FINAL REPORT

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In accordance with the provisions of SI 205 of 1997, the Chief Inspector of Accidents, on 28/6/05, appointed Mr. John Hughes as the Investigator-in-Charge to carry out a Field Investigation into this occurrence and prepare a Synoptic Report.

Aircraft Type and Registration:	Enstrom F-28A, G-BBHE
No. and Type of Engines:	1 x Lycoming HIO-360-C1A
Aircraft Serial Number:	153
Year of Manufacture:	1973
Date and Time (UTC):	28 June 2005 @ 10.15 hrs
Location:	Fethard, Co. Tipperary
Type of Flight:	Private
Persons on Board:	Crew - one Passengers - one
Injuries:	Crew - Nil Passengers - Nil
Nature of Damage:	Complete tail rotor section torn away. Main blades destroyed on landing. Undercarriage damaged on landing.
Commander's Licence:	UK PPL(H)
Commander's Details:	Male, aged 62 years
Commander's Flying Experience:	1400 hours of which, 400 were on helicopters.
Information Source:	Aircraft Owner. AAIU Field Investigation.

SYNOPSIS

The pilot took off in order to take his passenger friend on an airborne tour of the town of Fethard. At between 900 and 1,100 ft, the pilot heard a bang from the rear of the helicopter. He then realised he had no directional controls using the pedals. The pilot autorotated into a grass field and managed to crash land the helicopter. The horizontal stabilizer spar had failed in fatigue, and the departing stabilizer struck the tail rotor resulting in the bang heard by the pilot. There was no fire and both occupants exited the helicopter without injury. The Report makes two Safety Recommendations.

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1. FACTUAL INFORMATION

1.1 History of the Flight

At 09.48 hrs the pilot departed his home in G-BBHE from a private airfield near Fethard, 16 miles distant. He arrive at 10.00 hrs and picked up a friend who was a fixed wing pilot. The passenger carried a new video camera with him and the helicopter took off again for a trip around the town of Fethard.

The climb out was uneventful and the helicopter levelled out at between 900 and 1,100 feet. Approaching the town the pilot reduced speed from 80 mph to 60 mph. The helicopter had completed half the circumference of the town when both pilot and passenger heard a bang from the tail section of G-BBHE. At the same instant the helicopter yawed to the right. The pilot lowered the collective and backed off the power throttle. The right yaw stopped and then the helicopter yawed to the left. The pilot controlled direction using the collective and throttle controls. The foot pedals were ineffective in controlling helicopter direction.

There was a quarry below and some houses followed by four fields some containing boulders and some cattle. The pilot selected the next nearest suitable field about 0.5 miles distant and made a gradual autorotational approach to that field. The landing was heavy and the left front shock absorber lost its charging connection with the force of impact. During the landing the main rotor blades struck the tail boom.

Whilst the main blades were still turning the passenger exited the helicopter. Both he and the pilot were using a four point harness and there were no reported injuries to either.

1.1.1 Pilots Comments

Afterwards, the pilot commented as follows:

*"After the bang and the initial lurch to the right I lowered the collective full, simultaneosly backing off the throttle. Pushing down the right pedal then the left had no effect. I increased throttle and some collective to counter torque until I had some directional control . I made throttle and slight collective changes all the way keeping the "auto"(*autorotation*) at 60 (mph) and the blade RPM within the green arc. The engine RPM would vary commensurate with left or right direction changes. On the way down in autorotation, it was not dissimilar to normal except my method of directional control."*

Following a study of the Draft Report on this accident, the pilot made the following comment:

"I had very little cyclic control either directional or lateral. After entering autorotation I had to keep the cyclic stick full back in order to maintain 60 mph and then at the end of autorotation I had no flare and when I tried to level for a run on landing the cyclic gave no response when pushed forward for a run on landing."

He was also of the opinion that the stabiliser spar should be replaced after seven to eight hundred flight hours.

The pilot said that he was aware of the requirement for a pre-flight check on the stabilizer and usually carried it out. However, he could not specifically recall having done so on this occasion (ref. 1.8 below).

1.2 Damage to the Aircraft

Witnesses on the ground heard the bang and saw pieces falling from the helicopter. Several parts of the tail section including three sections of the R.H. stabilizer (**Appendix A**) were subsequently found in a quarry 0.5 miles before the final landing area. Tail rotor blade strike marks were found on the underneath surface of the larger of the RH stabiliser sections and on the inner top surface of the smaller section. With the exception of the tail rotor drive shaft and the RH section of the stabilizer spar, which were, despite regular searches, never located, the rest of the tail section including airframe and dynamic parts were all located within 20 metres of the helicopter landing area. The cylindrical stinger tube with part of the tail boom attached was found 18 metres to the right of the helicopter. A large dent, 15 inches from the tube end was compatible with a strike from one of the main blades.

All of the RH tail rotor control cable was found wrapped around the TR gearbox output shaft. It was impossible to rotate the output shaft by hand. It unravelled in two separate lengths of 78 inches and 156 inches. Strands were either broken or damaged at regular intervals. Its anchor point to the pitch change mechanism had broken off. The other end had broken at the thimble Nicropress sleeve (18-2-G), adjoining the cable to the turnbuckle (MS21251-33S), in the lower engine bay. After unravelling, the gearbox shaft was free to rotate by hand. One of the two pitch link retainers had cracked at its root.

The LH cable was found cut 36 inches from its tail rotor pitch change mechanism attachment lug. The remainder of the cable was found intact.

1.3 Aircraft Information

1.3.1 General

Accommodation is for a pilot and two passengers, side by side on a bench seat. The helicopter has a high inertia, three-blade fully articulated rotor head with blades attached by retention pin and drag link. The control rods pass inside the tubular rotor shaft to a swashplate inside the fuselage. It has a two-blade teetering tail rotor. The drive from the horizontally mounted engine to the transmission is through a grooved rubber belt.

Skids are carried on oleo-pneumatic shock-absorbers. The power plant consists of one 208 hp (@ 2,900 RPM) Lycoming HIO-360-C1A flat-four engine. The helicopter had only flown 1.5 hrs since a Star inspection and a renewal of its Certificate of Airworthiness (Cof A) on 7/3/05.

1.3.2 Transmission System

The main transmission unit provides an 8.7871 ratio between the engine and the main rotor. The ratio between the tail rotor and the main rotor is 7.154. The transmission incorporates a free-wheeling unit in the upper pulley assembly, which is mounted on the output pinion shaft. The free-wheeling unit provides a dis-connect from the engine in the event of a power failure and permits the main and tail rotors to rotate in order to accomplish safe autorotation landings.

1.3.3 Tail Rotor (TR) and Transmission

The tail anti-torque rotor counteracts the torque of the main rotor and functions to maintain or change the helicopter heading. The tail rotor is a two-bladed, teetering, delta-hinge type assembly.

The tail rotor transmission, mounted at the aft end of the tail cone, supports and drives the tail rotor. The tail rotor transmission is equipped with a self-contained lubricant supply and level gauge at the rear of the housing and a magnetic plug can be removed to inspect for metal particles. Its capacity is ½ pint of No.10 oil.

1.4 Meteorological Information

The actual weather recorded by the pilot on the day through www.aviationweather.gov was:

Wind: 320/04-06 MPH
Visibility: In excess of 30 miles.

The weather as supplied later by Met Eireann was:

Wind: 050-080/04-07 kts
Visibility: 10 KM

1.5 Audio Recording

A frequency analysis of the audio output of the video camera carrided by the passenger is shown in graphical format at **Appendix B**. The results are not too clear, due in part to the aerodyanamic noise when the camera was pushed out into the slipstream. The noise recorded in the cockpit is a complex signal produced by a number of dynamic sources in flight. These sources can be broadly classified as deterministic or stochastic (random) in nature. In engine noise these occur simultaneously. The engine produces pulses at a rate proportional to engine speed. In this four cylinder engine, fuel is ignited and two pulses emanate every crankshaft revolution.

Other sources would include the large engine cooling fan which produces both deterministic and stockastic (turbulent air flow) components. Sound sources, both random and deterministic are shown and this produces the mottled effect. However, the basic engine deterministic noise both before and after TR control failure, can clearly be seen.

The operating speeds of the dynamic components taken from the Flight Manual are shown in the table below. The rotational speed for the engine and TR (two bladed) are multiplied by a factor of 2 giving the frequency of the pressure pulses in each case. Likewise, the MR speed is multiplied by a factor of 3 representing three pressure pulses for each revolution of the main rotor.

Operating Speeds	RPM	Cycles/Sec	X2	X3
Engine (green orc)	2900 max 2750 min	48.33 45.83	96.66 91.66	
Tail rotor (TR)	2365	39.42	78.84	
Main Rotor (MR)	330	5.50		16.50
MR Aotorotation Range (Green awc)	313-385	5.22-6.42		15.66 - 19.26
Tail rotor Autorotation Range	2243-2759	37.40-46.00	74.80 – 92.00	
Engine Idling (clutch disengaged)	1400	23.33	46.66	

1.6 Inspection of Airframe

As parts of the L.H. stabilizer were found approximately 0.5 miles from the landing site a detailed examination of the stabilizer system was considered necessary. A section of the stabilizer spar was not recovered with these parts and it was considered necessary to examine the R.H. stabilizer and the remainder of the spar. This component was examined in detail by a metallurgist and a report ensued.

The conclusions of the report are as follows:

1. Failure of the spar (tube) has occurred through fatigue cracking.
2. The cracking appears to have initiated at the inner edges of the bolt holes, where burrs were observed.
3. The extent of fatigue cracking, with only a small ligament in which final failure occurred, indicates high cycle fatigue.
4. There was no indication of any inherent defect in the material of the tube.

The spar was held in the fuselage fitting by means of a nut, bolt and washers at its LH side. It was observed that the nut was tightened to the end of the threaded portion of the bolt, and it appeared that the bolt was too long for the assembly,(**Appendix A**). The fitting appears to have been machined to accommodate the washers so that the assembly could be tightened up with the bolt head, the washers and the nut parallel to one another and perpendicular to the longitudinal axis of the bolt. The fitting of the spar on the RH side was a plain fitting with no bolt. A grease mark on the spar indicates that there had been relative movement between the spar and its RH fuselage fitting. The wall thickness of the spar tube was 0.48 inch. Burrs were observed on the insides of both bolt holes. Initiation points for fatigue fracture appear to have been at the inner edges of the bolt holes.

1.7 Flight Manual

With a tail rotor drive system failure during crusing flight the Flight Manual instructs the pilot to cut the throttle full off immediately and complete an autorotational landing.

The Flight Manual states that on tail rotor control system failure at low airspeed power settings under approximately 18" Hg the helicopter will yaw to the left. With power settings over 18" Hg the helicopter will yaw to the right.

1.8 Technical History

The first recorded instance of failure of a spar was in 1972 with a steel tubular spar having a 0.035 inch wall thickness. The wall thickness was subsequently increased to 0.049 inches and this appeared to correct the problem.

Following an accident in October 1987, involving a spar with the increased wall thickness, the manufacturer issued Service Bulletin SDB0076 in December of that year, followed by the issue of FAA Airworthiness Directive AD 88-11-06 effective May 31 1988. This AD requires that the stabilizers be removed and the spar examined for cracks every 100 hours. It also stipulated pilot checks to be carried out during the pre-flight of the first daily flight. This involved applying slight up and down pressure to the stabilizer during the walk-around inspection.

For G-BBHE the log book entries were as follows:

SDB0076 complied	@ 716.3 hrs	On 30/5/1988 ("out of phase")
AD 88-11-06 complied	@ 737.7 hrs	On 20/5/1989 (Annual)
AD 88-11-06 complied	@ 905.7 hrs	On 20/8/2001 (Annual)
"FAA ADs Complied"	@ 927.0 hrs	On 9/8/2002 (Annual)
"FAA ADs Complied"	@ 948.0 hrs	On 18/10/2003 (Annual)
"No effective ADs present"	@ 964.0 hrs	On 7/3/2005 (Star Annual)

It is noted that SDB0076 requires a specific entry in the logbook in order to verify the inspection. The last verification of AD 88-11-06 was at 905.7 hrs. The next inspection of the spar was not due therefore until 1005.7 flight hours. As the helicopter had a total time of 969.6 flight hours at the time of the accident, the inspection was not due until another 36 flight hours.

1.9 Manufacturers Comments

The manufacturers said that they would have expected to find the tail rotor drive shaft between 50 and 200 yards back from the landing site along the reciprocal of aircraft heading. From photos it appeared that the tail rotor blade struck the RH stabilizer. A similar incident of a spar failure occurred to a US registered helicopter in 1987 but none had occurred since that time. They were of the opinion that most of the damage they observed in this accident was typical of a hard landing where the tail strikes the ground and the main rotor flexes down and contacts the tail boom. They said that the tail rotor normal operating RPM is 2240 to 2375 with a maximum of 2750 in autorotation.

2. ANALYSIS

Three sections of the R.H. stabilizer were found in a quarry 0.5 miles before the final landing area. The location coincides with that at which the loud bang was heard. A dent in the stabilizer airfoil matches one of the tail rotor blades. The stabilizer departing the helicopter and striking the tail rotor therefore initiated the sequence of events that followed.

In the sonogram, the main rotor blades can be detected at 16.78 c/s prior to the event, corresponding to a speed of 335 Rotor RPM. Following the event, there is a tail rotor blade frequency of 84 c/s, which corresponds to a tail rotor speed of 2520 RPM. This would indicate that there was no disconnect between the main rotor and the tail rotor during autorotation.

Appendix C demonstrates the most likely sonograms for engine, main rotor blades and tail rotor blades. The pilot said that he maintained engine RPM at about 2950 prior to the event. This corresponds to a frequency of 98.3 c/s, which is difficult to see on the sonogram. Hearing the bang and loss of pedal control were instantaneous so that one or possibly both cables were severed at that point. The pilot took action immediately following the loud bang and on suddenly discovering that tail rotor control was absent. In autorotating on to the chosen field (**Appendix D**) he had to traverse a 10 kv electricity line and a boundary hedge before he made the final landing. The severe drop in engine RPM after the event can be clearly seen. The average engine RPM during autorotation is of the order of 1440 RPM. This rises to 2040 RPM and apparently drops to 1800 RPM at impact. The tail rotor blades continued to rotate at a speed of 2520 RPM. The directional control following the incident was remarkably constant and is an indication that for most of the autorotation sequence the tail rotor blades assumed a nearly neutral pitch condition thus maintaining a certain degree of directional stability. The reduction of engine RPM to near idling speed during autorotation would indicate that engine RPM had little control over main blade speed and tail rotor blade speed as the freewheeling unit had effectively disconnected the engine.

Near the impact site, the sonogram frequency for the tail rotor blades becomes indeterminate. At this point it is likely that the RH tail rotor control cable started to wrap itself around the perimeter of the gearbox shaft. With a tail rotor speed of 2520 RPM, it would have taken less than a second for the RH control cable to do this. The wound cable squeezed between the rotating pitch link retainers and the fixed bearing housing assembly. The resulting force was sufficient to break one of these retainers before the gearbox seized and the rotating flexible drive shaft broke away.

The pilot intended to carry out a flare and run-on landing. He maintained a speed of about 60 mph down to approximately 4 to 5 ft in height and increased the collective to initiate the flare. Following the flare, the helicopter dropped vertically with the left skid making initial hard contact with the ground.

The main blades struck the tail boom causing the tail rotor to sever from the boom and fall to the ground whilst the rear section of the boom departed the helicopter and was found almost 20 yards from the body of the helicopter. Most of the damage to the helicopter appears to have been done when the main blades struck the boom on landing. The long bolt found in the LH stabilizer assembly, whilst not a contributing factor to this accident, was an indication of poor in-service maintenance at some stage prior to this event.

At the rate at which the helicopter was being flown, SDB0076 or AD 88-11-06 would not have been due for at least 2 years. The Investigation is of the opinion that these Directives should be re-examined in order that stabilizer spars are inspected at least once a year.

The pilot is to be complimented for landing the stricken helicopter, under difficult circumstances, without injury to either himself or his passenger.

3. CONCLUSIONS

(a) Findings

1. The stabilizer spar fractured in high cycle fatigue at the mounting point/bolt hole for the RH stabilizer airfoil.

2 The mating portion of the spar and the RH stabilizer airfoil detached in flight.

3 The RH stabilizer contacted the tail rotor.

(b) Cause

1 Failure of the spar occurred through high cycle fatigue cracking.

2 The cracks initiated at the inner edges of the bolt holes holding the RH stabilizer airfoil to the stabilizer spar.

4. SAFETY RECOMMENDATIONS

4.1 The manufacturer should revise SDB0076 with a view to stipulating that the SDB should be carried out at the aircraft annual inspection if it has not been carried out since the previous annual inspection. **(SR 05 of 2006)**

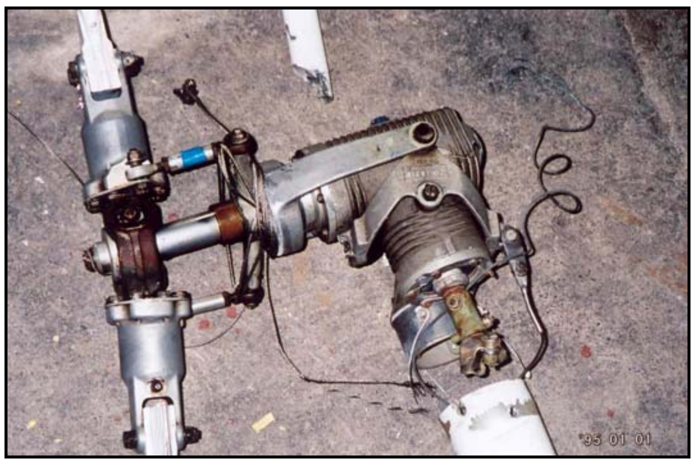
4.2 The FAA should consider an amendment to AD 88-11-06 with a view to stipulating that the AD should be carried out at the aircraft annual inspection if it has not been carried out since the previous annual inspection.**(SR 06 of 2006)**

- END -

APPENDIX A

Three sections of the RH stabilizer found 0.5 miles from the landing site

Spar /fuselage attachment bolt, nut and washer.
Note long bolt and space between washer and housing.



Tail rotor gearbox , pitch change mechanism and control cables
as found separated from the tail boom at the helicopter landing site.

APPENDIX B

Frequency analysis of audio output from video camera onboard aircraft

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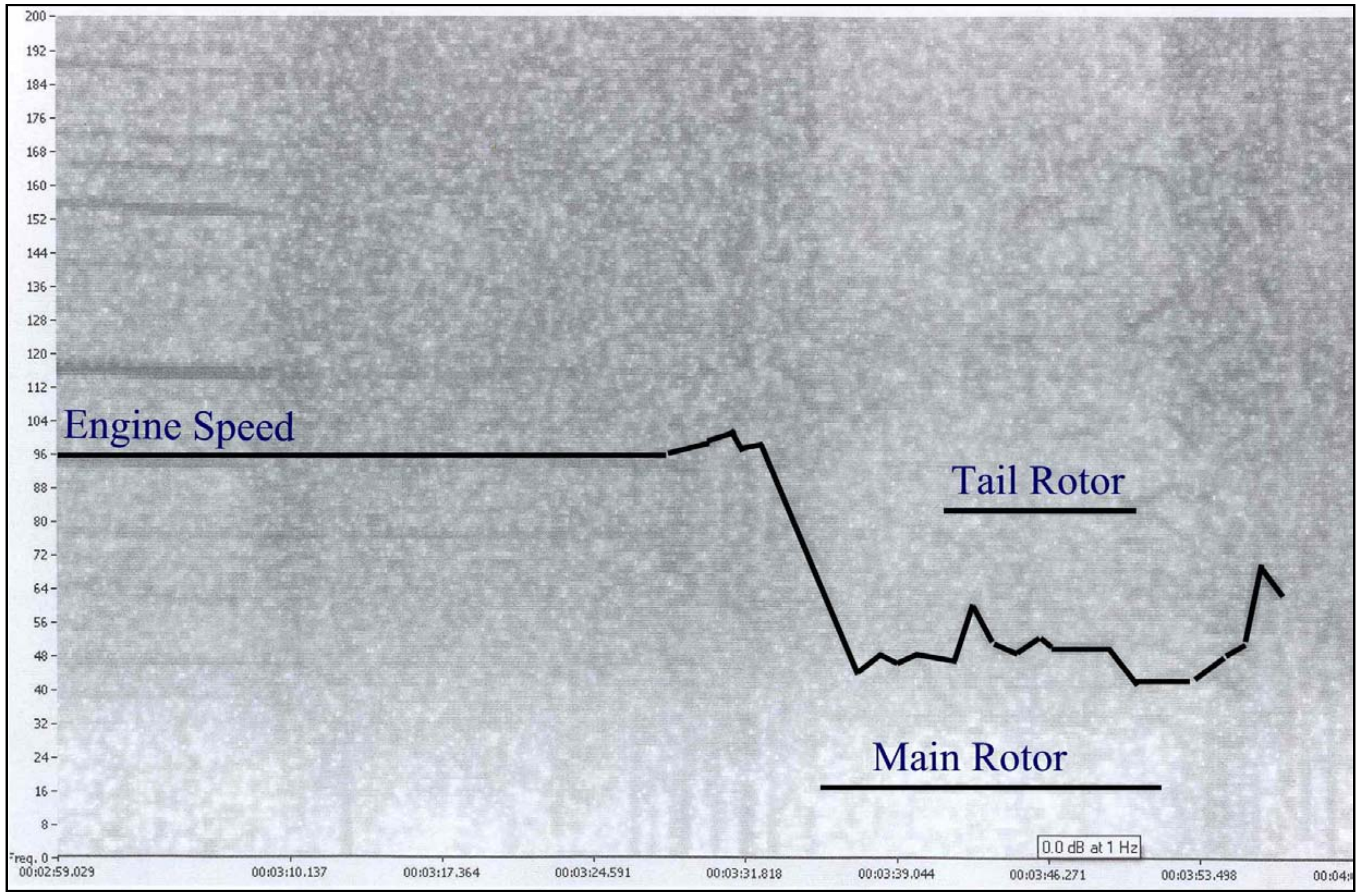
APPENDIX C



Sonogram of engine, main rotor and tail rotor speed

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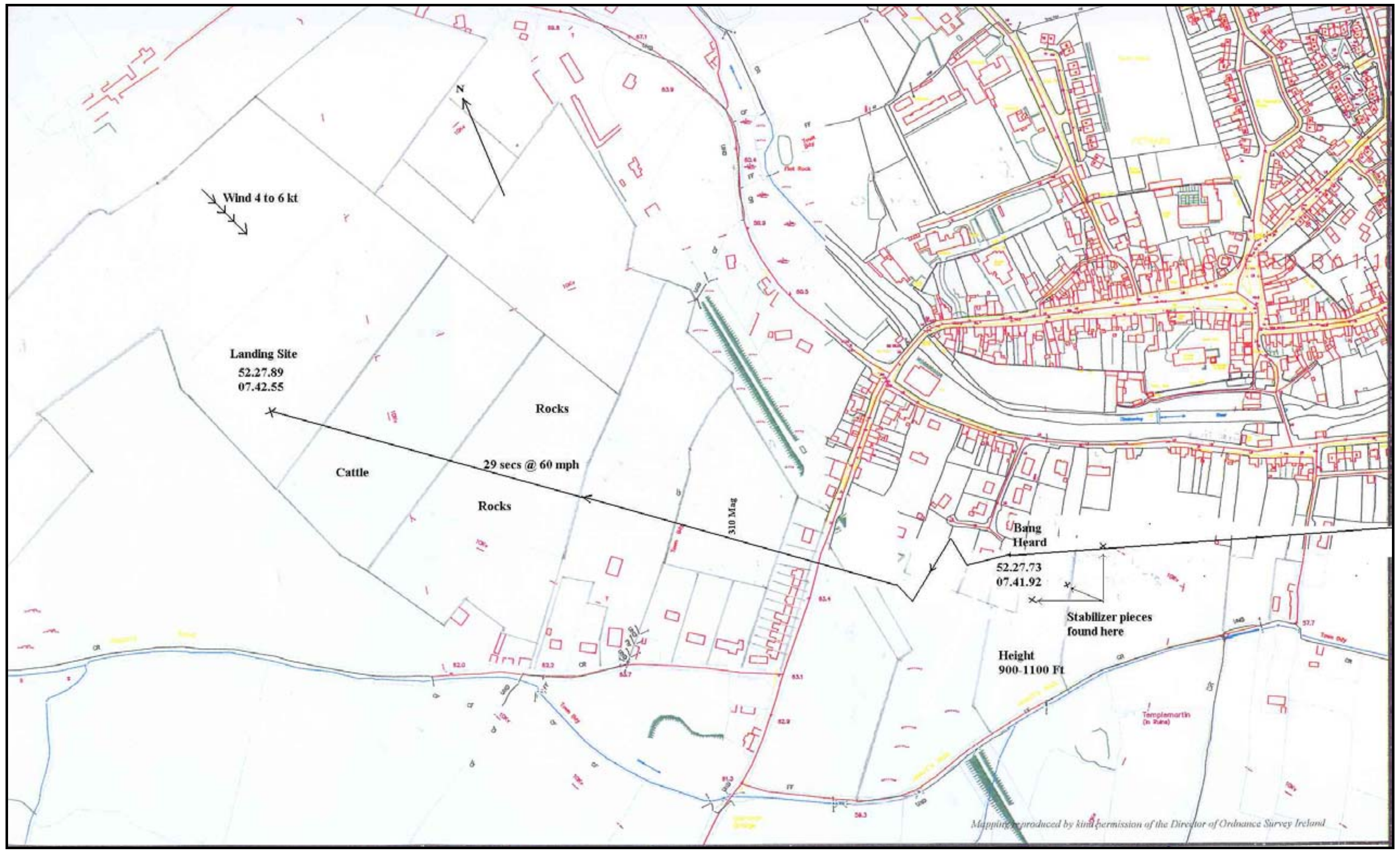
APPENDIX D



Final track of G-BBHE