CIAIAC

COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
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AVIACIÓN CIVIL

Report A-068/2004

Impact into the Guadalquivir River of Agusta Bell AB-412 helicopter, with registration marks EC-GBE, at San Juan de Aznalfarache (Seville), on 14 November 2004

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SECRETARÍA GENERAL DE TRANSPORTES

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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 and its causes and consequences.

In accordance with the provisions of Law 21/2003 and pursuant to Annex 13 of the International Civil Aviation Convention, the investigation is of exclusively a technical nature, and its objective is not the assignment of blame or liability. The investigation was carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents.

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

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

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Abbreviations

00°	Sexagesimal Degree(s)
00 °C	Degree(s) Centigrade
ADI	Attitude Director Indicator
AGL	Above Ground Level
AP	Airport
ATR	Air Traffic Regulations
CAVOK	Visibility 10 km or more; no clouds below 5,000 ft
CTR	Control Zone
CG	Center of Gravity
DEG	Sexagesimal Degrees
ft/m	Feet per minute
h	Hour(s)
kg	Kilogram(s)
km	Kilometer(s)
kt	Knot(s)
m	Meter(s)
mm	Millimeter(s)
METAR	Meteorological Aerodrome Report
MTOW	Maximum Takeoff Weight
OEI	One engine inoperative
s	Second(s)
S/N	Serial number
T	Eyewitness
TQ	Torque
VFR	Visual Flight Rules

Synopsis

Operator:	Transportes Aéreos del Sur, S. A.
Aircraft:	Agusta Bell AB-412, registration marks EC-GBE
Place of the accident:	San Juan de Aznalfarache (Seville)
Date and time of the accident:	14 November 2004 at 10:30 local time
Persons aboard:	One pilot and four passengers
Type of flight:	General aviation. Private. VFR

Date of approval of the report: December 20, 2006

Summary of the accident

The helicopter took off from the La Cartuja airport in Seville, at approximately 10:30 hours with four people and the pilot aboard for a local flight with an estimated duration of less than 30 minutes. After climbing to the east, the pilot initiated a turn to the right on a southwesterly course before heading toward San Juan de Aznalfarache by flying over the left bank of the Guadalquivir River. As the helicopter approached the runway zone at Tablada Airport, while directly overhead the iron bridge (Puente de Hierro) and flying over the river at an altitude of 100 ft (30 m) above the water, the helicopter altered its nose attitude downward and began to descend until it impacted the water.

It has been determined that factors such as the low altitude over the terrain, the large amount of low-level general and recreational aviation present in the flight path, and the possible influence over the pilot by the passengers, with whom he was acquainted, may have contributed to the accident.

During the last phase of the flight, while following the path of the Guadalquivir River, the aircraft initiated a prolonged descent without changing appreciably the speed, course or slope of its trajectory before impacting the water. This may have been the consequence of spatial disorientation on the part of the pilot.

1. FACTUAL INFORMATION

1.1. History of the flight

The Agusta Bell 412 helicopter, registration marks EC-GBE, was normally used for the public transportation of passengers. It was based out of Malaga Airport and had been moved to the operator's facilities at La Cartuja Heliport (Seville), where it underwent scheduled maintenance. Once the maintenance and test flights were concluded, the positioning flight back to Malaga was scheduled for Sunday, November 14.

The pilot designated for the flight had flown from Ceuta to Seville on Saturday afternoon. There, he invited some of his acquaintances on a flight over Seville and the surrounding area before making the positioning flight to Malaga.

The helicopter took off from the La Cartuja Heliport at approximately 10:30 with four people and the pilot aboard for a local flight with an estimated duration under 30 minutes and in accordance with visual flight rules.

The helicopter climbed to the east and initiated a turn to the right on a southwesterly course before heading to San Juan de Aznalfarache, following the left bank of the Guadalquivir River.

On approaching the runway zone at Tablada Airport, at an estimated altitude of 100 ft (30 m), while directly above the iron bridge (Puente de Hierro) and while flying over the river, the helicopter modified its nose attitude downward and started to descend until it impacted the water.

After the impact, the helicopter tilted forward and sank. Moments later four of the occupants emerged to the surface and were picked up by a boat downstream from the crash site. A fifth person remained underwater.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Other
Fatal		1	1	
Serious	1	2	3	
Minor		1	1	Not applicable
None				Not applicable
TOTAL	**1**	**4**	**5**	

1.3. Damage to aircraft

The forward part of the helicopter cabin structure, from the nose to the area of the engine bay, was completely destroyed, resulting in a mass of wreckage (see Photo 1).

The main transmission gearbox, along with the mast and main rotor head, became detached from the helicopter structure and presented multiple breakages and warping.

The whole tail boom and rotor was left almost intact; only the horizontal stabilizer and the tail rotor pitch control rods were damaged.

As a consequence of the direct impact with the water, the helicopter was so heavily damaged that it was essentially destroyed.

1.4. Other damage

A nearby house suffered slight damage to a wall on the terrace as the result of the impact from a tip from one of the main rotor blades, which was ejected when the rotor crashed into the water.

Photo 1

1.5. Personnel information

1.5.1. *Captain*

Age:	31
Nationality:	Spain
Certificate:	Commercial helicopter pilot
Certificate valid until:	6 March 2005
Valid ratings:	A 109/109K, Bell 206/206L, Bell 412*
Total flight hours:	3,969:30 h
Total flight hours on the type:	2,313:25 h

1.5.2. *Passengers*

The passengers aboard the aircraft at the time of the event were four adult males, all friends of the pilot. Passenger Px 1 (see Figure 1) was in the copilot's seat. Passenger Px 4 remained under water and had to be retrieved by divers from the Guardia Civil.

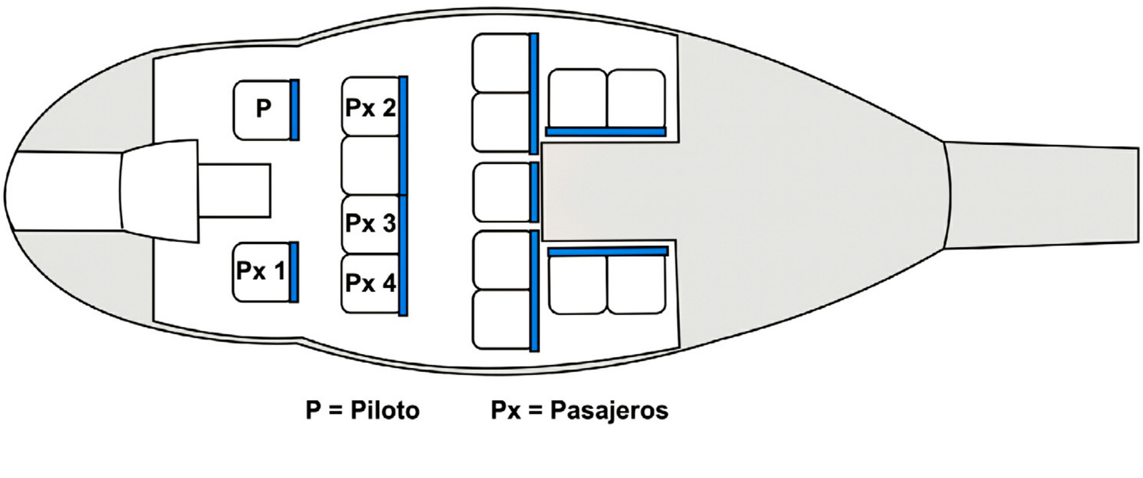


Figure 1. Arrangement of the passengers in the cabin

* A B-412 helicopter rating implies an AB-412 rating.

1.6. Aircraft information

1.6.1. *General*

The aircraft had a valid airworthiness certificate. The aircraft's registration data are follows:

Type:	Agusta Bell
Model:	AB-412
Construction number:	25503
Registration:	EC-GBE
Engines:	2 Pratt&Whitney PT6T-3B S/N: 63199/63200
MTOW:	5,402 kg
Minimum crew:	One pilot
Owner:	ING LEAS (España) E.F.C., S. A.
Operator:	Transportes Aéreos del Sur, S. A.
Airworthiness certificate:	N.° 3780. Valid until 8 May 2005

1.6.2. *Helicopter Maintenance*

After examining the helicopter's maintenance records, it was verified to be in compliance with the established maintenance program.

The day before, the following maintenance tasks had been performed:

- 25-hour inspection.
- Main and tail rotor balancing.
- Replacement of the horizontal stabilizer control bar due to clearance concerns and of the tail rotor pitch links.
- Replacement of the governor in n.° 2 engine.

After finishing the aforementioned maintenance tasks, a test flight was performed with satisfactory results.

1.6.3. *Helicopter weight*

The weight of the helicopter and the longitudinal center of gravity at the time of the event were estimated according to the following data:

	Weight (kg)	Moment arm length (mm)	Moment
Basic weight	3,221.00	3,681.00	11,728,845.00
Pilot and passenger n° 1	184.00	1,194.00	214,920.00
Passengers n° 2, 3 and 4	260.00	2,210.00	574,600.00
Fuel	630.00	3,881.00	2,445,030.00
Luggage compartment	10.00	6,223.00	62,223.00
Total weight	4,305.00	3,519.93	15,153,281.00

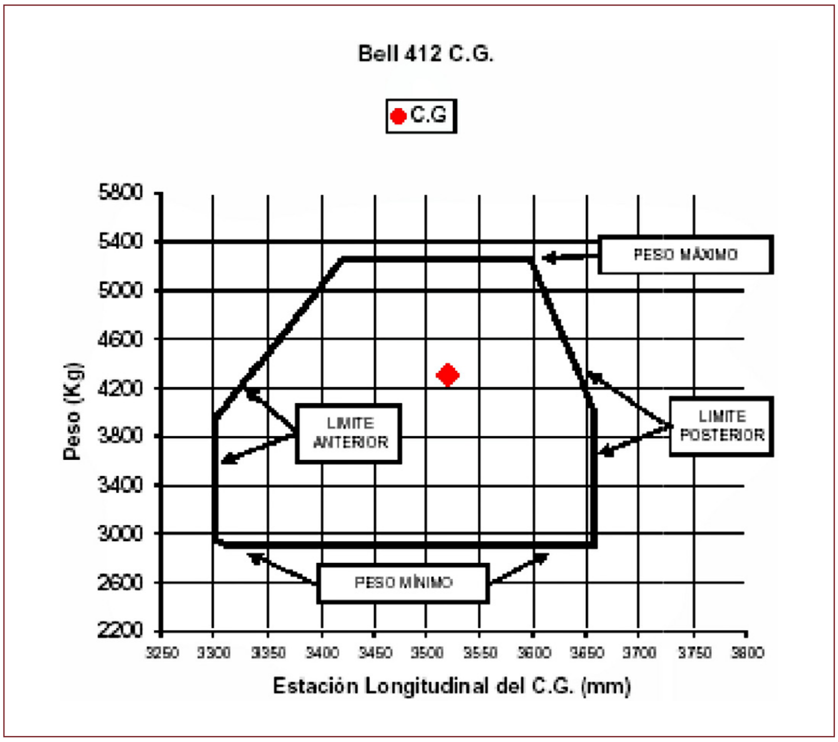


Figure 2. Longitudinal center of gravity

The basic weight was calculated starting with the empty weight, adding the weight of the engine oil, the seat configuration at the time of the event and the lateral steps used to access the passenger cabin.

In accordance with the previous diagram (see Figure 2), the aircraft's weight and center of longitudinal gravity at the time of the event were within limits.

1.7. Meteorological information

The Seville Airport METAR for 10:00 local time reported winds from the north at 8 kt, CAVOK and an ambient temperature of 15 °C.

According to information provided by the pilot, the day was sunny and winds were calm at the departure heliport.

At that time the Sun's azimuth was 139° and its height above the horizon 23°.

1.8. Aids to navigation

Not applicable.

1.9. Communications

The pilot did not establish radio contact with either the Seville Airport Tower or with Seville Approach Control.

1.10. Aerodrome information

1.10.1. *La Cartuja Heliport*

La Cartuja Heliport is within Seville Airport's CTR and within the final approach area for Runway 09. It is located to the west of the airport, near the CTR's outer boundary. The city of Seville is between the airport and the heliport and stretches to the southeast. See the Seville Airport visual approach chart (Figure 3).

1.10.2. *Former Military Airport at Tablada*

Airport no longer in use whose runway is located to the south of La Cartuja Heliport at a distance of 4,500 m (see Figure 3). It was open to the general public and its runway and surrounding areas were used for flight activities which included paragliding and radio control flying, along with other motoring and motorcycling activities. Its facilities are on the outer boundary of the Seville CTR.

1.11. Flight recorders

The aircraft was not equipped with flight recorders. Regulations in effect at the time did not require flight recorders to be installed on helicopters of this type.

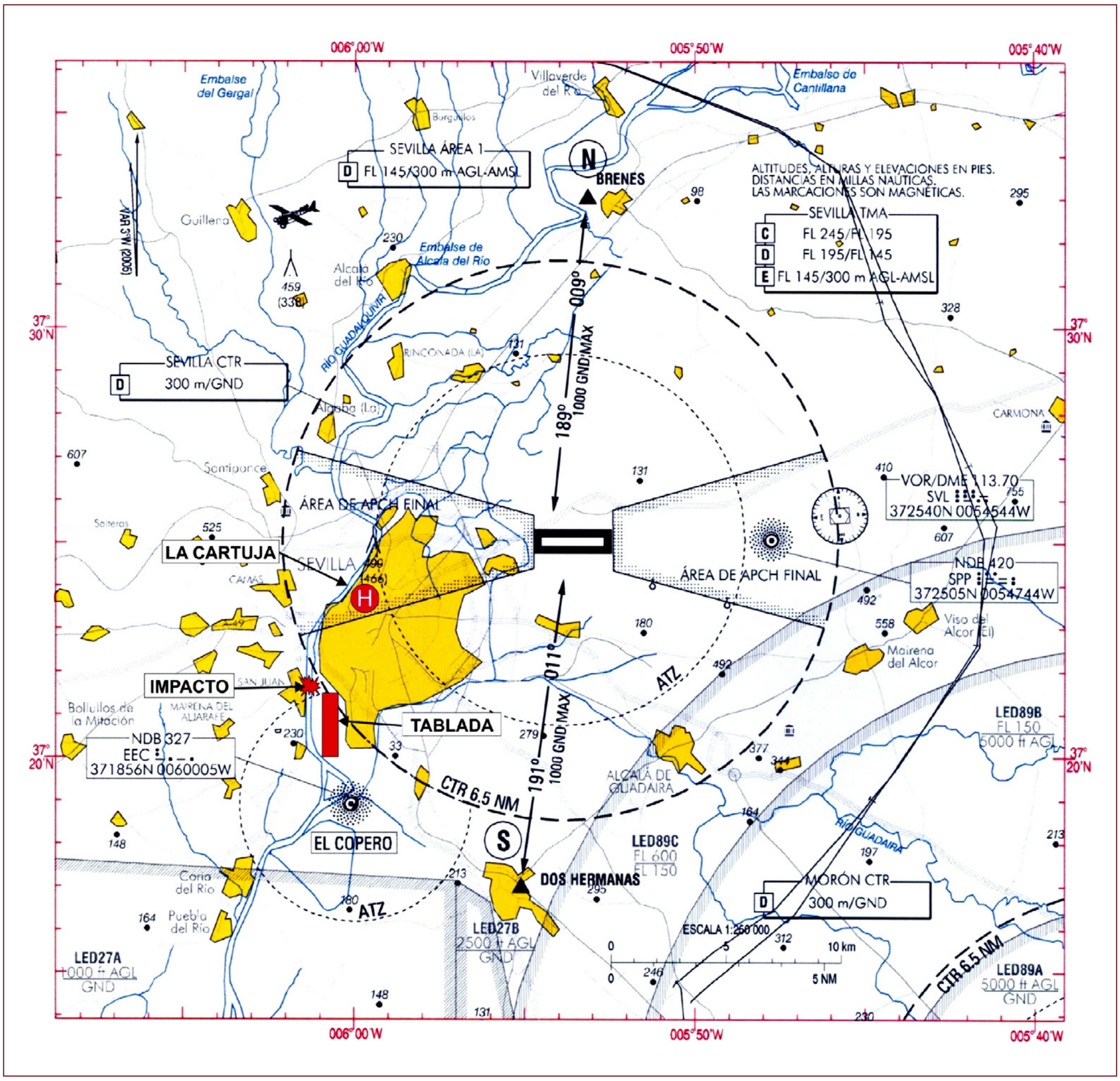


Figure 3. Visual approach chart for Seville Airport

1.12. Wreckage and impact information

1.12.1. *Impact zone*

The final impact took place within the Guadalquivir River, near its central axis, 600 m downstream from the Puente de Hierro, between the runway at Tablada and San Juan de Aznalfarache.

The river flows from north to south.

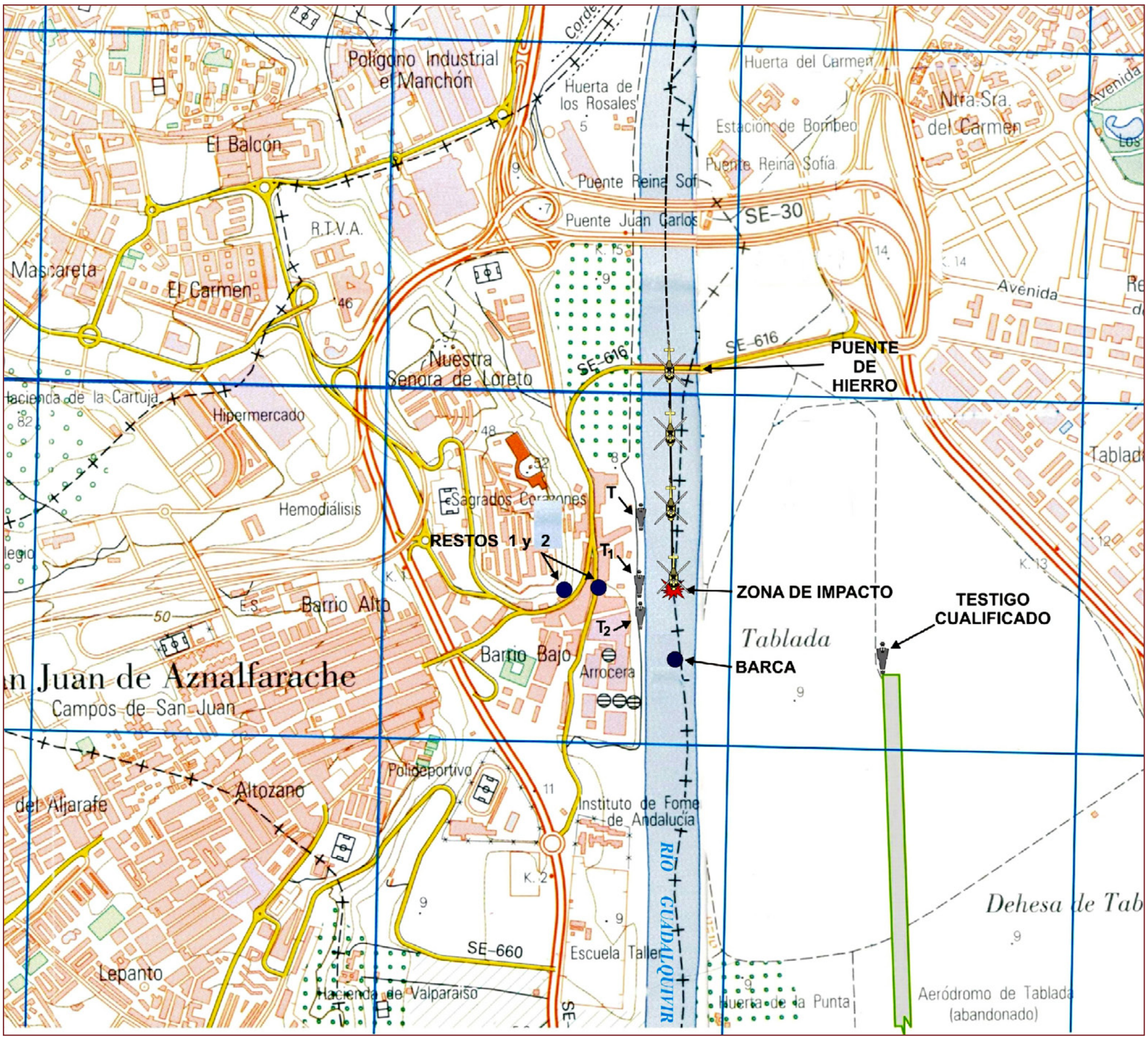


Figura 4. Zona del impacto

The river is the point of lowest elevation in the area surrounding the crash site. The elevation of the terrain around Tablada is only 5 m above sea level, but the structure of the iron bridge (Puente de Hierro), some 20 m in height, and the trees on the riverbanks, some up to 30 m tall, constituted obstacles close to the helicopter's likely flight path.

1.12.2. *Location of the wreckage*

After the event, the aircraft's structure, visible at low tide, was marked with buoys and tied off to a vessel until the tide could facilitate its transport to the port of Gelves, where it was hoisted to dry land.

Once the structure was recovered, the impact zone and surrounding areas were inspected by a team of rescue divers with experience in the Guadalquivir River.

They found the remains of the main transmission gear box, the mast, and the main rotor head with parts of the blades still attached.

Other scattered remains, like sections of the main rotor blades and two helicopter doors, were found floating in the surrounding water.

Two blade tips were found outside the river, both measuring between .60 and .80 m in length, one in the terrace of an apartment building 100 m away from the crash site and the other in the public park around the Monumento de San Juan de Aznalfarache, 300 m away from the crash site. Both points are situated on a line perpendicular to the helicopter's flight path and to the right of the crash site (see Figure 4).

The recovered pieces of wreckage were taken to a hangar at Seville Airport for subsequent analysis.

1.12.3. *Examination of the wreckage*

The remains of the helicopter were examined and analyzed with the help of technical personnel from the aircraft and engine manufacturers, as well as by the helicopter's own operator and maintenance crew.

The forward part of the helicopter was completely destroyed. The passenger and crew compartment was crushed by the impact, the instrument panel was detached and the main spars in the cabin structure were broken (see Photo 5).

An examination of the main structure's wreckage, of the buckling and breakage, and the subsequent reconstruction allowed the investigators to conclude that the cause had been a frontal impact with a high translational velocity and a moderate descent velocity caused by the helicopter's low nose down attitude at the impact.

An oil pressure indicator, the ADI and the triple torquemeter were all that remained of the instrument panel. This last gauge, of particular interest due to its engine power indication, froze on impact with the following readings (Photo 2):

— Transmission TQ: 68%
— Number one engine TQ: 33%
— Number two engine TQ: 35%

The pedestal had become detached, and some of its switches had been damaged by the impact. The relevant information extracted from the switches was as follows:

— Governor switches for No. 1 and No. 2 engines in AUTO (normal in-flight position).

Foto 2. Triple torquímetro

- — No. 1 and No. 2 fuel switches ON.
- — Fuel cross-feed valve switch in NORMAL (normal in-flight position).
- — No. 1 fuel pump switch OFF (not the normal in-flight position, but at this flight altitude it does not lead to fuel starvation).
- — No. 2 fuel pump switch halfway between the normal ON and OFF positions.
- — No. 1 and No. 2 hydraulic systems ON (normal in-flight position).
- — Cyclic control FORCE TRIM[1] switch ON with switch-guard in place (position selected by the pilot).

Most of these switches are easy to operate, do not have a switch guard and none was locked, so they could have been repositioned by the impact or even afterward.

Of the overhead panels, which were also detached, only the right one was found, with some of the fuses popped out.

The pilot-side cyclic and collective control sticks were found, and only the collective control from the copilot's side. Part of the main rotor's connection and servo-actuator control systems were missing, some had been detached from their anchor points and oth-

[1] The force trim system provides an artificial force in the cyclic control as well as a way to compensate or trim this force during each phase of flight.

ers were broken in various parts due to static fracture resulting from the stress of the impact.

The driveshaft from the engines to the main transmission gearbox broke in two places near the coupling gear. The male coupling on the transmission side had lost several teeth, which were found on the female coupling joined to the main gearbox. There was no evidence that the gear overheated.

The main rotor blades were warped and broken at several points due to torsion loads and drag and reaction forces far in excess of any flight condition.

In the main rotor assembly, the breaks in all the moving parts, in the blade pitch links, in the head and in the blades obviously resulted from the sudden stoppage of the main rotor (as the blades stopped upon impacting the water).

The fairings, cowlings and firewalls of both engines were significantly buckled, while the engine mounts, located behind the main transmission gearbox, barely showed any signs of damage. Both engines were in their proper place after the impact.

The tail rotor transmission shaft was broken in the first segment leading from the main transmission gear box. Aft of that point, the transmission shaft was in good condition and rotated freely. The 42- and 90-degree gearboxes were in place without any apparent damage.

The tail boom suffered minor damage to the driveshaft cover and to the right horizontal stabilizer. The left side had become detached due to a static fracture of the support tube.

The tail rotor showed no significant damage to the blades. Minor warping was observed in one of the blades and the pitch control assembly, and the static stop on one side was fractured.

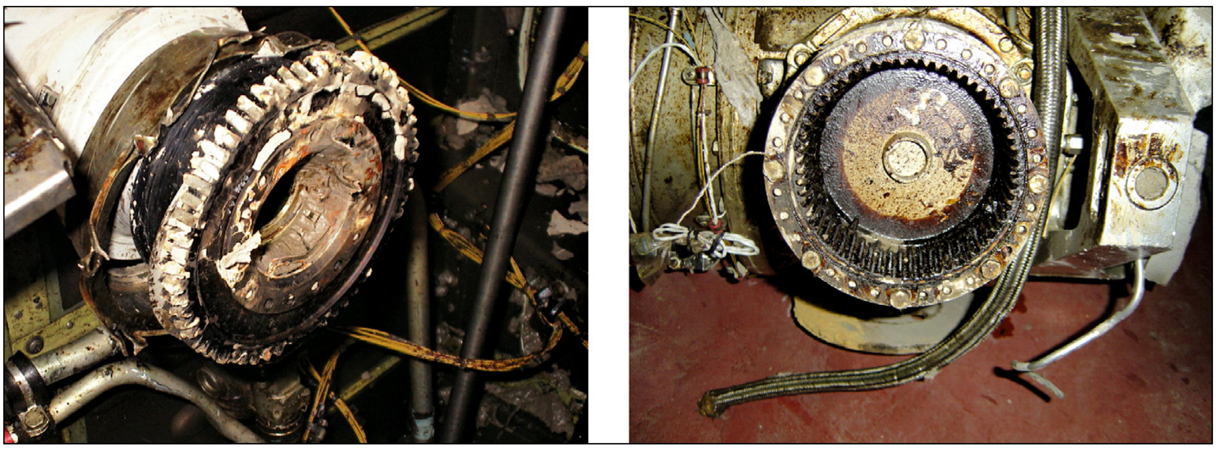


Photo 3. Driveshaft from the engines to the main transmission gearbox

Photo 4. Main rotor blades

1.12.4. *Examination of the power plant*

Neither engine showed evidence of bleed air, fuel or oil leaks. There were no signs of overheating or fire damage. There was only slight damage from the impact. Both engines had become dirty from the mud at the bottom of the river.

There were no particles or other foreign objects in the engine bay. There was also no trace of oil or any other material in the gas exhaust duct.

The air inlet screen and labyrinths on the engine air intakes were clean and intact.

The first stage compressors in both engines were inspected with mirrors. A boroscope was also used on No. 1 engine. They showed no signs of ingestion damage. Both compressors rotated freely by hand without making noise.

The exterior of both engines combustion chambers were intact. All tubes and injectors were in place.

The fuel control units were found with all their connections, caps and tubes tight and lockwired, and the levers attached to their respective control cables. An inspection of both governors likewise revealed the fittings were tight and lockwired.

The reduction gear box was in good condition, without any visible external damage or signs of oil loss.

In general there were no mechanical anomalies which may have led to a partial or total loss of power.

1.13. Medical and pathological information

The pilot, who was in the front right seat, had his injuries limited mainly to the right limbs, and the passenger, who was in the copilot's position in the front left seat, had trauma injuries confined mainly to the left limbs.

Both front seat occupants suffered facial trauma and cuts and superficial injuries, mainly to the face and chest. One of the two survivors seated in the passenger cabin suffered head trauma and neck injuries.

There is no information concerning the injuries sustained by the fatal victim or about the cause of death since the forensic report was unavailable.

1.14. Fire

No fires broke out as a result of the impact with the water.

1.15. Survival aspects

After impacting against the water, the helicopter tipped forward and sank. Three passengers and the pilot were able to make their way to the surface, where they were picked up almost immediately by the occupants of a nearby powerboat.

The helicopter's fifth occupant did not emerge to the surface under his own strength, and was pulled out from the still-submerged wreckage of the aircraft at 15:15 by a team of divers from the Guardia Civil.

According to statements from the occupants, later confirmed by an examination of the remains, everyone on board had their seatbelts fastened and the occupants of the pilot's and copilot's seats were wearing their harnesses.

The passenger in the copilot's seat did not remember how he had gotten out of the seat, which was found with its seatbelt and safety harness fastened when it was recovered from the river.

None of the five occupants was wearing a life vest.

1.16. Tests and research

1.16.1. *Analysis of airspeed as a function of TQ*

In addition to the high estimated translational, or horizontal, velocity obtained from examining the helicopter wreckage, an additional calculation was made based on the helicopter's performance and the corresponding graph in the flight manual for fuel flow versus airspeed, taking into account the following data:

— 68% TQ (obtained from the triple torquemeter which froze on impact).
— 15 °C ambient air temperature taken from the Seville AP METAR.
— Estimated helicopter weight of 4,305 kg (9,490 pounds).

The above data were input to the graph (see Figure 5), with a resulting airspeed value of 113 kt.

1.16.2. *Description of the final trajectory*

As the helicopter approached the Puente de Hierro, which spans the Guadalquivir River, it was in stable flight, maintaining airspeed, altitude and heading, according to information provided by the pilot, one of the passengers and eyewitnesses.

As it went over the bridge, the helicopter transitioned to and maintained a downward nose angle, resulting in the descent which led to its impacting the water. The only correction the pilot remembered for that leg was a slight course correction to the right which he effected with a gentle movement of his right hand to the right.

The helicopter covered approximately 600 m as it descended toward the river and lost about 100 ft (30 m) in altitude.

1.16.3. *Eyewitness accounts of the impact*

According to the accounts of eyewitnesses on the riverbanks, the helicopter did not change its flight attitude or heading before impact. The skids impacted first, followed quickly by the nose. The helicopter then tipped forward and started to sink. It was dragged forward a few meters by the current.

The place where the helicopter crashed into the water is located, according to eyewitness statements, in the approximate center of the river, some 600 m away from the Puente de Hierro.

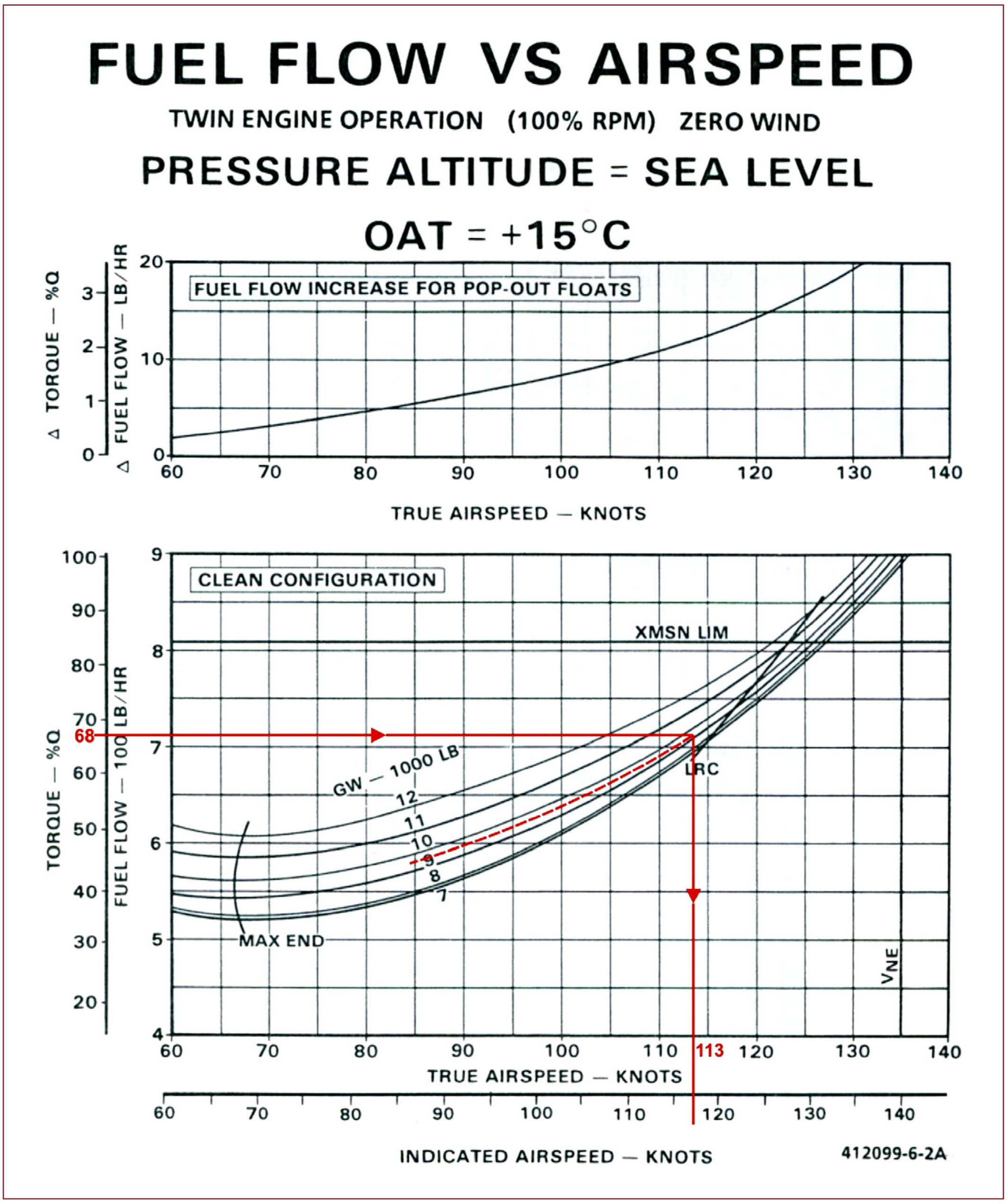


Figure 5. Chart of fuel flow versus airspeed

From the bridge until the point of impact, the river is approximately 90 m wide.

The part of the river where the impact took place is influenced by tides from the Atlantic Ocean. The high tide had reached its maximum height of 2.52 m at 07:55 local time. The water was therefore flowing out to sea in the same direction as the helicopter was flying. The north-south direction of river was the same as the helicopter's flight path.

The water was of a uniform color and murky from the mud.

Photo 5. Lower part of the cabin

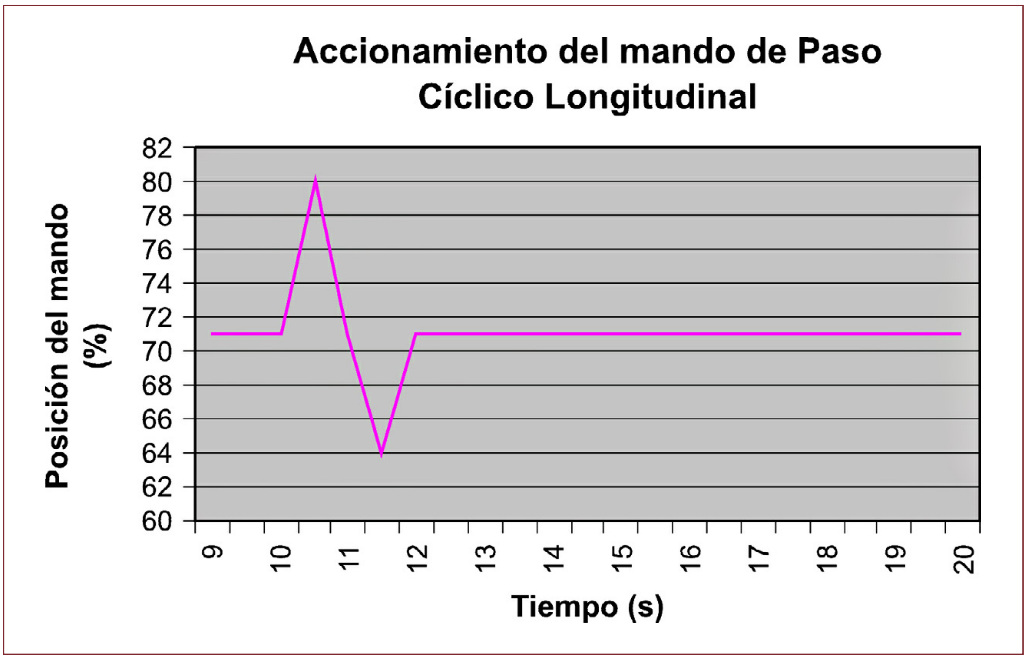
1.16.4. *Simulation of the final flight path*

Several computer-aided simulations were performed with the help of the manufacturer, the goal being to reproduce the final phase of the accident helicopter's flight.

The following assumptions were made for the simulations:

- A helicopter weight of 4,305 kg and a position for the longitudinal center of gravity at 3,520 mm (see 1.6.3).
- Initial TQ value of 68% (engine 1 = 33% and engine 2 = 35%), similar to the TQ level indicated by the triple torquemeter which froze on impact (see Photo 2).
- Constant collective pitch throughout the descent.
- Initial airspeed of 113 kt (see 1.16.1).
- Initial altitude: 100 ft (30 m).
- Ambient temperature: 15 °C.
- Vertical profile of the helicopter's trajectory in accordance with passenger and eyewitness accounts, starting with level flight at 100 ft (30 m) AGL and concluding at 0 ft AGL after covering a horizontal distance of 600 m.
- Time to descent from 100 feet AGL to the ground of 10 seconds.

The aim of the simulations was to see what adjustments to the main rotor's longitudinal cyclic control could cause the helicopter to descend 100 ft in 10 seconds without adjusting the collective pitch control or the throttle.



The result concluded that a 9% forward movement of the cyclic control stick and back again in one second, followed in the next second by a 7% movement backward and a return back to its original place could cause the helicopter to descend 100 ft in 10 seconds, in accordance with the profile described (not symmetrical cyclic reversal input).

At the same time it was noticed that starting from level flight, the pitch angle changed to –5° down[2] in the first two seconds of the descent, followed by a slow recovery to –2° in the subsequent 8 seconds. The descent velocity reached –4 m/s and was reduced to –3 m/s by the time the ground was reached (see Appendix A).

1.16.5. *Eyewitness statements*

1.16.5.1. Pilot

According to information provided by the pilot, the goal of the flight was to fly for a few minutes over the Monumento de San Juan de Aznalfarache area, which is located atop a hill and is a good lookout point from which to enjoy a panoramic view of Seville, return to the heliport, disembark the passengers and continue flying to Malaga.

He took off to the east and then turned to the southwest, reaching an approximate altitude of 100 feet. He leveled off at this altitude and once over the river, he turned downstream and followed the river.

[2] According to the sign convention used, the minus sign (–) indicates a nose down attitude.

As he approached the runway at Tablada, he saw paragliders flying in the area around the Puente de Hierro (see Figure 4) and had to divide his attention between the inside and the outside of the helicopter. Outside the helicopter he was watching for paragliders in his flight path, while inside the helicopter he was attempting to control the needles for the engine torque gauge which were showing a slight separation. The "force trim" switch on the cyclic control was activated. This being the situation, the pilot stated his surprise when he saw the water. In his own words, "... I suddenly noticed the water approaching at great speed, as if we were being drawn to it".

After the impact he remembers everything going black and a strong odor of fuel.

His experience flying at low levels over water was limited to filming a few commercials.

1.16.5.2. Passenger seated in the copilot's seat (Px 1)

He remembers the nose pitching down in the last moments of the flight, but he did not feel his body coming up off the seat. He went on to say that only a few moments elapsed before the helicopter impacted the water, although he could not give a time estimate in seconds. He also did not notice any variations in the helicopter's final trajectory, hence the direct impact with the water.

When he boarded, his seatbelt and harness were fastened and the door had been closed all from the outside. He did not receive any information on their proper use.

He did not remember how he had gotten free from the seat.

1.16.5.3. Passenger situated in the center passenger seat (Px 2)

According to his statement, "the flight was like a flash, it all happened too quickly". He pointed out how it felt like they were losing altitude shortly after takeoff.

He also stated that everyone had their seatbelts fastened and that they had all received information on their proper use, particularly the passenger in the copilot's seat, since that one had a more complex arrangement (seatbelt and a four-point harness).

After taking off from the heliport at La Cartuja, he saw paragliders ahead of them and pointed them out to the other two occupants seated on either side of him.

When they approached the area with the paragliders, the helicopter began to lose altitude, as if trying to get out of the area.

He stated that the pilot had stayed at his house the previous night and that he had gone to bed before midnight.

1.16.5.4. Eyewitness on the ground with helicopter-flying experience

An eyewitness on the runway at the old Tablada Aerodrome (see Figure 4, testigo cualificado) with experience flying helicopters saw how the helicopter, which had been on a stable and level flight, pitched down 10° as it flew over the Puente de Hierro, initiating a nose dive. The helicopter disappeared from his view behind a line of trees and, after two or three seconds, he heard a loud crash, after which the noise stopped.

1.16.5.5. Other eyewitnesses on the ground

One eyewitness (see Figure 4, indicated as T) located near the right shore of the river, about 15 m upstream from the point of impact, saw the helicopter about 300 m away from his position at an altitude of between 10 and 15 m above the water. He defined its trajectory as constantly heading for the water. At no time before the impact did the sound of the helicopter change. He did not see any paragliders or any other kind of device above the river. As for the impact, he related how the helicopter impacted nose-first. It tipped forward and quickly sank while being dragged downstream by the current until it came to a stop. He saw the people inside begin to emerge a short time later.

Another eyewitness (see Figure 4, indicated as T1) was on the right shore of the river perpendicular to the point of impact. He told how the helicopter was losing altitude at a constant rate. The sound was the traditional one for a helicopter and did not change.

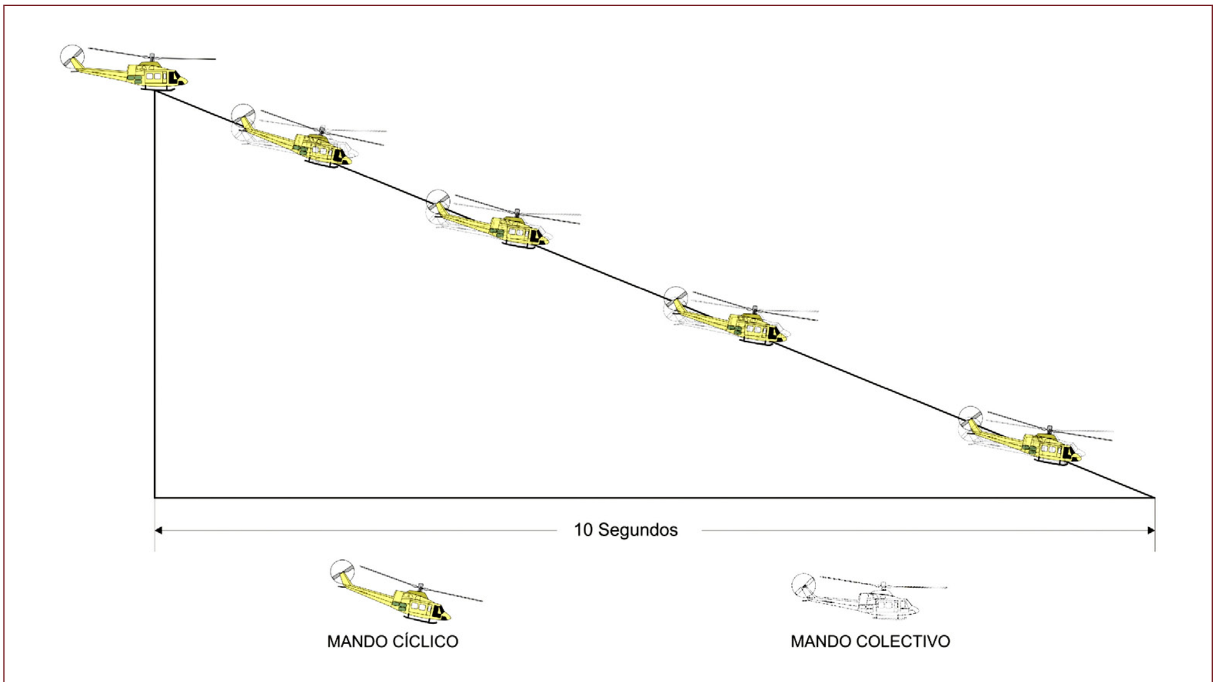


Figura 6. Actitud y trayectoria final del helicóptero

A third eyewitness (see figure 4 indicated as T2) was on the right riverbank some 40 m downstream from the impact point. He said that from the time he saw the helicopter until the impact, some 10 seconds had elapsed. The helicopter was following the center axis of the river, losing altitude. Its trajectory did not change before impact. He also noted no change in the sound of the helicopter. As for the impact, he said the helicopter's skids hit the water first followed immediately by the nose.

1.16.5.6. Eyewitnesses on the boat

Two people were aboard a small powerboat downstream of the crash site, in the center of the river and about 800 m away from the Puente de Hierro.

One of them saw the helicopter just before it overflew the bridge, defining its flight as normal. He stopped looking at it and when he saw it the second time, it was already past the bridge some 20 m above the water.

Both eyewitnesses saw how it impacted the water and how a few seconds later people appeared on the surface. They went to their aid, lifting them up onto their boat. They then went to the port at Gelves (Seville), where medical personnel took charge of the survivors.

1.17. Organizational and management information

1.17.1. *Positioning flight*

The operations manager had programmed a positioning flight for this pilot for the same day as the event, the objective being to move helicopter EC-GBE from La Cartuja Heliport to Malaga Airport. Said flight was to take place in accordance with a visual flight plan filed at Malaga Airport.

Though the flight which resulted in the accident was not scheduled and did not have an open flight plan, the company's operations manager had authorized the local flight in the area surrounding the heliport.

1.17.2. *Minimum altitude for VFR flight*

Rules in effect at the time of the event specified that no VFR flights were authorized below an altitude of 150 m (500 ft) excepting takeoffs and landings without authorization from the competent authority (ATR 2.4.6).

The operator's operations manual made no mention of any limits on minimum altitude above the ground for helicopter VFR flights between bases or for personnel transport.

To engage in low-level flights for certain specific commercial tasks undertaken by the operator, the only requirement was to avoid circumstances which may lead to impacts against obstacles.

An examination of the height-velocity, or H-V, diagram in Chapter 1 of the helicopter's flight manual, which shows the areas where the flight entails a certain risk in the case of a partial loss of power, reveals that this flight at 113 kt was not outside the safe operating envelope regardless of the altitude AGL.

1.18. Additional information

1.18.1. *Characteristics of low-altitude flights*

This report uses "low-altitude flight" to refer to a helicopter flying at an altitude of 100 ft (30 m) or less AGL, water or nearby obstacles.

In a helicopter, the possibility of flying at low speeds without encountering stall conditions results in high maneuverability in terms of its ability to make low radius turns, or even reverse course, so as to avoid colliding against an obstacle. The height is only limited in the lower portion of the H-V diagram in its flight manual since it affects the capability of landing with OEI.

A low-altitude, high-speed flight in the vicinity of elevated obstacles forces the pilot to anticipate climbs, descents and turns, and to pay special attention so that the helicopter's trajectory will clear obstacles by a wide enough margin of safety.

This type of low-altitude flight at cruising speeds limits the time and space available to control the additional risks involved with maneuvers, whether they result from improper inputs to the flight controls or from the loss of visual references to the crew due to a reduced field of view. Training aids the pilot to familiarize himself with the maneuvers and to widen his field of view when engaged in this type of flight.

Said flights also require a great deal of specialization on the part of the crew to implement, especially on flights above water or uniformly-colored terrain without relief, since the proximity of the water or terrain brings into play the use of special techniques involving the flight controls. Moreover, specific knowledge about vision is required to be able to correctly evaluate the helicopter's height and velocity using references on the ground or water.

1.18.2. *Spatial disorientation and field of vision*

The phenomenon of "spatial disorientation" refers to the inability of a subject to correctly determine his relative position and movement with respect to the reference points available as he moves above the terrain. Three types of spatial disorientation have been identified in pilots:

Type I. The pilot is unaware of his disorientation.

Type II. The pilot is completely or partially aware of the situation.

Type III. Incapacitating, regardless of whether or not he recognizes the situation or illusion.

Errors in perception are associated with a lack of external references, such as occurs during flights at night, in fog or clouds, or simply when flying over featureless terrain (water, snow, grass, sand). The relative movement of an aircraft flying over uniform terrain without any special characteristics, as might be the case with a river, leads the pilot to focus his attention on unreliable visual references, which in turn leads to a false sense of depth perception.

This false sense of depth perception, associated with the lack of visual references, is usually accompanied by the phenomena of channelized attention and abstraction.

During spatial disorientation, the visual system is of vital importance to orienting the pilot in space. The stimuli received from the peripheral areas of the retina make up what is known as ambient, or peripheral, vision. This vision is the orientation mechanism par excellence and is related to the other two orientation systems, namely the vestibular system and the propioceptive system.

A VFR flight depends to a large extent on the processes carried out on the stimuli gathered by the retina's peripheral areas. The capacity to integrate and perceive images on the retina's periphery is a function of the aircraft's speed: the higher the speed, the lower that capacity because the pilot's field of view is considerably reduced.

2. ANALYSIS

2.1. Flight phase leading up to the accident

Helicopter EC-GBE took off from the La Cartuja Heliport toward the east and then turned to the right on a southwesterly heading until intercepting the Guadalquivir River, before reaching San Juan de Aznalfarache, and followed the river to the south.

In the vicinity of Puente de Hierro, the helicopter was flying downstream over the center of the river, keeping a level altitude of 100 ft (30 m) above the surface of the water.

Its airspeed at that point was 113 kt on a course due south. The highest point on the Puente de Hierro is at least 20 m above the river's water at high tide, meaning the clearance between the helicopter and the bridge was very small and the airspeed very high. There were some tall trees on the riverbanks, some of them reaching up to 30 m above the water.

To the left of the helicopter's course was the old Tablada Aerodrome, where various aerial activities, such as paragliding, were taking place.

There are no limitations in the aircraft's flight manual prohibiting or warning against the flight characteristics like those carried out by helicopter EC-GBE. There is no evidence that the permission required to fly at an altitude lower than that stipulated in the ATR (500 ft – 150 m) was requested or granted. Such low-altitude flying also demands extra attention on the part of the pilot to any unforeseen circumstances, normally physical obstacles in the flight path.

It is our considered opinion that a high-velocity, low-altitude flight over obstacles and in close proximity to other very slow-flying aircraft, such as paragliders, entails an obvious safety risk. Piloting a helicopter under those conditions requires the undivided attention of the pilot, who should be cognizant that any distraction could bring with it disastrous consequences. While a low-altitude helicopter flight can usually be considered safe, given the helicopter's ability to cruise at very low speeds and its high maneuverability and ability to avoid obstacles, these characteristics are diminished at high airspeeds.

Additionally, in this case, there was no need to operate the helicopter at such a high speed and low altitude, apart from the pilot's desire to showcase and demonstrate the flight characteristics to his invited guests.

2.2. Descent and impact with the water

It was during these low-altitude, high-velocity conditions that, according to passenger and eyewitness statements, after flying over the Puente de Hierro, the helicopter's nose dipped noticeably, assuming a -5° pitch angle, according to the manufacturer's flight simulation. The helicopter then started on a downward trajectory, with no perceptible change from the standpoint of eyewitnesses and the passengers aboard, until impacting the water.

The impact of the helicopter skids and nose revealed that it reached the water with a slightly negative pitch angle, confirming eyewitness accounts and the analysis of the flight simulation.

The fractures and warping on the helicopter's moving parts clearly indicated that the helicopter was flying under its own power at the time of impact. The same conclusion was reached from pilot, passenger and eyewitness statements.

There was no indication found among the wreckage of any mechanical fault which may have forced the pilot to change the helicopter's attitude. Likewise, eyewitness accounts on the sound of the helicopter revealed no significant changes before the helicopter's sudden pitch change.

The separation between the TQ needles in the triple torquemeter for both engines was within limits, with values consistent with level flight at an airspeed of 113 kt. The high airspeed was also confirmed by the 600 m horizontal displacement from the time it overflew the bridge until the impact with the water 10 seconds later.

Meteorological conditions in the area were adequate for a VFR flight.

No circumstances were identified indicative of pilot fatigue.

The analysis of this investigation, therefore, focused on a study of the operational actions which could have influenced the aircraft from the moment it initiated the change of trajectory with the introduction of the downward pitch angle until the impact with the water.

2.3. Analysis of the final flight trajectory

2.3.1. *Loss of altitude*

As previously stated, the helicopter was overflying the river at an altitude of 100 ft over the water. Its height over the structure of the bridge would have been greatly reduced and its airspeed was estimated at 113 kt.

After flying over the bridge, the helicopter initiated a descent with a slight downward flight attitude, or pitch angle, according to eyewitness accounts, reaching the surface of the water after losing 100 ft in altitude over a span of 10 seconds.

Such a descent over a 10 second time period is consistent —given the weight and environmental conditions present during the flight and according to the manufacturer's simulation— with a 9% forward movement and a 7% aft movement of the cyclic control without any inputs to the collective control or adjustments to engine power. That motion of the cyclic control will induce a negative, or nose down, pitch angle in the helicopter, after which the descent path stabilizes.

2.3.2. *Pitch angle*

The pitch angle calculated in the simulation was –5° in the first moments following the dive, settling out to –2° at the moment of impact. The qualified eyewitness estimated a pitch angle closer to –10°. That discrepancy is of no consequence to this analysis considering the difficulty involved in estimating the attitude of an aircraft from the ground. This eyewitness's account is still relevant, however, in that it confirms that a significant change did indeed take place in the helicopter's pitch angle.

Since the "force trim" system was engaged, moving the cyclic control would have required a forceful input from the pilot. For this reason we believe that the negative pitch angle which started the downward trajectory, once the Puente de Hierro was cleared, was introduced by the pilot, possibly in an effort to distance himself from the aerial activity over the runway at Tablada or because he decided to further reduce his altitude after flying over the bridge.

2.3.3. *Flying techniques. Exclusive use of the cyclic control to descend*

The information gathered from pilot, passenger and eyewitness statements about the helicopter attitude in this last phase, as well as the simulation carried out by the manufacturer, lead us to believe that the dive was initiated, and the helicopter's negative pitch angle throughout the descent glide maintained, exclusively with the cyclic control.

The exclusive use of the cyclic, and therefore the non-use of the collective, would mean that the 68% TQ reading observed on the triple torquemeter should match the TQ values from the previous, level-flight phase and the entire subsequent trajectory until the final impact.

An altitude change maneuver involving only the cyclic control is possible and, moreover, can be completed in less time than an altitude change maneuver using the collective control aided by the cyclic control. The subsequent time to level off, however, is slower. Executing such a maneuver 100 ft above water therefore entails a certain risk.

Survivors and eyewitness accounts suggest that the pilot did not take any actions with the aircraft's controls to attempt to correct the downward trajectory.

2.4. Spatial disorientation

The fact that the flight path was constant, with no sign of any significant changes in the helicopter's attitude indicative of any corrective action on the part of the pilot to avoid impacting the water, led us to analyze the possibility that the pilot was suffering from spatial disorientation.

The path taken by the helicopter may be suggestive of a pilot who has temporarily lost the ability to correctly assess his position (height) and his relative motion with respect to the references available when moving over terrain.

According to what has been described above on visual fields, the ability to integrate and perceive images received from the periphery of the retina is a function of the aircraft's airspeed: as the airspeed increases, this ability decreases. Said ability to integrate images, therefore, may have been affected by the 113-kt airspeed.

It is normal for a pilot to be aware of his surroundings during a visual flight, with slight head movements that allow him to keep an overall view of the situation. The nuances of a low-altitude, high-velocity flight tend to take a pilot away from this technique. In such circumstances it is especially important to focus on the ground and on the space directly ahead, since it is in these two directions where the greatest dangers lie. If under these conditions the pilot diverts his view to the sides or to the inside of the helicopter where there might be elements to distract the pilot's attention, a situation involving pilot disorientation could arise which would reduce his ability to react once he re-focused on the helicopter's path again.

Additionally, the helicopter was on a descent path which initially had an 8° field of view encompassing the entire 90 m width of the river, assuming the pilot was looking 600 m ahead of him. If he was looking only 200 m in front, the field of view required to take in both river banks at the same time would have been approximately 25°. It seems unlikely, then, if he was looking forward and given the helicopter's airspeed, that he would have lost enough visual references from the riverbanks, trees, boats, etc., so as to trigger an episode of spatial disorientation from lack of references. There may be other, additional factors to explain the pilot's disorientation.

There are many factors which may trigger the possible Type I spatial disorientation (unrecognized by the pilot) that may have led to the aircraft's impacting the water:

a) Meteorological conditions: Calm winds, glassy water without ripples and uniform in color.

b) Focused attention: fascination or fixation on a task, in this case flying at low altitude and high airspeed over the Guadalquivir River.
c) Limited experience in low-altitude flights over water.
d) A reduction in the number of peripheral references or vision resulting from the high airspeed and diminished field of view.
e) Attention drawn toward the flight of the paragliders.
f) Distraction from flight tasks while demonstrating his abilities to his friends.

3. CONCLUSIONS

3.1. Findings

- The helicopter was flying under visual conditions with four passengers, all of them acquainted with the pilot.
- The pilot had a valid license for the helicopter type.
- The aircraft had a valid airworthiness certificate and had been maintained in accordance with the approved maintenance program.
- Meteorological conditions were satisfactory for a visual flight and did not influence the outcome of the flight.
- The helicopter was flying at an altitude of 100 ft AGL following the path of the river toward the vicinity of the old runway at Tablada.
- The helicopter changed its flight path, initiating and maintaining a descent that led to its impacting the water.
- It seems certain that the exclusive use of the cyclic control led to the loss of altitude in the final phase of the helicopter's trajectory.
- The introduction of a pitch angle equal to or greater than –5° required an input to the flight controls greater than that required to maintain level flight.

3.2. Causes

Flying in the vicinity of an area with a great deal of general and recreational aviation, along with the presence on board the aircraft of passengers who were acquaintances of the pilot, may have contributed to a reduction in the high level of attention required for a low-altitude, high-velocity flight over water.

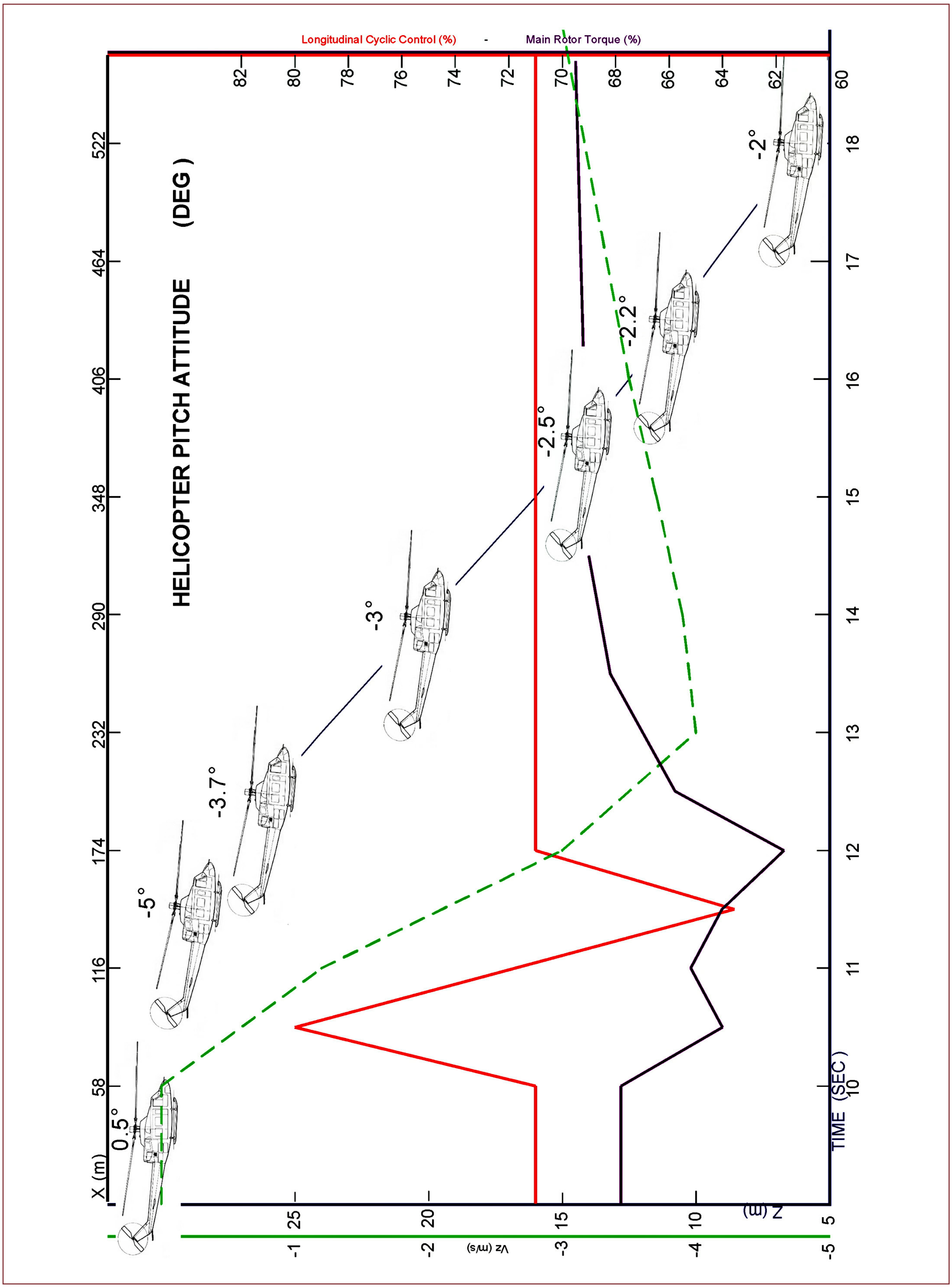
In the final phase of the flight, the aircraft initiated a constant descent without any appreciable changes in speed, heading or slope until the impact with the water. It is possible that the event resulted from an episode of spatial disorientation which affected the pilot.

4. SAFETY RECOMMENDATIONS

None.

APPENDICES

APPENDIX A
Maneuvers by the helicopter on the final descent until impact



Maneuvers by the helicopter on the final descent until impact