HELICOPTER ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9738		
Helicopter Registration	ZS-HLP	**Date of Accident**	23 October 2018		**Time of Accident**	0730Z	
Type of Helicopter	Bell Richard's Heavy Lift UH-H1 Huey		**Type of Operation**		Commercial Part 127		
Pilot-in-command Licence Type	Commercial Pilot		**Age**	70	**Licence Valid**	Yes	
Pilot-in-command Flying Experience	Total Flying Hours		12350		Hours on Type	Unknown	
Last Point of Departure	Dedicated Landing Zone, Vermaaklikheid, Western Cape						
Next Point of Intended Landing	Dedicated Landing Zone, Vermaaklikheid, Western Cape						
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)							
At Vermaaklikheid, Western Cape, on a farm with GPS co-ordinates (S 34°19'30.88", E 0 21° 2'23.58") and a field elevation of 454ft above mean sea level							
Meteorological Information	Wind direction:350° ; Wind speed:20kt ; Air temperature:32°C ; Visibility: CAVOK; Dew-point: 04°C;						
Number of People On-board	1+0	**No. of People Injured**	0	**No. of People Killed**	1		
Synopsis							

On 22 October 2018, a helicopter was dispatched for a fire-fighting operation at Vermaaklikheid in the Western Cape province; the operation was successfully completed. On 23 October 2018, the same helicopter which was stationed at Still Bay located about 35 kilometres (km) east of Vermaaklikheid, was again dispatched (with a different pilot) to continue with the fire-fighting operation. The helicopter took off from Still Bay at approximately 0415Z and arrived at the fire site at about 0440Z. The helicopter landed on a dedicated landing zone where a Bambi Bucket was connected to the helicopter, and safety checks carried out. All systems were found to be in satisfactory condition. At approximately 0450Z, the helicopter took off to commence with the fire-fighting operation. It was reported that the pilot completed the first operation of the day, which took 1.1 hours, before he uplifted 578 litres of Jet A-1 fuel. He then carried out a pre-flight inspection before continuing with the fire-fighting operation.

Eyewitnesses stated that they saw the helicopter making a left turn towards north-west to fetch more water from the valley. Moments later, they heard a loud bang from the direction where they had last seen the helicopter. They then spotted the helicopter flying at approximately 50 metres (164ft) above ground level (AGL), shaking violently. One of the fire-fighting crew members who was stationed near the accident area attested to having heard a loud bang and seeing the helicopter with a Bambi Bucket above the main rotor and near the tail rotor, shaking violently. The helicopter began drifting towards the right and rolled twice before impacting the ground. It rolled further until it came to a stop next to the trees. A post-impact fire erupted. A few eyewitnesses ran towards the accident site to render assistance. The pilot was found lying near the helicopter and the first responders moved him away from the burning helicopter. The pilot was fatally injured, and the helicopter was destroyed by impact forces and a post-impact fire.

The investigation revealed that during a left turn, the Bambi Bucket swung high after coming into contact with the tail rotor and, thus, struck by the main rotor. This caused the helicopter to vibrate (shake violently) before the pilot lost control and crashed.

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ABBREVIATIONS	DEFINITIONS
°	Degrees
°C	Degrees Celsius
AIID	Accident and Incident Investigations Division
AMO	Aircraft Maintenance Organisation
ASL	Air Service License
CAR	Civil Aviation Regulations
CAVOK	Ceiling and Visibility OK
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
E	East
FAGG	George Airport
ft	Feet
GPS	Global Positioning System Coordinates
hPa	Hectopascal (1 hPa = 100 Pa)
km	Kilometres
kt	Knots
L	Litres
m	Metres (distance calculation in relation with the ground level in this report)
Mast bumping	The rotor blades exceed its flapping limits causing the main rotor hub to bump into the rotor shaft.
MPI	Mandatory Periodic Inspection
MSG	Meteos at Second Generation image
S	South
SACAA	South African Civil Aviation Authority
QNH	Query Nautical Height
UH-H1	Huey helicopter
UTC	Co-ordinated Universal Time
Z	South African Standard Time is UTC plus 2 hours

Reference Number	: CA18/2/3/9738
Name of Owner/Operator	: FFA Assets
Manufacturer	**:** Richards Heavy Lift Heli Inc.
Model	**:** Bell UH-H1
Nationality	**:** South African
Registration Marks	**:** ZS-HLP
Place	**:** Vermaaklikheid, Western Cape
Date	**:** 23 October 2018
Time	**:** 0730Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011 this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and ***not to apportion blame or liability****.*

Investigations process:

The accident was notified to the Accident and Incident Investigations Division (AIID) on 23 October 2018 at about 09:30Z. The Investigator/s went to Vermaaklikheid, Western Cape, on 24 October 2018. The Investigator/s co-ordinated with all authorities on site by initiating the accident investigation process according to CAR Part 12 and investigation procedures. The AIID of the SACAA is leading the investigation, as the Republic of South Africa is the State of Occurrence.

Disclaimer:

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1 A Huey helicopter (UH-H1) with registration ZS-HLP and a call sign (Ch-Papa) operated by Kishugu Aviation was engaged in a commercial fire-fighting operation in Vermaaklikheid, Western Cape, when the accident occurred. Every year, fire-fighting operations take place in the Western Cape where veld fires often occur due to, for example, extremely high weather temperatures especially in the summer months.

1.1.2 The fire started on 22 October 2018. The Ch-Papa was dispatched to the site. The fire was still not contained on 23 October 2018, thus, a fixed-wing Spotter aircraft with call sign Sp14 and the Ch-Papa helicopter were deployed for the fire-fighting operation. The Sp-14 took off from George Aerodrome at approximately 0336Z and, on arrival at the site, the pilot began with his aerial survey. The helicopter was stationed at Still Bay following a dispatch of fire-fighting operation the previous day at the same site (Vermaaklikheid). It was reported that the pilot completed a pre-flight inspection, followed by a Jet A-1 fuel uplift of approximately 586 litres. The helicopter took off from Still Bay, which is approximately 35 kilometres (km) east of Vermaaklikheid at about 0415Z, headed for the fire site. On arrival at approximately 0440Z, the helicopter landed on a dedicated landing zone to connect the Bambi Bucket. At approximately 0450Z, the pilot took off after conducting safety checks, which were satisfactory, before commencing with the fire-fighting operation. During this time, the helicopter was joined by one of the residents flying an R44 helicopter who assisted with the fire-fighting operation. The helicopter conducted the fire-fighting operation for approximately 1.1 hours before uplifting 578 litres of Jet A1 fuel at approximately 0556Z.

Figure 1: The helicopter engulfed in flames.

1.1.3 At about 0623Z, the Sp-14 pilot reported that he was going to uplift fuel at the Mossel Bay airfield. He communicated that the fire was getting out of control and he handed over communication to the Incident Commander (IC). At that time, the R44 helicopter had also landed (elsewhere) for fuel uplift. Meanwhile, the Ch-Papa took-off again at approximately 0650Z and commenced with the fire-fighting operation. At approximately 0737Z, while airborne, the Sp-14 pilot was made aware by one of the operational controllers that the Ch-Papa helicopter had crashed and caught fire in the vicinity. At this time, the R44 pilot was refuelling, he was also informed that the Ch-Papa helicopter had crashed. The R44 completed its refuel and took off to the accident site where the Ch-Papa helicopter was found engulfed in flames and the ground fire fighters assisting to put out the fire.

1.1.4 Eyewitnesses who were helping with fire-fighting in the area had observed the Ch-Papa helicopter water bombing the fire at the fire line and then made a left turn towards the north-west to fetch more water from the valley. Moments later, they

heard a loud bang from the direction of the helicopter. It was during that left turn that the accident sequence started; the Ch-Papa helicopter did not make it to the valley. Eyewitnesses stated that they saw the helicopter flying at approximately 50 metres (164 feet) above ground level (AGL), shaking violently and with what seemed like objects flying off from the tail section. According to one of the fire-fighting crew members who was stationed as a ground support near the area where the Ch-Papa helicopter was operating stated that at the time when they heard a loud bang, he saw the helicopter shacking violently with an orange object (Bambi Bucket) flying above the main rotor, and near the tail rotor. The Ch-Papa helicopter began drifting towards the right with its nose slightly pointing towards the right and barrel-rolled twice in the drifting direction (north-north west) before impacting the ground. It continued to roll until it lost momentum and came to a full stop next to the trees. A post-impact fire erupted which engulfed most of the Ch-Papa helicopter's fuselage. Eyewitnesses who were near the accident site ran towards the Ch-Papa helicopter with the intention to rescue the pilot. The pilot was fatally injured, and the Ch-Papa helicopter was destroyed.

1.1.5 Emergency responders were contacted while other people who were close to the accident site rushed to the crash site. They found the pilot lying next to the burning Ch-Papa helicopter and moved him away from it. By this time, the R44 helicopter had arrived at the site and extinguished the fire using two water bombs. Later that evening, the veld fire spread towards the wreckage and further consumed the helicopter.

1.1.6 The helicopter accident occurred during daylight visual meteorological conditions (VMC) with GPS co-ordinates (S 34°19'30.88", E 021° 2'23.58") and a field elevation of 454 feet (ft) above mean sea level (AMSL).

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	1	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3. Damage to Aircraft

1.3.1 The helicopter was destroyed by impact forces, post-impact fire and, later, the veld fire, refer Figure 2..

Figure 2: The helicopter wreckage post fire.

1.4 Personnel Information

1.4.1 The pilot joined Kishugu Aviation in 2014 as an operational pilot and was stationed in the Western Cape Province. He was contracted by the operator as one of its regional leaders stationed in the Western Cape. The pilot was tasked with fire-fighting operations, as well as any other demands, which were deemed necessary. The pilot had complied with the operator's contractual requirements and was responsible for the monitoring and the renewal of his licence validation. At the time of the accident, his licence was valid based on the yearly medical revalidation completed on 25 May 2018 following a competency and instrument rating renewal, which was conducted on 17 May 2018, with an expiry date of 30 November 2018.

Nationality	South African	Gender	Male	Age	70
Licence Number	**********	Licence Type	Commercial Pilot Licence (Helicopter)		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument, culling, sling load, winching, instructor grade 2				
Medical Expiry Date	30 November 2018				
Restrictions	Corrective lenses				
Previous Accidents	None				

Flying Experience:

Total Hours	3408
Total Past 90 Days	Unknown
Total on Type Past 90 Days	Unknown
Total on Type	Unknown

1.4.2 According to the pilot records, his last aircraft licence renewal correspondence indicated that he had a grand total flying experience of approximately 8942.0 hours on aircraft. The helicopter total flying hours provided by the operator indicated that he had a grand total of approximately 3408 experience of flying hours. All hours stipulated in paragraph 1.4.1 were extracted from the last validation records the pilot submitted to the operator in May 2018. According to the historical records of the pilot's aviation career, he was once involved in an incident with the helicopter where it impacted the ground hard during a hovering exercise. As per the investigation report referenced J10/2/6336 of 28 March 1995, the pilot was performing hovering exercises on a Bell 47G helicopter. The helicopter experienced an un-commanded yaw and sharp swing to the right at approximately 3m AGL on which the helicopter landed hard, resulting in substantial damage to the skids. At the time, the pilot had 10250 hours combined helicopter and aeroplane experience, with 35 hours on the helicopter type.

Please note the information above was provided by the operator based on the information contained in the supplied documents. The pilot's logbook could not be found during investigation; the pilot's family and the operator were requested to assist.

1.5 Aircraft Information

Airframe:

Type	Helicopter	
Serial Number	68-15554	
Manufacturer	Richards Heavy lift Heli Inc.	
Date of Manufacture	1967	
Total Airframe Hours (At time of Accident)	9494.8	
Last MPI (Date & Hours)(Phase 1-6)	26 February 2018	9454.9
Hours since Last MPI	39.9	
C of A (Expiry Date)	31 December 2018	
C of R (Issue Date) (Present owner)	9 July 2012	
Operating Categories	Part 127	

Engine:

Type	Honeywell TS3-L-13B
Serial Number	LE-15746B
Hours since New	5423.3
Hours since Overhaul	1840.8

Main Rotor:

Type	Bell Helicopter 204-011-250-113	
Serial Number/s		
Rotor Blades	A000000632	A886
Hours since New	2460	2460
Hours since Overhaul	Life limit not yet reached	Life limit not yet reached
Transmission Type	Main Transmission	
Serial Number/s	B12-779A	
Hours since New	299	
Hours since Overhaul	TBO not yet reached	

Note: *Both main rotor blades serial numbers A00000632 and A886 with 2161.0 life hours were installed on 21 June 2016 at 9195.8 airframe hours. Main rotor blades have a life limit of 4000 hours.*

Tail Rotor:

Type	V.H.A LCC 2042200-101	
Serial Number/s		
Tail Rotor Blades	A369	A365
Hours since New	396.6	396.6
Hours since Overhaul	Time limit not yet reached	Time limit not yet reached
Transmission Type	Tail rotor drive shaft and 42-degree gearbox	
Serial Number/s	HPI-80FM	
Hours since New	396.6	
Hours since Overhaul	TBO not yet reached	

Note: *The tail rotor blades serial numbers: A369 and A365 were installed with zero (0) hours on 4 December 2015 at 9098.2 airframe hours during phase 5 & 6 inspection.*

Figure 3: The accident helicopter Bell UH-H1 .

1.5.1 The following information was extracted from Richard's Heavy-lift Helicopter Operator's manual and Bell official website:

The Huey UH-H1 helicopter is a Richards's heavy-lift helicopter type, mostly used by military and civilian commercial operations. It is certified for both military and civilian operations, including cargo slinging, fire-fighting and passenger transportation. The UH-H1 has two bladed semi-rigid see-saw bonded all metal main rotors and two bladed rigid delta hinged all metal tail rotor. The helicopter has a turning radius of feet when pivoted around the mast. Its landing gears skids consists of two aluminium arched cross tubes mounted laterally.

1.5.2 A review of the maintenance records revealed that the helicopter scheduled maintenance was a phase 1 to 6, conducted on 26 February 2018 at 9454.9 airframe hours. The helicopter was then issued with the certificate of airworthiness with the original issued date of 23 December 2015 and an expiry date of 31 December 2018.

1.5.3 Bambi Bucket and its operation:

The information was extracted from Bambi Bucket (5566-HL99800 Model) Service Manual Version D as provided by the operator:

Bambi Bucket with serial number: SR 16993- Bag No: KA 26.

Bambi Buckets are designed for a 24-volt electrical system. The water drop button, usually installed in the cockpit in civil helicopters, or operated by a crew chief in military aircraft, should be a momentary, normal open switch. The installation of the drop button and associated wiring must meet the applicable regulations, whether military or civilian. Use approved methods with wire size designed to meet the load carrying needs and with fuse/ circuit breaker protection. The switch itself should be mounted securely in a way that it is protected from damage and is easily operated by the pilot. It is suggested that it be mounted on either collective or cyclic stick grips.

In the case of the accident helicopter, the pilot operated the Bambi Bucket control switch as they were utilising a sole crew system. The helicopters are fitted with a bottom view mirror used to monitor the Bambi Bucket position during flight operations. The operator was utilising a sling-connecting strop of approximately 5 metres. The total length of the slung Bambi Bucket was approximately 9.45 metres. These measurements were obtained from comparing different lengths of similar connecting strop and the Bambi Bucket used by the operator. A review of both the Bambi Bucket and connecting strop service history revealed that all were in order with no indication of service anomalies.

1.6 Meteorological Information

1.6.1 Meteorological conditions provided by the South African Weather Service (SAWS) for George Aerodrome (FAGG) on 27 October 2018 at 0730Z read as follows:

Wind direction	350°	Wind speed	20kt	Visibility	>10km
Temperature	32°C	Cloud cover	None	Cloud base	None
Dew point	04°C	QNH	1019hPa		

1.6.2 Riversdale (where Vermaaklikheid is located) is not equipped with meteorological station. Two of the available weather stations in the Western Cape, namely Cape Town and George, were considered for this accident. Although both weather stations are distance apart from the accident site, George weather was considered due to its proximity to the accident site.

1.6.3 Provided meteorological information for George Aerodrome related to the conditions observed and attested to by the eyewitnesses at the accident site.

The Figure 4 shows the satellite view of the weather conditions around the accident site as provided by the South African Weather Service for the accident date.

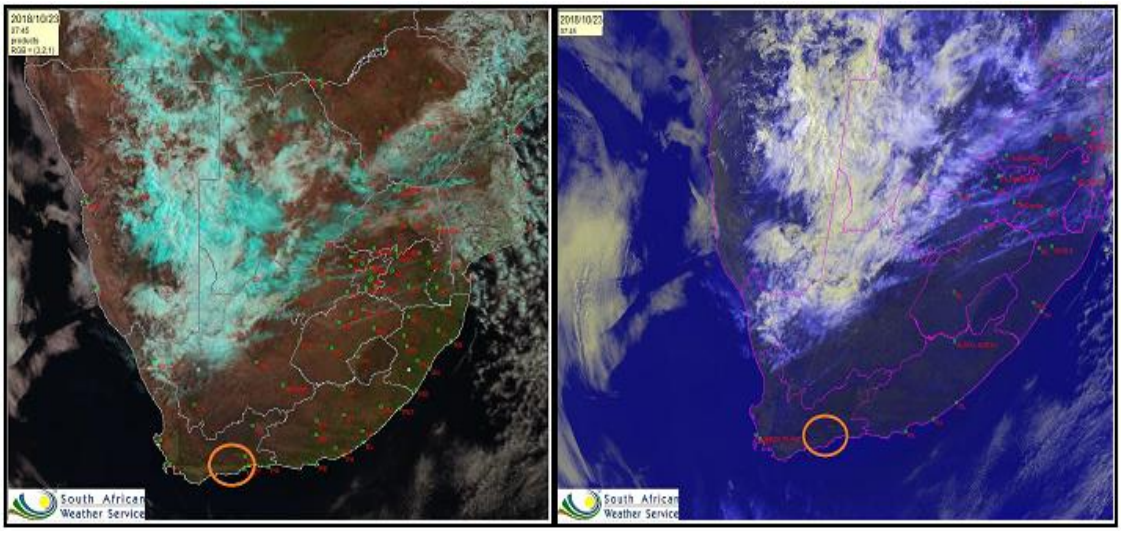

Figure 4: Shows the cloud enhanced MSG satellite taken at 0745Z covering both Riversdale and George areas

1.7 Aids to Navigation

1.7.1 The Ch-Papa helicopter was fitted with navigational equipment approved by the Regulator (SACAA). There were no recorded defects of the equipment prior to the accident.

Communication

1.8.1 The Ch-Papa helicopter was equipped with a standard high frequency radio approved by the Regulator. Communication with other aircraft and the operation's IC was conducted via the helicopter-equipped radio.

1.8 Aerodrome Information

1.9.1 The accident occurred on a bushy terrain at an area with the following GPS co-ordinates: S 34°19'30.88", E 0 21° 2'23.58" and at a field elevation of 454 feet AMSL.

1.9 Flight Recorders

1.9.1 The Ch-Papa helicopter was neither equipped with a flight data recorder nor cockpit voice recorder, nor was it required by the relevant aviation regulations.

1.10 Wreckage and Impact Information

1.10.1 The area at which the fire-fighting operation was being conducted is close to the coast at approximately 4.6 kilometres, which is likely to be subjected to strong coastal wind conditions. These winds contribute in making the operation more intense as fire was directionally driven at a high speed. The terrain has thick vegetation. At the time of the accident, the strong wind condition of 20 knots from the north north-westerly direction prevailed. The helicopter was fetching water from the valley's water stream, as it was the closest source.

1.10.2 At the time, as the helicopter had just dropped the water on the fire line, it was observed making a turn to the left towards the north-west direction with the intention to fly along the ravine towards the water stream. This was noted from the beginning of the operation that day. A cloud of thick smoke was observed moving at a low profile towards the valley and then rising high, an indication of strong turbulence due to the updraft resulting from strong wind conditions at the time of the accident.

Figure 5: Google view of the surrounding environment at the accident site.

1.10.3 A review of the post-accident photos provided by the first responders who helped to extinguish the helicopter revealed the following (Refer to Figures 6, 7 and 8):

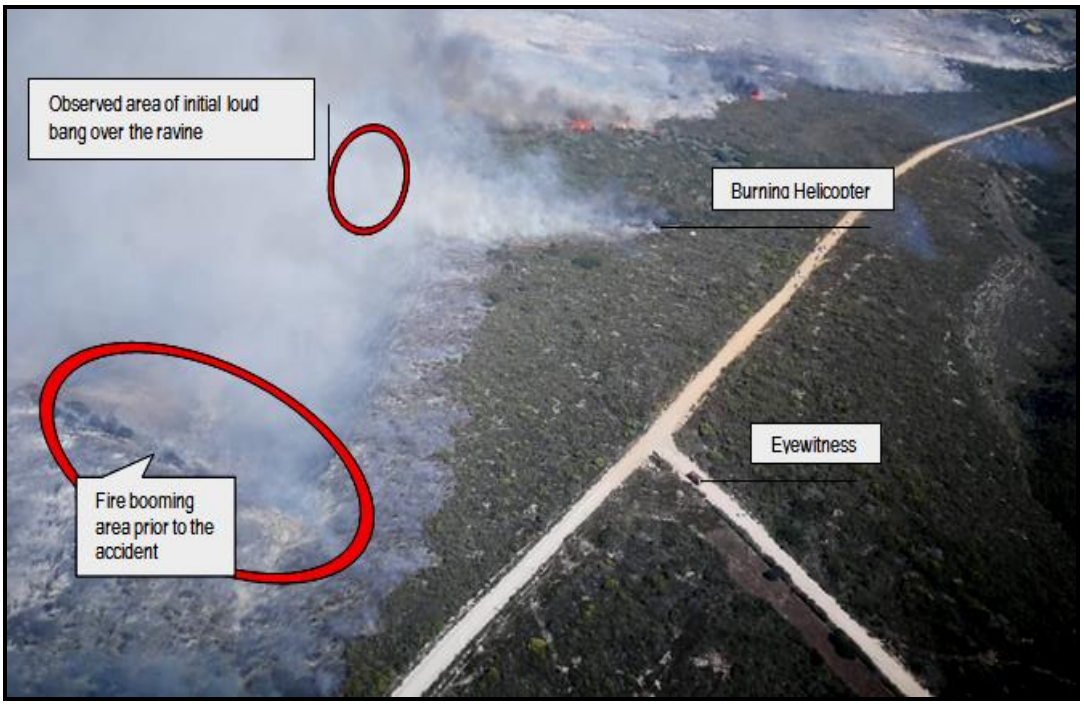

Figure 6: Aerial view of the accident site after the accident.

- The direction of the airflow was indicated by smoke direction, which also indicated high rising smoke over the ravine, which is consistent with high rising strong turbulence.

Figures 7 and 8: The Bambi Bucket on the main rotor blade before it was burned by veld fire.

- The investigation team found the accident site as shown in Figure 9. The wreckage distribution was located approximately 150m from the ravine edge in the direction north-north westerly. The wreckage pattern was indicative of an in-flight break-up at low height to the ground surface. Although the site was burned overnight due to the veld fire, some of the trees were bent in the direction towards where the main wreckage was found lying on its right side with the fuselage burnt to ashes and facing north west.

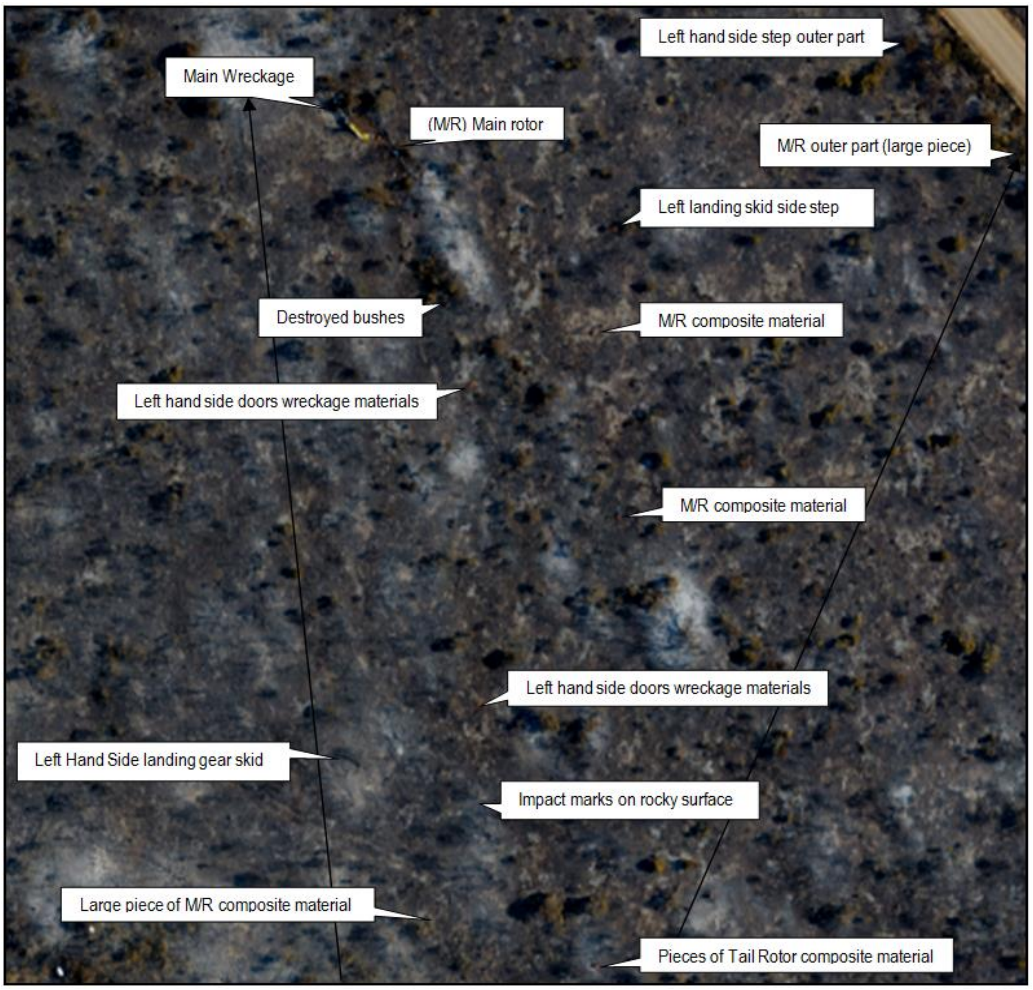

Figure 9: The accident site and the wreckage spread pattern.

- Some of the tail rotor composites were found at the edge of the ravine. This is consistent with the statement of the eyewitness who saw pieces of objects mid-air coming from the tail rotor section.

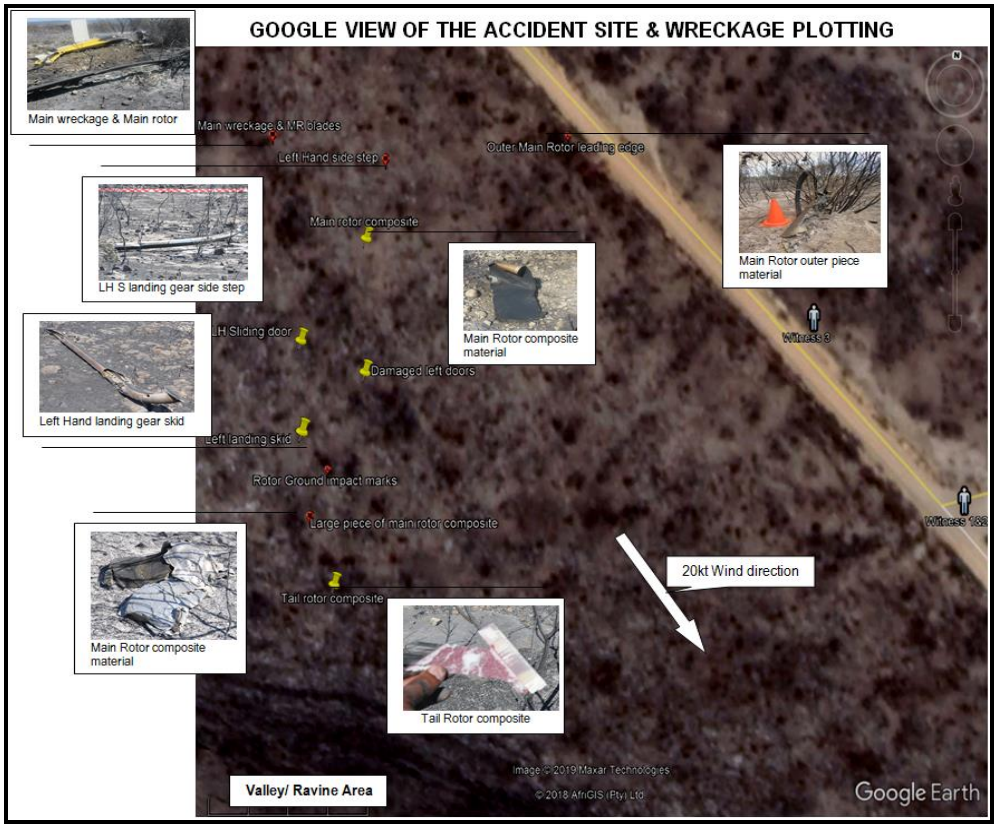

Figure10: Google Map view of the accident site after the veld fire.

- A large piece of the main rotor composite material was found in the bush approximately 30m from the ravine edge towards the direction where the main wreckage was located.

- Approximately 8m from the main rotor composite material, ground scar marks on the rocky surface were observed, which could be related to the main rotor strike damage as observed on each main rotor blade. This damage could be associated with the large composite material of the main rotor, which is likely to have disintegrated due to the hard impact with the ground.

- Both main rotor blades sustained fracture damage on likely similar points. The one blade had completely disintegrated which is indicative of the damage caused by a high main rotor rotational energy. A large piece of the main rotor outer part was found near the road on a tree approximately 90m from the wreckage. This main rotor blade is likely to be the one that impacted the ground first. Its structural composites were the first ones to be found near the impact ground marks.

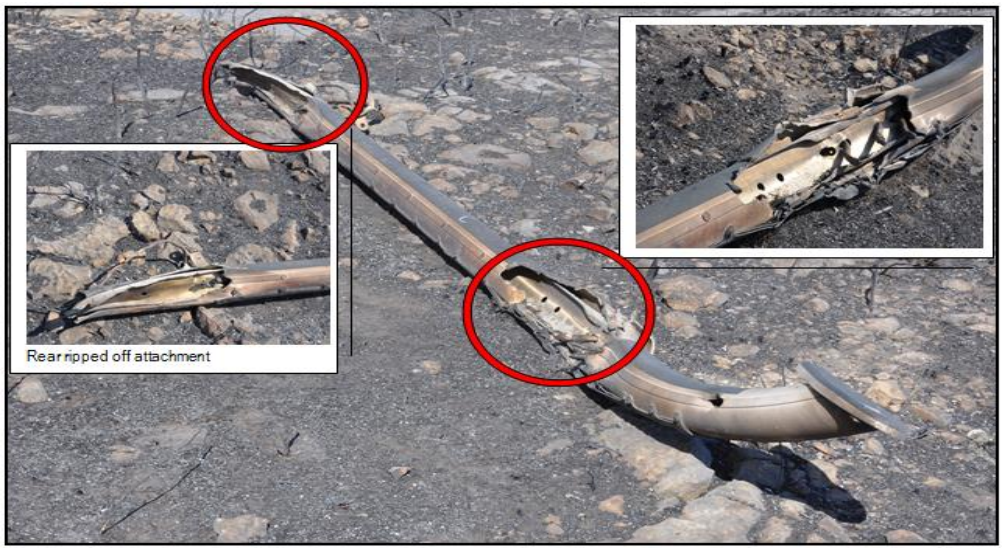

Figure 11: Damaged left skid gear caused by a cable.

- Next to scar marks at approximately 12m from the wreckage, the left skid gear was found facing in a north-easterly direction. It had some scar marks associated with an object that was ripped from both mounting attachments. The marks are indicative of damage caused by a strong metal cable at high-tension force.
- The left-hand side doors of the helicopter were also found near this section, bent, as if they were pulled towards the back from their assembly position.

- About 75m from the main wreckage, broken bush trees were observed along the route path of the wreckage, bending towards it. Along the path, parts of the fuselage pieces were also found.

Figures 12 and 13: The main rotor blade piece and the left-hand side step.

- With reference to the main wreckage position, at approximately 100m near the road, a large piece of the main rotor leading edge was found hanging on some trees. Next to it was a short front part piece of the left-hand side step. The remaining large piece of the left-hand side step was found about 50m from the right-hand side of the main wreckage. The two pieces were compared for separation damage. The damage was also associated with objects cut off by a cable.

- More of the main rotor composite materials were found closer to the main wreckage, along the wreckage trail. The wreckage was found to be mostly consumed by the veld fire. The main rotor blades with the connecting rotor head were found lying next to the main helicopter wreckage.

- The Bambi Bucket was found lying over the main rotor. Both main rotor blades composite material were disintegrated. One of the main rotors was missing a part, a rotor leading edge outer piece of approximately 1.5m, which was found next to the road hanging on a tree. The damage that contributed to the separation of the main rotor piece is associated with hard contact with the ground. Further observation revealed that the same rotor blade had lost most of the composite material, which was found along the wreckage trail marks. The other main rotor blade was bent at approximately the same point where the other piece had separated.

Figures 14 and 15: The main rotor blade that has a missing piece of the outer part with a sling strap cover and an electrical wire.

- The Figures 14 and 15 show evidence of the Bambi Bucket sling connecting strop cover with the bucket electric wires for the release mechanism found at the edge of the damaged piece. The main rotor blades damage is consistent with hard impact with the ground at high rotational energy, resulting in them breaking off. At the time of this impact, more rotational energy was absorbed. The second main rotor blade (Refer to Figure 8) impacted the ground, however, the rotational energy was not as severe, thus, it was only bent. The ground impact with each main rotor blade resulted in disintegration of composite material, which was spread along the wreckage distribution.

Figure 16: The remaining large piece of a tail boom and the Bambi Bucket connecting strop.

- A large piece of the tail boom was found damaged near the fuselage. The damage was indicative of an object that was ripped by a strong cable at high tensile force. A sling strap that connected the Bambi Bucket was found lying on the ground as shown in Figure 16. More damage was observed on the tail rotor tips and the tail rotor fin as illustrated in Figure 17. Composite materials were found around the area where witnesses stated that they heard a loud bang when the Ch-Papa helicopter turned left. The tips of both tail rotor blades were damaged. More composite material was found within the tail fin faring cover, which was also damaged. (The tail rotor blades had damaged the tail faring cover). The tail rotor blades had damage associated with forced bending near the blade root neck.

Figure 17: The damaged tail rotor blades and the tail rotor drive shaft faring cover.

Figures 18 and 19: The damaged tail rotor drive shaft and tail rotor blades.

Figures 20: Damaged water-release cable and the Bambi Bucket holing cables.

- The tail rotor drive shaft had broken. More evidence of the damaged tail rotor shaft was observed near the engine-connecting coupling, which had a twisted deformation. This damage is associated with drive shaft twisting after the tail rotor impacted an object when the shaft was turning at high engine-driven power.

Figures 21 and 22: The damaged tail rotor drive shaft due to a suddern stop (interruption) caused by a foreign object in the tail rotor.

- There were also marks indicating an entangled object over the tail rotor drive shaft from the tail rotor gearbox. The same object was also associated with the scuff marks on the tail rotor blades as shown in Figures 18 and 19. One suspension cable of the Bambi Bucket was found separated from the connecting string with twisting signs associated with marks on the tail rotor drive shaft.

Figures 23 and 24: The right-hand side elevator mounting position and the damaged elevator.

- The right-hand side synchronised elevator was damaged. Part of the outer elevator section had damage which demonstrated that it was ripped from the inner part of the trailing edge through cross-section towards the outer part of the leading edge and by impact forces during the accident sequence.

Figures 25 and 26: The mast assembly connecting point of the main rotor head.

- The mast assembly damage at the point where the main rotor head connects to the assembly was broken off and separated. This damage is consistent with mast bumping, which occurred at a high main rotor rotational energy. All other main rotor connecting links were damaged and broken off during the accident sequence.

1.11 Medical and Pathological Information

1.11.1 According to the pathological report, the pilot died of multiple blunt force injuries.

1.12 Fire

1.12.1 The helicopter was destroyed by impact and a post-impact fire.

1.13 Survival Aspects

The accident was not considered survivable due to the high vertical impact with the ground which destroyed the cockpit area, as well as the post-impact fire that erupted.

1.14 Tests and Research

1.14.1 Fire-fighting operation

The information below is extracted from a research article posted on the web by Thomas Eggleston which was published in 1998. [Source: http://www.sonnet.com/usr/wildfire/]

The helicopter water bucket is used extensively as a tool for wildland fire suppression. The bucket is slung externally below the helicopter, utilizing the helicopter's cargo hook. It has a low cost when compared to fixed tanks, simple installation, is easily jettisoned, and is readily filled from lakes and streams. The SEI Bambi Bucket is extremely reliable and is almost fool proof in its operation. Rapid response in initial attack is important in containing a wildfire to a small size and preventing large conflagrations. The bucket fills this need quite well, allowing it to be carried internally while en-route at high cruise airspeed. Since a cargo hook is standard equipment on almost all civil and military helicopters, a water bucket is an efficient accessory that can be shared among several helicopters.

The lightweight and portability of the Bambi bucket makes it possible to carry one within an aircraft most of the time. This is especially useful when operating in remote regions far from other firefighting resources. Worldwide, swift wildland firefighting has become an important issue as natural resources become more scares and as populations move into heavily vegetated areas, further and further from local fire agencies. The Bambi bucket provides an exceptional and cost-effective tool for aerial firefighting.

Factors affecting the fire-fighting Operation

Fire is the combustion of a fuel in the presence of oxygen. Heat is required to maintain combustion. The three factors that make up the combustion are heat, fuel and oxygen.

***Wind:** the driving force behind wildland fires is wind. Wind is the source of oxygen and is a propelling force in the forward movement of a fire. On a windy situation is very different. The wind propels the fire along, providing ample oxygen for combustion. Additionally, the wind carries the heated air from the fire forward, preheating and drying the fuels that are ahead of it, making them ignite more readily. Wind always presents the possibility of spot fires, from sparks being carried by the wind. Wind on a wildland fire must be constantly monitored since all strategic planning is dependent on it. If wind shift occurs, the fire will move in a new direction and the efforts that have been made to contain the fire may now be rendered useless.*

***Terrain:** The surface features of the terrain have a great influence on fire behaviour. If a fire starts from a low area, the heated air from the fire will warm and dry the fuels that are above it. These fuels will burn readily and will warm and dry the fuels above them, all in the absence of a prevailing wind. The effect is even more pronounced in rising troughs or gullies in hilly or mountainous terrain. These are called chutes and they funnel and increase the action of this preheating making these areas burn with great intensity.*

Drop procedures

Airspeed/Altitude Management

Controlling drop density is done with varying airspeeds and altitudes. It is recommended that initially the pilot start with airspeed of 60kt or above (consult the flight manual for the best single engine climb speed or the best auto-rotational airspeed), and a bucket altitude above the drop zone of approximately 50ft. As the pilot develops his flying technique with this starting point, departure from it can be practiced for different conditions. On light fuels (grasses), fly at higher airspeeds up to 90kts to lay the longest line. If length is not needed, but a greater width in a small space is required, then go slower but at a higher altitude. The greater altitude will allow the water/foam to aerate more and be dispersed over a large area.

Heavier fuels or more concentrated areas such as brush piles may dictate slower or lower drop to help concentrate the water. This is a compromise with safety as low airspeeds and low altitudes do not allow any margin for error or mechanical failure. A slow drop at a high altitude may provide the wetting necessary without undue rotor wash, but it may place the aircraft in a critical part of the height-velocity envelope. Experience has shown the low airspeeds usually do not gain as much benefit as expected for the increased risk. Wonder why they do it if there is no benefit

Basic flying with a water bucket

Flying a water bucket is very straightforward. Use good basic technique, keeping the ball centred, avoiding slipping, skidding, and keeping turns coordinated. Clumsy or careless use of the pedals will certainly start sideways oscillations of bucket. When a bucket is full of water, it is very stable and should not present any problems to the pilot. When empty however, it may have a tendency to swing at certain airspeeds. The important point to remember is that like other external loads, airspeed must be adjusted accordingly.

Fore and aft swinging of the bucket is also a result of pilot induced oscillations. To stop these, it is usually easiest to slightly increase airspeed and then maintain it. Notice any fore and aft movement of the cyclic stick, you may not be aware that you are inducing it.

Wind Drift

For precise drops, a correction for wind must occur. The higher the drop, the greater the drift will be. In high wind conditions, it may be necessary to lower the drop altitude. If possible, do a turn after the drop; visual check information can be used to adjust the next drop. An area towards the un-burnt area of the line is more efficient than having the water land inside the burn.

Approach and Departure

When approaching the drop zone it is important to plan the approach and departure routes. The safest way in to the drop zone must allow for the safest way out, and must consider the possibility of a bucket malfunction and the ability to release the water. A cautious pilot will be constantly planning for an engine failure.

Flight Safety

Aerial firefighting operations are frequently conducted in steep terrain, with turbulent wind conditions, and with reduced visibility due to smoke. Fires are often very congested, with many aircraft in a small area, the potential of mid-air collision or a wire strike is present. You must constantly think safety and know your own limitations.

Mast Bumping

Mast bumping on a helicopter is when the main rotor blades exceed its flapping limited and cause the main rotor hub to bump against the main rotor shaft. This is caused by abrupt manoeuvring input of the cyclic

1.15 Organisational and Management Information

1.15.1 The operator is stationed in Mpumalanga province and is contracted to the State as an emergency fire-fighting agency which assists in fighting fires anywhere within the domestic borders, as well as internationally, if requested. The operator holds a valid air service licence (ASL) for its operations issued by the department of transport air service licensing council on 10 August 2016 and was attained in accordance with approved procedures. The operator has an air operating certificate (AOC) Part 127, with the helicopter type endorsed for its fire-fighting operation specification, issued by the Regulator (SACAA) on 17 January 2018 with an expiry date of 31 December 2018.

1.15.2 Section 10 of the operator's fire-fighting standard operating procedure (SOP) subsection 10.2.3(xvii) requires, *"The spotter pilot is to remain airborne until the last resource has returned and landed safely at the air base…"*

1.15.3 The aircraft is an asset of FFA, which is the main contract holder. According to the investigation, the operator's aircraft maintenance organisation (AMO) approved by the Regulator conducts maintenance on the helicopter in accordance with manufacturer's prescribed and approved procedures. The AMO was in possession of a maintenance approval certificate issued by the Regulator on 29 January 2018, with an expiry date of 31 December 2018.

1.16 Additional Information

Figures 27 and 28: The helicopter type carrying a bucket full of water (left) and when empty (right).
The investigator took the photo while on-site when the firefighting operation was continuing.

1.16.1 Figures 27 and 28 demonstrate the Bambi Bucket position when it is full of water and when it is empty. On the day of the accident site investigation, a similar helicopter type was seen during fire-fighting operation with the Bambi Bucket used similar to the one used by the Ch-Papa helicopter which is connected using the connecting strop cable. The helicopter pilot uses the fitted bottom mirror to monitor the position of the Bambi Bucket during flight. According to eyewitnesses, the Ch-Papa helicopter had dropped water on the fire line and then turned to the left and flew towards the valley to fetch more water. The investigating team observed the same routine which was undertaken by the military chopper that was also helping with fire bombing.

1.16.2 Figure 29 shows the position of the Bambi Bucket in-flight during water dropping. When the bucket is full of water, it hangs straight below the helicopter during flight. When the Bambi Bucket is empty during flight, it swings towards the rear, due to the airspeed resistance of the relative air flow.

Figure 29: The top view of the Bambi Bucket when empty during fire-fighting operation

The Bambi Bucket which is connected under the helicopter by a five-metre connecting strop is also attached using bucket holding cables of approximately 2.4m. The slinging of the Bambi Bucket extends to a maximum length of approximately 9.45m. Following the dumping of water, the Bambi Bucket has a tendency to swing backward as it gets empty. The Bambi

Bucket experiences centrifugal forces towards the right as it turns to the left which tends to act in the initial direction of inertia pulling away from the pivot point. During a turn to the left, the Bambi Bucket will most likely move towards the right-hand side of the tail-boom as it follows through during a turn due to centrifugal forces. Because of the hooking strop, the Bambi Bucket is prevented from pulling away. With the element of the wind direction (which acted as a cross-wind component in relation to the helicopter direction of the flight path at the time), the Bambi Bucket gained height during a turn into the wind. As soon as it (helicopter) began to complete the turn initiating a straight follow through path, the cross-wind gained strength and pushed the Bambi Bucket in its direction towards the helicopter tail.

1.16.3 The Bambi Bucket

This information was extracted from the Bambi Bucket (All Models) Operation Manual-Version G, Issue Date July 2013

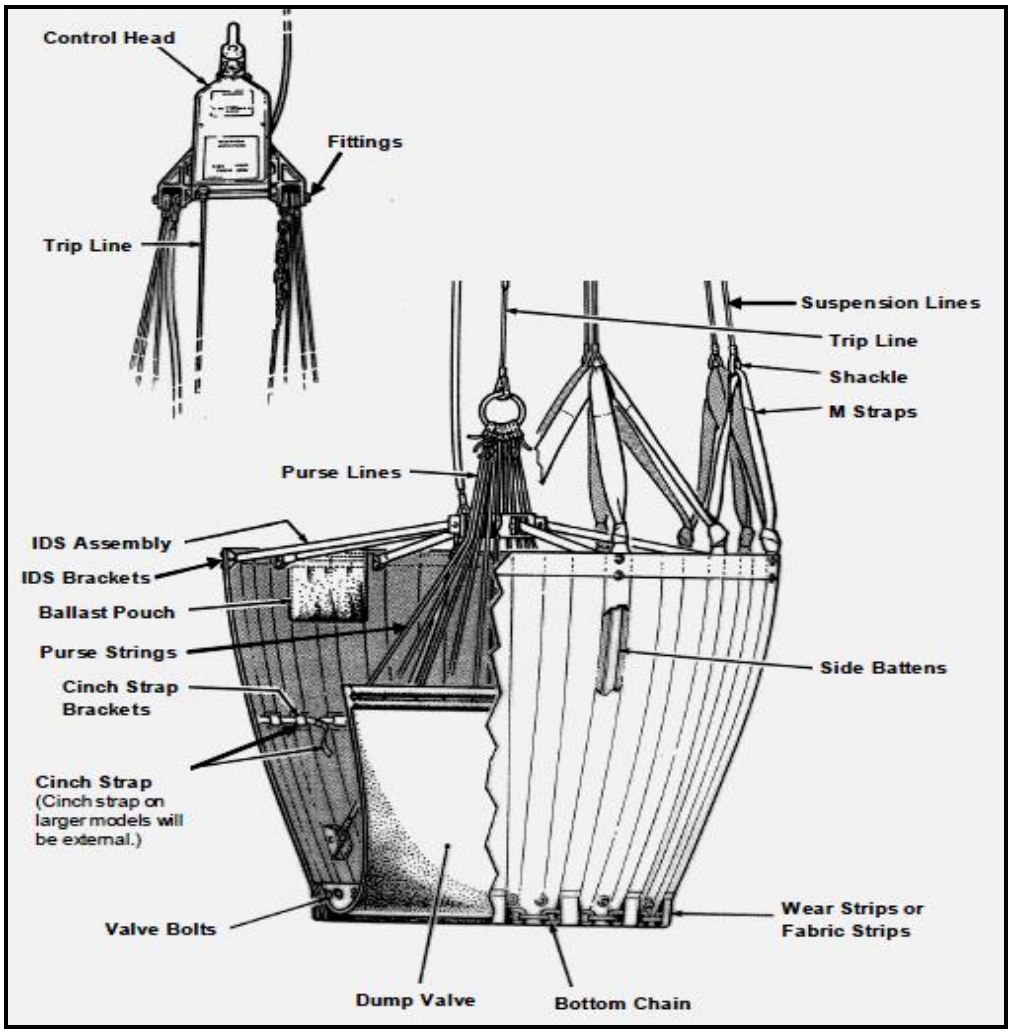

Figure 30: Shows the schematic view of the Bambi Bucket and its components

Attaching to the cargo hook: The Bambi bucket is rigged for a cargo hook. Correct attachment is indicated when the name plate on the control head faces forward in flight. This insures that the ballast on the Bambi will face forward in flight.
The control head orientation on Models 5566-HL9800 use the second shackle to rotate the bucket 90º. The Bambi bucket 's electrical supply is connected through a breakaway plug. The purpose of the plug is to offer a clean breakaway if the Bambi bucket must be jettisoned from the aircraft in an emergency. It is suggested that the be lightly taped together with vinyl tape, while in use, to the longline, duct tape should be wrapped every 3ft(1m) to prevent any damages to the cable.

Note: *To operate the solenoid and release the water, a momentary contact switch is used. The solenoid has a 10% duty cycle (designed to not be operated more than 10% of the time). Operating the solenoid continuously will result in solenoid failure.*

Checking the tail rotor clearance: When the Bambi bucket is attached directly to the helicopter cargo hook or attached using a longline less than 50ft(15m) in length, it is important to confirm that there is adequate tail rotor clearance. Before using the bucket, the Bambi bucket check the tail rotor clearance.

Flying the Bucket: The Bambi bucket should be flown in accordance with the United States Forest Service recommendations limiting all helicopters, other than tandem rotor, to a maximum 80KIAS while conducting external cargo hook operations. The recommended never exceed speed (VNE) for the Bambi Bucket is 80KIAS, however, this is not a flight manual limitation. Speeds above 80KIAS should be approached with caution and any decision to exceed this speed should be based on flight characteristics, aircraft flight manual limitations, aircraft/ bucket configuration and load stability etc.

In order to reduce drag on the bucket when empty, it can be flown in a valve open position by pressing the release mechanism once while in forward flight. The dead weight of the load ensures different handling characteristics than when flying empty. As a result, the Bambi Bucket does not 'pulse' or 'throb' under load in flight.

1.16.4 According to eyewitnesses, they observed the helicopter releasing water over the fire line and made a turn to the left to refill the Bambi Bucket. Moments later, they heard a loud bang and the helicopter was observed shaking violently with debris seen in mid-air. It was noted, as per the accident photos, that strong wind conditions prevailed in the area at the time of the accident. According to eyewitnesses, the helicopter was flying at a height of approximately 164ft AGL when the accident occurred. A research relating to the centrifugal force acting on the slung object at the time of operation was established. Twenty (20) knots surface winds prevailed in the area at the time of the accident.

1.16.5 According to the UH-1H TM 55-1520-210-10, Operator's Manual Chapter 5 Section VII: 5-13 Environmental Restrictions, Page 5-3

The helicopter is qualified for flight under instrument meteorological conditions. Intentional flight into known moderate icing conditions is prohibited.

Wind limitations: Maximum cross wind for hover is 30kts and maximum tail wind for hover is 30kts.

Wind limitation for starting helicopter can be in a maximum wind velocity of 30kts or a maximum gust spread of 15kts. Gust spreads are normally not reported, to obtain spread compare minimum and maximum wind velocity.

1.16.6 Pilot reaction to emergency conditions

A pilot with over 3000 flying hours experience on helicopters (including over 1500 hours experience on the type), stated that when flying over a mountainous area (valley, ravine, slope) and one experiences an emergency during a turn, the response will be to first locate a relevant surface to attempt a safe landing. In this accident, it was explained that most of the time, the helicopter was flying over the valley as it was fetching water from the stream. The helicopter crashed over a flat surface towards the right-hand side, away from the valley. The pilot also spoke of the known tendency of the helicopter experiencing hydraulic failure during the helicopter operation (Control stiffness and Flight Control Servo Hard-over).

According to the helicopter Operator's Manual, Chapter 9 Emergency procedures, page 37–39:

P37. Hydraulic Power Failure:

Hydraulic power failure will be evident when the force required for control movement increases, a moderate feedback of the controls when moved is felt, and /or the HYD PRESSURE caution light illuminates. Control movements will result with normal helicopter response.

In the event of hydraulic power failure

Irreversible valves are installed on the cyclic and collective hydraulic servo cylinder to prevent main rotor feedback to the cyclic and collective in the event of hydraulic system malfunction. The two-position toggle type labelled HYD CONTROL ON\OFF control switch located on the miscellaneous panel.

9.38 Control Stiffness

A failure within the irreversible valve may cause extreme stiffness in the collective or two of the cyclic control quadrants. If the failure is in one of the two cyclic irreversible valves, caution is necessary to avoid over controlling between the failed and operational quadrants.

Correction 1 HYD CONT switch-OFF then ON and check for restoration of normal flight control movements. Repeat as necessary if control response is not restored.

HYD CONT switch –OFF if normal operation is not restored.

Land as soon as possible at an area that will permit a run-on landing with power

9.39. Flight control servo Hard-over

Cyclic hard-over is caused by a sequencing valve failure within the Irreversible valve on either or both cyclic servos. Cyclic servo hard-over will cause the cyclic to move full right forward, full left rear, full left forward or full right rear.

1.17 Useful or Effective Investigation Techniques

1.17.1 None.

2 ANALYSIS

2.1 General

The following analysis was made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

2.1.1 The pilot was licensed and qualified for the fire-fighting operation with the helicopter type endorsed on his licence. The pilot's licence was issued on 25 May 2018 following the medical certification renewal; and would have expired on 30 November 2018.

2.1.2 On the day of the accident flight, the pilot was the sole occupant of the aircraft; this is in accordance with the operational requirements for crew resource management whereby during fire-fighting operations, the helicopter is operated by a sole pilot. The helicopters are equipped with a bottom view mirror used to monitor the Bambi Bucket position during operation. The pilot uses a sling of approximately 5m for the Bambi Bucket operation, which was approved by the Regulator.

2.1.3 According to information in the maintenance records, the helicopter was maintained in accordance with the manufacturer's recommended procedure by a Regulator-approved AMO who held a valid certificate of maintenance. The latest maintenance carried out on the helicopter was phase 1-6 on 26 February 2018 at 9454.9 airframe hours. No recorded defects were available prior to this accident. The helicopter was issued a certificate of airworthiness, in accordance with approved regulatory procedures, which was valid at the time of the accident.

2.1.4 On the day of the accident, the pilot took off in the morning from Still Bay to Vermaaklikheid where the fire-fighting operation was conducted for approximately 1.1 hours. The Ch-Papa helicopter, following a fuel uplift of approximately 578 litres, took off for the operation in which it crashed, following water bombing while en-route to refill the Bambi Bucket with water. There was enough fuel on-board the helicopter during operation, this was indicated by the amount of dark smoke resulting from the fire that erupted during the impact sequence and destroyed the helicopter wreckage.

2.1.5 According to the meteorological report, there was a north-westerly wind of 20kt in the area on the day of the accident, intensifying the fire-fighting.

2.1.6 According to the eyewitnesses, a loud bang was heard, and they observed the Ch-Papa helicopter with debris originating from the helicopter and an orange object flying above the main rotor. At this point, the helicopter was shaking violently and began drifting towards the right with its nose slightly pointing towards its right side. An on-site visit revealed pieces of the tail rotor composite material and large pieces of the main rotor blades composite materials near the point where the eyewitnesses indicated to have observed the Ch-Papa turning left. The evidence of the tail rotor blade composite material found near the ravine edge confirmed the eyewitnesses' report in which they stated that they observed the helicopter shaking violently and debris coming from the Ch-Papa helicopter mid-air. The wreckage trail further revealed pieces of the left-hand side doors, left landing skid gear, impact marks and more of the main rotor blades composite. The right-side skid gear was still attached to the helicopter.

2.1.7 Further on-site investigation revealed evidence of a small orange piece of the Bambi Bucket connecting strop cover together with the electrical wires similar to the ones used for water release mechanism on the damaged main rotor edge (Refer to Figures 14 and 15). Although the connecting strop had burned from the connecting hook, approximately 3m of the strap, the electrical wires of the water release mechanism had damage relating to them being cut off, which is consistent with the evidence on the main rotor blade. The tail rotor shaft had evidence of a winding object around it, relating to one of the Bambi Bucket suspension cables, which was found separated from the connecting string with evidence of windings.

2.1.8 Regarding the possibility of the hydraulic power failure, no testing of any of the helicopter system equipment was conducted due to extensive damage caused by the post-impact and the veld fire. The amount of fuel which was available

at the time of the accident contributed to the significant damage, destroying most of the helicopter system components. However, based on the eyewitnesses' statements in which they stated that they heard a loud bang and saw the Ch-Papa helicopter shaking violently override, or rather, overshadow the possibility of a hydraulic power failure.

2.1.9 The helicopter wreckage was found lying approximately 150m from the valley in a north-north westerly direction. The initial helicopter flight path heading was towards the west direction with a cross-wind component of 20kts. It is likely that, following a loud bang, the pilot might have pulled the helicopter towards the right away from the valley. This is possibly because the pilot was avoiding the surrounding conditions around the operational area with the veld fire smoke on his left and the valley ahead, he (might have) pulled the helicopter to the right with an advantage of a flat surface area in which he would have attempted to land the helicopter safely.

2.1.10 At the time of the flight, reported meteorological conditions with surface wind speed of approximately 20kt and air temperature of 32°C prevailed in the accident site. In addition, the high rising fire blazes over the valley burning upstream were observed, of which the helicopter was attempting to extinguish. When veld fire is intense, the fire-fighting operations also become intense. At the time, the Ch-Papa helicopter was turning towards the valley with the intention to get more water for the operation. The empty Bambi Bucket which was swinging backward and was following through was subjected to centrifugal forces during a turn. The Bambi Bucket was flying into the wind which caused it to gain height. When the Bambi Bucket completed the turn and was compelled to move towards the helicopter, the bucket was pushed by the strong cross-wind, which propelled it onto the tail rotor and further made contact with the main rotor during the accident sequence.

2.1.11 The accident and damage sequence analysis:
The initial impact contact of the Bambi Bucket with the tail rotor blades caused the bucket holding strand cable to be cut and, later, entangled onto the gearbox's blades connecting shaft. The entanglement created tension that resulted in forcing the blades towards the tail boom aft section and made contact with it. This resulted in the initial loud bang heard by the eyewitnesses. Discuss/add the Bambi Bucket sling/mechanism

- The impact caused damage to the tail boom aft section and the tail rotor blades, forcing it to stop rotating. Subsequently the tail rotor transmission drive shaft got twisted near the main transmission gearbox and was severed.
- The Ch-Papa helicopter drifted, which caused the pilot to lose control and the helicopter to experience a barrel roll towards the right-hand side.
- During this time, the Bambi Bucket connecting strop got hooked onto the main rotor, causing damage to the right-hand side synchronised elevator before ripping off the left landing gear skid from its mounting cross tubes and further damaging the rear side step mountings and the left side tail boom near the attachment point.
- The left-hand side doors were also affected at the time when the left landing gear skid was damaged.
- Subsequently, the main rotor blade that was entangled by the Bambi Bucket connecting strop impacted the ground at a high rotational energy whereby the tip of the main rotor blade piece broke off at the point where the connecting strop was hooked with most of the blade composite material separating. The connecting strop then separated and left evidence on the first main rotor blade broken edges as it 'jumped' to the second blade. The main rotor piece of approximately 1.4m was found at a greater distance near the road.
- The second blade followed through and impacted the ground; however, the rotational energy was not severed as with the first blade. About 1.6m of the outer part of the main rotor blade was bent and the composite material separated and was flung around. This resulted in the main rotor completely stopping. The Bambi Bucket remained hooked over the second rotor blade during the impact sequence, while the main rotor head separated from the main wreckage and was found as demonstrated in Figures 7 and 8.
- It is evident that during the above impact sequence, the main rotor also experienced a mast bumping.
- Following these events, the helicopter was also observed completing several rolls over the trees towards the right-hand side until it got to a full stop where a post-impact fire erupted. The main rotor was found lying near the burning main wreckage with the Bambi Bucket still hooked to the second main rotor blade.

2.1.12 The investigation revealed that during a left turn, the Bambi Bucket was swung high after coming into contact with the tail rotor and later, got struck by the main rotor. This caused the helicopter to vibrate (shake violently) before the pilot lost control and crashed.

3 CONCLUSION

3.1 General

3.2 The following findings, causes and contributing factors were made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

To serve the objective of this investigation, the following sections are included in the conclusions heading:

- **Findings —** are statements of all significant conditions, events or circumstances in this accident. The findings are significant steps in this accident sequence but they are not always causal or indicate deficiencies.
- **Causes —** are actions, omissions, events, conditions, or a combination thereof, which led to this Accident.
- **Contributing factors —** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the accident or incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.3 Findings

3.3.1 The pilot was licensed and qualified for the fire-fighting operation with the helicopter endorsed in his licence. The pilot's licence was issued on 25 May 2018 following the medical certification renewal that would have expired on 30 November 2018.

3.3.2 The Ch-Papa helicopter was maintained by a Regulator-approved AMO. It had a valid certificate of airworthiness, which was attained from the regulator in accordance with the regulatory procedures.

3.3.3 No anomalies were noted of any of the helicopter components prior to the flight. The helicopter accident occurred during operation following a fuel uplift of approximately 586 litres. There were no issues relating to fuel system reported that could have contributed to the helicopter accident. The on-board fuel, following the impact sequence, contributed in fuelling the fire that engulfed the helicopter wreckage.

3.3.4 According to eyewitnesses, the Bambi Bucket made contact with both the main and tail rotors, which led to the accident sequence.

3.3.5 There was enough evidence revealed during the investigation which relates to damage caused by the Bambi Bucket connecting strop that support the observation narrative.

3.3.6 It is evident that the helicopter's main rotor experienced mast bumping during the accident sequence.

3.3.7 The post-impact fire destroyed the Ch-Papa helicopter before it could be extinguished. There was veld fire in the area, of which the helicopter was attempting to extinguish, which later further destroyed the Ch-Papa helicopter.

3.3.8 The investigation revealed that during a left turn, the Bambi Bucket was swung high after coming into contact with the tail rotor and, later, got struck by the main rotor. This caused the helicopter to vibrate (shake violently) before the pilot lost control and crashed.

3.4 Probable Cause/s

3.4.1 During a left turn, the Bambi Bucket swung high up after coming into contact with the tail rotor and, later, got struck by the main rotor. This caused the helicopter to vibrate (shake violently) before the pilot lost control and crashed.

4 SAFETY RECOMMENDATIONS

4.1 General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation, and are based on the conclusions listed in heading 3 of this report; the AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2 Safety Recommendation/s

4.2.1 None

5 APPENDICES

5.1 None.