	+ 103	+ 121	+ 191	+ 107	+ 109	+ 121	+ 191	+ 113	+ 115	+ 121	+ 191	+ 119	+ 121	+ 121	+ 191	+ 128	+ 130	+ 121	+ 191
No Rev	0	0	+1633	+3766	0	0	+1633	+3766	0	0	+1633	+3766	0	0	+1633	+3766	0	0	+1633	+3766

Flaps 40 Required Runway Landing Length - Feet

Gross Weight 1000 Lbs	Pressure Altitude (Field Elevation) - 1000 Feet																			
	Sea Level				2000				4000				6000				8500			
	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR	DRY	WET/ GOOD	FAIR/ MED.	POOR
100	3876	4457	5080	6430	4052	4659	5420	6930	4240	4876	5770	7420	4441	5107	6110	7920	4716	5422	6540	8540
110	4173	4798	5460	6970	4364	5018	5810	7460	4569	5254	6150	7960	4787	5505	6500	8450	5086	5848	6930	9070
120	4469	5139	5850	7500	4675	5376	6190	8000	4897	5631	6540	8490	5133	5903	6880	8990	5456	6274	7310	9610
130	4835	5560	6230	8040	5061	5820	6580	8530	5304	6100	6920	9030	5563	6398	7270	9520	5916	6803	7700	10140
140	5208	5989	6640	8600	5454	6273	6980	9100	5720	6578	7330	9590	6003	6903	7670	10090	6387	7344	8100	10700
144	**5348**	**6150**	**6800**	**8830**	**5602**	**6443**	**7140**	**9320**	**5876**	**6758**	**7490**	**9820**	**6168**	**7093**	**7830**	**10310**	**6564**	**7548**	**8260**	**10930**
150	5559	6392	7040	9170	5824	6698	7380	9660	6111	7028	7730	10150	6416	7378	8070	10650	6829	7854	8500	11270
160	5892	6775	7440	9730	6176	7102	7790	10220	6483	7455	8130	10720	6808	7829	8480	11210	7252	8338	8910	11830
170	6222	7155	7840	10290	6525	7503	8190	10790	6852	7880	8530	11280	7198	8278	8880	11780	7670	8820	9310	12390
174.2	6361	7315	8010	10530	6670	7671	8360	11020	7007	8057	8700	11520	7361	8465	9050	12010	7845	9021	9480	12630
Headwind	- 21	- 21	- 32	- 48	- 22	- 22	- 32	- 48	- 22	- 22	- 32	- 48	- 23	- 23	- 32	- 48	- 23	- 23	- 32	- 48
Tailwind	+ 97	+ 98	+ 119	+ 187	+ 99	+ 100	+ 119	+ 187	+ 101	+ 102	+ 119	+ 187	+ 103	+ 104	+ 119	+ 187	+ 105	+ 106	+ 119	+ 187
No Rev	0	0	+1461	+3347	0	0	+1461	+3347	0	0	+1461	+3347	0	0	+1461	+3347	0	0	+1461	+3347

Landing Data

Required Runway Landing Length is based on:

- Dry or Wet/Good Runway Conditions
  - FAR demonstrated landing distance on a dry runway plus a 67% (92% wet) margin.
  - Maximum Manual braking without reverse thrust.
  - Includes demonstrated "air distance" from runway threshold to touchdown.
- Medium/Fair or Poor Runway Conditions
  - Manufacturer's estimated landing distance plus 15% margin.
  - Maximum manual braking (or Max autobrakes, whichever is longer) **with** normal reverse thrust.
  - Includes 1000 feet "air distance" from threshold to touchdown.

If the visibility is less than ¾ mile (RVR 4000), use the Wet/Good braking action column, unless the Medium/Fair or Poor braking action apply.

Observe both the Required Runway Landing Length and the Landing Climb Limit. Landing climb limits are shown in the Landing Section of the Aircraft Operating Manual Performance Section.

MEL / CDL

Apply any applicable MEL/CDL Landing Performance Penalty.

- If the penalty is a landing length correction, add the correction to the Required Runway Landing Length.

  If the length penalty is different for Dry and Wet, apply the following factors to the penalty if the runway condition is either Fair or Poor. Multiply the Wet penalty by 1.4 for runway condition Fair, Multiply the Wet penalty by 1.8 for runway condition Poor.
- If the penalty is a weight penalty, add the weight penalty to the actual landing weight before entering the Required Runway Landing Length chart.

Headwind / Tailwind Correction

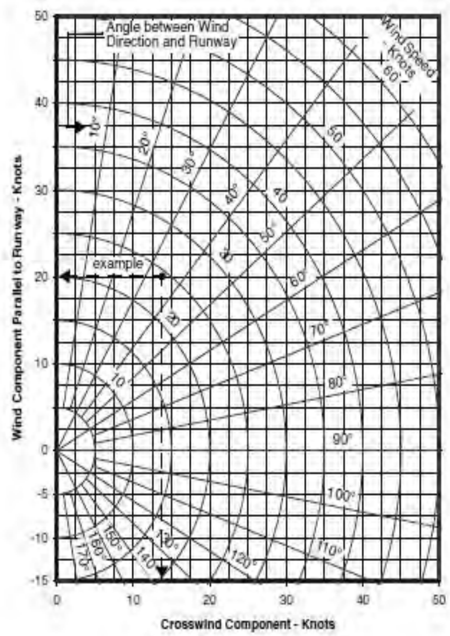
Multiply the Headwind / Tailwind Correction by the wind value and Add / Subtract to the required runway landing length to obtain the required landing length with wind.

Reverse Thrust Correction

Add the reverse thrust correction to the required runway landing length to obtain the required landing length without reverse thrust.

B-737 Wind Component and Landing Data Card
11-27-06

Headwind / Tailwind & Crosswind Component Graph



B-737 Crosswind Limits

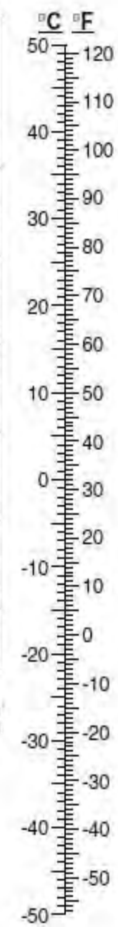
If more than one condition applies, observe the most restrictive.

- Dry (max demonstrated) .... 36 kts
- Dry (max demonstrated) - Winglet...................... 33 kts
- Braking Action Fair / Medium .... 20 kts
- Braking Action Poor .... 10 kts
- Visibility Less than 3/4 mile (RVR 4000) .... 15 kts
- HUD CAT II / III Approach.................................. 15 kts

Crosswind Component - Knots

Difference between Wind Direction and Runway Heading Degrees	Wind Speed - Knots									
	5	10	15	20	25	30	35	40	45	50
10	1	2	3	3	4	5	6	7	8	9
15	1	3	4	5	6	8	9	10	12	13
20	2	3	5	7	9	10	12	14	15	17
25	2	4	6	8	11	13	15	17	19	21
30	3	5	8	10	13	15	18	20	23	25
35	3	6	9	11	14	17	20	23	26	29
40	3	6	10	13	16	19	22	26	29	32
45	4	7	11	14	18	21	25	28	32	35
50	4	8	11	15	19	23	27	31	34	38
55	4	8	12	16	20	25	29	33	37	41
60	4	9	13	17	22	26	30	35	39	43
65	5	9	14	18	23	27	32	36	41	45
70	5	9	14	19	23	28	33	38	42	47
75	5	10	14	19	24	29	34	39	43	48
80	5	10	15	20	25	30	34	39	44	49
85	5	10	15	20	25	30	35	40	45	50
90	5	10	15	20	25	30	35	40	45	50

This data is identical to the graph shown on the panel to the left. This is in tabular format and the other in graphical format.



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APPENDIX 8

American Airlines Estimated Wet And Contaminated Runway Landing Distances

16 PERFORMANCE - LANDING

5-9-00 **737 Operating Manual** AA

Estimated Wet and Contaminated Runway Landing Distances

Based On:
- Sea Level Airport Elevation
- Landing Flaps 40
- Calm wind and zero runway slope

Landing Distance - Feet

Braking Configuration	Landing Weight 1000 lbs	Reported Braking Action			
		DRY	GOOD	FAIR	POOR
Autobrake Setting 2	100	5730	5730	5890	6670
	110	5860	5860	6020	6800
	120	5990	5990	6150	6930
	130	6120	6120	6280	7060
	140	6500	6500	6670	7540
	150	6880	6880	7060	8020
	160	7260	7260	7450	8500
Autobrake Setting 3	100	4450	4460	5010	6340
	110	4580	4590	5140	6470
	120	4710	4720	5270	6600
	130	4840	4850	5400	6730
	140	5220	5230	5790	7210
	150	5600	5610	6180	7690
	160	5980	5990	6570	8170
Autobrake Setting MAX	100	3060	3390	4260	5340
	110	3190	3600	4590	5800
	120	3320	3810	4920	6260
	130	3450	4020	5250	6720
	140	3830	4400	5640	7200
	150	4210	4780	6030	7680
	160	4590	5160	6420	8160
Maximum Manual Braking	100	2390	3230	4220	5330
	110	2520	3440	4550	5790
	120	2650	3650	4880	6250
	130	2780	3860	5210	6710
	140	3160	4240	5600	7190
	150	3540	4620	5990	7670
	160	3920	5000	6380	8150

Corrections

Condition	Correction	Reported Braking Action			
		DRY	GOOD	FAIR	POOR
Altitude	per 1000 Ft Field Elev.	100	120	150	190
Wind	per Knot of Headwind	-18	-21	-28	-40
	per Knot of Tailwind	62	74	106	164
Approach Speed	per Knot above VREF	38	40	44	46
Runway Slope	per 1% downhill	30	70	190	510
	per 1% uphill	-40	-70	-150	-320
Reverse Thrust	One reverser only	40	160	560	1480
	no reverser	60	350	1600	4910

- These distances are actual landing distances based on VREF at a point 50 feet above the landing threshold, then continuing to a point on the runway to effect a full stop.
- This data is for guidance only and must be used with pilot judgement.
- Landing distances are based on Landing Flaps 40 and VREF 40 approach speed.
- Data shown above reflect actual landing distances from 50 ft over landing threshold to full stop.
- Landing distances includes 1000 ft. for air distance between landing threshold and touchdown.
- Includes the use of 2 engine max reverse thrust.

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APPENDIX 9

Boeing Landing Distances Charts

ADVISORY INFORMATION

Normal Configuration Landing Distances

Flaps 30
Dry Runway

	LANDING DISTANCE AND ADJUSTMENT (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°C		APP SPD ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	130000 LB LANDING WEIGHT	PER 10000 LB ABOVE/ BELOW 130000 LB	PER 1000 FT STD/ HIGH*	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 10 KTS ABOVE VREF30	ONE REV	NO REV
MAX MANUAL	2920	180/-150	60/80	-105	370	35	-30	60	-60	215	55	120
MAX AUTO	3720	190/-185	80/105	-135	460	15	-15	85	-85	320	0	0
AUTOBRAKE 3	5220	320/-310	135/180	-230	775	20	-20	140	-140	545	0	0
AUTOBRAKE 2	6670	450/-445	195/255	-315	1070	95	-115	185	-185	565	210	210
AUTOBRAKE 1	7320	525/-520	235/305	-365	1255	195	-220	210	-210	525	635	915

Good Reported Braking Action

MAX MANUAL	4040	235/-230	105/135	-180	635	95	-85	95	-100	305	215	485
MAX AUTO	4450	245/-240	105/145	-185	655	95	-80	100	-100	320	230	520
AUTOBRAKE 3	5230	320/-315	135/180	-230	790	35	-25	140	-140	545	10	45
AUTOBRAKE 2	6670	450/-445	195/255	-315	1070	95	-115	185	-185	565	210	210

Medium Reported Braking Action

MAX MANUAL	5480	365/-350	160/220	-290	1050	245	-195	145	-145	395	575	1400
MAX AUTO	5730	365/-355	165/220	-290	1055	245	-195	145	-145	400	585	1420
AUTOBRAKE 3	5850	375/-360	165/225	-300	1080	190	-130	155	-155	545	425	1260
AUTOBRAKE 2	6830	465/-460	200/265	-340	1210	180	-175	190	-190	565	335	705

Poor Reported Braking Action

MAX MANUAL	7080	515/-490	230/315	-430	1655	585	-385	190	-195	465	1220	3270
MAX AUTO	7370	515/-490	230/315	-430	1660	585	-385	190	-195	465	1220	3275
AUTOBRAKE 3	7370	515/-490	230/320	-435	1660	585	-370	190	-195	495	1225	3280
AUTOBRAKE 2	7620	545/-520	240/330	-450	1710	535	-350	205	-210	565	1010	2890

Reference distance is for sea level, standard day, no wind or slope, VREF30 approach speed and two engine detent reverse thrust.
Max manual braking data valid for auto speedbrakes. Autobrake data valid for both auto and manual speedbrakes.
For max manual braking and manual speedbrakes, increase reference landing distance by 180 ft.
Actual (unfactored) distances are shown.
Includes distance from 50 ft above threshold (1000 ft of air distance).
***For landing distance at or below 8000 ft pressure altitude, apply the STD adjustment. For altitudes higher than 8000 ft, first apply the STD adjustment to derive a new reference landing distance for 8000 ft then apply the HIGH adjustment to this new reference distance.**

APPENDIX 10

Airports Group Report

Jamaica Civil Aviation Authority
4 Winchester Road
Kingston Jamaica

Report Date: December 31, 2009

Accident:
Operator: American Airlines
Airplane: 737-823,
Location: Kingston, Jamaica
Date: December 22, 2009
Time: 2222 EST (approximate)

Aerodromes Group

Group Chairman	Jamaica Civil Aviation Authority
Member	U.S. Federal Aviation Administration
Member	Norman Manley International Airports Limited
Member	National Transportation Safety Board
Observer	Air Jamaica Flight Safety Manager

Summary: On December 22, 2009, about 2222 Eastern Standard Time, N977AN, a Boeing 737-823 airplane, registered to Wells Fargo Bank Northwest N.A. Trustee, and operated by American Airlines Inc., as a Title 14 CFR Part 121 international passenger flight from Miami, Florida, to Kingston Jamaica, overran the runway while landing at NMIA, Kingston Jamaica. Instrument meteorological conditions prevailed in the area with reportedly heavy rain at the time, and an instrument flight rules flight plan was filed. Of the 154 persons on onboard the flight, the pilot, copilot, four flight attendants, and 134 passengers were not injured. Fourteen passengers received injuries, of which six passengers received serious injuries. The flight originated at Miami International Airport, Miami, Florida, about 2022.

Details of the Investigation:

1. Aerodrome Configuration: Norman Manley Airport is located on the Palisadoes Peninsular on 532 acres, some 10miles from the major City of Kingston and 2 miles northeast of the town of Port Royal at the end of the peninsular, on the island of Jamaica. The reference point for this aerodrome is N17°56.0’ W076°47.3’ (WGS84).The aerodrome elevation is 3.04 meters above sea level with a geoid undulation of 19.27 meters.

The airport is described as an Airport of Entry and is the major airport serving the south side of the island. For navigation purposes and air traffic control all international flights are controlled by the Kingston Flight Information Region prior to handing off to Kingston Area Control Center for further rerouting to the Airport. The airport is open 24 hours. The airport is not certified in accordance with ICAO Annex 14 Standards.

The airport is served by a single Runway (12/30) designated as a Code 4E with an asphaltic concrete surface. Runway End Safety Areas and Stopways are not provided. The reference temperature for this runway is 31° C. A runway strip 2730 meters long and 300 meters wide is provided to ICAO Annex 14 Standard with regards dimensions.

A Code 4E parallel taxiway is provided with four service taxiways with entry to various points to the runway. A Taxiway strip is provided which meets the physical dimensions required by ICAO Annex 14.

2. Aerodrome Certification: The ICAO requirement for aerodrome certification is specified in ICAO Annex 14 (effective November, 2003). It specifies that every aerodrome used for international operations be certificated by the state civil aviation authorities in that particular state. The authority for aerodrome certification in Jamaica has been promulgated in the Civil Aviation Regulation, as modified in 2004. Although the NMIA has initiated the certification process in conjunction with the JCAA, currently the state has not issued an operating certificate to NMIA, and thus the aerodrome according to ICAO standards is not certificated. The airport operator has developed the requisite aerodrome manual, aerodrome programs, aerodrome emergency plan, and has submitted them (along with the appropriate application) to the JCAA. However, certification is still pending.

3. Aerodrome Manual: The Norman Manley International Airport (MKJP) has developed a detailed aerodrome manual that was reviewed in the course of the investigation. The manual as reviewed would meet the basic requirements of ICAO Annex 14 (aerodrome certification) and ICAO Document 9774 (Manual for the Certification of Aerodromes) in terms of content and specificity. It included an emergency plan as required. It also contained the minimum essential information on site, facilities, services, equipment, operating procedures, organization and management as specified by Doc 9774. However, the manual did not appear to include detailed information on Safety Management Systems as required by Annex 14 and JCARs regulation 142. The manual has been submitted to JCAA for review and is pending approval at this time.

4. Aerodrome Emergency Plan:

4.1 General Information: The NMIA has developed an emergency plan that has been submitted to JCAA for consideration of approval. The plan as reviewed as part of this investigation addressed the minimum elements required of ICAO Annex 14 and ICAO Doc 9774. Those subsections included aircraft emergencies, sabotage, unlawfully seized aircraft, dangerous goods, structural fires and response, natural disasters, and emergencies that are site specific (that is, water rescue in this particular case). The manual has not currently been approved by JCAA. A copy of the plan was found available to RFF staff during the inspection/review of RFF facilities.

4.2 Water rescue plan (specialty rescue services): As MKJP and particularly Runway 12/30 is surrounded by water, ICAO Annex 14 (9.1.14) requires development of a site specific water rescue plan. The MKJP aerodrome emergency plan had information on water rescue but the information provided in the manual was sparse at best. The response procedures alluded to a aerodrome owned boat (which did not physically exist) operated by trained RFF firefighters (who are not currently trained) using flotation devices (which are currently not on hand) to aid victims in the water. The plan also relied heavily on resources to be provided from mutual-aid agencies (specifically the Jamaican Defense Force Coast Guard and the Port Authority of Jamaica). The JDF Coast Guard is currently adequately staffed and does operate from an operating base that sits within 5 miles of the aerodrome. Response from the JDF-CG would most likely be adequate and would occur within a reasonable time (assuming that JDF-CG resources are not deployed on other missions at the time of an aerodrome accident). Currently, MKJP has initiated Memorandum of Understanding (MOU) agreements with both the JDF-CG and the Ports Authority. These documents are currently in legal review and when completed will enhance the water rescue capability of the aerodrome. In addition, aerodrome management stated that they are currently in final negotiations of the purchase of a 27 foot water rescue boat that would be stored with RFF and would be operated by that service. There is an existing boat ramp in the vicinity of the RFF station that could be used by the rescue boat.

5. Runway Condition

5.1 Existing Runway Data

The runway is 2716 meters long and 46 meters wide. The runway slope for Runway 12 is 1% U while the slope for Runway 30 is 1% D. The runway is designed with 0.1% transverse slope along the full length. The geometric centre of the runway is 1357.80 meters west of the threshold at runway 30 on the center line. The threshold elevations for runway 12/30 are 2.34 / 5.31 meters respectively.

Threshold elevations/geoid undulation for runway 12 is 2.34 meters / 18.41meters and that of runway 30 is 5.31 meters/ 21.09 meters, respectively. Touchdown zone elevations for Runways 12/ 30 are 2.40 / 3.02 meters respectively.

The bearing strength of runway 12/30 is adequate to allow continuous operations by the aircraft for which designed. (PCN 68/A/W/T). Taxiways and holding bays are of the same bearing strength as the runways.

5.2 Visual runway condition assessment

The runway was visually inspected. The macro surface appeared in good condition with the runway surface rough to the touch. There was evidence of runway edge damming beginning to form along the entire length of the south side. There was also evidence of significant runway edge damming forming on the north side, at the runway shoulder edge from taxiway Echo to Taxiway Charlie.

The water flow had built dams from 6 inches to almost 12 inches in height. Examination of Surveyors drawings and measurements constructed in 1995, demonstrated that the edge of the threshold of runway 30 was 5.3 meters while a low point of 2.10 meters was measured at a point 800 meters from the runway 30 end. This was borne out by the physical evidence observed on the north side of the runway between taxiway Echo and Charlie. The runway from this point eastward appear to rise slightly showing evidence on the north side between Taxiway Echo and Delta of a counter flow of water, borne out by the building of a debris mound just off the shoulder appearing to separate the two water current flows. It is apparent from the surveyor's drawings that it is possible to have significant water flow. From the physical evidence observed, there is edge damming for a significant distance along the edge of the runway north side between Taxiways "Echo" and "Charlie" from the runway 30 threshold. The evidence of water flow in this area indicates that further observations would be required.

Due to the positives transverse slope of the runway water flows to the runway strip on both sides of the runway and then soaks away. In the area on the north side of the runway between taxiways "Echo" and "Delta" the water flows to a swale for further distribution to drainage ducts.

The maintenance of the swale and the areas immediately surrounding the ducts is poor, in fact over time the surface has receded below the level of the ducts causing them to be ineffective in moving the water to the drainage system. In examination of the surveyor's drawings there was no evidence of the drainage system in the runway strip being linked to the main drainage system or sewer lines routed under the apron.

Throughout the runway strip there were obstacles, such as blocks of concrete which need to be removed.

It is recommended that a proper maintenance plan be developed for the Runway strip and that a survey of the drainage system be conducted. A further visual check was conducted for distress on the runway surfaces in the following four major areas:

- Surface defects
  There were no visual signs of raveling or flushing; however in the touchdown zone area of Runway 12 along the center line there were signs of polishing and minor pock marks where small pieces of the surface area had popped out.
- Surface deformation
  There was no sign of rutting, distortion or rippling of any kind. In determining the transverse slope there was a continuous positive transverse slope along the entire length of the runway. A further informal engineering survey of several stations along the runway also demonstrated a positive transverse slope along the length of the runway however in one area within the landing zone of Runway 12 the transverse slope demonstrated less than 0.1% and a reading of approximately 0.45% was measured.

- Cracks
  There were no thermal, reflection or slippage cracks along the length of the Runway. There were however, several longitudinal joint cracks along the entire length of the runway on either side of the centerline; there are lateral cracks as well which could be associated with the methodology utilized while laying down the runway surface. These cracks showed no signs of lifting, demonstrating that water was not at this time seeping below the surface.

  In the landing zone area of Runway 12, particularly, between 1500 to 2000 feet from the threshold, there were signs of block cracking.

  There were signs of lightning strikes in the first 5000 feet of the runway from the Runway 12 end. This was demonstrated by small pop outs. These were of no significance and there was no debris on the runway.

5.3 Runway condition inventory

The runway surface overall was in good condition, however a crack sealing program would be appropriate to prevent further widening of the cracks by water penetration.

6. Taxiway Condition

All taxiway surfaces were inspected and found to be in good condition; however Taxiway “Alpha” “Echo” and “Delta” needs further discussion.

Taxiway “Alpha” is parallel to Runway 12/30 and is the main taxiway entering the runway at the threshold of Runway 12. Subsequently all heavy jet traffic are routed by this taxiway to Runway 12. There is evidence of deterioration of the taxiway surface in the turn leading to the Hold line. The surface area for approximately 200 feet back from the hold line on either side of the taxiway center line displays areas of surface distortion – rippling.

The shoulder entering the runway on the east side at Taxiway Delta shows sign of water erosion with a sinkhole in the peak of the curve. Although no threat to the taxiway surface at this time it is beginning to show signs of substrata erosion.

The shoulders entering the runway on the east side at taxiway “Echo” showed signs of water erosion. There is a sinkhole with the substrata deteriorating beneath the surface and in the peak of the curve, causing the surface to break away. At this time the taxiway surface is not affected.

Appropriate maintenance action needs to be taken to correct the anomalies.

7. Runway strip/Runway end safety areas

7.1 Runway strip: MKJP Runway 12/30 is designed and operated as a Code 4 Runway. Annex 14 requires Code 4 Runways with precision instrument approaches to maintain a Runway strip of 150M on each side of the runway centerline. Due to existence of an off-set ILS localizer on Runway 12 there is some question at MKJP regarding the applicability of Cat I precision approach criteria. Regardless of that question regarding precision approach criteria for 12, the aerodrome manual for MKJP as currently written states that the aerodrome will maintain Code 4 precision runway strip standards thus the runway was evaluated using 150M as the standard. The investigation conducted found that MKJP meets the runway strip criteria along the full length of 12/30 on both the North and South sides with the following notable exceptions:

- At both runway ends (12 And 30) the 60M runway strip as required by Annex 14 (3.4.2) does not exist. Physical examination of the Runways indicated a runway strip on Runway 12 of less than 15M and less than 10M on runway 30.

- Along the entire length of 12/30 on both sides of the runway there were a number of objects (such as rocks, concrete blocks as large as 1M wide, 1M long and .3M in depth) and manhole/junction box covers that protruded above the existing grade and would thus be in violation of the requirement of Annex 14 3.4.7 requiring that the only objects in the graded portion of the strip be limited to those items that are frangible and required by function to be there. In addition there was one sinkhole (approximately 4M long, 3M wide and 1-3M deep) that sat approximately 75M from the runway edge on the North side of the Runway between taxiways B and C. In addition to this sinkhole, there were sinkholes forming along taxiways D and E that were as deep as .5M and approximately .5M wide, running as long as 5M along taxiway D.

- The localizer antenna array on the South side of the 30 end of the runway currently sits on a concrete pad that is approximately .3M in height above grade. Although the aerodrome group was provided with documentation regarding the frangibility of the localizer antenna, the pad upon which the antenna currently rests would appear to be contrary to the recommended practice of Annex 14 (3.4.6) which states that objects which may endanger airplanes in a runway strip should be removed as far as practicable. In this case feathering of the existing grade to the base of the localizer antenna would remove this object and danger from the runway strip.

- The aerodrome group during inspection of 12/30 found numerous electrical junction box covers in the runway strip. These junction box covers measured approximately 1M x 1M. These covers were constructed of fiberglass and covered holes that appeared to be as deep as 2M. Although not specifically mentioned in Annex 14 the investigative team noted that these covers would not hold the weight of an aircraft during a runway excursion and thus we recommend that these covers be replaced with metal covers sufficiently strong to sustain the weight of a passing aircraft.

- Issues associated with runway edge ‘damming’ that is occurring along the entire runway length (both sides), but especially along the North side of the runway from the 30 end to Taxiway C is more specifically addressed in the runway pavement section of this report.

7.2 Runway End Safety Area (RESA): Currently no RESA is provided on either the 12 or 30 end of the sole MKJP Runway. To address this issue the aerodrome Master Plan currently contains plans for the extension of Runway 12 into the water combined with the displacement of the runway 30" threshold to provide a RESA compliant with Annex 14 requirements. The exact time of completion of this project is currently unspecified.

8. Markings: A physical examination of the apron, taxiway and runway markings at MKJP found the markings to be in good condition and compliant with the requirements of ICAO Annex 14. There were a few taxiway markings (particularly the taxiway edge markings on the West end of the airport near taxiway E and D) that had faded slightly and thus we would recommend a paint project be considered to enhance those markings.

In addition, we did not physically see, nor did the paint specifications provided to us by MJKP management indicate, that the aerodrome uses any reflective enhancement (glass beads) in the paint used on either the runway or the taxiways. Although only an Annex 14 recommended practice (5.2.1.7), the use of glass beads is discussed in ICAO Doc 9157 Parts 2 and 4 as having not only the ability to visually enhance markings but having the secondary benefit of providing a modicum of friction enhancement on the surface of the marking.

9. Sign Systems: A physical examination of the apron, taxiway and runway sign systems at MKJP found the signs to be in good condition and essentially compliant with the requirements of ICAO Annex 14. All signs were internally illuminated and appeared to properly maintained. The exceptions to full Annex 14 compliance are as noted:

- ICAO Annex 14 standards (5.4.2.8) require that a runway designation sign be installed on each side of the runway holding position marking at each taxiway/runway intersection IAW the standards and distances specified in the Annex. MKJP currently has only one designation sign per runway /taxiway intersection.
- Annex 14 (5.4.7.1) requires a road-hold position sign at all road entrances to a Runway. We noted two locations (in the vicinity of the ILS localizer antenna and at the approach end of Runway 12) where these signs were missing.
- The runway exit sign from runway 30 onto taxiway Bravo(high speed exit) was missing.
- The taxiway Charlie direction sign at taxiway Alpha was out of service during the night lighting inspection.

10. Lighting Systems: The runway and taxiway lighting systems at MKJP consisted of medium intensity taxiway lighting and high-intensity runway lighting on Runway 12/30. Systems are controlled from a Mimic board in the Air Traffic Control Tower. The Mimic board control currently operates all runway lighting with the exception of taxiway lighting on the East and West ends of taxiway Alpha. That lighting is currently controlled from the electrical vault and was on and operational during the night inspection. With minor exceptions Runway and taxiway lighting was found operational, well-maintained, and designed/installed in accordance with the requirements of Annex 14. The minor exceptions noted during the night inspection were:

- 1 light on the Runway 12 threshold lighting system was out of service.
- Four lens-cap fixtures on Runway 12/30 were found installed backwards and were thus not providing the correct light angle and luminosity. This can give a distorted sight picture to landing aircraft.
- 3 lights of the runway 30 threshold light system were missing.
- At the taxiway Delta high-speed exit from Runway 12/30 one in-pavement edge light was out of service.
- One amber/white split-lens runway edge light on Runway 12/30 at taxiway Echo was misaligned.
- 1 taxiway edge light at taxiway Alpha near taxiway Echo was out of service.

11. Visual Aids

11.1 Visual guidance slope indicators. Annex 14 (5.3.5.1) requires visual approach slope indicator systems for runways used by turbojet aircraft, regardless of other approach aids provided. Currently MKJP has installed and provided a Precision Approach Slope Indicator (PAPI) on both ends of 12/30. The normal PAPI configuration as specified in the Annex consists of 4 lights located to the left of centerline as viewed by the pilot. MKJP currently provides a 4-box PAPI on each side of centerline (8 boxes total) for each runway end. The systems were operational and appeared to be well-maintained. The last PAPI calibration (as determined by maintenance record) was December 26, 2009. The previous calibration/maintenance was performed August 08, 2008. Systems were found on December 26, 2009 to be within calibration standards. Although periodicity of maintenance is not specified in Annex 14 and is thus normally subject to manufacturers' specifications, we recommend that MKJP institute a specific maintenance/calibration periodicity and a periodic maintenance schedule to service the VGSI's.

11.2 Wind cones. Lighted wind-cones are provided at both runway ends of 12/30. The wind-cones were operational, the lighting was operational, and they met the installation/design and maintenance requirements of Annex 14.

11.3 Approach lighting systems. Currently MKJP provides a Simple Approach Lighting System (SALS) on both runway ends of 12 and 30. The 30 end system is modified due to geography of the terrain and does provide the standards specified in Annex 14. During the time of the inspection the SALS on 30 was operational, while the SALS on 12 was out of service. NOTAM records indicate that the SALS on 12 was out of service on December 22, 2009.

12. Aerodrome programs

12.1. Wildlife control programs: Annex 14 currently requires that states develop and promulgate a national procedure for recording and reporting bird strikes. Currently that requirement has not been established in Jamaica and all reporting (although it occurs and there are concerted efforts to collect bird strike data) tends to be local rather than nationally coordinated. At MKJP the aerodrome manual covered bird strike reporting and wildlife control in a cursory fashion, yet the aerodrome maintained a wildlife log was aware of the dangers associated with wildlife. During the assessment there were no significant wildlife issues noted. Some pelicans were observed, some cattle egrets were noted and there was colloquial evidence of feral dogs that would make their way onto airport property. In summary, although there is no national procedure for bird strike reporting, the issue of wildlife control does not appear to be a pressing issue for MKJP. However, there is always value in having a trained wildlife biologist conduct an assessment of the wildlife situation of MKJP and the surrounding area and we would recommend such.

12.2. Ground vehicle control: Annex 14 requires that each certificated aerodrome develop a Surface Movement and Guidance Control System (9.8.1) in addition to an appropriate Apron Management Service (9.5.1 where traffic conditions dictate). MKJP traffic control appeared adequate for the volume of traffic at the aerodrome. The aerodrome provides a driver training program and controlled driver access through a 'badging /licensing' system that differentiates between movement and maneuvering area driver authorization. In addition, with nine Operations Coordinators assigned to the Operations Department, the control of vehicles and runway access appeared to be in compliance with Annex 14 and met local condition requirements.

12.3. Self-inspection; Daily self-inspections are conducted by both the Operations Coordinators and RFF staff. These daily inspection are organized through use of a checklist and findings are consolidated in the electronic maintenance management system. We found however that even though the departments make every attempt to conduct adequate self-inspections and condition reporting there is evidence that additional effort and training may be warranted. Currently there is little to no standards training provided to staff who conduct self-inspections and little evidence that inspections are more than simple FOD and light checks. We would recommend that MKJP institute a more robust self-inspection training program for staff who conduct self-inspections, consisting of standards (Annex 14 and ICAO Doc) review, testing on standards, and management review of self-inspection findings.

12.4. Aerodrome maintenance: Currently the guidance for maintenance standards found in either the JCAR (2004), in JCAA guidance, or in the MKJP Aerodrome Manual is minimal at best. Standards instead seem to refer exclusively to ICAO standards as specified in Annex 14 and the associated ICAO documents. In many cases (particularly in the case of maintenance of runway strips and RESAs) this may be inadequate. We feel that the situation found along the runway edge associated with accumulation of debris and 'edge-damming' along the runway may be the result of insufficient guidance provided to self-inspection and aerodrome maintenance staff. In addition, we feel that the situation associated with the accumulation of debris associated with edge-damming is also the result of insufficient training being provided to maintenance staff. If staff had been properly trained in the ICAO requirements associated with provision and maintenance of runway strips, the situation that developed along the runway edges may not have developed. This is the one area where we feel that MKJP could do a better, more thorough job, and JCAA could provide more oversight. In our opinion this is the one specific area where the airport may not be in compliance with the recommended practice of Annex 14, chapter 10, and the requirements of ICAO 9774 for the provision of qualified staff.

12.5. Foreign object debris control. Annex 14.10.2.1 requires aerodromes maintain surfaces of pavements free from foreign object debris (FOD). The FOD control program appeared to be adequate and there was little to no FOD observed on surfaces during the investigation.

13. Rescue firefighting services

13.1 RFF program status: MKJP is designated a RFF Category 8 aerodrome and the aerodrome does meet the requirements of Annex 14, Chapter 9 in that regard. We found the RFF service at MKJP to be very professional and capable.

13.2 Equipment

13.2.1. RFF vehicles: To meet RFF Category 8 requirements MKJP would have to meet the Annex 14 requirements of Table 9.2. During the period of the assessment there were three operational RFF vehicles capable of discharging 24996 liters of water for foam, and capable of discharging 677 kg of dry chemical. This is in excess of the Annex 14 Table 9.2 requirements. The vehicles were found in good condition and were well-maintained. A preventive maintenance and daily inspection program was in place for the vehicles.

13.2.2 Rescue equipment. The RFF services maintained minimum rescue equipment ranging from simple hand-tools (which were available on all vehicles) to hydraulic spreaders (maintained on RFF14). We did find evidence of training having been completed on this equipment and firefighters seemed to aware and capable of using the equipment. We were told that a powered rescue saw was not available and we would recommend that RFF services acquire such. In spite of this we do believe that RFF services met the intent of Annex 14 recommended practice 9.2.20.

13.2.3. Personal protective equipment (PPE). The PPE requirements of Annex 14.9.2.38 (and as specified in ICAO Doc 9137, part 1) were determined to be met. Each firefighter had assigned to them a structural firefighter coat and pants, a helmet with shield, gloves, protective boots, a hood and a personal SCBA mask. There were 9 Scott Self-Contained Breathing units found and all were determined to be serviceable and full with air. In addition there were 15 additional SCBA bottles that were also found full. Re- supply of air comes from an agreement with JFB. We recommend that the aerodrome consider acquisition of their own re-supply system to refill SCBA bottles.

13.2.4. Medical. Emergency medical qualifications for RFF personnel are not clearly defined in Annex 14. MKJP RFF has elected meet emergency medical requirements through the training of all firefighters in basic first responder medical training and by maintaining a number of staff with Emergency Medical Technician (EMT) capability. This is commendable and as the RFF service also provides ambulance service, required to a degree by Jamaican governmental requirement. There are no Annex 14 issues associated with the emergency medical capability of MKJP. We do however recommend that the aerodrome (through the aerodrome manual and the emergency plan) more formally state their position. As there is currently no written minimum emergency medical standard for RFF services this current posture could evaporate. We recommend this be addressed through aerodrome standards coordinated with JCAA.

13.3. Staffing. Current staffing minimums require a minimum shift of 9 persons, of which would be three APS Officers and 6 firefighters. This staffing is maintained 24 hours/day and exceeds the requirements of Annex 14, Chapter 9 (and the guidance of ICAO Doc 9137, part 1).

13.4. Training. Annex 14.9.2.34 requires that all RFF staff be properly trained with the recommended training spelled out in Doc 9137, part 1. Our investigation found that the MKJP training program did address training detailed in Doc 9137 for both initial and recurrent training and we found the training program met the requirements of Annex 14. We found a training syllabus (conducted on an annual basis) and evidence that firefighters were being adequately trained IAW ICAO guidance. We also found that firefighters are rotated through the US South Carolina Fire Academy, Columbia, SC, on a recurring basis of approximately once every 3 years. This is an IFTSA certified 48 hour program that provides quality, professional RFF training. We do understand that this is a considerable expense for MKJP and we commend them for their professional consideration. We would recommend two items regarding training:

- RFF services should make greater effort to acquire rescue diagrams and detailed training material for each type commercial service aircraft that uses MKJP (that is, 737, A320, 747 etc.) In addition, we recommend continued effort to coordinate live ‘hands-on’ training on these aircraft as these aircraft may become available at the airport.
- We recommend development of detailed lesson plans of each required training subject on the annual training syllabus. This would include detailed training requirements, goals, objectives, outcomes and references required. Additional guidance can be obtained from NFPA 1003.

13.5. Agent available: MKJP RFF services currently use Aqueous Film Forming Foam (AFFF) as the primary agent, with protein-foam and PKP Dry Chemical as complementary agents. Each operational RFF vehicle had full AFFF tanks that were capable of discharging at least 2 operational loads of water for foam. In addition, on hand at the RFF station was an ample supply of AFFF, Protein-Foam and dry chemical. All agent stocks were found to be within serviceability dates and were stored properly. The RFF service also had arrangements for water re-supply during an emergency event with water tenders coming from the Jamaica Fire Brigade (JFB). We would recommend that these arrangements be made more formal through negotiation of a MOU and by inclusion of detail in the AEP.

13.6. Access roads. Previous audits of MKJP indicated an issue with the fact that RFF vehicle access to the runway is not direct to within 1000M from runway threshold. This access routing has not changed since previous audits. However, as there is direct access to taxiway Alpha and as this is an Annex 14 recommended practice (9.2.26) this does not appear to be a major issue. In addition, there was ample evidence of testing done on each watch shift (verified by investigators over the past 12 month period) to verify response times meeting the Annex 14.9.2.21 requirement.

13.7. Alerting

13.7.1. Station alerting process and equipment: Current staffing levels for RFF duty shifts require a minimum staffing of 9 persons. At all times (24 hours/day) one person is assigned to the watch-room to monitor and direct emergency communications. Besides radio communications between ATCT and RFF there was a direct line ring-down telephone that is tested daily. This ring-down system was utilized during the incident on December 22nd. During the investigation this phone was also tested. Communications meet the recommendations of Annex 14 (9.2.31).

13.7.2. Vehicle and on-scene communications. RFF vehicles are all equipped with VHF radios capable of transmitting on ATC frequencies. RFF vehicle 11 radio was out of service during the investigation. In addition, each vehicle has an additional radio used for internal APS/aerodrome communications.

13.8. Emergency medical services capacity: MKJP RFF services, currently maintains a 'mass-casualty' trailer that is stocked with a minimum basic load of medical supplies. It appeared that these medical supplies would be sufficient for a mass-casualty situation for an aircraft of the most demanding nature (in this case the 747). However, even though there appeared to be sufficient medical equipment we were not provided with an inventory and there was no evidence of periodic inventories and assessment of serviceability dates having been conducted. Although, there is little guidance in Annex 14 and the RFF service seemed to be proactive in the acquisition and maintenance of medical equipment, we would recommend a reassessment of need and more formal record keeping and inventory of this equipment.

14. Electrical power systems.

The power supply for this airport is normally routed from the national power grid; however in case of supply interruption, the airport administration has put in place auxiliary power systems that will automatically switch on to take up the load of all necessary power requirements needed. The main auxiliary power system is located at a remote site on Airport property with fuel quantity capable of supplying continuous operation for four days or longer depending on usage. The site is well constructed clean and appears well maintained. There is no fire suppression system. There is however a 20 lb fire extinguisher on site in case of minor fire events.

The power systems have a fifteen second switch over time, which meets the secondary power supply system requirement in ICAO Chapter 8 Table 8-1.

In case of failure of the main auxiliary supply system the each runway has its own system which will power the runway edge lights , taxiway lights, threshold lights runway end guard lights PAPI, ILS and VOR approach systems.

The following systems are in place:
Main substation

i.) Two 2MVA Caterpillar Diesels (automatic Switch over)
ii.) One 938 kVA caterpillar Diesel as additional backup (automatic Switch over)

Runways

i.) 12 (West Substation One 50 kVA standby generator
ii.) 30 East B Substation One 100 kVA standby generator

Administration
i.) One 300 kVA Standby generator located in the area of Stand 10 to operate Control Tower and Administrative facilities.

Stand by Lamps

Battery powered lamps are utilized for lighting the runway and taxiway in case of auxiliary power failure.

15. **Recommendations**.

Aerodrome Certification:
- Continue to move forward toward the goal of meeting the JCAA and Annex 14 requirement of full aerodrome certification.
- Consider coordination of a certification training program for both JCAA and MKJP staff on certification standards, conduct and development of a certification program, and self-inspection/condition-reporting.

Aerodrome maintenance:
- JCAA and MKJP develop specific maintenance standards and publish them, particularly on the subject of pavement and runway strip maintenance.
- Provide detailed maintenance training to those responsible for self- inspections and for aerodrome maintenance.

Aerodrome Emergency Plan:
- Coordinate additional detail in the emergency plan, particularly in the water rescue section of the plan.

Pavement:

- Coordinate a full runway assessment to determine current longitudinal slope, current transverse slope (along runway full-length), and the existing grade in first third of Runway 30 (from approximately taxiway D to the 30 threshold).
- Coordinate a hydrologic engineering assessment to determine water flow on the first third of runway 30 from approximately taxiway D to the 30 threshold.
- Coordinate completion of a full friction assessment of the runway to determine compliance with established friction maintenance standards and deviation from the findings of the last friction assessment (2004).

Marking/lighting signs:

- Add additional runway designation signs at every runway hold-position

- Consider revising current PAPI configuration to the ICAO standard Marking.

(PAPI 4L) by removing the additional 4 boxes on the right side of 12 and 30. This would reduce maintenance, minimize the potential confusion to aircrews that may occur due to the separate systems being out of calibration, and would still confirm to ICAO standards.

Rescue Firefighting Service:

-Develop detailed training lesson plans for required training subjects of initial and recurrent training.
-Consider acquisition of a simple SCBA bottle refill system for aerodrome use.
-Acquire powered rescue saw(s) for aerodrome use.
-Enhance existing training procedures used for aircraft familiarization…to include acquisition of current training aids for each commercial service aircraft currently using MKJP.

Declared Distances: Currently, the aerodrome operator complies with the requirement of Annex 14.2.8, for declared distance computations. The figures are published in the Jamaica AIP. Currently however, the only declared distance figures for MKJP 12/30 that differ from the distance representing 12 threshold to 30 threshold (2716M) distance, are the TODA figures for both 12 and 30 (currently published as 4074M). This represents acknowledgement of existing clearways on both runway ends. We recommend consideration be given to review of all declared distance figures to accommodate the fact that there is no existing runway strip or runway end safety area at either runway end.

Runway strip and Runway end safety area.

- Remove existing debris and vegetation from the existing drains in the runway strip between taxiway D to E. Verify that these drains are operational and that they are tied into the drain system and box-culvert under the aerodrome apron.

- Conduct periodic surveys of the runway strip and RESA (as provided) to determine safety issues and correct found deficiencies on a more frequent basis.
- Remove all current deviations (objects not required) from runway strip.
- Feather existing localizer base to grade.

Summary Statement:
In spite of the fact that MKJP (Norman Manley International Airport) has not fully met the JCAA-JCAR/Annex 14, Volume I, requirements of aerodrome certification, it is the opinion of the aerodromes group that the aerodrome as currently operated and managed meets or exceeds the requirements of what could be called 'safety critical items' associated with Annex 14 aerodrome certification compliance, except in the notable area of provision and maintenance of runway strip and runway end safety areas.

Attachments:

- Part 3, Aerodrome Particular to be reported to AIS (AIP Aerodromes Section).
- 12/30/09 Memo from Mr. Roy Williams re. Runway Cross Section Check MKJP
- APS Watch room Log Entries 12/22/09 (2225h) to 12/23/09 (0434h).
- MOU between NMIA and Port Authority of Jamaica
- MOA between NMIA and Jamaica Defense Force – Coast Guard
- Page 4-81 to page 4-83 of MKJP Aerodrome Manual regarding wildlife control procedures.
- Page 4-43 to page 4-56 of MKJP Aerodrome Manual regarding self-inspection, maintenance management, secondary power, and aerodrome works during construction.
- PAPI calibration check records 08/08/08 and 12/26/09.
- Localizer antenna Runway 12 statement of frangibility.
- Material Safety Data Sheet (paint specifications) for runway and taxiway paint used by aerodrome operator.
- Results of runway friction test conducted 07/17/04 of MKJP Runways 12 and 30 using a Grip-Tester Model GT289 system.
- Copy of daily preventive maintenance RFF vehicle systems checklist utilized by MKJP APS (RFF).
- 01/02/09 copy of Memo detailing RFF APS fire service training syllabus for the calendar year 2009.
- Page 6-1 to page 6-3 of MKJP Aerodrome Manual regarding reported airfield deficiencies (RESA, runway-taxiway separation, runway strip, runway longitudinal slope, aircraft holding position placement, and RFF services access to Runway 12/30).

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SECTION 2

ANALYSIS

2.0 Analysis

2.1 Aircraft

The aircraft, including all systems designed to decelerate the aircraft on landing, was serviceable and airworthy at the time of the occurrence, except for the air-conditioning pack temperature controller fault warning, which was deferred in accordance with the MEL in Miami before departure. As lack of deceleration was a major factor in the accident, the aircraft's braking system was examined in great detail, and no fault was found (see 1.12.4 and 1.16.5).

The investigation revealed no mechanical aspect of the aircraft that contributed to the accident. [82]

2.2 Flight Crew Qualifications

The captain and first officer were properly certified and qualified under Federal Aviation Regulations and company requirements. The investigation revealed no pre-existing medical or behavioral conditions which might have adversely affected the flight crew's performance during the accident flight. [83]

2.2.a NOTAMS

As described in 1.18.4, NOTAM AO208/09 announcing the planned closure of the runway at Montego Bay was given to the AA331 flight crew in their original briefing. However, it seems that NOTAM AO215/09 cancelling that closure was not a NOTAM per se, but simply resulted in the original NOTAM being cancelled and deleted from the list of active NOTAMS. Thus it is quite likely that there was no mechanism in the system whereby the dispatcher would be alerted of this change, and, as the dispatcher was busy with other flights and had no reason to re-check the NOTAMS for AA331, he would not have realized the NOTAM was cancelled, and hence would not have alerted the AA331 flight crew to this.

The investigation does not consider that the crew's decision making process during the planning of the approach and landing would have been any different if they had been informed that the planned closure of Montego Bay was cancelled, but nevertheless the investigation recognized that this characteristic of the NOTAM system could result in a hazardous situation in other circumstances. For this reason, the investigation recommends that NOTAMs cancelling other NOTAMs should be brought to the attention of flight crews using these NOTAMs. [84]

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[82] Section see 1.6

[83] Section 1.13

[84] Section 4.2.32, Safety Action Required

2.3 Airport

NMIA Airports Limited stated that the approach lights for runway 12 had been unserviceable since 30 November 2009, due to an underwater electrical fault. There was an active NOTAM regarding this included in the AA331 dispatch document. The approach lights for runway 12 were not an operational requirement for the use of runway 12 in Instrument Meteorological Conditions (IMC). [85]

The absence of the approach lights for runway 12 may have reduced depth perception cues for the captain during the final stages of the approach, but these were lead-in lights, and were there to assist the flight crew with acquiring and lining up with the runway during the final stages of approach, when transitioning to visual flight.

Although NMIA Airports Limited did not have its own friction measuring device, this was not an issue as friction measurements were needed less frequently for lightly used runways such as MKJP runway 12, and NMIA Airports Limited contracted the services from the Grantley Adams International Airport in Barbados when needed. It would have been desirable, but it was not essential, for the airport to have its own friction measuring equipment.

TDZ lights are not a standard for CAT 1 Precision Approach runways. Reflective markings are not a standard, but are an ICAO recommended practice. Therefore MKJP was in compliance with ICAO in these regards. However, the investigation believes that "black hole" approaches should be enhanced by runways having TDZ lighting and/or reflective markings. The lack of these may have been a factor as they would have assisted the pilot to establish with more precision where the aircraft was in relation to the touchdown zone during the landing. On a dark, horizon-less, rainy night such as it was, these would have been of great value to the AA331 flight crew.

Since NMIA was still undergoing certification at the time of the accident, the investigation carried out an inspection of the airport by subject matter experts. A list of some of the deficiencies identified during this inspection is in 1.10.2.4. [86]

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[85] Section 1, 1.8.2.1 and 1.10.2.6

[86] Appendix 10, Airports Group Report

The Summary Statement of this examination was as follows:

In spite of the fact that MKJP (Norman Manley International Airport) has not fully met the JCAA-JCAR/Annex 14, Volume I, requirements of aerodrome certification, it is the opinion of the aerodromes group that the aerodrome as currently operated and managed meets or exceeds the requirements of what could be called 'safety critical items' associated with Annex 14 aerodrome certification compliance, except in the notable area of provision and maintenance of runway strip and runway end safety areas. [87]

NMIA Airports Limited lacked operational procedures for the conduct of runway surface inspections during inclement weather and the lack of agreements between the airport, air traffic service and other users, for the furnishing and distribution of inspection results, precluded flight crews from being apprised of the most recent runway conditions prior to arrival. The investigation recommends that these measures should be implemented.

The lack of documentation of runway inspections, as described in 1.10.4.6, indicated a deficiency in the runway inspection procedures at NMIA.

The meteorological reports (See 1.7), the flight crew reports [88] and the evidence of the aircraft's performance from the FDR indicated that runway 12 was probably in a Fair/Medium braking action performance condition, not in a Wet/Good condition, as per the AA Landing Data Card. [89]

2.4 Runway

2.4.1 Runway Surface

As described in 1.10.3, the runway surface was examined and tested by GAIA and the frictional averages were found to meet and exceed the ICAO recommended minimum values. It was thus determined that the frictional characteristics of the runway surface did not contribute to the accident.

2.4.2 Runway Slope

The investigation accepted the information from the longitudinal survey of runway 12/30, prepared by EDM Consultants, dated February 1997, titled "Rehabilitation of Runway, Taxiway and Pavement Works, Runway Profile", which was provided to the investigation by

[87] Appendix 10

[88] See 1.1

[89] Appendix 7

the Airports Authority of Jamaica, as being a fair representation of the runway longitudinal profile at the time of the accident. [90]

In accordance with this information, the longitudinal slope of the runway was within the quoted ICAO recommendations, except that the slope of -1.233% in the first 260 m (853 ft.) of the first quarter of runway 30 exceeded the ICAO recommendation of a maximum slope of 0.8% in the first and last quarter of the runway. The slight upslope of runway 12 would have had a small decelerating effect on the aircraft during the landing roll.

Although the slope of -1.233% in the first 260 m (853 ft.) of the first quarter of runway 30 (that is, the upward slope at the end of runway 12) exceeded the ICAO recommendation of a maximum slope of 0.8%, ironically this upslope had the effect of giving the aircraft some upward propulsion just before it left the runway, thus resulting in the aircraft clearing the depression in which the road to Port Royal lay and having a softer and more level landing site on the sand berm on the east side of the road rather than the rock-faced slope beside the roadway, and also it reduced the speed of the aircraft at impact. These factors resulted in the cockpit and cabin being in a more survivable condition due to the absorption of energy; they also stopped the aircraft before it collided with the concrete pillars supporting the approach lights of runway 30, and before the aircraft entered the sea (see Photo 2). Thus, more serious injuries and/or fatalities to crew and passengers from G forces and damage to the aircraft structure, and possibly from drowning, were avoided.

2.5 Air Traffic Services (ATS)

Although the JCAA ATS Manual of Operations (MANOPS) stated that the controller, on initial contact, must give the current runway conditions and also the latest braking action report to the aircraft, or state that none had been received, RSC reports based on actual observations could not be obtained by ATC since there was no formal agreement with NMIA to provide this information to ATC. [91]

Flight crews rely on ATS to give them current and accurate runway conditions reports. MKJP ATS was not in compliance with this requirement with regard to AA331. The controller should have informed the AA331 flight crew that no braking action report had been received, in accordance with the MANOPs.

Evidence from the Tower controller, and local knowledge, indicated that, even with a tailwind, flight crews probably preferred to land using the Runway 12 ILS approach and landing when arriving from the north, as it afforded a quicker and more convenient procedure than the

[90] See 1.10.2.3

[91] Section 1.10.4.6

circling for runway 30 or the RNAV (GPS) Runway 30 approach, and required less taxi time to reach the terminal building. [92]

JCAA ATS MANOPS specified that the active runway should be the one most in line with the wind, if the wind was more than five knots. On initial contact with AA331, the Approach controller advised the flight crew to expect an ILS runway 12, while advising them the wind was 310 degrees at 10 knots and that they might have to conduct a circling procedure for runway 30. Based on the weather reported by the Enroute controller being ceiling 1,000 feet broken, the circling approach would not have been possible since the ceiling was below the circling minimums.

For AA331, a Boeing 737-800 aircraft, that is, Category C, the circling approach limits were 1,150 feet above sea level ground level, and 3.7 kilometers visibility. [93] The flight crew immediately replied that they could take a straight in approach to ILS runway 12. The option to conduct an RNAV (GPS) Runway 30 instrument approach to runway 30 was not suggested to the flight crew. Furthermore, the flight crew stated that they were not aware of the option of the RNAV (GPS) Rwy 30 approach, as further discussed in 2.7.

At 22:04 EST Manley Approach Radar informed AA331 that "… the information that was given to you by the Enroute controller is still the same, visibility five miles and there's moderate rain at the station". It appears that this weather given to AA331 by the Approach controller, which was not from official weather reports, may have been derived from the AWOS information and the Tower controller's observations (See 1.1.2). The Approach controller should have stated to AA331 that the weather he was giving was from controller observations. This was a procedural error, and the reason for it was not determined. Also, it was not determined whether or not the Approach controller had received the 22:00 EST (03:00 UTC) METAR by 22:04 EST.

The official METAR at the time of the final approach and landing of AA331, issued at 03:00 UTC, 22 minutes before the accident, was ceiling 1,400 feet broken, visibility 3,000 meters (about two miles) [94] JCARs Tenth Schedule, sub-paragraph 10.665(a), states Visual Flight Rules minima in controlled airspace are ceiling 1,000 feet and visibility 3 statute miles, if reported. Thus the weather was officially Instrument Meteorological Conditions (IMC), however the visibility given to AA331 by the Approach controller, based on a visual observation by the Tower controller (See 1.1.5), was Visual Meteorological Conditions (VMC). This difference may be ascribed to rain-shower activity, which can result in inconsistent visibility.

[92] Appendix 4 (3)

[93] Appendix 4(4)

[94] Section 1.7.6

The 03:00 UTC (22:00 EST) METAR was " … visibility 3,000 metres (about two miles) in heavy rain showers, ceiling broken at 1,400 feet, few cumulonimbus clouds at 1,600 feet … " (see 1.7.1 and 1.7.6). There is no evidence that this information was passed to the flight crew by the Tower controller, nor is there any evidence to confirm that the flight crew received the 03:00 UTC METAR on the ATIS. The RH (recorded history) on the flight dispatch document indicated that the 03:00 UTC METAR was sent to AA331 at 03:15 and 03:17 UTC (See 1.7.1) by ACARS, but there was no evidence, from the CVR or elsewhere, that the flight crew took this information into their situational awareness (see definition of situational awareness,), nor was it likely that the flight crew would look at an ACARS message at this busy stage of the approach.

In accordance with JCAA ATS MANOPS the controller should have advised AA331 of the latest runway condition report and braking action report. If no braking action report had been received, the controller was required to state this to arriving aircraft. In the case of AA331, none was available, and the controller did not inform the AA331 flight crew of this, nor did the AA331 flight crew request this information. The reason for this was not determined. This did not contribute to the accident, but it did show the flight crew's low level of situational awareness. This was another instance of an air traffic controller not following established procedures in accordance with JCAA ATS MANOPS.

The investigation considered that the circumstances of the landing of AA331, in 1½ miles visibility in heavy rain, at night, with a 14 knot tailwind, were difficult, and difficult to observe. However, the Weather Standby system, as described in 1.17.3.2, was not activated by ATS. The reason for this was not determined, but it may have been due to the fact that the weather conditions were described only qualitatively, not quantitatively, and were not clearly defined.

Some of the discrepancies with ATS, as described above, may have contributed to the accident. It was apparent that there were some instances where JCAA ATS procedures did not fully conform with ICAO guidance material.

The investigation was unable to conduct an in-depth examination of the ATS organization, but from what was revealed, as described in this section, the possibility of some systemic weaknesses was indicated.

2.6 Meteorological Information

There was evidence that heavy rain was falling at the airport, before, during and following the accident, with visibility as low as 1½ miles and ceiling broken at 1,400 feet, and the FDR data indicated that the surface wind on runway 12 had a 14 knot tailwind component and a seven knot crosswind component from the left, at the time of landing. [95]

The AA331 flight crew was informed of the wind conditions by ATC several times, and remarked in their post-accident interviews on the noise of the rain striking the aircraft. However, at no time was the AA331 flight crew advised by ATC that the rain was "heavy".

2.7 Operations

There was evidence from the AA dispatch document for flight AA331 that the aircraft's weight and centre of gravity were within the required limits for the duration of the flight, and the dispatch of the flight was within the regulatory requirements. [96]

The investigation determined that AA331 was legally dispatched. The interview with the dispatcher (see 1.17.2.4) indicated that AA dispatched only to Dry or Wet runway conditions

The dispatcher stated that he had never had occasion to report braking action at Kingston and all other Caribbean airports, to be other than good/wet. Also he stated that he had never received a report of standing water at Kingston.

AA information provided to flight crews about the Kingston runways included a caution of the possibility of pools of standing water on runway 12/30 after heavy rain, but neither the AA331 flight crew nor the dispatcher was aware of this. [97]

The dispatcher also stated that "the captain was expected to select the best runway for landing". The investigation determined that, under the prevailing conditions, the best runway for landing was runway 30, using the RNAV (GPS) Rwy 30 approach, but the captain did not select this runway. [98]

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[95] Section 1.11.2.2

[96] Section 1.6.3 and 1.17.1.2.4

[97] Appendix 5, Page 10-7X of AA Flight Manual, Part II

[98] Section 1.17.1.2.4

2.8 RNAV (GPS) Runway 30 Approach at Kingston

The statements of both of the flight crew indicated that they were not aware of the RNAV (GPS) Rwy 30 approach at Kingston (See 1.1.2) prior to the accident. The Jeppesen publications in the aircraft's cockpit library contained the plates for this approach and it was confirmed to have been in the aircraft's FMS database (See 1.6.12). It is possible the flight crew did not notice the availability of this approach as they had been focused on programming runway 12 ILS into the FMS. AA SOPs required that FMS approach programming be performed prior to the approach briefing, and normally this happened prior to descent. At this time the most recent wind report was 310 degrees at 9 knots, that is, suitable for runway 12.

At 22:04 EST, the Approach controller told AA331 to expect an ILS Runway 12 approach, wind from 320 degrees at 10 knots and suggested a circling approach for runway 30, however the flight crew chose to do a straight in approach for runway 12. At 22:14:34.7 EST the Approach controller cleared the aircraft for the ILS Runway 12 approach and advised the wind was from 330 degrees at 15 knots. This wind information, eight minutes prior to landing, was the second time the AA331 flight crew was informed that the tailwind had increased. At no time did the controller offer or ask the crew if the aircraft was capable of flying the RNAV (GPS) Rwy 30 approach; instead, at 22:14:56.7 EST the Approach controller asked if AA331 was still able to do the straight in approach to runway 12, to which AA331 responded affirmatively.

Although the AA331 flight crew was aware of the circle-to-land procedure to runway 30 from the ILS Runway 12 approach and that option was suggested to them by the Approach controller, they decided not to conduct that approach as it required a higher ceiling than was reported and they decided (as stated in the first officer's post-accident interview) that the straight in to runway 12 was more appropriate than doing a circling approach, and had more chance of a successful outcome. Given the weather conditions, and the fact that the flight crew was not aware of the RNAV (GPS) Rwy 30 approach, this was an appropriate decision. However, the straight in RNAV (GPS) Runway 30 approach would have offered a better option than the circle-to-land procedure, with a minimum descent altitude of 373 feet agl, and the advantage of an into-wind landing. All of the necessary elements for this flight to conduct the RNAV (GPS) Rwy 30 approach were available, except that the flight crew was not aware of it and the controller did not offer it as an option, which resulted in a continuing lack of awareness of it by the flight crew.

If the flight crew had used the RNAV (GPS) Rwy 30 approach and landed on Runway 30, the accident would probably have been avoided. At the time of handover to the Tower controller, it was evident from the transcripts that the Tower controller thought AA331 had requested the Runway 12 approach and so likely did not think to ask whether the AA331 flight crew would like an RNAV (GPS) Rwy 30 approach.

2.9 Crew Resource Management (CRM)

At 22:17 EST the 03:00 UTC METAR was sent to the aircraft by ACARS, but there was no evidence, from the CVR, or elsewhere, that the flight crew took this information into their situational awareness.

The training required to be completed by the crew in the AA Advanced Qualification Program (AQP) included CRM and the crew reported that they had completed it. AA AQP training programs were approved by the FAA.

The flight crew stated they had discussed Kingston weather in Miami, and had discussed the issue of enroute turbulence. At that time the available information to the flight crew indicated that the Kingston weather forecast was within wind and weather limits for approach and landing on runway 12 and offered no significant challenges. They knew there was an ILS Runway 12 approach, and were not concerned about the arrival. Scattered thunderstorms were in the weather forecast, as were rain showers, normal for the Caribbean, and by using the aircraft weather radar they could avoid these, so thunderstorms, while certainly of interest, would not have been a major concern. In the interviews the flight crew stated that a thorough approach briefing was conducted, although this was not captured on the CVR. The flight crew had prepared for the ILS runway 12 ILS approach and flew direct to KEYNO as cleared by ATC.

It was clear from the CVR record that throughout the approach the flight crew members were aware of weather, engine icing prevention, rain and cloud, and they turned the strobe lights off to avoid flicker distractions in cloud. They were alert concerning the weather shown on the aircraft radar during the approach and to the terrain constraints in the event of a missed approach. They were also aware of, and focusing on, their fuel quantity limitation that allowed them only one approach to land at Kingston. The fuel quantity was such that the aircraft was still slightly above maximum landing weight approaching KEYNO, and they had made efforts during descent and transition to burn off enough fuel to reduce the aircraft to maximum landing weight for the landing at MKJP, by slowing the aircraft and using flaps early to increase drag and burn more fuel. They were still focused on the landing weight consideration during the late stage of the intermediate approach.

In the latter stages of the transition to the final approach fix, some eight minutes before landing, AA331 was cleared for the ILS Rwy 12 and, in the same transmission, was advised by the Approach controller that the wind was from 320 degrees at 15 knots. The first officer read the clearance back and then the Approach controller asked if AA331 was still able to make a straight in to runway 12 and gave the wind from 320 degrees at 14 knots. The AA331 flight crew replied in the affirmative.

The CVR contained no spontaneous discussion between the flight crew in response to this weather information that was given by the Approach controller, which was the second indication to the flight crew that the tailwind had increased. This did not prompt further discussion between the flight crew regarding adjusting the landing technique (using additional flap or braking) for the increased tailwind, which would be expected. This lack of discussion may indicate that their

CRM was not adequate. It is possible that the flight crew may have been experiencing some attention tunneling due to distraction by the heavy rain they were flying through, and concentration on the weather picture on the radar between the aircraft and the runway. The early flap selections and speed reductions for fuel still to be burned off for landing, and announcing HUD settings and presentation may have also diverted their attention. As far as they were concerned, the wind was still within the company limit for landing. Less than five minutes prior to landing, the runway was reported as "Wet" by the Tower controller. This resulted in the first officer suggesting a change from autobrakes setting 2 to setting 3, to which the captain agreed.

The crew's CRM could have been better if they had conducted more discussion regarding the increased tailwind, had adhered exactly to AA Bulletin 737-07, and performed a last minute landing performance check when they knew the tailwind had increased. However, the evidence indicates that they were of the belief that the landing distance assessment ("advance analysis") the first officer described in his interview was sufficient to meet this requirement, and it appeared possible that use of this was normal practice in the company, so no concerns were raised. Until they were made aware of the runway surface condition as "Wet" by the Tower controller they were proceeding with some level of complacency, landing in rain with a tailwind (as they stated in interviews they had done in the past), maybe not the best condition, but certainly not an unusual situation for them. Until the Tower controller's report indicated to them that the runway was "Wet", they were proceeding as if the runway was dry to wet-good condition and using autobrakes 2 setting. The report of runway "Wet" did not raise any concerns to them since it had no modifying information, such as a braking action report.

Better CRM might have led them to a discussion of the risks associated with a tailwind landing on a wet runway with rain falling, but at this stage of the flight there was little or no time for such discussion as they were almost on final approach. The only change in their plan was the adjustment of the autobrake setting from 2 to 3. Any other change at this point, even a change of approach to RNAV (GPS) Rwy 30, would have meant a go-around, with reprogramming the FMS and considerable maneuvering. The crew had already decided against circling for runway 30 due to the weather conditions, and there was insufficient fuel for flying more than one approach, then diverting to Cayman. The crew was therefore committed to the approach for runway 12, without the option to fly the RNAV (GPS) Rwy 30 approach, even if it had been offered by ATC.

The ILS Rwy 12 approach was flown accurately and on-speed and was therefore unremarkable. The first officer gave extra callouts to assist the captain on short final, calling altitude at 500 feet, on-speed and sink rate 800 fpm, all normal parameters. The aircraft crossed the threshold of runway 12 at 70 feet RA, which was 20 feet higher than the ideal crossing height, and was on-descent to the touchdown point or very slightly beyond it at that moment. The captain had switched his attention from the HUD offset localizer to visual cues once the runway was visual, and was using outside references for landing. Both pilots described the aircraft as being "in the slot" as it crossed the threshold although this was confirmed by the FDR as being 20 feet high. Just as the aircraft was crossing the runway threshold the FDR recorded a nose up pitch motion on the controls and the rate of descent, which had been normal for that speed, was reduced. As the autothrottle was still connected and operating in speed mode the aircraft stayed on speed and a float ensued. Neither the captain nor first officer remarked on this.

It was raining heavily as the aircraft approached the runway and floated, before flaring and touching down. The first officer did not alert the captain to the fact that the aircraft was still airborne beyond the touchdown zone. Due to the heavy rain, lack of peripheral lights on the right side of the aircraft and the first officer’s duties that required his attention in the cockpit, this may not have been readily apparent to him. The captain disconnected the auto throttles manually at about 35 feet RA, and retarded the throttles to idle. The FDR indications show pitch control motions indicative of the captain “feeling for the runway”, and this prolonged the flare. The first officer's duties during the flare and landing phase were to monitor the flight instruments, observe the HUD pitch monitor and warn the captain if the pitch angle became too high, monitor the spoiler deployment, engine thrust reverser deployment and autobrake activation and call if there were deviations.

The RA auto voice call-out function was calling out the main wheel height above the runway as the aircraft descended. The first officer's attention during this phase would have been divided between the instrument panel and watching the flare and landing; also, during this time, he reached over to confirm that the ground spoiler lever was in the armed position. These duties required his attention during those few seconds, consequently he could not monitor everything the aircraft was doing related to the landing. The first officer had a lot of confidence in the captain's flying skills, as he stated in his interview, and it was possible that he was complacent for a few seconds, coupled with the distractions of his normal duties.

The first officer described the aircraft as floating for a short while, as did the captain, but neither of them reported a prolonged float, or of being aware of the aircraft passing the PAPI lights, or realizing the aircraft had passed the touchdown zone while still airborne, so neither called for a go-around.

Better CRM might have been displayed if there had been more discussion of the tailwind and its effect on landing distance, or even discussion related to the choice of landing on runway 12. However, it is probable that, since the crew was unaware of the option of the RNAV (GPS) Rwy 30 approach and believed that the landing distance assessment was covered by the “advance analysis”, they did not enter any such discussion. Overall, the CRM interaction was about what would be expected in the circumstances, and the only deficiency was that there appeared to be some complacency regarding the severity of the landing conditions.

2.10 Go-Around

There was no instruction in the AAB737 Operating Manual to the effect that a first officer who was the pilot monitoring could call for a go-around, with the pilot flying (that is, the captain) being obliged to follow through. [99] The instructions in the AA Flight Manual indicate clearly that the captain could disregard a first officer's go-around call. [100]

The investigation did not determine exactly what was the philosophy of AA regarding this, but it was considered to be possible, despite the company procedures in AA Flight Manual Part 1, Chapter "Crew Qualification and Responsibility", "First Officer Responsibility", that a first officer who was pilot monitoring might be reluctant to call for a go-around. [101]

Although go-around after landing can be a hazardous procedure for several reasons, the option for the flight crew to do so was open until such time as reverse thrust was selected, and the captain reported that he considered this when the aircraft was on the runway and not decelerating as expected (see 1.1.4), but chose not to do so. It is possible that, if the first officer had called for go-around after threshold crossing and before the captain selected reverse thrust, then the accident might have been avoided.

However, it was not guaranteed that a go-around would have been successful if attempted during the few seconds after touchdown, before the reversers deployed, since the aircraft was already on the ground decelerating, the engines were spooled down to idle, the flaps were at 30, the runway might have had pools of water on it in places, there was less than half of the runway remaining for takeoff and there was a strong tailwind.

FAA SAFO 1005, issued 3/1/10 (shortly after the accident), which recommended:

> *1. Either the pilot flying or the pilot monitoring may make a go-around callout, and*
> *2. The flying pilot's immediate response to a go-around callout by the non-flying pilot is execution of a missed approach,*

showed that the FAA was concerned about the standard operating procedures for go-around in the industry, and the reluctance of first officers and/or monitoring pilots to call for go-around.

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[99] Section 1.17.1.1.9

[100] Section 1.17.1.1.9

[101] AA Flight Manual Part 1, Chapter "Crew Qualification and Responsibility", Section 3, page 5, part 1.8, "First Officer Responsibility"

2.11 Flight Crew Fatigue

Although the flight crew had just had three days' rest, and their flight/duty/rest times were within the required limits, at the time of the accident they were at the end of the third flight of a long duty day. The captain’s statement indicated that getting off the gate was usually the most stressful part of a flight, and having so many passengers, the turbulence over Cuba and the noise of the rain striking the aircraft would have added to the flight crew’s stress on this flight. The flight crew had been on duty for nearly 12 hours, and awake for more than 14 hours, and it was almost “bedtime” in their recent diurnal cycle. Although the flight crew had just had three days off duty, they were at the end of a long duty day, and were possibly fatigued: however, the extent to which this affected their performance could not be determined.

The information in 1.18.7, NTSB Review of Fatigue in Major US Accidents, includes findings from this NTSB study regarding fatigue resulting in deteriorating decision making, task fixation and reluctance to discontinue a flawed approach.

2.12 Pitch-Up Inputs and Visual Illusions

Just as the aircraft flew over the runway threshold at about 70 feet RA, the DFDR indicates that the captain made several slight pitch up inputs. At this point the first officer made no comment, and the captain continued with the landing. The following night visual illusion factors and depth perception impediments may have contributed to the pitch up inputs and the subsequent long landing:

1. The landing was conducted in the hours of darkness, with visibility as low as 2,200 metres in heavy rain, as recorded in the SPECI taken three minutes after the accident.

2. Due to the absence of touch down zone and centre line lighting, and the absence of reflective material in the runway marking paint on runway 12, most of the light from the landing lights was reflected away from the runway surface and away from the aircraft instead of back to the cockpit; this, together with the halo effect caused by the diffusion of light by water when viewing runway edge lights through a wet windshield, may have limited the captain’s depth perception cues, and made it difficult for him to judge exactly the position of the touchdown zone.

3. The captain’s visibility may have been impeded by the heavy rain on the windshield, and the rapid movement of the windshield wipers.

4. The captain did not have a clear far visual horizon for horizontal and vertical reference due to the absence of lights beyond the runway and the reduced visibility in the rain.

5. The possibility that the captain experienced a visual illusion that the aircraft was lower than it actually was because its higher groundspeed, caused by the tailwind, resulted in the runway lights going by faster, may have caused the captain to prematurely make the pitch up inputs to flare for landing.

The combination of these factors may have made the captain uncertain of the position of the aircraft in relation to the touchdown zone while descending for landing, and caused him to inadvertently pitch the nose of the aircraft up.

2.13 Simulator Trials

The ¼ dot deviation above the glideslope noted during the simulator trials [102] happened as each pilot disconnected the autopilot and manually turned to the right (southward) about ten to fifteen degrees off the localizer track to intercept and then turn left (northward) again to line up visually with the runway extended centre line, at about 300 to 500 feet agl. In some cases a slight second correcting turn either right or left was required to establish the drift correction. All of these four or five examples resulted in the aircraft being about a quarter dot high on the ILS glide-path after lining up with the runway centre-line, perhaps due to the aerodynamic characteristics of the aircraft in the turn, or due to pilot technique in pulling nose up slightly on the elevators due to the visual illusion of descending in the turns.

It was concluded that this slight pitch up event may have been because the pilots had disengaged the autopilot and were manually flying the simulator.

As the simulator did not accurately replicate the wet runway conditions, no conclusion could be reached from the simulator trials regarding the aircraft stopping performance.

2.14 Runway Condition Report “Wet”

There was no record on the CVR or the ATC tapes or any other evidence of the AA331 crew having received a runway condition report from any ATC controller or elsewhere from the time of the AA331’s initial contact with the Enroute controller at 02:47:00 UTC until informed “Be advised runway wet … ” by the Tower controller, given with the landing clearance at 03:17:57 UTC, 4 minutes and 44 seconds before the accident. The information given to the crew by the Approach controller at 02:59:15 UTC, “he didn’t have any problem coming in”, was not a runway condition report. [103]

It was apparent that there were some differences in the use of the term “Wet” to describe

[102] Section 1.16.3

[103] Appendix 3

the runway condition. The evidence indicated that to the AA331 flight crew an unqualified "Wet" report meant AA "Wet/Good", that is, less than 1/8 inch of water, [104] whereas to the Tower controller "Wet" meant simply that the runway was wet, based on the fact it was raining, but did not include any measurement of depth or any description of the runway condition. In ICAO terms "Wet" meant "the surface is soaked, but there is no standing water." [105]

Although the flight crew had not requested or received a runway condition report until told by ATC "Be advised, runway wet" when they got their landing clearance, it is likely that the flight crew felt confident that the aircraft could land safely on the runway.

However, the flight crew:

- Had some evidence that there could be moderate to heavy rain at the airport, indicating that the worst-case braking action might be worse than Wet/Good (in the captain's interview he mentioned heavy rain, ATC reported moderate rain, aircraft radar was giving yellow return, the captain stated "That's some good rain shower sitting down here" from observation of the weather radar return, and the aircraft was in what was recorded as "heavy rain", (see 1.7.11, and as per the 03:00 UTC Metar), during the final approach and landing stage).
- Did not request a runway condition report before completing the approach briefing, or subsequent to this.
- Did not receive the (unsolicited) runway condition report from ATC of "Be advised, runway wet." until less than 5 minutes before landing.
- Did not request a braking action report, and ATC did not inform them that none had been reported.

Furthermore, the flight crew's briefings appeared to be incomplete and almost certainly did not include a review of Page 10-7X, which cautioned regarding the potential for standing water after heavy rain. Although the captain did not indicate in his interview whether or not he was aware of Page 10-7X *before* the accident, if he was aware of it before the accident then he should have anticipated pools of standing water, and done a Landing Distance Assessment for Fair/Medium braking action conditions, accordingly. In the reported weather conditions present (rain and thunderstorms) this warning should at least have been part of the Approach/Descent briefing, in which case the first officer would have been aware of it, but the first officer stated in his interview that he was not aware of it. Therefore it is justified to say that the captain was not aware of this warning before the accident. If the crew had been aware of this, it might have prompted them to change their plan to land in heavy rain conditions, and the accident might have been avoided.

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[104] Section1.17.1.2.10(6)

[105] Section 1.10.4.5

ATC should have given AA331 the runway condition report and braking action report (or lack of such) on initial contact. [106] It would have been better airmanship on the part of the flight crew if they had requested this information when it was not offered by ATC, as this information is a normal part of a flight crew's landing planning, and situational awareness. However, the flight crew's passivity in this regard was likely due to an expectation that ATC would have advised them of any significant information without being prompted. Also, in accordance with AA Bulletin 737-07, the flight crew was directed to confirm whether or not landing conditions had changed from the time of dispatch, hence it was necessary for the flight crew to obtain this information for approach and landing planning.

When the AA331 flight crew received this report of "Runway wet", the first officer said to the captain "Runway's wet. You want to go to brakes three?" (that is, change autobrake setting from 2 to 3). The captain agreed to changing to autobrake 3.

There was no further discussion of applying AA recommended guidance for tailwind landing on a wet runway, which the investigation considers would have been prudent.

The different interpretations regarding the meaning of the word "wet" probably were confusing. If the flight crew had been aware that the runway condition could have been less than Wet/Good, they might not have attempted to land on runway 12 with a 14 knot tail wind at that time. The lack of discussion on the part of the flight crew might have been due to a possible expectation that ATC would advise them of any significant conditions.

2.15 Inconsistency between AC91-79 and SAFO 06012

As stated in 1.17.4.3, it should be noted that AC91-79, Appendix 4, 10 b. (2), as above, stated "*If a runway is contaminated or not dry, that runway is considered wet",* and that SAFO 06012, item 4. Definitions, stated *"i. A wet runway is one that is neither dry nor contaminated"*. These two statements are inconsistent. As they are both FAA advisory material, these statements should be amended so that they are consistent.

2.16 Kingston Field Report

As described in 1.10.4 of this report, there was some confusion regarding responsibility for obtaining runway condition reports and how the information was disseminated to operators and flight crew.

The evidence indicated that the "WET 0.10 IN WATER" report on the runway was a standard one given by AA personnel at Kingston to AA dispatch in Dallas when it rained, and

[106] Section 1.17.3.3

that actually no observation or measurement was made, or obtained from any other source, by personnel of American Airlines.

This was contrary to American Airlines procedures, as described in the AA Kingston Station Manual. [107] The reason that these procedures were not followed was not determined. AA management should have ensured some means of obtaining a runway surface condition report.

ICAO guidance suggested that the airport operator, in this case NMIA Airports Limited, should inspect the runway and advise ATC of runway conditions during periods of inclement weather, but this guidance was not adopted and included in the MKJP Operations Manual as an instruction to staff, and was not done by MKJP during the approach of AA331. [108]

If a runway surface condition inspection had been conducted and passed on to ATC, it might have alerted the flight crew to the possibility the runway braking action was not AA Wet/Good, and prompted them to abandon their plan to land on runway 12 in heavy rain with a 14 knot tail wind.

ICAO guidance in Doc 4444 Para 7.5 required ATC to transmit the runway condition to incoming traffic during periods of inclement weather, but the NMIA ATC Unit Specific instructions did not require ATC to obtain runway condition reports from NMIA, and the ICAO definitions for reporting water on a runway (See 1.10.4.5) were not in JCAA ATS MANOPS nor in the NMIA Operations Manual. ATC simply reported "runway wet" when it rained. This may have been the result of the lack of any formal arrangement between the parties for the provision of runway condition reports.

The JCAA ATS MANOPS and the NMIA Manual should be amended to include these definitions.

In the case of AA331, the evidence indicates that AA331 was not given any runway condition report by ATC until the Manley Tower said " … be advised runway wet …" less than 5 minutes before AA331 landed. In any event, the statement " … be advised runway wet …" was not a runway condition report, as per ICAO recommendations, since the runway had not been physically inspected.

In addition to this, and as stated in the Jamaica AIP [109], there was no technical means for measuring standing water at NMIA, although the ICAO guidance could easily have been followed by NMIA (See 1.10.4.5).

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[107] Section 1.10.4.4

[108] Section 1.10.4.6

[109] Section 1.10.4.1

2.17 Determination of Depth of Water on Runway, and Runway Braking Action

As described in 1.18.6, the investigation determined that the stopping performance of AA331 on the runway was equivalent to AA RRLD Fair/Medium braking action.

This finding was supported by the:

- Captain's description of feeling "like he was on ice" after landing,
- Captain's statement that he thought the runway was "under water",
- Lack of deceleration with maximum manual braking,
- Evidence on some of the main landing gear tires that the braking was friction limited,
- Reports of heavy rain.

It should be noted that the water depth over an entire runway cannot be accurately measured, and qualitative reports made from visual inspections are needed in lieu of quantitative reports. ICAO does have guidance for description of such conditions. [110]

2.18 Survival Aspects and Injuries

The L1 door was jammed because the escape slide pack contacted the floor when it was prematurely released from the escape slide compartment. This could have had serious consequences and have resulted in serious injuries or fatalities if there had been a post-impact fire, or the aircraft had been submerged in the sea.

Apart from the L1 door, all the other exits worked, and the evidence indicated that all the passengers were evacuated from the aircraft within about 15 minutes of impact.

It was not determined why the R1 slide deflated. The L2 and R2 slide packs were released from the slide compartments, but did not inflate because the fuselage was too close to the ground for the slide packs to fall far enough to activate the inflation mechanisms.

Three of the four cabin crew members, according to their interviews, and 15 of the 17 passengers who answered questionnaires reported seeing no lights. However, many of the emergency lighting batteries were found discharged post-accident, indicating that some of the emergency lighting systems may have been working. There was insufficient evidence to determine conclusively whether or not the emergency lighting system worked as designed after the impact.

The evidence indicated that some of the passengers may have been injured by falling overhead bins and passenger service units.

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[110] Section 1.10.4.5

The captain's reported back injuries were possibly attributable to the failure of the captain's seat crotch belt bracket, the uncertified seat bottom cushion, or a combination of these two conditions. [111].

2.19 AA Bulletin 737-07 and Landing Data Card

AA Flight Safety Programs Management stated that American Airlines Bulletin 737-07 was generated for American Airlines to comply with FAA SAFO 06012.

Despite use of the word "should" in Bulletin 737-07, the AA Flight Safety Programs Manager stated: "AA management both expects and assumes flight crews will follow the instructions (recommendations) in Bulletin 737-07". [112] This left open the question as to whether or not it was mandatory for AA flight crews to conform to Bulletin 737-07.

AA stated that Bulletin 737-07 was part of the AA331 flight crew's Performance training, therefore it was assumed that the flight crew was fully aware of the information in this bulletin. However, the investigation was unable to determine why AA had not made it clear to the AA331 flight crew that following the directions in Bulletin 737-07 was mandatory (if that was their intention), nor why the AA331 flight crew did not follow these directions.

2.20 Bulletin 737-07 and "Advance Analysis"

AA complied with SAFO 06012 with Bulletin 737-07, [113] which stated " … the flight crew should use the charts …"; however the AA331 flight crew were using the "advance analysis", which was a "worst case scenario", although AA stated:

> *"no AA documents or training materials specifically define the "advance analysis" concept that the JCAA cites in the draft report. AA flight crews are not trained to use, required to use, or discouraged from using this method".*

The reason for this contradiction was not determined.

It should be noted that the "advance analysis" did not specify aircraft configuration at landing, [114] and the initial configuration planned by the flight crew, that is, autobrakes 2 and flap 30 would not

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[111] Section 1.12.6.2

[112] Section1.17.1.2.10 (4)

[113] Section 1.17.4.2 and Appendix 6

[114] Section 1.1.2

have enabled the aircraft to stop on a runway with AA Fair/Medium braking action with a 14 knot tailwind, with a 15% safety margin, even if it had landed at 1,000 feet from the threshold.

Furthermore, there was no evidence as to whether or not the "advance analysis" used by the AA331 flight crew had been modified to account for the increased landing distance that resulted when the AA B737 tailwind landing limit was increased from 10 knots to 15 knots.

2.21 AA Flight Crew Landing Distance Assessment

During his interview, the first officer described using a process for landing distance assessment that essentially constituted a worst case scenario analysis. The investigation was unable to determine exactly what the source of the data was used on this flight.

The first officer said they did not have to calculate landing distance before each landing. They had landing performance data and a tailwind was taken into consideration in that data. He said on a runway like at Kingston where it was 9,000 feet long, with wet conditions, there was no problem with the performance data for landing flaps 30 and they had both done this many times. He also stated that for runways shorter than 8,000 feet, if it was wet, the more factors like wet runway, tailwinds to consider; they were cumulative based on field elevation and landing weight. He said he was very comfortable with the runway data but it was more critical when there was a shorter runway and tailwind. [115]

For the purposes of the investigation, this was taken to mean that the AA331 flight crew believed that if the runway was more than 8,000 feet, and the tailwind was 15 knots or less, on a wet runway, with the aircraft at maximum landing weight of 144,000 pounds, with flap 30, then a safe landing was assured, and it was not necessary to calculate landing distance before each landing. The investigation also considered that it might be possible that the above assumption was based upon a 9,000 foot runway, rather than an 8,000 foot runway.

This method of estimation was later referred to as “advance analysis” by the American Airlines Flight Safety Programs Manager (see 1.17.1.2.10, #7).

[115] Section 1.1.2

When the AA Flight Safety Programs Manager was asked:

> *"Why did the AA331 flight crew use an assumption that if the runway was more than 8,000 feet, was "wet", the tailwind was less than 15 knots, aircraft at max landing weight, then it was safe to land? Is this method approved by AA, taught by AA, commonly used by AA flight crews?"*

he responded:

> *A runway condition report of "Wet" with no other modifying information, e.g. "braking action Poor", would indicate braking action 'Good'. An acceptable technique for a flight crew who flies into a certain airport frequently is to conduct an* ***"advance analysis"*** *of the worst case scenario for the landing runway, that is, for a known landing length, braking action, wind component, landing weight, etc. the flight crew could determine in advance that as long as they landed below the maximum weight for these worst case conditions the runway length was acceptable. A review of this "advance analysis" prior to landing using the actual conditions at time of landing is acceptable* (Emphasis added).

The AA manuals contained all the required data to make such a worse-case calculation; however they did not describe or recommend this technique. Guidance to AA flight crews was contained in AA Bulletin 737-07, which recommended confirming landing performance limits just prior to landing using the actual runway conditions at the time of landing, noting that if landing conditions had not changed from time of dispatch there was no need to do this assessment again.

The "advance analysis" used by the flight crew of AA331, and as alluded to by the first officer in his interview, did not specify the following aspects:

1. Method of braking,
2. Use of reverse thrust,
3. Distance of touchdown point from the runway threshold.

Also, it assumed Wet/Good braking action at worst, without confirmation of this.

The question remains, how did the AA331 flight crew arrive at the "advance analysis" of, *"if the runway was more than 8,000 feet, and the tailwind was 15 knots or less, on a wet runway, with the aircraft at maximum landing weight of 144,000 pounds, with flap 30, it was not necessary to calculate landing distance before each landing"*?

2.22 Calculation of landing distances

There was no evidence that the flight crew had followed the exact recommendations of Bulletin 737-07 to perform a landing distance assessment, but instead, as described by the first officer in his interview, had used a landing distance assessment worst case scenario, that is, "advance analysis", which one AA manager considered to be an acceptable means of compliance. The exact figures used to make this "advance analysis" were not stated during the flight crew interviews and the investigation later used the AA B-737 Landing Data Card tables to reconstruct a worst case scenario based on the following assumptions:

- Aircraft at maximum landing weight
- Tailwind component 15 knot limit
- Flaps 30 (as used)
- Auto spoiler deployment
- No reverse thrust for AA Dry Runway and AA Wet/Good braking action: two engine, detent two, reverse thrust for AA Fair/Medium braking action.
- Use of maximum manual braking or maximum autobrakes
- Sea level
- On speed
- On path and slope
- Anti-skid wheel braking operative

The Dry runway figures are from demonstrated certification flight tests, and include the demonstrated air distance to touchdown (assumed to be about 1,000 feet), and a 67% safety factor. The Wet/Good braking action data include the demonstrated dry runway air distance (assumed to be about 1,000 feet) and safety factor of 92%, while the figures for Fair /Medium braking action are derived using a constant aircraft braking coefficient associated with the braking action/runway surface condition, air distance of 1,000 feet and considerations for the aircraft configuration, spoiler use, reverse thrust, autobrake MAX setting or maximum manual braking, plus a 15% margin.

The table below compares the worst case scenario at 15 knot tailwind component with the actual tailwind component and the reported tailwind component that could have been used in the calculation of landing distance required at the time of the approach briefing at top of descent.

Tailwind Component	**Dry Runway** **67% safety factor** **(feet)**	**Wet/Good braking action** **92 % safety factor** **(feet)**	**Fair/Medium braking action** **15 % safety factor** **(feet)**
15knots (maximum tailwind landing limit) (1,000 foot air distance included).	7,230	8,120	9,000
Actual, at landing, 14 knots (1,000 foot air distance included).	7,130	8,010	8,870
Reported at 02:48 UTC, about the time of the approach and landing briefing, 310/7.5, equivalent to a 7 knot tailwind (1,000 foot air distance included).	6,420	7,290	8,030
Received at 02:35 UTC was 02:28 UTC SPECI via ACARS, 310/09 knots equivalent to 9 knot tailwind (1,000 foot air distance included).	6,620	7,500	8,270

Table 7 : Tailwind Component

Note 1: The numbers in this table are derived from the American Airlines B737-800 Required Runway Landing Length tables in Appendix 7.

Note 2: The numbers in this table do **not** include the effect of 5 knots above Vref.

Tailwind Component	**Dry Runway** **(feet)**	**Wet/Good braking action** **(feet)**	**Fair/Medium braking action**
Autobrake 3 un-factored (1,000 foot air distance included and 14 knot tail wind).)	7,110	7,140	8,250
Autobrake 3 factored (+ 15%)(1,000 foot air distance included, and 14 knot tail wind).)	8,170	8,210	9,490
Autobrake Max un-factored (1,000 foot air distance included and 14 kt tail wind)	4,840	5,930	8,000
Autobrake Max factored (+ 15%)(1,000 foot air distance included, and 14 knot tailwind)	5,570	6,820	9,200

Table 8: Autobrake Data

Note 1: The Autobrake 3 data for 30 flap comes from the Boeing B737-800 Landing Distance tables in Appendix 9. This information would not have been available to the AA331 flight crew on the accident flight.

Note 2: The numbers in this table include the effect of 5 knots above Vref, temperature correction for ISA +5° C and two engine, detent two reverse thrust.

1. **For Runway length 8,000 feet or more.**

If an 8,000 foot runway is accepted for the "advance analysis", then the "advance analysis" was either incomplete or incorrect, because it did not accommodate a 15 knot tail wind with 30 flap.

The following scenarios fall within an 8,000 foot runway "advance analysis" for a wet runway surface condition, or a runway with Wet/Good braking action:

(a) 10 knot tail wind, with 30 flap (former tail wind landing limitation).
(b) 15 knot tail wind, with 40 flap (tail wind limitation at time of accident).
(c) 13 knot tail wind, with 30 flap (maximum tail wind for 30 flap landing).

2. For Runway length 9,000 ft. or more.

If a 9,000 foot runway is accepted for the “advance analysis”,

(a) Covers all scenarios for runway Wet.
(b) Covers accident scenario, including Fair/Medium.
(c) Covers all scenarios including Fair/Medium, but yields slightly less than 15% margin for Kingston.

The above data indicates that a landing within the runway, in Fair/Medium conditions, could have been achieved, but not with a 15% safety margin, had the flight crew landed the aircraft at 1,000 feet and used the AA recommended maximum deceleration techniques for the circumstances.

The CVR indicated that the flight crew originally planned to use autobrake 2 setting for deceleration and later, on being informed that the runway was wet, elected to use autobrake 3 setting. Post accident analysis of the FDR data indicated that the aircraft could have been stopped on the available runway using autobrake 3 setting, with no safety margin, if it had touched down within the first 1,600 feet, and reverse thrust was immediately applied.

The captain stated that he thought for this landing he was better off with flaps 30, and he said flaps 40 can cause the aircraft to float sometimes. The aircraft was landed with flap 30.

2.23 Flight crew compliance with Bulletin 737-07

Although Bulletin 737-07 stated “ … the flight crew **should** … ”, it is evident from the statement of the Flight Safety Programs Manager (see 1.17.1.2.10, Item 4) that AA expected the flight crews to comply with this bulletin. [116] The flight crew, in using the “advance analysis”, was therefore not strictly following the guidance of Bulletin 737-07. However, the AA Flights Safety Programs Manager indicated for the investigation that he considered the "advance analysis" method to be an acceptable means of complying. The reason for this contradiction was not determined.

2.24 Discussion of “advance analysis”

The investigation was informed that the FAA advocated and briefed the equivalent concept of “advance analysis” within the aviation industry in 2006, prior to the release of SAFO 06012. It was stated that operator time of arrival landing distance assessments can be effectively implemented in multiple ways, including, but not limited to, a pre-calculated matrix of conditions/thresholds that flight crews may be able to quickly reference or recall to ensure that landing performance requirements are met for many landing conditions (without repeated or

[116] Section 1.17.1.2.10, Item 4

detailed calculations prior to every landing), and that an “advance analysis” may take into consideration the most adverse conditions likely to be encountered.

The discussion in 1.17.4.2 refers to voluntary compliance with OpSpec/MSpecC382, but there was no evidence that AA had used this option.

The investigation was unable to further research or substantiate this information.

However, the investigation believes that there may be risk inherent in entrusting critical performance information to memory, and believes that when the advance analysis technique is utilized that the operator should ensure the flight crews employ the recommended aircraft configuration and deceleration techniques to match the runway conditions.

AA stated that no such concept as the “advance analysis” was defined, approved or trained by American Airlines. The investigation determined that a flight crew using an "advance analysis" needs to know what conditions (that is, assumptions, technique, deceleration devices, runway surface condition) the analysis is based on. The "before landing" assessment is then to confirm whether or not the time of arrival conditions are within those used in the "advance analysis."

2.25 Placement of Bulletin 737-07 in AA Manuals

AA Bulletin 737-07 stated:

> *“ … if (landing) conditions change, or deteriorate (as they had, as described in 2.23), the flight crew should use the charts on the revised Wind Component landing Data Card … to confirm adequate runway length for landing (taking into account) meteorological conditions, surface condition of the runway … (etc.).*

Bulletin 737-07 was specifically addressing an action, that is landing performance assessment, required by AA flight crews to complete before landing. This information should have been included or referenced in the AAB737 Aircraft Operating Manual, Vol 1, P. 5 – 7, “Considerations prior to descent”, but was instead placed in the Performance Section. This may have resulted in it not being brought adequately to the attention of AA flight crews.

There was no mention of, or requirement to, perform a landing performance assessment *per se* in the above mentioned “Considerations prior to descent”. [117]

[117] Section 1.17.1.1.5

2.26 Issue of Autothrottle/Autopilot use

The investigation considered that the captain's leaving the auto-throttle engaged (after disengaging the autopilot) until the aircraft was about 1,200 feet past the threshold, at about 40 feet RA [118] was a factor contributing to the accident, as the aircraft then touched down at 148 knots, that is, Vref + 5, instead of the desired Vref of 143 knots [119], making the landing ground speed faster, the flare longer, and the required stopping distance longer.

As described in 1.17.2.4, "Autopilot/Auto-throttle Use During Approach", it is stated in the Boeing 737 NG Flight Crew Training Manual, page 1.34, that auto-throttle use is recommended only when autopilot is engaged in CMD.

Furthermore, although it was not established whether or not AA management was aware of the article by Bill McKenzie of Boeing [120], and this article referred to the Boeing 757, there was no evidence that the article was not valid for the Boeing 737-800, and it presented strong arguments for not using auto-throttle when auto pilot was disengaged.

The investigation determined that:

- AA did not follow Boeing's recommendation in this regard.
- The FAA approved the AA B737 Flight Crew Training Manual without this recommendation being included.
- AA flight crews were not required to follow the Boeing guidance on use of the auto-throttles.

The investigation considers that the Boeing guidance and the McKenzie article provide justifiable reasons for following the Boeing guidance on the auto throttle and that there is sufficient evidence for the FAA to require that all Boeing 737-800 operators follow the Boeing guidance in this regard.

[118] See 1.11.2.2

[119] Section 1.1.3 and 1.6.4

[120] Section 1.17.2.4

2.27 FAA Safety Information SAFO 06012 and AC 91-79, and AA Bulletin 737-07

The investigation reviewed NTSB recommendation A-07-61, FAA AC-91-79 and AA Bulleting 737-07 guidance and safety recommendations in relation to this accident and determined that there is:

- No evidence that AA incorporated the guidance in AC 91-79 into AA guidance material, nor was it mandatory for AA to have done so;

- Evidence of conflict within AC 91-79 in relation to runway surface condition assumptions (See 1.17.4.3 last sentence in paragraph 10) and between that conflict and the contents of paragraph 11 of AC 91-79; and,

- Evidence of conflict between AC 91-79 and SAFO 06012 with relation to the conflict within AC 91-79 (cited above).

With reference to the above:

The statements "*If a runway is contaminated or not dry, that runway is considered wet" from AC 91-79, Appendix 4, Page 3,* has two possible literal interpretations:

1. If a runway is contaminated, that runway is considered wet.
2. If a runway is not dry, that runway is considered wet.

   Interpretation 1 conflicts with guidance below which states "*If there is rain actively falling on the runway, standing water should be assumed"*.

   Interpretation 2 is incomplete as it does not account for any contaminated runway performance levels (when contaminants other than water are reported).

   Interpretations 1 and 2 conflict with Guidance from SAFO 06012 in Item 4i, Definitions, Runway Surface Conditions (Page 2).

The investigation believes that there is a safety risk if guidance material provided to the industry contains information that may not be correct or that may conflict with other pertinent guidance material, and that clarity, accuracy and consistency are needed to avoid any ambiguity or misunderstanding on the part of the target audience of flight crew and operators.

FAA SAFO 06012, dated 31/08/06 and FAA AC 91-79, dated 06/11/07 [121] were available to American Airlines.

SAFO 06012, 6 e 2, stated that standing water is equivalent to Poor Braking Action, and this was passed on to the flight crews in Bulletin 737-07.

AC 91-79, Appendix 4, Paragraph 11, stated "If there is rain actively falling on the runway, standing water should be assumed" (Note: this is NOT qualified by the preceding statement " ... if there is no clear report of runway condition … ") (see 1.17.4.3.). Thus, if this recommendation was followed, AA flight crews should have been using Fair/Med or Poor Required Runway Landing Length tables for landing distance calculations when rain was actively falling, rather than Wet/Good. There was no evidence that AA had passed this statement on to their flight crews in the form of a Bulletin or manual amendment. It is possible that the flight crew of AA331 might not have attempted the landing under the assumption that the runway braking action was AA Wet/Good if they had been instructed to assume standing water when rain was falling on the runway.

The AA Performance Manual, Section R14, Bulletin 737-07 (dated 11-26-06), as quoted in 1.17.1.1.5, stated: *"The new FAA recommendation is to confirm landing performance limits just prior to landing, using the actual runway conditions at time of landing."* This information was not appropriately placed as a mandatory part of the approach briefing to be performed by the flight crews, but was more of a reported recommendation in the Performance section, and the wording does not appear as a clear AA instruction to the flight crews. It appears that the flight crew of AA331 were not familiar with this information, as they continued with the approach for landing in heavy rain and a tailwind close to the limits, assuming the runway was in a Wet/Good condition without confirming the landing performance limits just prior to landing.

2.28 Landing Conditions and Landing Performance Assessment

AA Bulletin 737-07 stated "If the landing conditions, from the time of dispatch do not change, there is no need to do this assessment.", and " … if landing conditions change, the flight crew ***should*** … confirm adequate runway length for landing. This assessment must take into account meteorological conditions …" Thus it should be noted that, in accordance with AA Bulletin 737-07, "landing conditions" included meteorological conditions as well as runway conditions.

The "KIN FIELD REPORT" received by the flight crew at the time of dispatch was "WET 0.10 IN WATER". There was no evidence that the flight crew received any updated runway condition report which would have been used in the approach briefing, and the runway condition report of "Wet" from ATC was a very general term differentiating Wet from Dry, and was not

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[121] Section 1.17.4.3

referring to less than 1/8 inch of water, as was the AA Wet/Good. The report was received less than five minutes before landing, long after the pre-approach briefing.

The forecast landing conditions at Kingston at the time of dispatch were:

```
KIN 221500Z 2218/2318 12016KT 9999 -RA FEW016 BKN032
TEMPO 2218/2302 6000 TSRA BKN016 SCT018CB BECMG 2302/2304 35008KT
TEMPO 2304/2312 8000 SHRA BKN016 FEW018CB SCT032 BECMG
2314/2316 20006KT
```

that is, Kingston, issued 22 December (2009) at 15:00 (all times UTC), forecast from 18:00 on 22 Dec to 18:00 on 23 Dec, wind from 120 degrees at 16 knots, visibility more than 10 kilometres, light rain showers, few clouds at 1,600 feet agl, broken cloud at 3,200 feet agl, temporarily from 18:00 on 22 Dec to 02:00 on Dec 23 visibility 6000 metres, thunderstorms and moderate rain, (ceiling) broken cloud at 1600 feet agl, with scattered cloud with cumulonimbus cloud at 1800 feet agl, becoming from 02:00 to 04:00 wind 350 degrees at 8 knots (balance not relevant to investigation as the aircraft was estimated to land at Kingston before 0400).

The Special Weather Observation (SPECI) received by AA331 from dispatch at about 21:48 EST, around the time the flight crew did the approach briefing, was:
SPECI MKJP 230228Z 31009KT 5000 TSRA BKN014 FEW016CB SCT030 BKN100
22/19 Q1013

That is, Kingston (MKJP) special weather observation at 21:28 EST (02:28 UTC, 23 Dec), wind 310 degrees at 9 knots, visibility 5,000 metres in thunderstorms and moderate rain, ceiling broken at 1,400 feet, few clouds at 1,600 feet in cumulonimbus clouds, scattered clouds at 3,000 feet, broken cloud at 10,000 feet, temperature 22° C, dew point 19° C, altimeter setting 1013 mb." This was sent to AA331 by dispatch at 21:48 EST, because thunderstorms were not in the previous METAR.

Comparison of the presumed weather at the time of dispatch to "the actual landing conditions at the time of landing", that is, the weather given by the Approach controller at 03:04 UTC, shows that the wind had changed from forecast 350 degrees at eight knots to reported 320 degrees at 10 knots, visibility had changed from forecast three and a half miles (6,000 metres) to reported 5 miles, and ceiling had changed from forecast 1,600 feet to reported 1,000 feet. Strictly speaking, the "actual landing conditions at the time of landing" included wind from 320 degrees at 14 knots.

Thus, in accordance with the requirements of Bulletin 737-07, as the weather had not significantly changed when the landing briefing was probably completed at top of descent, a landing distance assessment was not required at that time; however, when the wind reports increased to a 15 knot tailwind at about 03:15 UTC, about seven minutes before landing, and the increased wind speed would have required a landing distance assessment, it was too late in the approach for the flight crew to do so. Nevertheless, there was no obligation for the flight crew to continue with the landing under these circumstances, and it would have been prudent for them to have performed a go-around.

The information regarding the new 15 knot tailwind limit, SPC MSG NBR 9482, was in the AA331 dispatch document, Page 18, and it **required** pilots to determine landing performance when landing with tailwinds.

It read:

```
/// SPECIAL INFO MESSAGES ///
SPC MSG NBR 9482
SUBJECT-   15   KNOT   TAILWIND   AUTHORIZATION
REFERENCE- 737 OPERATING MANUAL VOLUME 1
EFFECTIVE IMMEDIATELY, AA 737 AIRCRAFT ARE AUTHORIZED TAKEOFFS AND
LANDINGS WITH UP TO AND INCLUDING 15 KNOTS OF TAILWIND COMPONENT FOR
VISUAL, CIRCLING, NON-ILS, AND CAT I ILS APPROACHES ONLY. THE
RESTRICTION OF 10 KNOTS TAILWIND MAXIMUM STILL APPLIES FOR HUD LOW
VISIBILITY TAKEOFFS AND CAT II OR III APPROACHES. RESTRICTED CAPTAINS
EXERCISING FAA EXEMPTION 5549
MUST COMPLY WITH THE WIND LIMITATIONS IN FM I, SECTION 10,
PARAGRAPH 2.2. AS ALWAYS, PILOTS MUST ENSURE THE REPORTED
TAILWIND COMPONENT COMPLIES WITH AIRPLANE PERFORMANCE
REQUIREMENTS FOR THE RUNWAY IN USE.
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As confirmed by American Airlines, the words "***must ensure***" indicated that it was not optional and it was mandatory for it to be done for all tailwind landings. “Performance requirements” are not the same as “tailwind limitations.”

The evidence indicated that AA informed the Boeing 737-800 flight crews of this new increased tailwind limitation without providing them with any additional training, or making any restrictions for wet or contaminated runway operations, or un-grooved runway operations. It also indicated that the persons in AA who had responsibility for training may have been complacent regarding the hazards of tail wind landings. [122] The same concern applies regarding the FAA personnel who provided oversight for American Airlines, and who approved the increase in tailwind landing limits from 10 to 15 knots, without requiring a training program for tailwind landing, although this may have been because the FARs did not require it to be trained or tested.

There was no evidence of any discussion between the two flight crew members of AA331 regarding these requirements for landing performance assessment, that is, Bulletin 737-07 and SMN 9482, and they were not mentioned by either pilot in the interviews. In his interview the first officer, however, alluded to using an “advance analysis” [123], which was interpreted by the investigation to mean that it was safe to land on a wet runway of more than 8,000 feet with a tailwind of up to 15 knots. An examination of this “advance analysis” revealed that it depended on the runway being at the worst Wet/Good, as per the AA RRLL tables (See 2.22), and that landing with 30 degrees of flap, maximum braking at touchdown, at about 1,000 from the threshold was required to achieve the published performance.

[122] Section 1.17.1.2.9

[123] Sections 1.1.2

Although the first officer stated (See 1.1.2) that during the flight they received updates from Manley Tower on the runway condition and that it was reported as “Wet”, and also that they did not receive any advisory regarding braking action being less than good and no report of any significant runway contamination, in fact the evidence from the CVR and ATC transcripts (see Appendices 2 and 3) indicated that the AA331 flight crew did not request or receive any runway surface condition report from the time of first contact with Enroute control at 21:47:00 EST until told “Runway wet” at 22:17:57 EST with landing clearance, less than 5 minutes before impact, and about 26 minutes **after** the approach briefing, and they received no braking action report, nor were they advised that none was available. The only exception to this is the evidence from the ATC transcripts that at approximately 21:59 EST, just before being transferred from Enroute to Approach, AA331 contacted Approach, asked if any arriving aircraft had reported turbulence on approach, and was told by the Approach controller that none of the aircraft landing were reporting “anything out of the ordinary” (See 1.1.2 and 1.1.5 and Appendices 2 and 3). However, this was not a runway condition report, and it should have been apparent to the flight crew that the runway was wet, from the weather reports, the aircraft radar and their actual observations. They had landed at MKJP before in rain and with a tailwind, so they were complacent, or at least comfortable with the situation, having landed successfully in similar conditions many times before.

At 22:17:57 EST (03:17:57 UTC) the Tower controller said “American three three one, cleared to land runway one two. Be advised runway wet.” Note that no braking action was included in this report. The first officer’s comment to the captain immediately after this, that is, “Runway’s wet. You want to go to brakes three, perhaps?”, indicated surprise, as if this was new information necessitating a change of plan (that is, go from autobrake 2 to autobrake 3), and yet the aircraft was in rain on the approach, and rain was in the Forecast and the latest SPECI and METARS for MKJP, and rain was displayed on the aircraft radar. As stated, the condition Wet from ATC did not necessarily specify Wet/Good, as in the AA RRLL tables, therefore the flight crew could not determine from this whether or not the runway condition had changed from the dispatch report of “WET 0.10 IN WATER”.

Thus, it is evident that, in accordance with Bulletin 737-07, the flight crew should have gathered the relevant information, and assessed whether or not it was necessary to “check runway length before landing, using actual reported conditions”, then performed the necessary check. However, as the Bulletin 737-07 stated “the flight crew ***should*** use the charts … ” it was not mandatory for them to do so. As stated by AA Flight Safety Programs Management, the company expected and assumed that flight crews would follow the instructions, but the evidence did not indicate that this was made clear to the AA flight crews.

The AA331 flight crew would not get a worse runway condition report from ATC than Wet, because the ATS MANOPs did not contain any other descriptive term for precipitant contamination; it was either Dry or Wet. The evidence indicated that the flight crew was not aware of this. Thus, the runway surface condition could have been worse than Wet.

Note that Bulletin 737-07 stated "The flight crew ***must*** use … the most adverse expected conditions" (Emphasis added).

The SPECI at 02:28 UTC, and the METAR at 03:00 UTC included thunderstorms and moderate rain, and heavy rain showers, respectively, the controller reported moderate rain to the flight crew, and the captain reported in his interview that the approach was noisy because of the heavy rain showers. Thus, in the absence of runway condition report and braking action report, the flight crew should have planned for "the most adverse expected (braking action) condition", which was not Wet/Good.

In accordance with the investigation's interpretation of the flight crew's "advance analysis" regarding Required Runway Landing Length, they were safe to land on an 8,000 foot runway with Wet/Good conditions, and a 15 knot tailwind, so landing on a runway of 8,911 feet with a 14 knot tailwind and unknown braking action (not verified as Wet/Good as per the AA Landing Data Card), but quite possibly worse than Wet/Good, was not in accordance with AA procedures, and clearly showed the flight crew's reduced Situational Awareness (see definition 2.32.1) regarding the landing conditions.

Thus, the AA331 flight crew did not follow the direction of Bulletin 737-07, nor that of SPC MSG NBR 9482, to do a landing performance assessment, although the circumstances indicated they should have considered this.

AC 91-79 recommended that flight crews should assume standing water if rain is actively falling on the runway.

2.29 Tailwind Landing Hazards and Tailwind Landing Training

Paragraph 1.18.12, "Hazards associated with tailwind landings" demonstrates clearly what these hazards are. This is in contrast to the lack of awareness demonstrated by AA Training Management and Training staff (See 1.17.1.2.9) and the resulting lack of this training for AA flight crews. The investigation was unable to determine the reason for this gap in knowledge and training in American Airlines. This gap created a great potential threat in the AA operations and it is likely that this accident may have been avoided if the AA331 flight crew had been adequately trained in this respect. Furthermore, there was no FAR requirement for tailwind landing training, nor was there in ICAO Annex 6.

2.30 AA Management And Operational Control

The following factors, which were shown to have possibly contributed to the accident, indicated that there was some weakness in parts of the AA Management and Operational Control system:

1. AA dispatch use of a Field Report for Kingston which included an unmeasured "measurement" of water depth, contrary to company procedures (see 1.10.4.4).
2 AA331 flight crew not following some prescribed and recommended operating procedures.
4. AA lack of a clear definition of the term "Wet" in runway condition reporting.
5. The lack of understanding by AA flight training staff of the hazards of tail wind landing.
6. The lack of AA flight crew training on the hazards of tail wind landing.

The investigation considered that factors such as these should have been corrected during training, Line Checks, internal audits or FAA Inspections.

2.31 FAA Advisory Circular (AC) 91-79

It should be noted that, in the sentence sequence from FAA AC 91-79:

> *"For example, if there is no clear report of runway condition, but the pilot knows rain has been in the area, that pilot should assume the runway is at least wet. If there is rain actively falling on the runway, standing water should be assumed. If there is any doubt, assume the most conservative condition that requires the longest landing distance."*

the sentence "If there is rain actively falling on the runway, standing water should be assumed." is not qualified by "if there is no clear report of runway condition".

The AA331 flight crew did not ask for a runway condition report, and were not given one by ATC until less than 5 minutes before landing, when the tower controller said "Be advised Runway wet". The first officer then said to the captain "Runway's wet. You want to go to brakes three, perhaps?" as if this was new information, and required a change of plan.

However, AC 91-79 was not mandatory and it is not known whether or not the flight crew on AA331 was ever provided of a copy of this document, nor was it mandatory that they follow the caution in this circular. Also, the report of "Be advised runway wet" was received less than 5 minutes before landing, therefore was not used in the flight crew's initial planning of the landing. The flight crew landed with no braking action report, and the evidence indicates it was highly probable that they would have completed the landing without any runway condition report at all.

The investigation considers that the information in AC 91-79 would enhance safety awareness if included in safety promotion programs aimed at prevention of runway overruns by Part 121 operators.

2.32 Situational Awareness

2.32.1 Situational Awareness – Definition

Situational Awareness in Aviation (Endsley, 2005)

> *Situational awareness is a term used to describe a person's awareness of their surroundings, the meaning of these surroundings, a prediction of what these surroundings will mean in the future, and then using this information to act.*

For the purposes of this investigation, "Situational Awareness" includes information available to the AA331 flight crew.

2.32.2 Situational Awareness before Departure

From their training the flight crew should have followed the instructions in the AA B737 Operating Manual, which stated "To optimize situational awareness, planning for the approach and landing should begin before departure." [124]

The evidence indicated that neither of the flight crew was aware of the Page 10-7X standing water warning, nor of the RNAV (GPS) Rwy 30 approach. If the flight crew had been aware of Page 10-7X, they would have had to consider the possibility of standing water on the runway.

Thus, at this point, before departure, with the information in their possession, even though ILS Rwy 12 was the most convenient for approach and landing, the flight crew should have been aware of other landing options, the obvious one being RNAV (GPS) Rwy 30, which offered low minimums.

However, the flight crew reported that their pre-flight briefing did not include any discussion about planning the approach and landing, contrary to 1.17.1.1.5. (Note: the investigation considered that the captain may not have attempted to land with a strong tailwind in heavy rain on a runway of limited length for which there was published a warning of "pools of standing water after heavy rain").

[124] See 1.17.1.1.5

Before departure the crew checked the NOTAMS and weather for destination enroute and alternate and would have been busy with pre-departure preparation.

They were distracted by a baggage removal before start and later during taxi by an MEL item which also delayed the flight. It may be that they did not check all Jeppesen information for Kingston because they had both flown there before. The airport briefing page for NMIA that indicated items of interest and operational significance, Page 10-7X (see Appendix 5), included a warning of standing water on runways after heavy rain. In their post-accident interviews, neither pilot mentioned using this page in discussion of the arrival during the flight preparation or pre-landing stages.

Thus, the flight crew did not make themselves familiar with all the available information before departure. Beyond seeing that the forecast was above landing limits, they did not give any consideration to the expected landing conditions at Kingston before departing from Miami, nor is there any evidence that they had any concerns about the runway conditions or braking action at Kingston until just before landing.

This shows that the flight crew's Situational Awareness before departure was incomplete, partly due to the inaccurate information given to them, and partly because they did not make themselves aware of the resources available to them, predict more accurately what the possible landing conditions at Kingston could be (most adverse), and make an appropriate landing plan.

2.32.3 Situational Awareness during Approach and Landing

The evidence indicates that the flight crew probably did not receive the ATIS for Kingston while still at cruise (see 1.18.3) as they did not report having received the ATIS to the Approach controller on first contact as they normally would, and they requested the latest weather from the Enroute controller. Also, the only mention of the ATIS in the flight crew interviews was the first officer's statement that he did not recall what the weather was on the ATIS. However, the flight crew could request whichever runway they deemed suitable. In this case, during the approach, the Approach controller queried the flight crew twice, and the Tower controller did so once, on their intention to land on runway 12, and alerted the crew to the unfavourable wind direction and strength, but the captain still decided to land on runway 12.

The evidence indicated that the flight crew was probably not aware of the ACARS transmitted at 03:00 UTC containing the METAR (22:00 EST) for Kingston, and there was no discussion regarding this on the CVR. It is highly unlikely that a crew in the later stage of an IFR approach in poor weather would have the opportunity to read an ACARS message.

The flight crew reported that they performed the approach briefing before commencing descent. They described doing a "particularly thorough" briefing, and they discussed the preference to do an ILS Rwy 12 approach rather than attempting the circle-to-land approach for runway 30 with a low ceiling, which showed they were aware of the tailwind factor. However, there is no evidence of the flight crew having done the landing performance assessment as per Bulletin 737-

07 and SPC MSG NBR 9482, nor that they looked "thoroughly" at the Jeppesen information for MKJP, which included the Page 10-7X warning of standing water after heavy rain, and the RNAV (GPS) Rwy 30 approach at MKJP.

Contrary to AA "Considerations Prior to Descent" (see 1.17.1.1.5), which states "*Both flight crew should review field conditions and special procedures for the arrival airport, including Ops Advisory pages.",* there was no evidence that the flight crew requested or received any runway condition or braking action report, nor that they were concerned about runway conditions on runway 12 at Kingston during the approach, until less than 5 minutes before landing, when the first officer suggested to the captain changing from autobrake 2 setting to autobrake 3.

The probability that Fair/Medium braking action conditions might exist was indicated when dispatch sent the flight crew a Special Weather Observation just before descent, reporting 3 miles in thunderstorms and moderate rain, with wind from 310 degrees at 9 knots; however, there was no evidence that the flight crew incorporated this new and less favourable information into their Situational Awareness.

During the approach briefing the flight crew had decided to use flaps 30 and autobrake 2 for landing. This was contrary to AA procedures (See 1.17.1.1.8) which recommended flap 40 for tailwind and wet runway landings, and the use of maximum manual braking on wet runways. This configuration decision demonstrated that the flight crew's Situational Awareness was inadequate, considering the landing conditions and the necessity to decelerate and stop as soon as possible after landing.

At the commencement of descent, the crew's Situational Awareness was that there was moderate rain in thunderstorms at Kingston, that there was a 9 knot tailwind, and that the braking action condition was Wet/Good. They seemed to have omitted to take into account any consideration of runway braking action being less than Wet/Good, despite all of the indications, and they did not plan to appropriately configure the aircraft for landing on a wet runway with a tailwind close to the recently increased tailwind limitation.

The decision-making process of the flight crew indicated that their thinking was narrowed at this time, as evidenced by the lack of discussion about the worsening conditions, and the lack of any further discussion about a possible go-around. The conversation between the flight crew and the controllers indicated that the flight crew was concerned mainly with the tail wind being 15 knots or less, and the controllers appeared more concerned with the tailwind conditions than was the flight crew.

Throughout the 30 minutes of the CVR recording, the flight crew had no discussion or extra briefing about the hazards of the tailwind landing (See 1.18.12). This may have been due to the lack of training by AA regarding tailwind landings, and the resultant lack of awareness by the flight crew. If the flight crew had been aware of these hazards, they might not have attempted to land on runway 12 with a 14 knot tailwind in heavy rain, and the accident might have been avoided.

It appeared to the investigation that, as the flight crew continued the approach, their Situational Awareness was diminishing as the situation changed, and they were embarking on a difficult and hazardous landing without any concerns. The plan upon which they were acting was inadequate, and did not include consideration of the AA recommended techniques for a tailwind landing on a wet runway.

Heavy rain showers were reported in the 03:00 METAR, 22 minutes before landing, and at the time of landing, and the captain reported they were flying in heavy rain on the approach.

22:14 EST, eight minutes before landing, the flight crew started receiving tailwind reports of up to 15 knots from ATC. Even within their incomplete state of Situational Awareness, this should have triggered a serious warning to the flight crew. They should have known that with the rainfall reported and what they observed through the cockpit windows (described by the captain as "heavy rain") that a safe landing with a 15 knot tailwind would be marginal, as the braking action was probably not Wet/Good. However, they continued the approach without any discussion or extra briefing, and, at each wind check from ATC of less than 15 knots, they immediately responded they would land with the tailwind, despite the heavy rain and the controllers' querying of the intention to land on runway 12.

Less than five minutes before landing, when the flight crew received the first runway condition report, which was simply " … be advised, runway wet … ", the first officer said to the captain " … runway's wet, you want to go to brakes three perhaps?", which showed he took the landing distance into consideration. It also indicated that the crew had not given the runway condition much consideration. Even though the controller's report of "wet" was not equivalent to the Wet/Good braking action of American Airlines, the crew continued on this "advance analysis" assumption of Wet/Good.

At this point, if their Situational Awareness had been adequate, with the increased tailwind and the observed heavy rain, they should have known that the safety margin was probably greatly reduced, and a go-around was advisable.

When the aircraft passed over the threshold of runway 12, then pitched up slightly and went above the ILS and the PAPI glide paths, and the vertical speed flattened out, as signified by the Vertical Speed Indicator and the slow Radar Altimeter voice count-down, the captain did not appear to realize that the landing was going to be long, and it would not be safe to land when the runway length available was already so limited. However, the captain continued with the landing, and the first officer made no comment.

As discussed, the lack of touch down zone lighting or reflective runway markings to give the captain cues to know exactly where the touchdown zone was, might have contributed to causing the captain to inadvertently pitch up slightly over the threshold. The subsequent float did not appear to have alerted the flight crew to the fact that the aircraft was going to land long, and that a go-around should be conducted immediately.

The crew did not describe any of the specific assumptions regarding their "advance analysis" during the crew interviews, nor was the crew questioned or queried about the specific configuration requirements. It should be emphasized that the "advance analysis" upon which the crew were relying to ensure a safe landing did not specify runway condition/braking action, flap setting, use of maximum brakes, use of reverse thrust or distance of touchdown point from the threshold.

In fact, as shown in 2.19.3, landing at 1,500 feet with autobrakes 2 (as originally selected) would require more than the available runway, and with autobrakes 3, the landing distance available would be marginal. Also, the flight crew had missed the signs of landing long, telling them that the landing would probably not be successful. Had they realized this, it should have dictated that a go-around was the only acceptable action at this point; however, the captain continued with the landing and attempted to stop the aircraft before the end of the runway. The aircraft then landed long, did not decelerate as the crew expected and ran off the end of the runway.

2.33 System Safety

As described in Section 1 of this report, the NTSB strongly urged the FAA to make Landing Distance Assessments (LDA) mandatory before every landing, stating (see 1.17.5.2)

> "*As another winter season approaches, the urgent need for safety margin becomes more critical"*

It also stated:

> "*Further, the Safety Board concludes that although landing distance assessments incorporating a landing distance safety margin are not required by regulation, they are critical to safe operation of transport-category airplanes on contaminated runways. Therefore, the Safety Board believes that the FAA should require all 14 CFR Part 121, 135, and 91 subpart K operators to accomplish arrival landing distance assessments before every landing based on a standardized methodology involving approved performance data, actual arrival conditions, a means of correlating the airplane's braking ability with runway surface conditions using the most conservative interpretation available, and including a minimum safety margin of 15 percent."*

The FAA responded with SAFO 06012, which recommended LDAs be performed, but only if landing conditions had changed from those presumed before the flight. AA responded to SAFO 06012 by issuing Bulletin 737-07 to AA flight crews, reflecting SAFO 06012, but, as is evident in the investigation, did not make it compulsory for AA flight crews to follow this. The AA331 flight crew, in turn, used an unapproved method of landing distance calculation.

Thus, this system of NTSB-to-FAA-to-Operators-to-Flight Crew, which should have ensured that an extremely urgent safety issue within the industry be resolved, as evidenced by the NTSB's strongly worded appeal to the FAA, failed to have the desired effect, and this failure can be said to have contributed to this accident.

2.34 Conclusion

Section 2.32 describes how the flight crew started off with an incomplete Situational Awareness, and how this Situational Awareness became gradually degraded as the flight progressed, and eventually resulted in this accident.

A degradation of Situational Awareness, as described above, provides a description of ***what*** happened, but does not satisfactorily answer ***why*** it happened.

This was a very experienced flight crew flying in a familiar aircraft type, familiar with the Caribbean and in circumstances which they must have encountered numerous times in their years of flying, so they were not dealing with conditions with which they were not familiar.

There was no obvious reason for the flight crew not performing the pre-flight and approach briefings completely, and thus not being aware of the Page 10-7X standing water warning and the RNAV (GPS) Rwy 30 approach. These omissions did not reflect the expected actions of an experienced captain (who had also been a check airman), nor of an experienced first officer, and there was no evidence that either of the flight crew was unwilling to conform to company directives and training. These omissions cost the flight crew awareness that landing on runway 12 in heavy rain with a 14 knot tailwind was marginal, and that there was a safer option to land on runway 30 using the RNAV (GPS) Rwy 30 approach. This contributed to causing the accident.

The fact that AA had not made mandatory the instructions in Bulletin 737-07, as the NTSB had recommended, may be related to the accident. If AA had made it mandatory and ensured their flight crews understood and followed this, the accident might have been avoided. Nevertheless the flight crew should have been aware of Bulletin 737-07, as it was part of their training, and it was, in any case, the flight crew's duty to ensure the aircraft could land safely.

Furthermore, the statement in SPC MSG NBR (SMN) 9482 meant that under the circumstances of this tailwind landing it was mandatory for the crew to check the landing performance requirements by direct reference to the AA RRLL card, or AA Bulletin 737-07, which they did not do.

It is evident that the training received by the flight crew regarding completing a landing performance assessment, with respect to Bulletin 737-07 and SMN 9482, was inadequate, and did not ensure that the flight crew fully understood what was expected of them.

The deficiencies in the information provided to the flight crew regarding the runway condition could be said to have caused the flight crew to consider runway 12 braking action to be Wet/Good and led them to land on it, but the heavy rain during the approach and landing should have prompted the flight crew to consider the possibility that the braking action was worse than Wet/Good, as indeed turned out to be the case. Also, ATC could have assigned runway 30 as the active runway, and suggested the RNAV (GPS) Rwy 30 to the flight crew.

The first officer was the "pilot monitoring" during the flight, but his CRM was inadequate, and he should have called for go-around when there were indications that the aircraft would land long. It is possible that he had been inadequately trained, and also possible that he, as first officer and pilot monitoring, was reluctant to call go-around to the captain, pilot flying (See 1.17.1.1.9). If he had called for a go-around when there were indications that the aircraft was landing long, the accident could have been avoided. [125]

The lack of tailwind landing training by AA was certainly significant, as the flight crew seemed to have no concerns about this. If they had been appropriately trained and better informed, they probably would not have elected to land in these tailwind conditions on a wet runway, and the accident could have been avoided.

The circumstances indicated that, even before departure, the flight crew had formed the opinion that it would be safe to land on the wet runway 12 at Kingston as long as the tailwind did not exceed 15 knots, and that they maintained this belief and stuck to this plan right until the aircraft left the runway. This was partly due to not following company guidance, inadequate planning and awareness, lack of training, poor judgment and because they did not take in new information as the flight progressed and modify their plan accordingly; in other words, their Situational Awareness was not adapted to the changing circumstances as the flight progressed.

The flight crew should have realized that the worst case scenario in the heavy rain was Fair/Medium runway condition, consulted the RRLL tables, and found with an 8 knot tail wind they needed 8,148 feet to land on the 8,911 foot runway (including touchdown at 1,000 feet, maximum braking, normal reverse thrust) and with only a 15% safety margin. With this knowledge the crew would have realized that, when the tail wind increased to 14 knots, a safe landing was almost certainly not possible. As it was, the crew used the "advance analysis", landed the aircraft at 4,100 feet, and did not apply maximum braking until 6,900 feet down the runway.

The long landing itself could be said to be a result of deficient Situational Awareness, in as far as the lack of reflective markings and touch down zone lighting would have made it difficult for the captain to know exactly where the aircraft was, in relation to the touch down zone. Nevertheless, if either of the crew was uncertain as to whether or not the aircraft landed in the touchdown zone, he should have called go around, as per AA procedures.

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[125] See 2.9

Before the aircraft flew over the runway threshold the flight crew had plenty of indications that the runway available would be minimal, even if the aircraft landed in the prescribed touch down zone. Therefore the investigation questioned why, when there were indications that the aircraft was going to land long, the flight crew did not initiate a go-around.

In answer to this, it is probable that the flight crew, as is typical of persons doing a complex and repetitive task, had become complacent and narrowed their performance down to a minimal level, which had served them well for many years; however, in this case, it resulted in an accident. The system within which they were operating this flight, that is, that of American Airlines, the FAA and the JCAA ATC, appeared on the surface to be adequate and had multiple safeguards and redundancies, which should have ensured the safety of the flight, despite there being some deficiencies within this system, as described in this report. However, the major deficiencies in the circumstances of this flight, and the ones which probably precipitated the accident, were the flight crew's lack of awareness of the dangers of a tailwind landing on a wet runway and the Approach controller not offering the RNAV (GPS) Rwy 30 approach as an option when the wind exceeded the limit for designating 12 as the active runway. The AA331 flight crew did not ask for runway 12, it was assigned to them. If the flight crew had been aware of the dangers of a tailwind landing on a wet runway, they may have abandoned the landing attempt when they got close to the runway, and diverted safely to Grand Cayman.

Another significant factor was the crew's use of the "advance analysis" with an incomplete recollection of the conditions associated with this, that is, use of maximum manual braking and landing at 1,000 feet from the threshold.

It is also possible that the flight crew was by that time tired, and in a state of narrowed attention, focused upon the landing and convinced that a safe landing was possible; thus, awareness of the constraints of the landing they were attempting may have been no longer part of their thinking, and they continued the landing attempt even though the landing was long.[126]

2.35 Findings as to Causes and Contributing Factors

The investigation determined that the most probable cause of this accident was that the aircraft touched down 4,100 feet beyond the threshold, and could not be stopped on the remaining runway. The flight crew's decision to land on a wet runway in a 14 knot tailwind, their reduced situational awareness and failure to conduct a go-around after the aircraft floated longer than usual contributed to the accident.

[126] See 1.18.12

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SECTION 3

FINDINGS

3.0 Findings

3.1 Findings as to Causes and Contributing Factors

(Definition: "Each Finding identifies an element that has been shown, through the results of thorough analysis, to have operated in the occurrence or to have almost certainly have operated in the occurrence. These Findings are related to the unsafe acts, unsafe conditions or safety deficiencies which are associated with the safety significant events that played a major role in causing or contributing to the occurrence").

1) In the dispatch document, the flight crew was not provided with an accurate and current report on the runway condition at Kingston, nor was it required.

2) The flight crew did not review the Page 10-7X or the approach options, and consequently was not aware of the standing water warning at Kingston on Page 10-7X, and was not aware of the RNAV (GPS) Rwy 30 approach at Kingston.

3) ATC did not offer AA331 the option of the RNAV (GPS) Rwy 30 approach (the flight plan showed the aircraft was RNAV capable).

4) The flight crew's Situational Awareness was incomplete in that they did not realize that the standing water warning of Page 10-7X, the heavy rain, the weather reports they were receiving and the lack of runway condition reports or braking action reports indicated that a Medium/Fair braking action condition was a possibility, and hence was the worst case scenario.

5) The flight crew decided to land in heavy rain on a wet runway in a tailwind close to the tailwind landing limit.

6) The flight crew did not perform an adequate landing distance assessment.

7) The flight crew did not use the RNAV (GPS) Rwy 30 approach, and land into wind on runway 30.

8) The flight crew initially briefed to land with autobrake 2, then changed this to autobrake 3 on final approach, whereas "MAX autobrakes or manual braking" was the recommended American Airlines procedure for the conditions.

9) The flight crew did not plan for "the most adverse conditions", as instructed in the American Airlines B737 Aircraft Operating Manual.

10) The flight crew elected to land with flap 30, rather than the flap 40 recommended for short field and tailwind wind landing in the AA B737 Operating Manual (See 1.17.1.1.8).

11) The flight crew did not adjust their landing plan to the rapidly changing weather conditions.

12) The flight crew did not select the most suitable runway for landing.

13) The captain did not disengage the autothrottle when he disengaged the autopilot, nor was this required per AA SOPs, although it was part of Boeing recommended procedures (see 1.17.2.2).

14) The aircraft crossed the runway threshold 20 feet above the ideal height, and landed long.

15) The captain did not follow the company SOPs for landing technique and go-around.

16) The captain did not follow company recommendations for landing configuration, for landing with a tailwind and on a wet runway, or for the landing profile to be flown.

17) The captain pitched the nose of the aircraft up when passing over the threshold, resulting in the aircraft floating in the flare, then landing long.

18) The first officer did not provide all the necessary and appropriate monitoring and CRM input during the flight, especially during the final stages of the landing.

19) The aircraft touched down at 4,100 feet from the runway threshold.

20) The flight crew planned to land the aircraft without determining the runway surface condition and the braking action.

21) The aircraft did not land within the desired touchdown point or within the touchdown zone.

22) There was a 14 knot tailwind component when the aircraft landed.

23) The aircraft touched down at Vref plus 5 knots, thus increasing the landing distance required.

24) The flight crew did not conduct a go-around when the long landing made this necessary.

25) There was evidence of heavy rainfall and reduced visibility at NMIA before and during the landing of AA331.

26) There was reduced friction on the runway, as evidenced by the longitudinal deceleration rate recorded on the FDR. The presence of melted rubber balls on some of the aircraft's main landing gear tires could also be an indication of reduced friction.

27) There was evidence of water on the runway at NMIA, from the measured rainfall, ATC runway report, weather reports, FDR data and the captain's statement.

28) The flight crew did not apply maximum manual braking until the aircraft was more than 6,800 feet from the threshold.

29) The application of speed brakes, maximum manual braking and full reverse thrust was not sufficient to stop the aircraft before the runway end.

30) The flight crew's situational awareness became degraded as the flight progressed.

31) The flight crew members were possibly fatigued after being on duty for nearly 12 hours, and awake for more than 14 hours.

32) The CRM in the cockpit was not adequate, and the first officer, as "pilot monitoring" did not call for go-around when the aircraft was landing long.

33) The American Airlines staff at Kingston did not follow the American Airlines, Kingston Station Manual procedures regarding runway condition reporting to AA Dispatch during inclement weather.

34) The "Field Report" of "0.10 IN WATER" by AA staff at Kingston was not the result of any measurement or inspection, but only indicated that there was water on the runway.

35) The AA dispatcher was unaware of the Page 10-7X standing water warning at MKJP.

36) AA had not made mandatory to B737 flight crews in Bulletin 737-07 the FAA recommendation in SAFO 06012 that flight crews conduct landing performance assessments before landing, although AA Flight Safety Programs management expected that all AAB737 flight crews would conform to Bulletin 737-07.

37) The use of the "advance analysis" in place of conformance to Bulletin 737-07, was considered to be acceptable by AA Flight Safety Programs management.

38) The "advance analysis" used by the AA331 flight crew was not adequate as it did not stipulate flap setting, braking technique, planned touchdown point, use of reverse thrust or runway condition/braking action.

39) The "advance analysis" used by the AA331 flight crew did not meet the requirements of a landing performance assessment.

40) AA stated "Note: no AA documents or training materials specifically define the 'advance analysis' concept that the JCAA cites in the draft report. AA flight crews are not

trained to use, required to use, or discouraged from using this method."

41) The advice in FAA AC 91-79, to assume standing water when rain was falling on the runway, was not included in the American Airlines operating procedures, nor was it required to be included.

42) There was no evidence that AA B737 flight crews had received ground or flight training related to the techniques and considerations for landing in tailwind conditions, and the attendant hazards, even when the B737 tailwind landing limit was recently increased from 10 knots to 15 knots.

43) The flight crew did not follow the requirements of SPC MSG NBR 9482, which stated "As always, pilots must ensure the reported tailwind component complies with airplane performance requirements for the runway in use."

44) ATC runway surface condition reporting did not fully conform to the ICAO recommendations.

45) The flight crew did not request a runway condition report or a braking action report from ATC.

46) ATC did not alert the crew that no braking report had been received, as required by ATS MANOPS.

47) ATC did not inform AA331 that the runway was wet until less than five minutes before the aircraft landed.

48) ATC did not inform AA331 of the reported "heavy rain".

49) ATC did not assign runway 30, the into-wind runway, as the active runway, as required by ATS MANOPS.

50) ATC did not follow the ATS MANOPS in terms of active runway assignment, placing of Weather Standby, reporting of weather, and giving the arriving traffic a braking action report.

51) The Enroute and Approach controllers gave the AA331 flight crew estimated weather reports, and did not state that this was ATC observed weather, not official weather reports.

52) Neither NMIA nor ATC had any specific procedures for conducting runway condition inspections during inclement weather, and disseminating this information to landing traffic, contrary to ICAO recommendations.

53) The recommended ICAO terminology for describing water on a runway was not used by ATC, NMIA or American Airlines.

54) There was a lack of consistency in the terminology used for runway condition reporting by ICAO, ATC, NMIA and American Airlines.

55) Runways 30 and 12 at NMIA did not have embedded centre-line or touchdown zone lighting, and the painted runway markings did not contain reflective material, as recommended by ICAO.

56) NMIA did not perform a runway surface condition inspection before AA331 landed, nor was this part of their procedures.

57) There was no Runway End Safety Area (RESA) at the end of runway 12.

58) The investigation indicated that there may have been some weaknesses in the FAA oversight of the AA Boeing 737 operations related to tailwind landing training, and approval of an increased tailwind landing limit.

59) The investigation indicated that there were some gaps in the management and operational control of American Airlines, specifically runway condition reporting, and flight crews following recommended procedures.

60) There was no MOU between NMIA and ATS that bound NMIA to keep ATS currently informed of runway conditions, in accordance with ICAO Annex 11, Chapter 7, 7.2, and ICAO Annex 14 2.9.2.

3.2 Findings as to Risk

1) The L1 door slide deployed prematurely, causing the door to be jammed and unusable for evacuation.

2) The captain's seat crotch belt bracket broke during the impact sequence.

3) Although most of the overhead bins remained in place, the overhead bins in the first class section through the forward break, and at the aft break, dislodged.

4) All of the passenger service units throughout the airplane became dislodged.

5) The AA KIN FIELD REPORT of "0.10 IN WATER" was based only on the observation of water on the apron, and not of water on the runway

6) The AA landing performance tables were predicated on landing at 1,000 feet from the threshold, whereas AA Standard Operating Procedures spoke to the "desired touchdown point" as being 800 – 1,500 feet, and the "touchdown zone" as being 1000 – 3000 feet, or first third of the runway.

7) Both of the cabin crew members seated at L1 reported that they were unable to retrieve their flashlights because the doors to the emergency equipment compartments under the jump seats were jammed due to the buckling of the floor.

8) Some parts of the aircraft's emergency lighting system did not function after the accident.

9) There was a conflict between the recommendations of the NTSB and FAA for flight crews to perform landing distance assessments according to specific parameters, and the much less specific "advance analysis" used by the AA331 flight crew.

10) There was no written or recorded record of the ATIS, and none was required by ICAO, JCARs, or the Air Traffic Services Planning Manual (Doc 9426).

11) JCAA ATS lacked recurrent training and proficiency checks for controllers.

12) There was inconsistency between AC 91-79 and SAFO 06012 related to runway surface condition reporting.

13) There was no clearly defined policy in the American Airlines B737 Operating Manual to the effect that the first officer could call for a go-around, with it being compulsory for the captain to follow through with this.

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SECTION 4

SAFETY ACTIONS

4.0 Safety Actions

4.1 Safety Actions Taken

4.1.1 AA- General

As a result of the accident involving AA331, American Airlines reported that the company has taken the following safety initiatives:

<u>Administrative</u>

- A letter dated February 2, 2010 to all the pilots from the Managing Directors Of Flight on adherence to Standard Operating Procedures.

<u>FOT Bulletins</u>

- Flight Operational Informational Bulletins distributed to all pilots on issues of importance.
- 737 Approach and Landing Overview- 2010-03
- Revised Stabilized Approach and Go-Around-2010-06
- Landing Data Card-2010-13

<u>Posters</u>

- Posters that were placed in all briefing rooms as a result of a Safe Ops Committee recommendation.
- Go-Around
- SOP Flight Manual PT I
- Pink Bulletins generated to address important procedural changes.
- Stabilized Approach Requirements-FM-009 4-27-10
- Landing Touchdown Point-FM-017 8-03-10

Human Factors

- Presentation to pilots at all Recurrent Human Factors classes

737 Operating Manual-VOL I

- Manual changes as a direct result of lessons learned or renewed emphasis in procedures resulting from AA331.
- Special policy for runways 6,000 feet or less available landing length
- (APP/LNG/GA 15.2)
- Standard Callouts- All Descents, Approaches and Landings (15.5)
- Deviation Callouts (15.7)
- Go-Around Requirements (15.8)

- Stabilized Approach Requirement (15.10)
- 737 Approach and Landing Summary (37.1/2)
- Go-Around After Touchdown/Rejected Landing (40.4)

<u>Recurrent Training (R-9/R-18)</u>

- Additions and/or renewed emphasis in the 737 briefing and simulator recurrent training as a direct result of AA331. Similar changes have been made in initial/transition, requalification and upgrade 737 training programs.
- Landing Performance Check (Slides 25-26)
- Landing Performance Check Problem including contaminated runway and tailwind corrections (Slides 27-31)
- Stabilized Approach (Slides 35-37)
- RAD Mandatory and Variable Events including Tailwind Landing and Rejected Landing (Slides 44 and 53)

4.1.2 AA- Go Around

Subsequent to the accident, AA has revised their B737 OM, page 15.8, with the following language:

"Go-Around Requirements"

On final, the Pilot-Flying is responsible for executing a go-around if any of the parameters listed below are exceeded without Pilot-Flying correction. If the Pilot- Monitoring observes that the Pilot-Flying is not executing a go-around, he or she is responsible for directing a go-around by calling – "GO-AROUND". The directed go-around will be executed unless an emergency situation overrides this requirement."

4.1.3 AA – Reversion to 10 knot tailwind landing limit

The following message was appended to all AA737 flight plans from 08 February 2012.

SUBJECT- 737 TEMPORARY 10 KNOT TAILWIND LANDING LIMIT

REFERENCE - 737 OM VOL 1, REV 61, LIMITATIONS PAGE 10.2

FLIGHT OPS AND FLIGHT SAFETY WILL BE CONDUCTING A SAFETY RISK ASSESSMENT ON THE USE OF THE 15 KNOT TAILWIND LIMITATION FOR LANDING.

IN THE INTERIM, THE TAILWIND LIMITATION FOR LANDING IS NOT TO EXCEED 10 KTS. THIS LIMIT MAY BE FURTHER RESTRICTED BY ANY LANDING PERFORMANCE CALCULATIONS BASED ON THE CURRENT RUNWAY CONDITIONS AT THE TIME OF LANDING.

CAPTAIN BOB JOHNSON, MANAGING DIRECTOR OF FLIGHT

4.1.4 Jamaica Civil Aviation Authority

Following this occurrence the JCAA has required controllers to be stricter in assignment of active runway based on wind considerations and give pilots less choice to land with a tailwind.

4.1.5 The Boeing Company

As a result of the malfunction with the escape slide pack on the L1 door the Boeing Company reported that they have produced a proposed revision to the Boeing 737 Maintenance Manual to avoid the installation error from recurring.

4.1.6 Airports Authority of Jamaica

The Airports Authority of Jamaica has included RESA in the runway extension project.

4.2 SAFETY ACTION REQUIRED

4.2.1 Operators of Transport Category Aircraft

Operators of Transport Category Aircraft should be required to conduct landing performance assessments before every landing, based on a standardized methodology involving approved performance data, actual arrival conditions, a means of correlating the airplane's braking ability with runway surface conditions using the most conservative interpretation available, and incorporating a minimum safety margin of 15 per cent.

4.2.2 Advisory Circular 91-79

Following previous runway excursion and overrun accidents the FAA issued Advisory Circular AC No. 91-79, "runway Overrun Prevention", which was sent to all U.S. airlines. It was, by its nature, advisory, a recommendation for a particular action or conduct, and was not mandatory by regulation. In Paragraph 11 of Appendix 4 of this AC, it was stated: *"If there is rain actively falling on the runway, standing water should be assumed"*. This part of the Advisory Circular should be made mandatory for operations of Transport Category Aircraft, such that when active moderate to heavy rain is falling on the runway, the runway surface condition shall be considered to be in a Wet/Poor or Contaminated state for the purposes of landing performance assessments, that is, water depth more than 1/8 inch.

4.2.3 AC 91-79 and SAFO 06012

The FAA should ensure that the guidance related to runway surface descriptors in AC 91-79 and SAFO 06012 is unambiguous and compatible, so that operators and flight crews have ready access to consistent FAA guidance regarding runway surface condition definitions and their proper use in FAA acceptable landing distance assessments.

4.2.4 Training for Tailwind Landing

At the time of the accident there was no FAR requirement for tailwind landing training, nor was there such a requirement in ICAO Annex 6. Training in tailwind landing, and the hazards involved, should be made a mandatory part of Transport Category Aircraft flight and ground training programs.

4.2.5 Go-around Callout

Operators of Transport Category Aircraft should include in their Standard Operating Procedures a requirement that either pilot, whether acting as pilot flying or pilot monitoring, should be required to call for go-around if he/she sees that the aircraft will not land in the touchdown zone, and that the other pilot will follow through with the go around procedure without question or hesitation.

4.2.6 Tailwind Landings on Contaminated Runways

The landing of Transport Category Aircraft in tailwind conditions on contaminated runways and on runways where heavy rain is actively falling should be firmly discouraged.

4.2.7 Tailwind Landings on Wet (not contaminated) Runways

(i) Operators of Transport Category Aircraft should caution their flight crews against conducting tailwind landings on wet (not contaminated) runways, when an alternative and suitable into-wind runway is available.

(ii) Operators of Transport Category Aircraft should inform their flight crews of the hazards related to tailwind landings on wet (not contaminated) runways when the aircraft is at or near its maximum landing weight.

4.2.8 Deceleration Techniques on Contaminated Runways

Air operators should ensure their flight crews follow the company's recommended procedures for landing on wet or contaminated runways.

4.2.9 Landing Distance Assessment

When heavy rain is actively falling on the runway of intended landing, flight crews of Transport Category Aircraft should assume the runway is contaminated and complete a landing performance assessment based on contaminated runway surface performance data.

4.2.10 Runway End Safety Area Requirements

Runway End Safety Areas that meet the standards of ICAO Annex 14 for a Code 4D precision approach runway should be established and/or Engineered Materials Arrestor Systems (EMAS) of an appropriate length for the airport's design aircraft should be installed at NMIA. NMIA has a plan to extend the runway 12-30 and RESA is included in this plan. EMAS or RESA is the recommended solution since the runway abuts the sea at both ends.

4.2.11 Runway Surface Condition Reporting

(i) ICAO guidance for runway condition inspection and reporting procedures should include a description of the recommended training for airport operations personnel carrying out these procedures. The training syllabus should cover the criteria for conducting routine and non-routine inspections and provide guidance on reporting the results of those inspections.

(ii) Guidance in (i) above should include criteria for determining the frequency for performing special runway surface condition inspections when there is, or has been, heavy rainfall on the active runway.

4.2.12 Runway Surface Condition Inspection and Reporting at MKJP

i) Until ICAO publishes the guidance material, it is recommended that NMIA Airports Limited should conduct regular inspections of the runway surface during or following inclement weather, prior to aircraft landings, and should report runway standing water coverage as a percentage of runway covered to the aerodrome control tower for inclusion in ATC voice advisories and/or ATIS at MKJP.

ii) An inter-unit agreement between NMIA Limited and ATC should be developed to structure the responsibilities and procedures each organization will follow for runway surface condition inspection and reporting at MKJP.

4.2.13 Runway Markings at MKJP

It is recommended that the runway surface guidance markings at MKJP be replaced as soon as practicable using retro-reflective glass bead paint markings. Runways 12 and 30 both have a "black hole" approach, beginning and ending at the sea, with very little settlement or lighting on either side of the runway.

At night, when the runway is wet, pilots cannot see the runway markings, as the light reflects from the wet surface away from the aircraft. The installation of reflective paint would make night landings a lot safer.

4.2.14 Distance-To-Go Markers at MKJP

Although it is not an ICAO standard, safety would be enhanced by the installation of reflective distance-to-go markers for the last 4,000 feet of each runway at MKJP.

4.2.15 Runway Lighting

It is recommended that NMIA International Airports Limited install touch down zone lighting and centerline lighting on runways 12 and 30 to enhance the safety of aircraft landing in inclement weather.

4.2.16 Cabin Crew Jump Seat Emergency Equipment Stowage Area

All the cabin crew members at each of the cabin crew stations reported that they were unable to retrieve their flashlights from under their jump seats as the doors to the emergency equipment stowage compartments were jammed due to the buckling of the floor. Therefore, it is recommended that these compartments are relocated to a position, and/or the doors to those compartments are made of a softer cover, to allow for easy access in emergency conditions.

4.2.17 American Airlines L1 Slide

American Airlines should ensure that the proposed revision to the Boeing 737 Maintenance Manual regarding installation of the slide pack is followed in the company's maintenance procedures.

4.2.18 American Airlines automation mode matching re: autopilot/autothrottle use

The FAA approved manuals for the American Airlines Boeing 737 should reflect the instruction of the Boeing 737 NG Flight Crew Training Manual, page 1.34, which states:

> *Autothrottle use is recommended during takeoff and climb in either automatic or manual flight. During all other phases of flight, auto throttle use is recommended only when the autopilot is engaged in CMD.*

4.2.19 Emergency Lighting

Boeing should design an emergency cabin lighting system for the B738 aircraft which will continue to operate when there are breaks in the fuselage after an accident.

4.2.20 AA Runway Condition Reporting

AA should develop a means of verifying the field reports of runway surface conditions reports sent by its outstations.

4.2.21 AA "Advance Analysis" of runway condition

AA should immediately instruct their flight crews that if they use an "advance analysis" technique to assess landing performance, they should take all factors into account, including runway surface condition, recommended aircraft configuration, and use of recommended deceleration techniques. If the flight crews do not use an "advance analysis", they should be instructed to perform, when required, the Landing Performance Assessment prescribed in AA Bulletin 737-07, prior to landing.

4.2.22 American Airlines, use of the word "Wet" to describe runway conditions

AA should immediately ensure that their flight crews understand that a runway described as "wet" by ATC in overseas locations does not necessarily signify that the runway surface is in a condition equivalent to AA Landing Data Card "Wet/Good".

4.2.23 American Airlines, information from FAA Advisory Circular AC 91-79

AA should instruct all their flight crews that, in the absence of a runway condition report, where there is rain actively falling on a runway, standing water should be assumed, as per FAA AC 91-79.

4.2.24 Jamaica Air Traffic Services

- The JCAA ATS MANOPS should clearly define the circumstances under which Air Traffic controllers informs Aerodrome authorities of conditions associated with inclement weather, so that the Aerodrome authorities conduct runway surface inspections and provide the results of these inspections to ATS units.
- JCAA Air Traffic Controller ab initio, advanced and recurrent training should include sensitization to the hazards to Aerodrome and ATS operations which are amplified by the presence of inclement weather.
- The JCAA should have a consistent system of QA Audits.
- JCAA Air Traffic controllers should undergo awareness training of performance based navigation procedures, including RNAV.
- JCAA Air Traffic controllers should have recurrent training and proficiency checks.

4.2.25 Boeing 737 overhead bins and PSUs

It is recommended that further investigation of the means of securing the overhead bins and PSUs in Boeing 737 aircraft should be conducted with a view to modifying these means to avoid injuries to passengers in similar accidents.

4.2.26 Captain's seat belt crotch bracket

It is recommended that the requirements for captain's seat belt crotch bracket be further investigated, and modifications made to prevent failure of this in similar accidents.

4.2.27 Captain's uncertified seat cushion

AA should take action to prevent the use of uncertified replacement seat bottom cushions, as described in 1.12.6.2. Use of uncertified seat cushions invalidates the TSO C12 7a certification basis of the seat, and compromises the occupant injury performance and decreases the protection against spinal compression loading to flight crew in the event of an accident.

4.2.28 Runway Grooving

It is recommended that runway 12/30 at NMIA is grooved. It has been demonstrated that runway grooving is an effective means for improving tire traction during aircraft ground operations under adverse weather conditions. A number of airport runways, both military and civil, have been transversely grooved in an effort to improve all-weather airplane ground performance. Grooving the runway improves the drainage of some runways, provides skid resistance and prevents hydroplaning during wet weather. Test results demonstrated that, on similarly wetted grooved runways, the transverse runway grooves produced substantially greater aircraft braking friction levels than were shown by the wetted un-grooved surface data. The data also suggest that the effects of tire tread wear are secondary to the greatly enhanced tire/pavement water drainage capability available on grooved runways.

4.2.29 Airports Group Recommendations

4.2.29.1 Aerodrome Certification

- Continue to move forward toward the goal of meeting the JCAA and Annex 14 requirement of full aerodrome certification.
- Consider coordination of a certification training program for both JCAA and MKJP staff on certification standards, conduct and development of a certification program, and self-inspection/condition-reporting.

4.2.29.2 Aerodrome Maintenance

- JCAA and MKJP develop specific maintenance standards and publish them, particularly on the subject of pavement and runway strip maintenance.
- Provide detailed maintenance training to those responsible for self-inspections and for aerodrome maintenance.

4.2.29.3 Aerodrome Emergency Plan

- Coordinate additional detail in the emergency plan, particularly in the water rescue section of the plan.

4.2.29.4 Pavement

- Coordinate a full runway assessment to determine current longitudinal slope, current transverse slope (along runway full-length), and the existing grade in first third of runway 30 (from approximately taxiway D to the 30 threshold).
- Coordinate a hydrologic engineering assessment to determine water flow on the first third of runway 30 from approximately taxiway D to the 30 threshold.
- Coordinate completion of a full friction assessment of the runway to determine compliance with established friction maintenance standards and deviation from the findings of the last friction assessment (2004).

4.2.29.5 Marking/lighting signs

Add additional runway designation signs at every runway hold-position

- Consider revising current PAPI configuration to the ICAO standard(PAPI 4L) by removing the additional 4 boxes on the right side of 12 and 30. This would reduce maintenance, minimize the potential confusion to aircrews that may occur due to the separate systems being out of calibration, and would still confirm to ICAO standards.

4.2.29.6 Rescue Firefighting Service

- Develop detailed training lesson plans for required training subjects of initial and recurrent training.
- Consider acquisition of a simple SCBA bottle refill system for aerodrome use.
- Acquire powered rescue saw(s) for aerodrome use.
- Enhance existing training procedures used for aircraft familiarization…to include acquisition of current training aids for each commercial service aircraft currently using MKJP.

4.2.29.7 Declared Distances

Currently, the aerodrome operator complies with the requirement of Annex 14.2.8, for declared distance computations. The figures are published in the Jamaica AIP. Currently however, the only declared distance figures for MKJP 12/30 that differ from the distance representing 12 threshold to 30 threshold (2716M) distance, are the TODA figures for both 12 and 30 (currently published as 4074M). This represents acknowledgement of existing clearways on both runway ends. We recommend consideration be given to review of all declared distance figures to accommodate the fact that there is no existing runway strip or runway end safety area at either runway end.

4.2.29.8 Runway strip and runway end safety area

- Remove existing debris and vegetation from the existing drains in the runway strip between taxiway D to E. Verify that these drains are operational and that they are tied into the drain system and box-culvert under the aerodrome recording pron.
- Conduct periodic surveys of the runway strip and RESA (as provided) to determine safety issues and correct found deficiencies on a more frequent basis.
- Remove all current deviations (objects not required) from runway strip.
- Feather existing localizer base to grade.

4.2.29.9 Maintenance of PAPI

It is recommended that MKJP institute a specific maintenance/calibration periodicity and a periodic maintenance schedule to service the PAPIs.

4.2.30 CVR

It is recommended that all aircraft manufactured after 2002 should be equipped with CVRs capable of recording 120 minutes. This would enhance the CVR's usefulness in accident/incident investigation.

4.2.31 FAA Advisory Material ref: Wet Runways

The statements in AC91-79, Appendix 4, 10 b. (2), "*If a runway is contaminated or not dry, that runway is considered wet",* and in SAFO 06012, item 4. Definitions, *"i. A wet runway is one that is neither dry nor contaminated"*, both being FAA Advisory material, are inconsistent. It is recommended that they are amended to be consistent.

The need to review the guidance and to make it consistent is to eliminate the opportunity for operator and/or flight crewmember confusion or non-conservative interpretation that could negatively affect the arrival landing distance assessment advocated by the FAA, the NTSB and other stakeholders.

4.2.32 Cancelling of NOTAMS

This should be like normal NOTAMS, not just result in a cancelled NOTAM disappearing, as this could be hazardous to crew not having the necessary information.

4.2.33 Recording of ATIS

The ATIS should be recorded, as the record might be necessary for occurrence investigation.

4.2.34 ATS Procedures

Given that the investigation revealed that the JCAA ATS MANOPs was partially, but not fully, aligned to the provisions in Doc 4444 in some cases, it is recommended that regulations be promulgated to require the JCAA, as the ATS provider, to align procedures with ICAO provisions and that the ATS provider should comply with those requirements.

4.2.35 ATS and NMIA MANOPS

It is recommended that the JCAA ATS MANOPS and the NMIA MANOPS should be amended to include the ICAO definitions for reporting water on the runway.