CIAIAC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Report A-022/2012

Accident involving a Bell 412 aircraft, registration EC-KSJ, operated by Inaer, at La Forata reservoir (Valencia, Spain), on 2 July 2012

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COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) n.º 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1, 4 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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Abbreviations

00°	Degree(s)
00 °C	Degree centigrade(s)
AEMET	Spain's National Weather Agency
AESA	Spain's National Aviation Safety Agency
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CAT A	Category A. Operations with multi-engine helicopters
CPL(H)	Commercial Pilot License (Helicopter)
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Dara Recorder
DGAC	Spain's Civil Aviation General Directorate
ED	Electronic Devices
EU	European Union
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
ft	Foot
g	Acceleration due to gravity (9,81 m/s2)
GEAS	Civil Guard's Special Submarine Activities Group
GPS	Global Positioning System
h	Hour(s)
IAS	Indicated Airspeed
IR	Instrument Rating
Kg	Kilogram(s)
KHz	Kilohertz(s)
KIAS	Indicated airspeed in knots
Kph	Kilometer(s) per hour
kt	Knot(s)
km	Kilometer(s)
m	Meter(s)
MOE-LCI	Operator's Special Operations Manual for Firefighting
min	Minute(s)
Nr	Main rotor RPMs
N2	Turbine shaft RPMs
OEI	One Engine Inoperative
P/N	Part Number
rpm	Revolutions per minute
s	Second(s)
RCA	Spain's Air Traffic Regulations
S/N	Serial Number
TDP	Takeoff Decision Point
ULB	Underwater Locator Beacon

Synopsis

Owner and operator:	INAER
Aircraft:	Bell 412
Date and time of accident:	2 July 2012; at 13:53 local time
Site of accident:	La Forata reservoir (Yátova - Valencia, Spain)
Persons onboard:	1; killed
Type of flight:	Aerial work – Commercial aviation – Firefighting
Date of approval:	27 January 2014

Summary of accident

On 2 July 2012, a Bell 412 helicopter, registration EC-KSJ, disappeared while on approach to La Forata reservoir to take on water. It was taking part in efforts to fight and control a fire that had broken out five days earlier in the municipality of Cortes de Pallás (Valencia).

The search started shortly afterwards. Some debris was found near the shore of the reservoir. The aircraft was found at 13:30 the next day at the bottom of the reservoir. The pilot's body was recovered at 15:00.

The helicopter was refloated nine days after the accident. The flight recorders (Digital Flight Data Recorder - DFDR and Cockpit Voice Recorder - CVR) were recovered, though parts were noted to be missing, since the part housing the memories had detached in both cases after being struck by one of the blades.

A search team was assembled to look for the memories, an effort that continued for two months before the memory from the DFDR was located on 6 September. This memory was able to provide data on the accident flight. The memory from the CVR was never found.

The investigation has concluded that the accident occurred because during the water loading maneuver, the tank that was suspended beneath (known as a bambi bucket) entered the water with the helicopter at speed, instead of descending while in a hover. This introduced a large amount of drag, with the tank acting like an anchor. When the

tank was pulled out of the water, it swung back and forth uncontrollably, causing the tank itself, the load hook (which is part of the helicopter) and the top of the tank to strike the bottom of the helicopter, damaging the fairing. This affected the control bars on both engine throttles and the left horizontal stabilizer, damaging its lower surface and the leading edge. The pilot then lost control of the aircraft, which fell into the reservoir.

Two safety recommendations has been issued to the Civil Aviation General Directorate, one to Spain's National Aviation Safety Agency and two to the operator.

1. FACTUAL INFORMATION

1.1. History of the flight

On 2 July 2012, a Bell 412 helicopter, registration EC-KSJ, departed from the Siete Aguas base in Valencia at 12:55[1] to take part in fighting a large fire that had broken out five days earlier in Cortés de Pallás. The helicopter flew toward La Forata reservoir, located 20 km further south, in the municipality of Yátova.

Its mission consisted of wetting down the ground where the flames had already been extinguished. It was carrying a tank[2] (known as a bambi bucket) for picking up water from the reservoir, which it then dropped over the burned ground.

All of the water loading operations were being conducted in the central part of the reservoir. The approach to the chosen spot was executed by flying from west to east. The pilot then hovered over the spot and, while continuing to hover, descended to fill the tank, then climbed and proceeded to drop the water on the hillsides located north of the reservoir.

Each water pick-up and drop cycle involved flying along an elliptical route, always returning to the same part of the reservoir to take on more water.

By 13:53 the pilot had made several water drops. While making a new approach to the reservoir to take on more water, the aircraft fell in and sank.

Moments later, when the fire coordinators realized they had lost radio contact with the pilot, they started an aerial search using the other aerial assets that were in the area.

After an hour, parts of the wreckage were found on the north shore, near the site where the pilot had been taking on water. There was also a large fuel slick in the water.

Divers from the regional Valencia firefighting brigade found the aircraft at about 13:30 on the following day in the same area. The pilot's body was recovered at 15:00 by divers from the Civil Guard's Submarine Activities Group (GEAS).

The helicopter was refloated by GEAS divers on 11 July and towed by two boats along the water to the dam located 1,800 m east of the place where it had been submerged. It was lifted out of the water by a crane positioned on the road that crosses the dam.

[1] Unless otherwise indicated, all times in this report are local.
[2] The assembly consisting of the tank, supporting cables and opening and closing device is known by the trade name bambi bucket.

Figure 1. Description of the operation

Recovered from the wreckage were the two flight recorders. Missing on both units was the part that housed the memories, which had detached on impact.

On 6 September a team of GEAS divers recovered the DFDR memory, from which investigators were able to extract the data on the accident flight. The search for the CVR memory continued until November, but it was not found despite after several attempts to locate it.

1.2. Injuries to persons

The pilot was the helicopter's sole occupant. He was killed in the accident.

1.3. Damage to aircraft

The aircraft suffered significant damage after the impact and subsequent sinking.

1.4. Personnel information

The pilot, 58, had had a commercial helicopter pilot license (CPL(H)) since 1984. He had type ratings for the Bell 212/412 helicopters, as well as instrument (IR) and agricultural (firefighting only – obtained on 7 June 2004) ratings.

The license, all the ratings and the associated medical certificate were all valid.

He had a total flying experience of 3,991:45 h, acquired first in the army and then as a civilian pilot flying the following helicopters:

- Bell 205: 855:20 h
- Bell 206: 279:55 h
- BO 105: 509:10 h
- Bell 212/412: 1,400:50 h
- Others: 946:30 h

The operator reported that during his time in the army, he had taken part in firefighting missions in the three years from 1986 to 1988, although investigators were unable to determine for certain what experience he had gained during that period.

Investigators did confirm, however, that during those years, the operations employed by both the military and civil operators to fight forest fires with helicopters did not include dropping water from bambi buckets over areas affected by fire.

The pilot obtained his agricultural rating (firefighting only) in 2004 and started working for the operator, doing civil protection flights (mainly medical flights) and only very occasionally helping out with firefighting missions. Since obtaining this rating, he had flown 1,236:05 h, of which only about 14 involved firefighting work.

He had flown 7:50 h in the month before the accident, 16:30 h in the previous 3 months and 98:15 h in the previous year.

1.5. Aircraft information

1.5.1. *General information*

The helicopter was manufactured in 2008 with serial number 36467. Its maximum takeoff weight was 5,355 kg and it was equipped with two Pratt & Whitney PT6T-3D engines.

It had a valid airworthiness review certificate.

The last maintenance inspection, a 300 h check, had been performed on 13 June 2012 with 2,017:50 h of operation on the aircraft (4,765 landings), 1,311:50 h on the left engine (2,666 cycles) and 2,017:50 h on the right (3,589 cycles). The inspection did not reveal anything unusual. It was carried out by the operator (Maintenance Center part nº ES 145.002) in accordance with the aircraft maintenance program approved by the Civil Aviation General Directorate (DGAC) on 30 June 2008.

1.5.2. *Helicopter performance in case of an engine failure*

The most relevant information contained in the flight manual regarding the aircraft performance in case of an engine failure is as follows:

a) The maximum takeoff weight with a load suspended is 5,398 kg.

   Its dry weight, as determined during the last weighing, carried out on 13 June 2012, was 3,561.61 kg.

   It is estimated that the basic operating weight at the time of the accident was about 4,228 kg, assuming a pilot weight of 80 kg and a fuel weight after an hour of flight time of 586.7 kg.

   Once these were calculated, it was determined that the center of gravity was within both its longitudinal and lateral limits.

   The weight of the helicopter as per the flying conditions at the time of the accident was the result of adding the basic operating weight, the weight of the bambi bucket and the weight of whatever water it was carrying at the time.

b) It is estimated that at a pressure altitude of 1,080 ft (the altitude at the time of the accident) and an ambient temperature of 30 °C, the helicopter had enough thrust to take off at its maximum weight from a hovering position outside the ground effect.

c) The position in which the helicopter hovered in order to take on water was within the zone to be avoided in the altitude-velocity diagram, which defined a flight zone that must be avoided based on the height of the skids above a flat, level and firm surface and on the speed of the helicopter.

d) The helicopter was a category A (CAT A), as per the definition in Annex I to EU Regulation 965/2012, which lays down technical requirements and administrative procedures related to air operations. This means that it was a multi-engine helicopter capable of operations using takeoff and landing data scheduled under a critical engine failure concept that assures adequate designated surface area and adequate performance capability for continued safe flight or safe rejected take-off in the event of engine failure.

e) The CAT A operations for this helicopter are listed in Supplement 62.3 and 62.4, CAT A Operations with PT6T-3D Engines. These operations define the takeoff and landing profiles in such a way that an engine failure at any time once the takeoff or landing is initiated allows for a safe landing on a pad or runway or for a continuation of the flight on a single engine to a selected safe landing area.

   In this regard, the takeoff decision point (TDP) is a point located a certain height above the ground at zero speed. If the engine failure occurs before the helicopter reaches said point, the CAT A operation instructs the pilot to return and stop on the pad or runway. If the engine failure occurs after the TDP, the flight can continue.

   The minimum height of the skids above the ground required to determine a TDP for this helicopter type when taking off from ground level is 80 ft, 103% Nr (main rotor RPMs) and all engines operational.

   CAT A operations do not consider taking off from a hover, climbing and continuing the flight with one engine inoperative.

f) Section 3 of the manual describes the emergency stoppage of an engine in flight and explains that cruise flight can continue to a desirable landing location with one engine inoperative. A caution states that if corrective actions are not taken immediately, the main rotor RPMs (Nr) may drop excessively.

   To prevent this, the collective must be reduced as needed to maintain said RPMs within the limits for operating with one engine inoperative (OEI).

g) The constant operating value for main rotor RPMs (Nr) is between 91 and 100%, whereas N2 can be between 97 and 100% with one engine inoperative.

h) The constant operating value for engine torque with one engine inoperative is between 5 and 73.2%. This range can be expanded up to 73.2-81% for 2.5 minutes, with 81% being the maximum operating value.

i) The pilot must set the 2.5 minute adjusted OEI thrust and tip the nose slightly down if an engine fails before the TDP. He must also accelerate the helicopter by tipping the nose down 10° until a safe takeoff speed is reached.

j) The pilot's side door can be jettisoned in flight by actuating a lever that releases the hinges.

1.5.3. *Information on the bambi bucket assembly*

The bambi bucket was item number 2732 in the manufacturer's catalog. Its maximum length, including all its components, was 7.01 m, according to the manual.

If necessary, the bambi bucket can be released using a switch on the cyclic lever if the cargo release switch has been pre-armed. If not, it can be released using a pedal that is located next to the rear rotor control pedals.

The water is released by opening a valve at the bottom of the tank. This valve acts on rubber extensions that close upward and toward the inside of the tank, keeping it closed. When the valve is energized, these rubber extensions expand down and outward, releasing the water.

The valve closes again when the bambi bucket is submerged in the water. Its user's manual states that the pilot can check that the valve remains open and the rubber extensions are pointed outward once the water is released, and warns that sudden yawing movements near the water must be avoided when filling the tank, as this can result in the cables fouling the skids, which could cause the helicopter to tip over when the bambi bucket is taken out of the water.

1.6. Meteorological information

The National Weather Agency (AEMET) reported that on the day of the accident the skies over the region of Valencia were mostly clear with generally light winds. In the accident area at about 13:00, the wind was from the southeast at an average speed of 12 kph and the temperature was about 26 °C.

1.7. Flight recorders

1.7.1. *General information*

The helicopter was equipped with a combined DFDR and a CVR that recorded both the voices in the cockpit and some flight parameters.

Once the helicopter was taken out of the water, it was noted that the CVR was in its housing at the forward part of the helicopter. The DFDR was next to it but slightly out of its housing. When they were removed, both were noted to be incomplete, as the memory housing was missing. Attached to this housing is the underwater locator beacon (ULB). This beacon is activated when it is submerged in water, emitting on a 37.5 KHz frequency for a minimum of 30 days.

The DFDR was a SMITHS model, part number (P/N) 177045-01-01 and serial number (S/N) 0000065.

The CVR was also made by SMITHS, with P/N 175497-01-01 and S/N 00000520.

The recorders were installed in the forward part of the helicopter.

European Organization for Civil Aviation Equipment (EUROCAE[3]) document ED-112 (Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems), however, recommends that these devices be installed either at the rear of the fuselage or in the forward part of the tail boom.

Because of this, the helicopter manufacturer was asked about its reasons for placing the recorders at the front of the aircraft. The manufacturer cited three reasons.

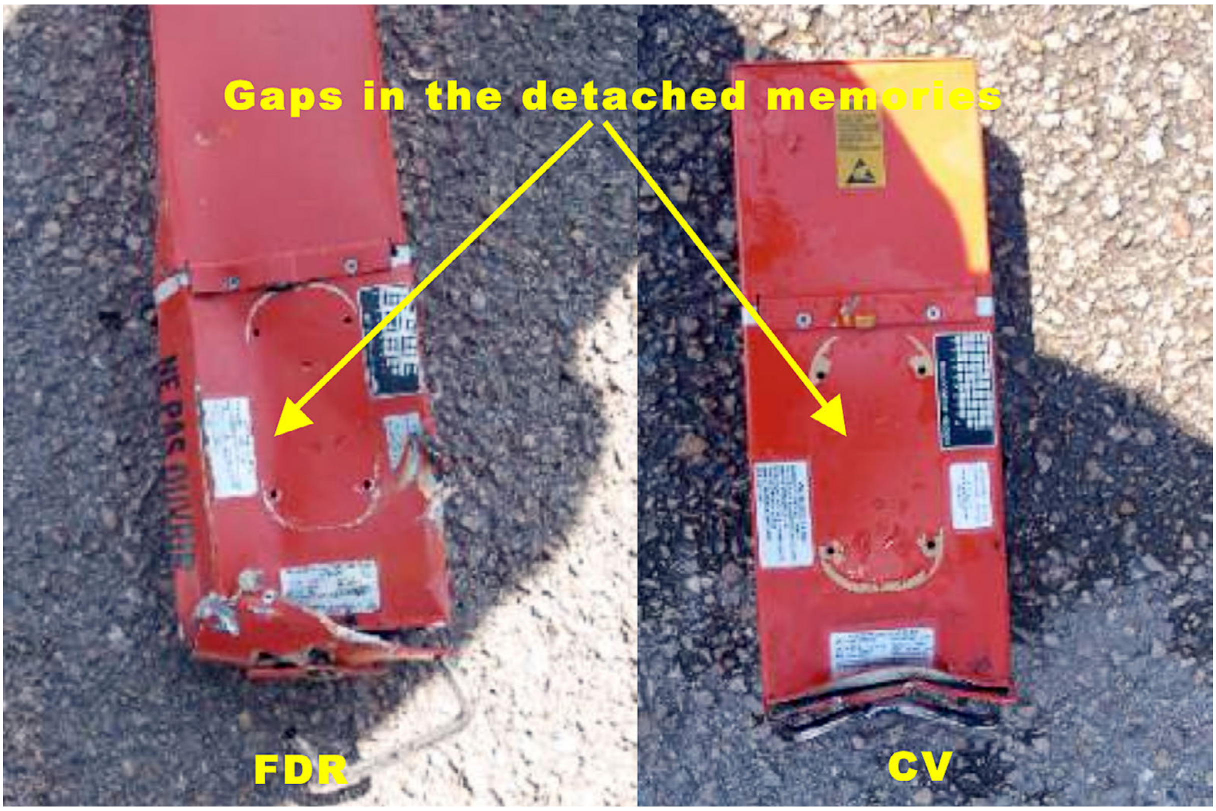


Figure 2. Recorders in as-found condition

[3] EUROCAE is charged with standardizing electrical and electronic devices in aircraft and land systems for location and air navigation. Its regulations and documents in these areas bear the abbreviation ED. The members of EUROCAE are international aviation authorities, airplane manufacturers, providers of air safety services, airport operators and other entities involved in aviation.

First, because experience showed that in most helicopter accidents, it was more likely that the impact take place with the tail boom. Second, because the fuel tanks are housed at the rear of the fuselage (meaning this area is most susceptible to fire damage). And third, because in the event of an impact with water, the tail boom can separate from the main helicopter fuselage, making it much more difficult to locate it in deep water.

It also stated that the helicopter was certified by the American aviation authority (the Federal Aviation Administration – FAA) with the two recorders housed at the front.

In addition to the two aforementioned recorders, the helicopter had two fleet tracking systems, one belonging to the operator and the other to the Ministry of Agriculture, Food and the Environment, which was the organization that had hired the operator to conduct the firefighting flights.

The first such device was working and yielded data on position, speed and altitude. The second system was not working.

On 24 July 2012, the search was started for the memory units that contained the information from the recorders. To aid with the underwater search, investigators requested the assistance of the French investigation commission (Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'aviation Civile – BEA), which sent two specialists to help with the recovery efforts.

The task of searching for and locating the units relied on a submersible hydrophone, model PRS275, which was capable of picking up the signal emitted by the beacons.

Also helping in the search for the beacons was a GEAS team from the Civil Guard.

The search was conducted from a vessel, with the omnidirectional receiver on the hydrophone being submerged to check for the presence and direction of the signal. Then, using a directional receiver, the vessel was steered in the direction of the highest signal strength and this process repeated several times until the site from which the signal was being emitted, and where the recorder would theoretically be, was located by means of triangulation.

Once the search area was narrowed down, a diver submerged with the hydrophone and continued on with the same process as had been used before from the vessel but over a smaller area.

This method managed to reduce the search area to a circle some 30 m in diameter in an area where the water was approximately 15 m deep. This area was marked using buoys and its coordinates recorded.

From then on the search continued using the methods normally employed by the GEAS, that is, going to the bottom of the reservoir and feeling along the 1.5 to 2 m thick layer of mud (where visibility is zero). This layer limits the use of a metal detector to aid in the search and location.

Also involved in the search was a specialized company that helped in the efforts by using a side-scan sonar, which managed to detect some faint signals in the area near the site from which the helicopter was recovered.

Even though the search went on for several days, neither memory unit was found.

On 5 September 2012, this same company started a new search using an underwater proton magnetometer[4], which narrowed down the search area even more, as shown by the three points in Figure 3.

As a result of this search, GEAS divers were able to recover the DFDR memory in the vicinity of point (1).

Once recovered it was placed in fresh water to prevent contact with the air from corroding any of its components.

The memory unit was sent to the BEA to see if the data recorded on it could be extracted. The BEA first checked the serial number to confirm that it was in fact the memory from the DFDR installed on the helicopter, and then downloaded the data from the accident flight recorded on it.

Efforts to locate the CVR memory continued for the next two months to no avail.

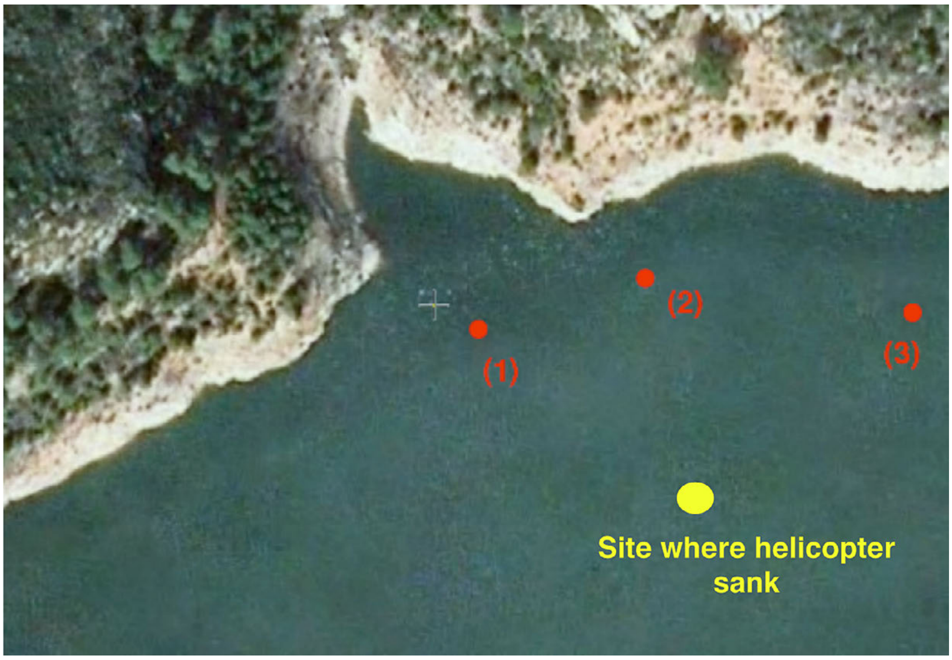


Figure 3. Points located with the proton magnetometer

[4] This device detects differences in the magnetic field caused by buried objects or structures.

Figure 4. FDR memory in its normal position

1.7.2 *Information recovered from the DFDR*

An analysis of the data recorded on the DFDR revealed that when the bambi bucket was submerged in the water, the helicopter was at an altitude of 1,040 ft.

Taking the time of takeoff as a reference, as determined from the data extracted from the GPS unit on the fleet tracking device, and based on the data extracted from the DFDR, investigators were able to establish the following sequence of events for the flight:

The helicopter took off from the Siete Aguas base at 12:56:43. A maximum altitude of 3,192 ft and speed of 90 KIAS were reached at 12:58:07, at which time it started the descent.

The table below gives a summary of the most significant parameters for the first eight water refills:

Refill number	1	2	3	4	5	6	7	8
Duration (s)	36	47	52	26	24	32	22	20
Initial altitude (ft)	1,056	1,056	1,056	1,040	1,056	1,072	1,040	1,088
Final altitude (ft)	1,152	1,152	1,152	1,136	1,120	1,104	1,136	1,136
Exit speed (kt)	11	38	22	26	22	33	24	16
Average value of N_2 for the left engine	98.8	98.6	98.6	98.5	98.5	98.8	98.5	98.5
Average value of N_2 for the right engine	98.8	98.5	98.6	98.5	98.5	98.8	98.6	98.5
Average torque value for the left engine	42.0	45.0	45.0	44.0	45.0	41.0	43.0	45.0
Average torque value for the right engine	38.2	38.5	41.1	41.7	42.1	36.9	42.1	42.4

During the eight water refills, the helicopter descended below 1,040 ft on several occasions, going as low as 1,008 ft.

At several points during the drops the helicopter's translational speed reached a value of 28 kt.

The recorded data show that in general all of the approaches exhibited a large descent rate in the final phase, which forced the pilot to brake the helicopter by flaring the front part excessively so as to halt both the descent rate and the translational speed. Also worth noting is the fact that the pilot did not always start the hovering descent maneuver at the same altitude, and that most of the time said maneuver was started below 40 ft.

The parameters for the water drops are summarized in the following table:

Drop number	1.ª	2.ª	3.ª	4.ª	5.ª	6.ª	7.ª	8.ª
Altitude (ft)	1,760	1,744	1,760	1,248	1,760	1,846	1,200	1,808
Speed (kt)	46	40	42	40	42	44	39	20
Average value of N_2 for the left engine	99.0	99.0	99.0	99.0	100.0	99.0	99.0	99.0
Average value of N_2 for the right engine	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
Average torque value for the left engine	45.0	33.0	43.0	39.0	30.0	41.0	33.0	51.0
Average torque value for the right engine	34.0	28.0	42.0	28.0	20.0	38.0	37.0	41.0

The accident took place on the ninth water refill. The table below shows the final moments of the flight:

Remarks	Time	Altitude (ft)	Speed		Attitude (°)		Engine % RPM[5]		Engine Torque	
			KIAS	N_r (%)	Pitch	Roll	L	R	L	R
Final approach. Instants prior to the last water refill.	13:52:55	1,104	34	98.4	13.5	–4	99	99	16	20
	13:52:56	1,104	34	98	13.5	–4	99	99	27	23
	13:52:57	1,088	33	98.2	13.2	–3	99	99	27	17
	13:52:58	1,088	32	98.9	14.1	–2	100	99	25	20
	13:52:59	1,072	32	97.8	13	0	99	99	42	29
	13:53:00	1,056	30	98.4	13.4	–1	99	99	20	20
	13:53:01	1,056	32	98.5	13.5	–1	99	99	33	28
Ninth refill. Instant when the tank was probably submerged for the first time at speed (about 31 kt).	13:53:02	1,040	31	98	14.5	–1	99	99	37	36

[5] Turbine shaft RPMs (N_2).

Remarks	Time	Altitude (ft)	Speed		Attitude (°)		Engine % RPM		Engine Torque	
			KIAS	N_r (%)	Pitch	Roll	L	R	L	R
Acceleration of 1.57 g reached. Probable moment when the tank impacted the left horizontal stabilizer in upward direction. Collective raised.	13:53:03	1,072	28	97.6	12.5	–1.6	99	98	43	56
Negative longitudinal acceleration of –0.19	13:53:04	1,040	28	97	7.3	–0.3	98	96	60	55
Significant drop in torque in both engines.	13:53:05	1,088	0	97.7	7.5	–2	97	98	58	51
	13:53:06	1,072	0	97.1	7.7	–3	98	98	52	43
No. 1 torque falls to 17%, no. 2 torque rises to 67%. Left 3.6° roll angle. Tank strikes engine control bars and left engine torque falls.	13:53:07	1,088	0	98.4	6.6	–3.6	99	99	17	67
Left engine torque falls again.	13:53:08	1,088	0	95.2	4.2	–3	97	96	13	65
	13:53:09	1,088	0	95.3	0.8	–2	96	96	20	69
Left engine torque keeps falling to 13.	13:53:10	1,072	0	94.4	3.6	–1.6	95	95	13	67
Asymmetric performance continues with the torque in both engines falling. Sudden changes in both pitch and roll.	13:53:11	1,072	0	95.1	4.9	–1	96	96	16	66
	13:53:12	1,072	0	95.1	5.7	–1	96	96	20	83
	13:53:13	1,072	0	94.1	5.1	–1	95	95	27	71
	13:53:14	1,120	16	94.7	4.5	–1	95	95	18	44
	13:53:15	1,120	26	94	1.6	2.4	96	94	32	58
	13:53:16	1,120	32	92.9	2	3	93	94	23	44
	13:53:17	1,104	40	94.7	2.1	2.5	95	95	11	36
	13:53:18	1,104	40	94.4	3.4	2.5	95	95	29	18
	13:53:19	1,088	40	92	4.2	4.2	93	92	11	22
	13:53:20	1,088	38	88.8	6.1	3.7	90	88	1	20
	13:53:21	1,072	38	82.6	6.7	4.4	84	82	4	24
	13:53:22	1,072	38	76.9	8.4	6.1	78	75	3	27
	13:53:23	1,056	38	72.3	9.7	–1	72	69	5	28
	13:53:24	1,056	38	66.7	11.8	1.4	67	64	4	30
	13:53:25	1,056	38	62.2	14.6	3.8	62	60	9	31
MASTER CAUTION activated. Vertical acceleration 3.37 g and longitudinal –0.76 g.	13:53:27	1,040	38	53.1	7	3.6	59	56	7	43
Increase in right engine torque.	13:53:28	1,008	29	56.2	3.2	7.2	53	51	10	81
	13:53:29	1,008	28	64.2	5.2	2.2	52	57	4	88
	13:53:30	1,008	25	76.4	6	–1	60	66	4	68
	13:53:31	1,008	25	85.2	33.7	–83	70	78	7	68
Increase in main rotor RPMs to 92.3%.	13:53:32	1,008	28	92.3	–123.5	–53.2	78	88	1	61

The table shows that at 13:53:02, while at 1,040 ft, which is the altitude at which the helicopter should have been to lower the bambi bucket into the water, its speed was 31 kt.

The next two seconds saw the maximum vertical acceleration value of 1.57 g. The maximum values recorded throughout the operation prior to that had not exceeded 1 g.

Shortly afterward the speed fell to zero with the collective lever at 50% (not shown in the table), similar to a hovering descent above the reservoir with the bucket full. The engine RPMs had fallen to 97 and 96 and were recovering to 99%.

When the two engine torques first dropped, the helicopter was at altitude of approximately 68 ft above the water, its IAS was 0 ft, it had an 8º pitch angle and a 3.6º left roll angle. Both engine RPMs were climbing through 98% to 99%. It was then that the torque on the no. 1 engine fell from 52 to 17% and the torque on the no. 2 engine rose from 43 to 67%. The pressure altitude at that moment was 1,088 ft.

One to four seconds after the first maneuver, the cyclic fell 7º in three seconds, followed by a 7º increase in the cyclic in two seconds. The collective lever remained in the same position as it had been at the start of the failure. In that time the right engine RPMs fell to 96% and the main rotor RPMs (Nr) to 95%. The IAS remained at 0 kt and the pressure altitude held for two seconds before dropping to 1,072 ft.

In the period of time 5 to 12 seconds later, the collective lever was moved to 59% in 2 seconds, followed by a drop to 43%, which was maintained for 6 seconds. Over this 8-second period, the right engine RPMs stabilized between 93 and 95%. The left engine RPMs increased in the first two seconds to 83% and then started to fall to 18%. Nr over this period fell to 92%.

The pitch angle was 7º for two seconds before falling to 2º, a value that was held for 4 seconds, during which time the IAS went from 0 to 40 kt.

The nose of the helicopter then climbed to a pitch angle of 5º, with the roll angle going from left to right. The pressure altitude reached 1,120 ft for 3 seconds before starting a descent to 1,104 ft, a descent that would continue through the next period.

From 13 to 18 seconds later, the nose of the helicopter continued to pitch up to an angle of 15º. The IAS remained constant and the pressure altitude kept dropping. The roll angle was to the right. The collective lever was raised almost to the limit of its travel and the right engine RPMs fell rapidly to 60%, the same value as the main rotor RPMs.

The altitude continued decreasing to 1,056, a value that stayed constant during the final 3 seconds of this period.

At t = 20 seconds, the helicopter's speed was 38 kt. It had a high pitch angle of 13°, a right roll angle of 5.9°, and the collective lever was at its upper limit. The main rotor RPMs were 58% and the right engine RPMs 56%. Its altitude was 1,056 ft.

At t = 21 seconds, there was a vertical acceleration of 3.37 g and a longitudinal acceleration of -0.76 g. The altitude fell through 1,040 ft, followed shortly by the minimum pressure altitude value of 1,008 ft.

1.7.3. *Information on the operator's fleet tracking system*

The fleet tracking data were obtained from the unit mounted in the helicopter and reflected the trip made from the base at Siete Aguas to the vicinity of the reservoir and the subsequent water drops and refilling operations.

The flight paths were separated into five flights consisting of eight full water pick-ups and drops. The pick-up and drop points were annotated for each. In the second flight, after the water drop, the helicopter landed at various points in the fire zone to engage in support tasks for the firefighting brigades.

Figure 5 shows the final moments of the ninth water pick-up, which is when the accident took place. Appendix 2 shows the entire trip, with the flight paths for the various water pick-ups marked in different colors.

Figure 5. Flight path in the final moments of the flight

1.8. Wreckage and impact information

1.8.1. *Inspection of the wreckage*

The helicopter came to rest upside down at the bottom of the reservoir in 14 m of water. The main rotor was partially buried in the mud and the fuselage was tilted slightly forward and to the left.

Based on the photographs taken by the GEAS, the bambi bucket was free from the load hook and the cables from which it was suspended were wrapped around the left rear skid. When it was removed from the water, the bucket was hooked on the front part of the right skid with the cables wrapped around it. The load hook was open (see photographs in Figure 6). The cables that opened the bucket had detached after impact.

One of the four main rotor blades (the one identified as blue) detached at the moment of impact, tearing at the attachment point. It was found later, still joined to its attachment components, very close to where the helicopter was located. There was a significant loss of material halfway along its length that extended along the chord, except for the leading edge.

When the helicopter was taken out of the water, it was noted that the three other blades were still anchored to the rotor and damaged to varying degrees. The orange blade was practically whole. It had some small scratches on the underside near the root and on the top surface 1 m away from the tip.

The other two blades were significantly damaged. The gray-red blade was missing about a third of its length and had also lost material from its lower surface. The green blade had also lost material from two sections of the lower surface. A part of this

Figure 6. Condition of the cables and bucket load hook

blade was also found in the cockpit when the helicopter was pulled up. All of the fractures and losses of material exhibited by the blades were in the same direction, at a 45° angle to their longitudinal axis, no doubt a result of the way in which they had been manufactured.

The subsequent inspection revealed that the recorder memories had detached because the screws that attached them to the body of the recorder had been sheared, probably when they were struck by one of the blades at the moment the helicopter impacted the water. Figure 7 shows the condition of the blades as the helicopter was being taken out of the reservoir, and Figure 8 shows the fractures exhibited by each.

The cable cutter, which was located at the top front part of the cockpit (see Figure 7), was torn off but later recovered.

The damage exhibited by the cutter was compatible with the impact from one of the blades, which struck it with a right to left motion (matching the direction of rotation of the rotor, as seen from above), sending the cutter backwards.

There was major damage to the main rotor area but the transmission exhibited continuity. Despite this, the main rotor was seized because the links and cams on the pitch control system had been torn off, causing significant damage.

The stringers on the blue and green blades exhibited bending fractures, consistent with impact stresses.

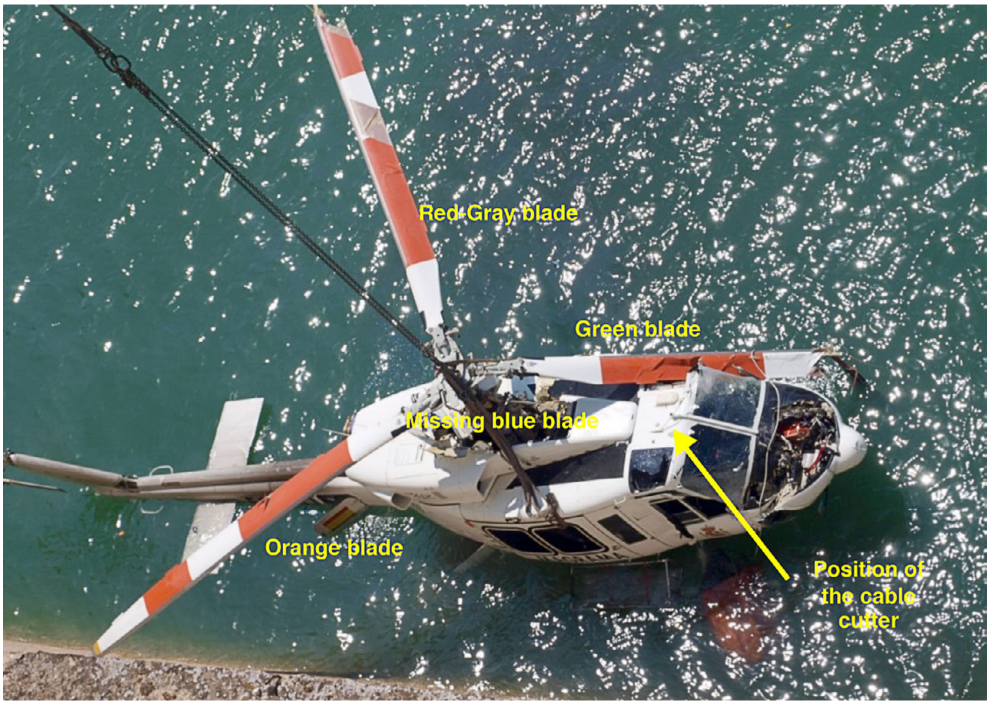


Figure 7. Condition of the blades

Figure 8. Condition of blades

After the helicopter and the rest of the debris were taken out of the water and subjected to an initial inspection, they were taken to a hangar for an in-depth inspection conducted by several experts sent by the aircraft and engine manufacturers and by the aircraft operator.

This inspection revealed friction marks that indicated that the bambi bucket had struck the left horizontal stabilizer, damaging its underside and the leading edge.

The bucket assembly, in contrast, had not sustained appreciable damage. When the attachment cables were stretched as far as they would go, they were verified to reach exactly as far as the part on the left horizontal stabilizer that had been damaged.

The head of the bucket was attached to the helicopter's load hook and when the cables were placed over the marks on the skid, it was noted that the rearmost mark had been made by three cables, and the most forward mark by four.

It was also determined that the both the load hook and the head of the bucket had struck the bottom of the helicopter, specifically, the area that houses the load hook, bending the fairing. There were marks from the tank cables that extended toward the rear and along the entire underside of the helicopter. This impact had affected the command bars for the throttles of both engines, which were fractured at various points on their travel.

Figure 9. Left horizontal stabilizer

The rear rotor blades did not exhibit any type of damage. The first two segments of the transmission shaft (horizontal

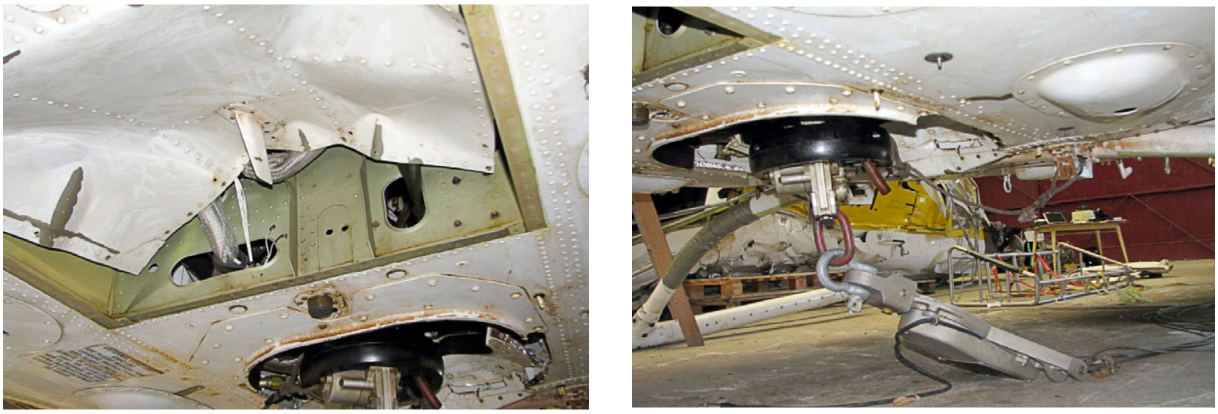


Figure 10. Dents in the bottom fairing in the area of the load hook

segment) were also intact. The third segment, however, the one that extended into the gearbox at the rear of the rotor, had a torsional fracture halfway along its length.

In the area of the torque indicator, which is located on the left side of the tail boom, the fairing was heavily scratched.

The ring to which the sling that holds the bucket is attached was not its position prior to the accident, and as a result the rope that keeps the bucket from swinging had been lost.

At the front of the helicopter, the heaviest impact was at the top of the cockpit, which was significantly warped. The front beams that held up the doors were broken, the one on the right along the bottom, and the one on the left along the middle and top parts.

The entire cockpit was shifted left, as seen from the front of the helicopter, although the central beam, which divides the windshield, was in its normal position.

Figure 11. Final segment of the transmission shaft to the rear rotor

1.8.2. *Analysis of the powerplant*

During the inspection of the wreckage, an exhaustive check was made of the powerplant, which ruled out any failure of the engines and concluded that all of the damage to these components had been as a result of the impact with the water.

The most relevant information from the analysis of the powerplant is provided below:

1. The engines did not exhibit major external damage or significant impacts. All of the components visible to the naked eye showed signs of having been submerged.
2. The structure, electrical connections and the fuel and lubrication systems were in the proper position and did not have major damage.
3. The main damage to the powerplant was to the pipes and control shafts on the two compressor throttle controls, and were consistent with the static overload produced by the impact.
4. Neither outer cover on either the right or left engine showed any apparent impact marks. Both sets of fuel pumps, manual fuel control systems, automatic fuel control units, turbine tachometers and the fuel manifold were in their positions and intact. The air intake to the left engine, however, had a dent in a direction that was practically perpendicular to the air flow.
5. All of the air lines were intact and exhibited continuity and all of the accessories were in good condition. Only one line was bent.
6. The hydraulic fluid tanks were ripped from their supports to the helicopter fuselage and the right engine hydraulic tank was missing.
7. The left engine throttle control cam was in the idle position, which was the same as the position of the throttle control for that engine when the helicopter was found in the water and also when it was taken out of the water.
8. In contrast, the right engine's throttle control was in a position close to maximum acceleration.
9. The main gearbox and its accessories were only slightly damaged but were seized.

1.9 Medical and pathological information

The autopsy determined that the death, which occurred at around 13:00, had been violent in nature. The immediate cause of death was respiratory failure and the fundamental cause was asphyxiation due to drowning.

The external exam revealed skin abrasions and injuries to the posterior of the right forearm, to the inner part of the left thigh, to the distal third of the posterior of the right thigh and a contusion to the posterior of the left tibia.

The internal exam of the thoracic cavity revealed that the first to seventh ribs on the right side were fractured.

The test conducted to screen for alcohol, illicit drugs and tranquilizers was negative.

When the pilot's body was recovered, it was noted that the upper limbs were in a typical flight position (right hand on the cyclic and the left on the collective).

1.10. Survival aspects

1.10.1. *General information*

When the pilot's body was found underwater, he was wearing the helmet but the safety harness was not fastened. He also was not wearing a life vest.

A vest with a flotation device was found in a compartment on the right side of the tail boom that was not accessible from the cockpit.

In the Operator's Special Operations Manual for firefighting (MOE-LCI), there is no information regarding the use of life vests during firefighting operations. There is also no information on evacuating a helicopter that is submerged under water nor on possible training given to crews to deal with this type of emergency.

Current regulations do not require this type of training.

The only aspect of the foregoing that is regulated concerns the use of life vests. Book five of Spain's Air Traffic Regulations, which contains the rules for helicopters, makes no mention of the use of life vests during special operations, which include fighting forest fires. Section 7.1.5.4 in book seven refers to the use of these devices in airplanes that fly over water, but this does not include helicopters.

1.10.2. *Engine failure over water*

When a helicopter is ditched in water, the main problem is that the sinking aircraft, which will usually be upside down, will go under very quickly, thus filling the cockpit with water in a matter of seconds.

Water ditchings of helicopters will also typically occur during critical phases of flight with the aircraft already close to the water, as is the case during approaches to take on water or hovering descents. The time to land is therefore very short, and if contact is made with the water and the aircraft sinks, there is little time to exit the aircraft via the normal escape routes, which are the side doors, windows or any opening that may have been made in the fuselage by the impact.

As a result, it is vitally important that pilots receive training on evacuating from a helicopter that sinks after being ditched in water, since relevant studies suggest that the survival rate for trained pilots rises to 91.5%, versus the 66% rate for those pilots who received no such training[6].

The pilot had not received any training on ditching a helicopter in water during his time working for the operator. There is no record of his having received this training earlier either.

1.11. Organizational and management information

1.11.1. *General aspects*

The investigation revealed that the operator did not have any written procedures listing the criteria utilized to select the pilots who would take part in fighting forest fires. After the accident, however, the operator reported that it was preparing a manual on how to select pilots.

Based on the MOE-LCI, the minimum experience required for captains taking part in fighting forest fires was 800 flight hours, of which 200 had to be in a similar scenario and 300 in helicopters of the same type they would be flying (turbine or piston engine). They also had to have a valid agricultural rating and have completed the firefighting (agricultural) training described in Chapter 4 of said manual.

This chapter states that the objective of the training was to familiarize captains with the procedures involved in fighting fires and with the specific equipment used in the helicopter. It also specifies that the training must include at least the following aspects:

1. Firefighting service.
2. Water dropping equipment.
3. Flying in mountainous areas.
4. Extinguishing different types of fires.
5. Safety regulations – emergency procedures.
6. Air-ground signals.
7. Cockpit resource management.
8. Communications.
9. Familiarization with the duties of other crew members.

Appendix 1 in the manual lists the specific training required for each of the areas given above, but it does not detail how to conduct each training point.

[6] Brooks CJ. The human factors relating to escape and survival from helicopter ditching in water. Neully sur Seine, France: NATO AGARD; 1989. AGARDograph 305(E).

1.12.2. *Technical aspects of the operation*

The MOE-LCI gives detailed instructions on how to conduct operations with a bambi bucket suspended from the helicopter.

It specifies that all operations are to be carried out in keeping with the assembly instructions and checks described in the manual for the bucket in terms of how to hook it up, the placement of the head, the length of the cables, securing the bucket and the opening mechanism.

It also provides clear indications on how to connect it and the possible ways to transport it.

As regards landing and taking off with the tank, the MOE-LCI explains that these operations are to be carried out with the helicopter hovering over the bucket without tensing the cables. The helicopter will then ascend vertically until the bucket clears the ground and the pilot will check the proper position of all the components using the mirrors. When placing the bucket on the ground, the helicopter will move in such a way that the fuselage is clear of the bucket's final position. In all of these operations, an effort must be made to avoid dragging the bucket so as not to damage the bag.

Once the bucket is in the air and a safe speed is reached, the cargo release switch will be placed in the ARM position, where it must be kept throughout the flight. The electrical cargo release switch must be placed in OFF after landing so that the bucket can be picked up and folded.

The supplement on the load hook in the helicopter's own flight manual, however, states that before takeoff, the electrical release lever must be armed, while the MOE-LCI instructs to arm this lever after takeoff when at speed. Once in flight, the flight manual instructs to place it "as desired".

The MOE-LCI specifies that the maximum speed for flying with the bucket empty is 80 kt, and that the helicopter must pick up speed slowly. A maximum safe speed must be determined based on the external operating conditions, avoiding sudden maneuvers. The maximum speed with the bucket full shall be as per the flight manual. While a full bucket is more stable, it also gives more inertia to the combined helicopter-bucket assembly.

As regards the filling operation, the MOE-LCI states that the bucket must not be lowered into the water if the helicopter has any translational speed, as this would lead to a dangerous situation. It does recommend, however, having some forward thrust so as to expedite the fill operation.

The bambi bucket manufacturer's manual for operators says that towing it is not necessary to submerge it since it is already weighted so that it will tilt and sink immediately when it contacts water.

In any event, the helicopter's speed must be such that the bucket does not create a wake in the water, which should be the reference used by the pilot to maintain a safe hovering position.

The MOE-LCI does not give a specific speed for flying with an empty bucket, though the operator stated that the speed limit in this case is 60 kt. The bambi bucket manufacturer's manual for operators, however, states that speeds up to 95 kt are safe, though this speed must be attained gradually so as to adapt the bucket's stability to the helicopter's flying conditions.

It also makes no mention of the altitude at which to level off the helicopter when hovering before starting the descent to take on water, though the operator stated that the typical altitude is approximately 15 m (50 ft) above the surface of the water.

2. ANALYSIS

2.1. Analysis of the operation

According to the data recorded on the DFDR, it took the aircraft nine minutes to fly from the base at Siete Aguas to the vicinity of the reservoir, which it did at an approximate altitude of 3,000 ft and a speed of between 80 and 90 kt.

As soon as it arrived it took on its first load of water, which confirms that the bucket was deployed from the start, that is, it did not land to make it ready. This means that it must have been flying at a speed above the operator’s reference speed for an empty bucket, which, as it reported during the investigation, is 60 kt. The helicopter’s speed was, however, still within the top speed allowed in the bambi bucket manufacturer’s manual.

The aircraft took on water eight times using the procedure contained in the Operator’s MOE-LCI, that is, by positioning itself over the load point with no translational speed, hovering down, submerging the tank in the water to fill it and then climbing and flying out to the drop point. However, both the speeds at which it started to descend and the speeds used to approach before tapering off to zero translational speed were different in every case.

Except for the eighth water pick-up, at no time was the altitude when the hovering descent began the 15 m (50 ft) referenced in the information provided by the Operator during the investigation. Only on the eighth load was the descent maneuver started at 48 ft, which is practically 15 m.

The recorded data also revealed that with each successive water pick-up and drop operation, the hovering descent maneuvers took less and less time.

After the second drop, the pilot made various landings in other places to help the fire brigades (probably transporting materials), since the data recorded corresponded to approaches and subsequent hovering descents at altitudes in excess of those used when taking on water at the reservoir. The data also revealed that on several occasions the MASTER CAUTION turned on and off, triggered by the opening of the helicopter doors.

Another aspect worth noting is that all of the approaches were made with a large descent rate in the final phase, which forced the pilot to brake the helicopter by flaring the nose up excessively to stop the descent rate and the translational speed. This occurrence was no doubt the most critically important factor during the ninth pick-up and resulted in the tank being lowered into the water with a translational speed of 38 kt. After that point, the MASTER CAUTION once again turned on, coinciding with a drop in torque in the left engine and also with the lowest rotational rate of the main rotor. There was also an increase in both the vertical and lateral accelerations, followed by an increase in the torque and RPMs in both engines. This would all have been fully compatible with the loss of control of the helicopter that caused it to impact the water.

A study of the DFDR parameters, however, shows that the pilot tried to control the aircraft after lowering the bucket into the water. According to these parameters, the aircraft continued flying, though with asymmetrical engine torque values, with the left engine torque rising while the right engine torque value remained normal.

In the 6 to 8 seconds after lowering the bucket in the water at speed, and following the failure of the left engine, the IAS rose to 40 kt.

Initially, the pilot maintained the collective control lever in the same position before raising it slightly. After 9 seconds he reduced it to its initial position or slightly lower, and 13 seconds later he increased its position again to 98% of its full travel.

The pitch angle dropped a little at first before regaining its original value. It then dropped to almost zero but remained positive. The nose then lifted up as the helicopter attained and held a pitch angle of about 15º.

The right engine RPMs, which were initially between 98 and 99%, started a continuous descent 2 seconds later to 56%, a transition that lasted 17 seconds. The main rotor RPMs, which were at 98% at the time of the failure, went to 95% in 1 second. This value held for several seconds before dropping to 58%. The torque and RPMs on the right engine continued to fall.

Since all of this took place with the fuel control for the right engine in the normal (Flight) position, it may be assumed that the pilot's intention was to resume flight or make it to shore.

A study of the helicopter's performance once one of its engines failed, however, reveals that given the position of the helicopter at the time of the failure, it was impossible to execute a takeoff profile with one engine inoperative similar to the CAT A profile over a surface-level platform.

Another consideration is the fact that at the time, the bucket was hanging below the helicopter, which was at an approximate altitude above the water of 68 ft. The bucket was either hanging from the load hook in its normal position, or it is very likely that it might by then have been hanging from the left rear skid, which would have resulted in an even more unfavorable situation.

For this reason, and in keeping with the other information taken from the Flight Manual, there was insufficient clearance between the bottom of the skids and the surface of the water to execute a takeoff maneuver on only one engine. Moreover, the distance was made even smaller by the hanging bucket.

Another indication that the pilot was trying to control the flight until the final instant was the position of the pilot's body when it was found, which was the same as that used in flight, with the right hand on the cyclic control and the left on the collective. Also, the cause of death was asphyxia due to drowning, meaning the pilot was probably knocked unconscious after the impact. It does not seem likely that a pilot with his experience would fly with the safety harness unfastened, and the fact that he was not wearing it when his body was removed from the water was undoubtedly due to the fact that he unfastened the harness when he realized the helicopter was going to hit the water, in order to more easily exit the aircraft. It is very possible that the fractures on the right side of the sternal ribs were caused by the large acceleration recorded at the time of the helicopter's bambi bucket first impact with the water while wearing the safety harness, and that he unfastened the harness afterward. The intense pain that the fractures would have caused could have been sufficient to leave the pilot unconscious to a certain extent, making it impossible for him to exit the helicopter.

As a result of the foregoing, it seems that the pilot did not at any time consider the possibility of ditching, but rather that the sole maneuver he attempted was to continue flying without realizing that the helicopter was no longer in a condition to do so.

What kept the pilot from considering the possibility of doing a controlled ditching was no doubt the fact that he had not been trained on that type of operation.

It is thus considered vitally important that pilots taking part in aerial work, and especially those involved in fighting forest fires, who are more likely to fly over large expanses of water, receive training on conducting controlled ditchings.

The most effective way of doing said training is in a simulator. A safety recommendation is thus issued to Spain's National Aviation Safety Agency (AESA) to require operators to conduct this type of training.

The investigation also noted that the operator did not offer training to its crews on underwater evacuations, as such training is not required by law.

Finally, the Air Traffic Regulations (RCA in Spanish) only consider the use of life vests in airplanes that fly over water and do not include helicopters. It seems reasonable to extend this requirement to helicopters as well. A recommendation is thus issued to the Civil Aviation General Directorate (DGAC) to take the necessary steps in their areas of competence so as to implement the mechanisms needed to modify the RCA to extend the use of life vests, already required for airplane operations over water, to include helicopters as well.

2.2. Analysis of the damage sustained by the aircraft

The evidence found during the inspection of the wreckage indicates that the bambi bucket had struck the engine control shafts and the left horizontal stabilizer. This is fully consistent with the maneuver described earlier in which the bucket is lowered into the water while the helicopter still has translational speed, causing the bucket to act like an anchor and resist any movement. The impacts caused damage to the underside of the fuselage and to the area where the load hook is secured. The bucket then swung forward, striking the engine control linkages, and then backward, hitting the horizontal stabilizer.

The fact that the helicopter's load hook was unrestrained and that the cables from which it hung ended up wrapped around the skid confirms that once the emergency occurred, the pilot tried to release the bucket, which was tangled in the cables, impeding its release and preventing the aircraft from resuming its flight.

In any event, the damage to the control shafts on both engines occurred before the head of the bambi bucket was released from the load hook, taking place during the initial swing of the bucket toward the front after being lowered into the water.

In this regard, the fact that the electrical release of the load hook was not armed when it should have been kept the pilot from being able to release the bucket as soon as it was lowered into the water, which would have prevented the forward movement that ended up striking the engine control shafts, resulting in the loss of engine control.

Once the pilot lost control and the helicopter fell in the water, the main rotor blades struck the water and the cockpit, as evidenced by the fact that the fractures they sustained were consistent with a bending force against the direction of rotation. This force undoubtedly occurred at the moment of impact with the water.

It was during this time when the blades struck the front of the aircraft and then the cockpit that the recorder memories were detached.

Experience in previous helicopter accidents supports the recommendations given in document ED-112 regarding the installation of this equipment so as to minimize the risk of destroying the recorders.

In those cases involving helicopters with this equipment installed at the rear of the fuselage or the front of the tail boom, its recovery has been easier and the damage to the equipment less severe than in this accident.

Despite this, the number of known events is insufficient to justify issuing a safety recommendation aimed at modifying the location of this equipment on this aircraft model, especially considering the reasons for its placement put forth by the aircraft manufacturer.

2.3. Organizational and management aspects

The investigation revealed that in the last few years, the Operator has tried to improve its procedures by drafting a manual containing special procedures for use during firefighting that details some of the aspects for conducting this type of operation.

Despite this, and even though it reported that it informed its crews of both the proper altitudes and speeds for these operations, the MOE-LCI does not include either the speed to be maintained with the bambi bucket empty nor the reference altitude at which the helicopter should be when starting the hovering descent in preparation for taking on water.

There is also no proper planning nor a procedure for selecting those pilots to be used in firefighting activities, resulting in cases like the one at hand in which a pilot has extensive experience, but not on the type of operation to be flown. There was also no prior planning involved in the operation even though the pilot had not flown on such a mission in quite a long time and was selected given the available personnel and the scale of the fire and the large area affected by it. Proof of this is the fact that pilot was not dropping the water on the flames given his lack of experience with this type of operation, but was engaged in a very similar activity and taking on equally high risks.

As a result, a safety recommendation is issued to the Operator to have it establish a proper procedure for selecting those pilots to be used in fighting forest fires so as to ensure that not only are these pilots sufficiently experienced, but receive the proper refresher training before being deployed on this type of operation.

The helicopter movements recorded on the DFDR 19 to 20 seconds after the asymmetrical engine torque values were not consistent with a controlled water ditching, but rather point to an uncontrolled loss of altitude with an indicated forward speed of 38 kt. The DFDR also recorded a roll to the right instants before the helicopter impacted the water. The investigation also revealed a total lack of training on emergencies involving water loading operations over reservoirs and similar areas.

Lastly, and though not specifically required by regulations, a final safety recommendation is issued to the operator so that it include a life vest as part of the equipment for pilots engaged in water loading operations over large expanses of water.

3. CONCLUSION

3.1. Findings

- The helicopter took off from the base at Siete Aguas at 12:52 and flew directly to the reservoir, a trip that lasted 9 minutes. The bambi bucket was suspended from the helicopter during the trip.
- The pilot took on water at the reservoir eight times and made the water drops over an area to the north of the reservoir where the flames had already been extinguished.
- After the second water drop, the pilot made several flights to transport firefighting personnel.
- The eight water loading operations were made while hovering, descending and lowering the bucket into the water to fill it, and then climbing and making the drop. At some point during these operations the helicopter had a non-zero translational speed.
- According to the pressure altitudes recorded on the DFDR, the helicopter's minimum altitude over the reservoir was 1,040 ft. This figure can thus be associated with the helicopter's altitude when the bucket was lowered into the water.
- Only for the eighth load did the helicopter establish an altitude of 15 m above the reservoir before starting the hovering descent.
- During the ninth water loading operation, the helicopter had a translational speed when the bucket was lowered into the water.
- The bucket stopped the helicopter's forward motion and swung forward, damaging the engine controls, and then backward, striking the left horizontal stabilizer.
- During this swinging motion the bucket also caused significant damage to the underside of the helicopter.
- As it fell into the reservoir, the main rotor blades struck the forward part of the aircraft, including the cockpit. One of them ripped the memory units from the DFDR and CVR.
- The DFDR memory was recovered and its data extracted.
- The pilot had little experience with this type of operation.
- The pilot had not been trained on forced ditching operations or on emergency evacuations under water.
- The pilot was not wearing a life vest.
- Regulations do not require life vests to be carried on helicopters engaged in operations over water.

3.2. Cause

The accident was caused by conducting a water loading operation in which the bambi bucket was lowered into the water before the helicopter had arrested its translational speed, instead of doing so in a hovering descent. This caused the bucket to impose such a large drag (behaving like an anchor) that it destabilized the aircraft. The bucket then swung uncontrollably and impacted the engine control linkages, resulting in a loss of power that made the pilot lose control of the aircraft.

The following factors are believed to have contributed to the accident:

- The high descent rates used by the pilot during all the water loading operations and which prevented him from being able to accurately determine his altitude when lowering the bambi bucket into the water.
- The fact that the electrical bambi bucket release switch was not armed, which would have allowed the pilot to activate it immediately with his finger and release it, thus avoiding the uncontrolled movements that caused the gradual loss of engine control.
- The pilot’s relative inexperience with this type of operation and the lack of training on water ditchings.

4. SAFETY RECOMMENDATIONS

REC 01/14. It is recommended that the Civil Aviation General Directorate establish the necessary stipulations to require that helicopter crews be trained on those emergencies that can arise during water loading operations over reservoirs or similar areas.

REC 02/14. It is recommended that the Civil Aviation General Directorate set in motion the necessary mechanisms within its purview so as to enable a technical modification to the Air Traffic Regulations that extends the use of life vests, currently only required for airplanes flying over water, to helicopters as well.

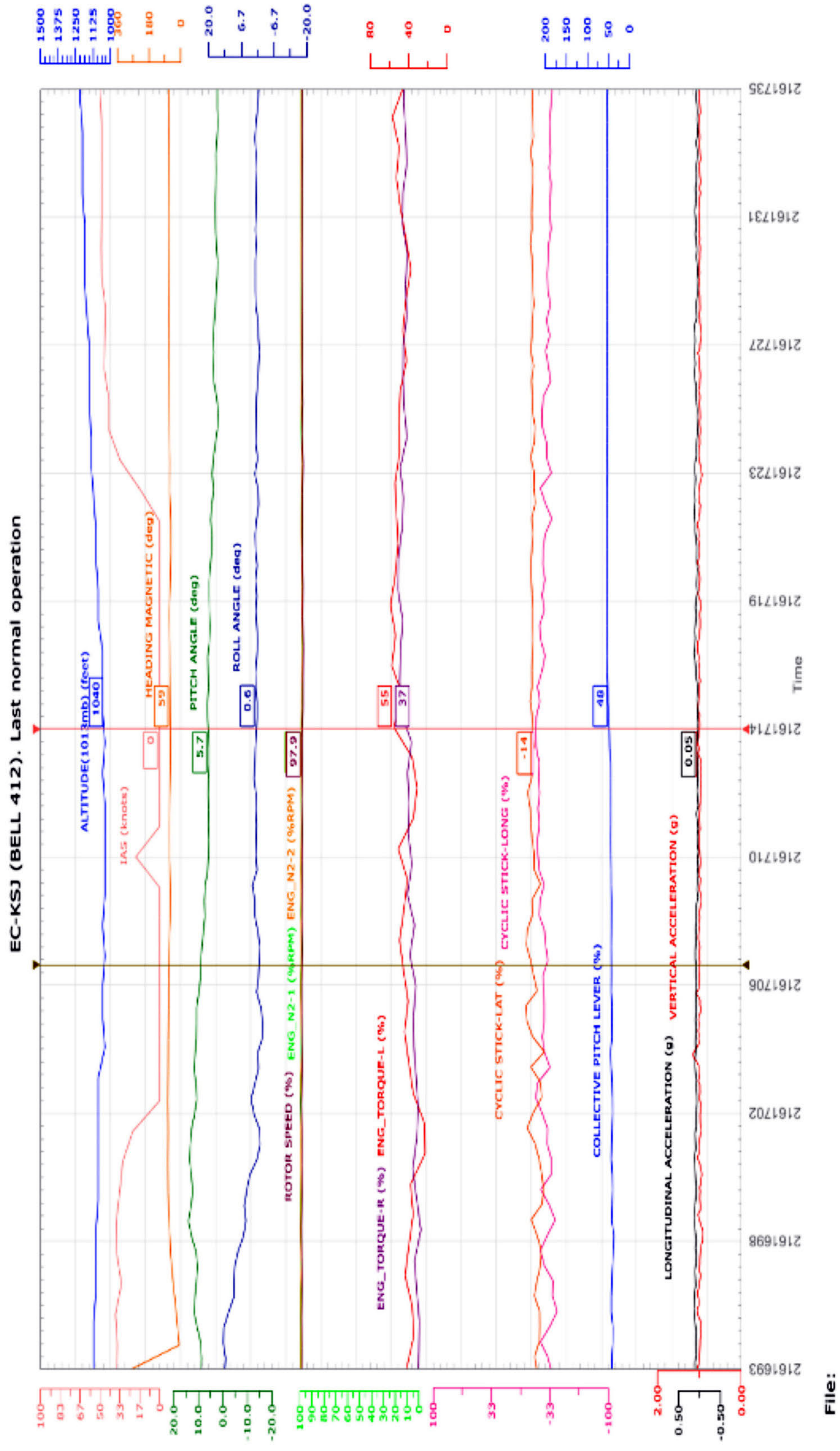
REC 03/14. It is recommended that the National Aviation Safety Agency conduct a campaign focused on raising the awareness of those pilots and organizations that conduct cargo operations over reservoirs and similar areas regarding the importance of respecting the water loading procedure.

REC 04/14. It is recommended that INAER include as part of the organization's refresher training the requirement that crews be trained on those emergencies that can arise during water loading operations over reservoirs or similar areas.

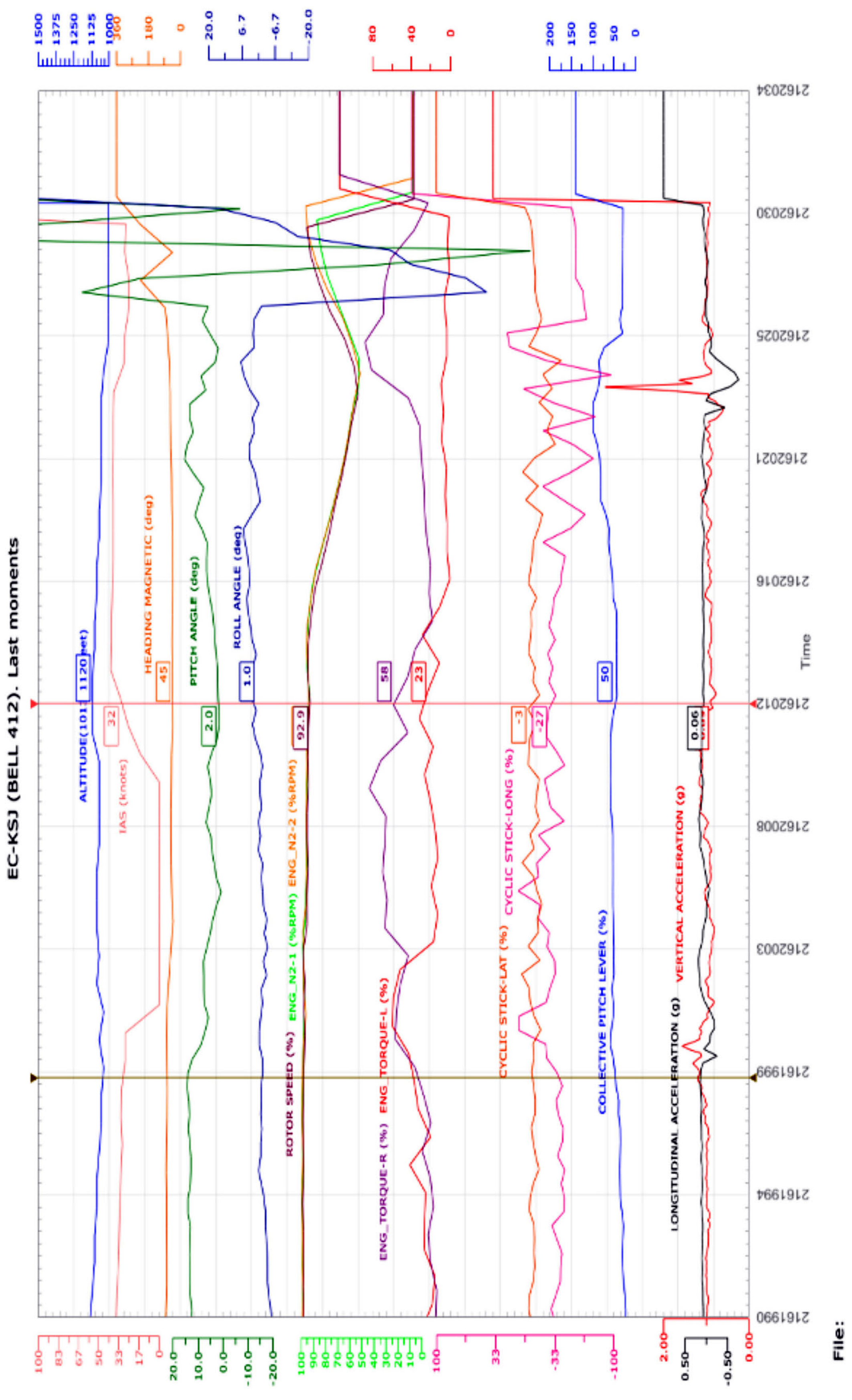
REC 05/14. It is recommended that INAER include a life vest as part of the equipment of crews that conduct cargo operations over large expanses of water.

APPENDICES

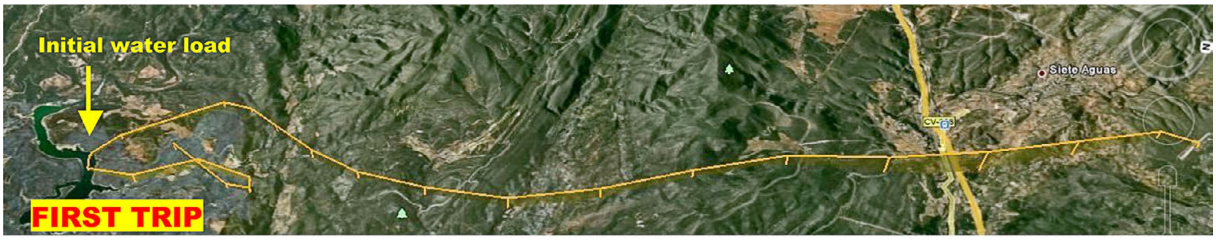
APPENDIX I
Graph of the parameters for the eighth water load

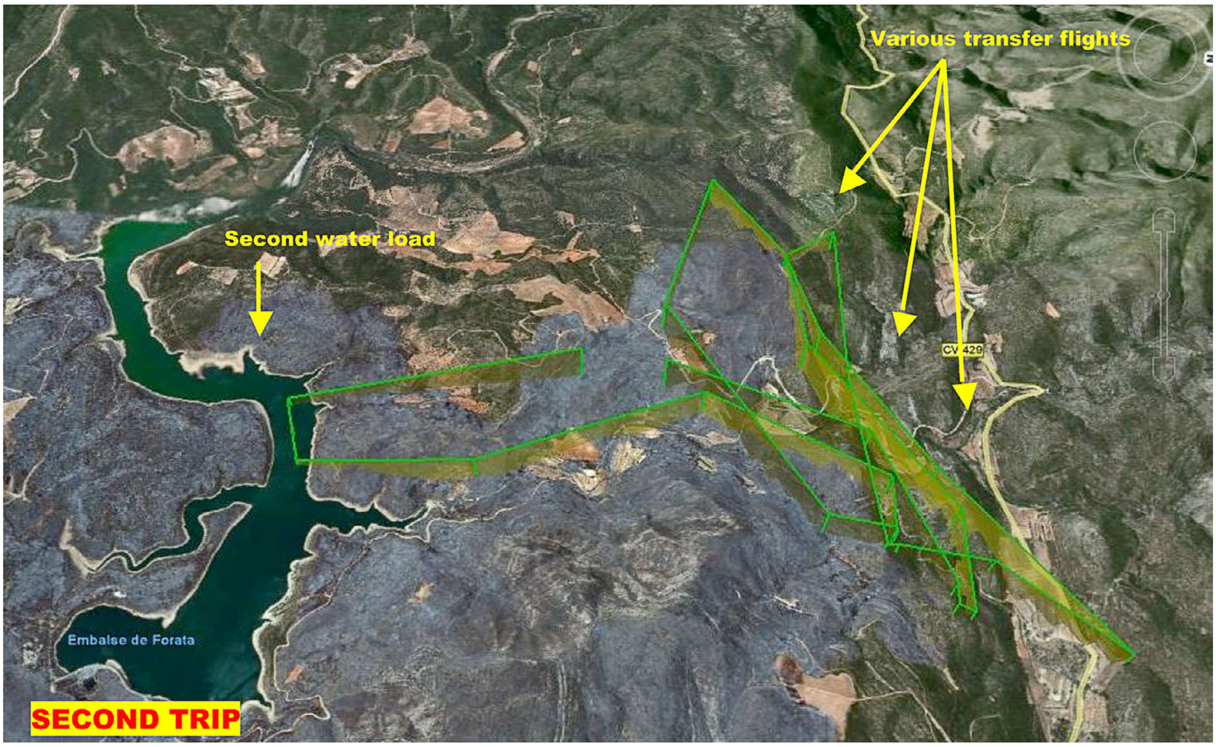

EC-KSJ (BELL 412). Last normal operation
ALTITUDE(1013mb) (feet)
IAS (knots)
HEADING MAGNETIC (deg)
PITCH ANGLE (deg)
ROLL ANGLE (deg)
ROTOR SPEED (%)
ENG_N2-1 (%RPM)
ENG_N2-2 (%RPM)
ENG_TORQUE-R (%)
ENG_TORQUE-L (%)
CYCLIC STICK-LAT (%)
CYCLIC STICK-LONG (%)
COLLECTIVE PITCH LEVER (%)
LONGITUDINAL ACCELERATION (g)
VERTICAL ACCELERATION (g)
1040
59
0
5.7
0.6
97.9
55
37
-14
48
0.05
Time
2161693
2161698
2161702
2161706
2161710
2161714
2161719
2161723
2161727
2161731
2161735
File:

APPENDIX II
Graph of the parameters for the last water load


EC-KSJ (BELL 412). Last moments
ALTITUDE(1013)(feet)
IAS (knots)
HEADING MAGNETIC (deg)
PITCH ANGLE (deg)
ROLL ANGLE (deg)
ROTOR SPEED (%) ENG_N2-1 (%RPM) ENG_N2-2 (%RPM)
ENG_TORQUE-R (%) ENG_TORQUE-L (%)
CYCLIC STICK-LAT (%) CYCLIC STICK-LONG (%)
COLLECTIVE PITCH LEVER (%)
LONGITUDINAL ACCELERATION (g) VERTICAL ACCELERATION (g)
Time
File:

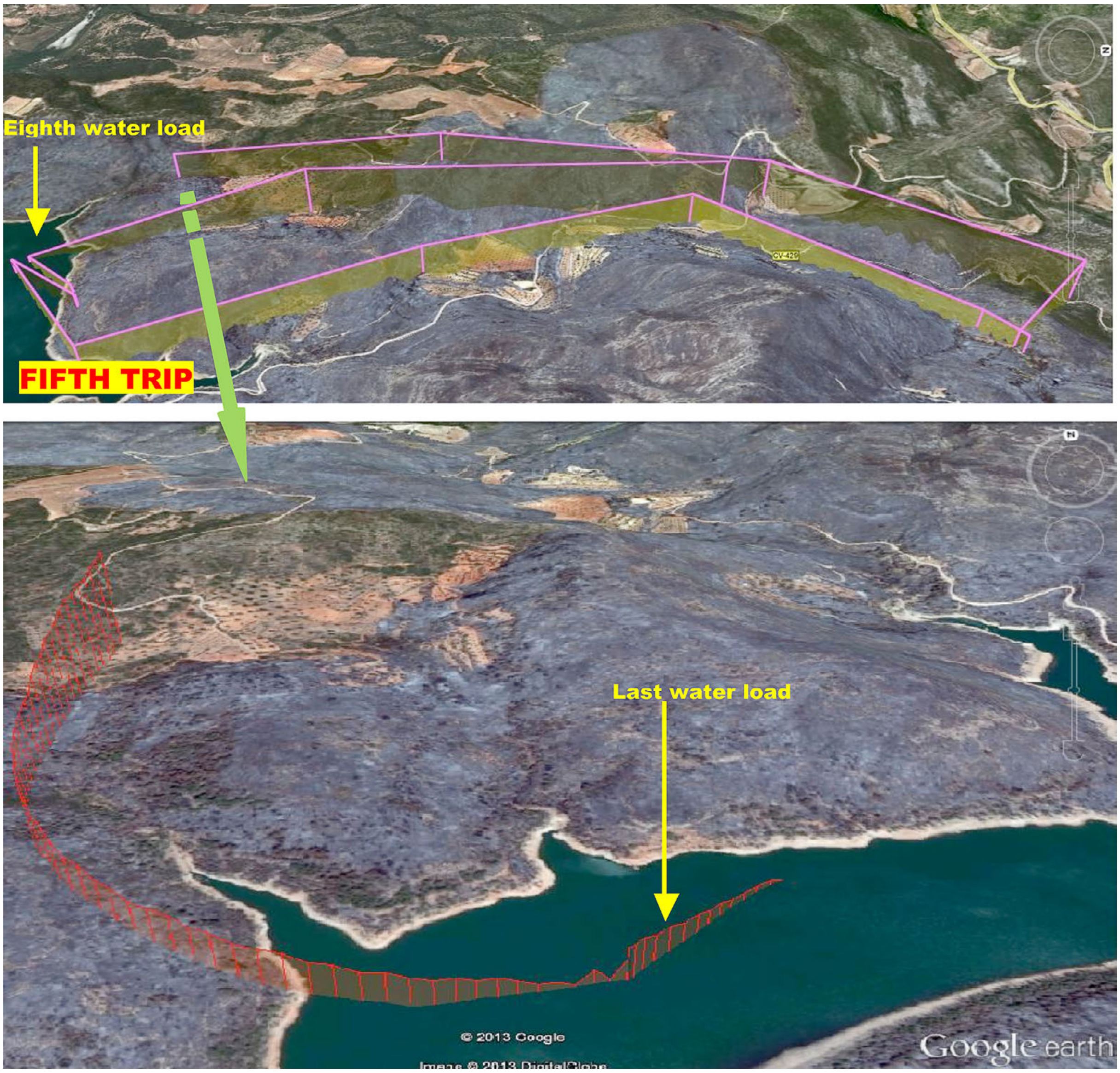
APPENDIX III
Flight paths from the fleet tracking system


Initial water load
Siete Aguas
FIRST TRIP


Various transfer flights
Second water load
CV 429
Embalse de Forata
SECOND TRIP


Third water load
Embalse de Forata
CV-429
THIRD TRIP


Four water loads
CV-429
FOURTH TRIP


Eighth water load
FIFTH TRIP
Last water load
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