The Use of Enhanced Ground Proximity Warning System (EGPWS) Data for Aviation Safety Investigation

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1.   INTRODUCTION

Enhanced Ground Proximity Warning Systems (EGPWS) are fitted to a large number of commuter and airline aircraft. These systems store flight history data in non-volatile flash memory. The original purpose of storing this data was to help operators and the EGPWS manufacturer to isolate system or terrain/airport runway database problems. EGPWS flight history data is now becoming increasingly useful for aviation safety investigation purposes particularly when flight data recorder (FDR) or quick access recorder (QAR) data is either unavailable or consists of a limited number of parameters.

2.   CASE STUDY

On 24 July 2004, the flight crew of a Boeing 737-838 aircraft, received a terrain proximity caution from the aircraft's enhanced ground proximity warning system (EGPWS) while descending to the south-south-east of Canberra Airport. The aircraft was being operated on a scheduled fare-paying passenger service from Perth to Canberra.

Due to staff shortages on the morning of the occurrence, the approach control services normally provided by the Canberra Terminal Control Unit did not become available until approximately 40 minutes after the scheduled unit opening time. This meant that the aircraft's descent below 9,000 ft was conducted without air traffic control radar assistance.

As the aircraft approached Church Creek (CCK), the copilot, under the direction of the pilot in command, entered the holding pattern details into the Flight Management Computer (FMC). In doing so, an erroneous entry was made, which resulted in the FMC computing a holding pattern with a leg length of 14 NM, instead of 1 minute or a maximum distance from Canberra of 14 NM.

By entering a leg distance of 14 NM, the crew inadvertently commanded the FMC to establish the aircraft in a holding pattern that would take the aircraft about 11 NM beyond the published holding pattern limit. The crew initiated descent to 5,000 ft after

passing overhead CCK. As it descended, the aircraft proceeded outside the airspace specified for holding. Consequently, the aircraft was operated closer to the surrounding terrain than would normally occur.

The aircraft was fitted with an EGPWS, which detected the aircraft's proximity to the terrain and provided the crew with a 'CAUTION TERRAIN' message to which the crew responded by climbing the aircraft to 6,500 ft. Sixteen seconds before the message, the crew had commenced a right turn to intercept the inbound track to CCK.

At the time of the message, the aircraft's height above terrain was 2,502 ft (radio altimeter indication).

During the turn, the aircraft passed 0.6 NM (1.11 km) north abeam and 810 ft higher than the closest terrain that had a spot height of 4,920 ft above mean sea level. It also passed 2.7 NM (5 km) north abeam Tinderry Peak. The aircraft climbed to 6,500 ft and subsequently joined the runway 35 localiser.

3. SOURCES OF RECORDED DATA

The aircraft was equipped with a cockpit voice recorder (CVR), a flight data recorder (FDR) and a quick access recorder (QAR).

The short recording cycle of CVRs (either 30 minutes or 2 hours) means that they are quickly overwritten and are usually not available for incident investigations. In this case the FDR was also overwritten before it was removed from the aircraft. Finally the QAR had malfunctioned so no data was available from any of the traditional accident/incident investigation recorders.

Air traffic control secondary surveillance radar data recorded on the ground and EGPWS data stored within the EGPWS computer onboard the aircraft were used in the investigation.

4.   EGPWS DATA

4.1   EGPWS Functions

The aircraft was fitted with an EGPWS which provided basic ground proximity warning functions and enhanced functions.

Basic Functions:

- Mode 1 – Excessive Descent Rate
- Mode 2 – Excessive Closure to Terrain
- Mode 3 – Altitude Loss After Takeoff
- Mode 4 – Unsafe Terrain Clearance
- Mode 5 – Excessive Deviation Below Glideslope
- Mode 6 – Advisory Callouts
- Mode 7 – Windshear Alerting

Enhanced Functions:

- Terrain Clearance Floor
- Terrain Look-ahead Alerting
- Predictive Windshear

4.2   Terrain Look-Ahead Alerting

"This is accomplished (when enabled) based on aircraft position, flight path angle, track, and speed relative to the terrain database image forward the aircraft.

Through sophisticated look-ahead algorithms, both caution and warning alerts are generated if terrain or an obstacle conflict with "ribbons" projected forward of the aircraft. These ribbons project down, forward, then up from the aircraft with a width starting at 1/4 nm and extending out at ±3º laterally, more if turning. The look-down

and up angles are a function of the aircraft flight path angle, and the look-down distance a function of the aircraft's altitude with respect to the nearest or destination runway. This relationship prevents undesired alerts when taking off or landing. The look-ahead distance is a function of the aircraft's speed, and distance to the nearest runway.

*A terrain conflict intruding into the caution ribbon activates EGPWS caution lights and the aural message **"CAUTION TERRAIN, CAUTION TERRAIN"** or **"TERRAIN AHEAD, TERRAIN AHEAD"**. An obstacle conflict provides a **"CAUTION OBSTACLE, CAUTION OBSTACLE"** or **"OBSTACLE AHEAD, OBSTACLE AHEAD"** message. The caution alert is given typically 60 seconds ahead of the terrain/obstacle conflict and is repeated every seven seconds as long as the conflict remains within the caution area. When the warning ribbon is intruded (typically 30 seconds prior to the terrain/obstacle conflict), EGPWS warning lights activate and the aural message **"TERRAIN, TERRAIN, PULL UP"** or **"OBSTACLE, OBSTACLE, PULL UP"** is enunciated with **"PULL UP"** repeating continuously while the conflict is within the warning area."[1]*

A description of the terrain look-ahead envelopes is given below[2]:
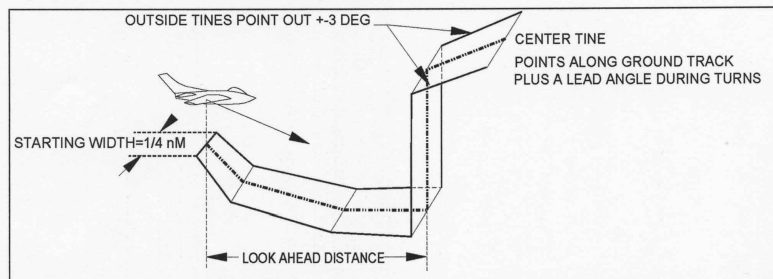
4.3 Investigation Procedure

The aircraft was fitted with a Honeywell EGPWS Computer (Part Number: 965-0976-003-212).

As no FDR or QAR data was available, the operator was asked provide a copy of the flight history data which was stored in NVM by the EGPWS Computer. This was the first occasion that the operator had performed this task and after liaison with the vendor the data was successfully downloaded and a copy forwarded to the ATSB.

The downloaded data consisted of six files containing status, fault, event, count and warning data. The data was interpreted using the Honeywell document "EGPWS and Flight History Stored in Non-Volatile Flash Memory".

4.4 Warning Data

Data from the warning file was searched and it was observed that a terrain caution alert had been recorded during flight leg 1364. This was the only terrain caution alert that had been recorded by the EGPWS computer and flight leg data from the status file showed that it had occurred on a Perth – Canberra flight. Latitude and longitude recorded at the time of the terrain caution alert correlated with radar position data so the recorded terrain caution alert was positively identified as the reported event.

Flight history data is recorded for a total duration of 30 seconds – covering 20 seconds before an event and 10 seconds afterwards. It is deliberately not time or date stamped.

The flight history data contains the following parameters:

Latitude *	Pitch Angle
Longitude *	Roll Angle B
Position Source	Body AOA
Position Uncertainty(HFOM) *	Longitudinal Acceleration *
Filtered Computed Airspeed	Normal Acceleration
True Airspeed	Inertial Vertical Acceleration
Ground Speed *	Static Air Temperature
Minimum Operating Speed	Filtered Shear/Total Shear
Standard Altitude(Uncorrected)	Shear Bias/VSBias
Corrected Altitude for Terrain *	HSBias
Corrected Altitude VFOM	Low Pass Filtered Glideslope
Geometric Altitude VFOM *	Localizer Deviation
GPS Altitude *	Range 1 *
GPS VFOM *	Range 2 *
GPS Calibrated Altitude *	Hazard Average Power
GPS Calibrated Altitude VFOM	Hazard Azimuth
Radio Altitude Calibrated Altitude	Hazard Range
RA Calibrated Altitude VFOM	Landing Gear Down
Runway Calibrated Altitude *	Landing Flaps Selected
Runway Calibrated Altitude VFOM *	In Air *
Radio Altitude B	Approach
Terrain Database Elevation *	Windshear Approach
Standard Altitude Rate *	Terrain Awareness & TCF inhibit *
Magnetic Track *	Terrain Display Enabled #1 and #2 *
True Track	Validities of all of the above signals *
True Heading	

Table I – EGPWS SIGNAL HISTORY

*EGPWS stored on Class B equipment

Each parameter was sampled once per second.

4.5   Accuracies

The EGPWS receives inputs from the same aircraft sensors that are used by the crew or autopilot to navigate the aircraft. The accuracy of the GPS latitude and longitude recorded by the EGPWS was ± 100 metres. The accuracy of the altitude recorded by the EGPWS was ± 10 feet.

It was observed that on four occasions successive samples of latitude and longitude were identical. Given the resolution of the data (5 decimal places) and the aircraft groundspeed this was unrealistic behaviour and may have been due to an insufficiently frequent update rate from the GPS receiver.

5.   TIMING CORRELATION

As the EGPWS flight history data was not time stamped it was necessary to correlate the EGPWS altitude with radar altitude to determine the time of the terrain caution alert. Radar data is time stamped from a source that is sychronised with UTC from the GPS.

EGPWS Corrected Altitude included a correction for the pressure setting (QNH) made by the flight crew while EGPWS Barometric Altitude did not include the correction. The correction was +175 ft and was due to the difference between the QNH (1020 hPa) and standard pressure (1013.2 hPa).

The altitude correlation showed that the EGPWS terrain caution alert occurred at 1944:24 UTC (tolerance ± 2 seconds).

6.   RESULTS

Plots 1, 2 & 3 contain flight history data obtained from the EGPWS computer. Figures 1 shows a 3D representation of the aircraft track obtained from secondary surveillance radar data. Figure 2 shows the EGPWS track and the radar track. There is a small offset between the tracks with the EGPWS track (sourced from GPS latitude and longitude) having the greater accuracy.
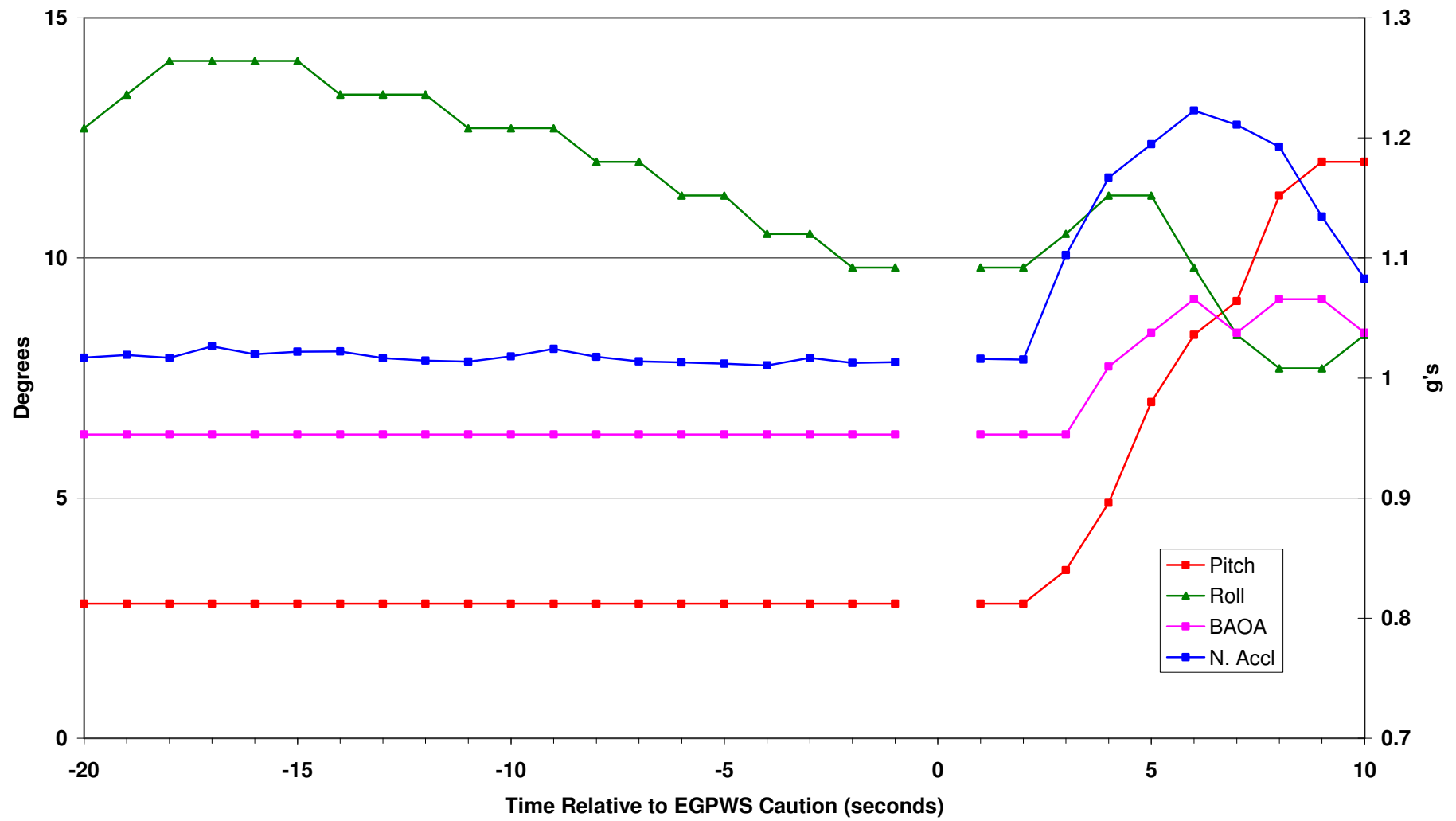
EGPWS Data - Plot 1
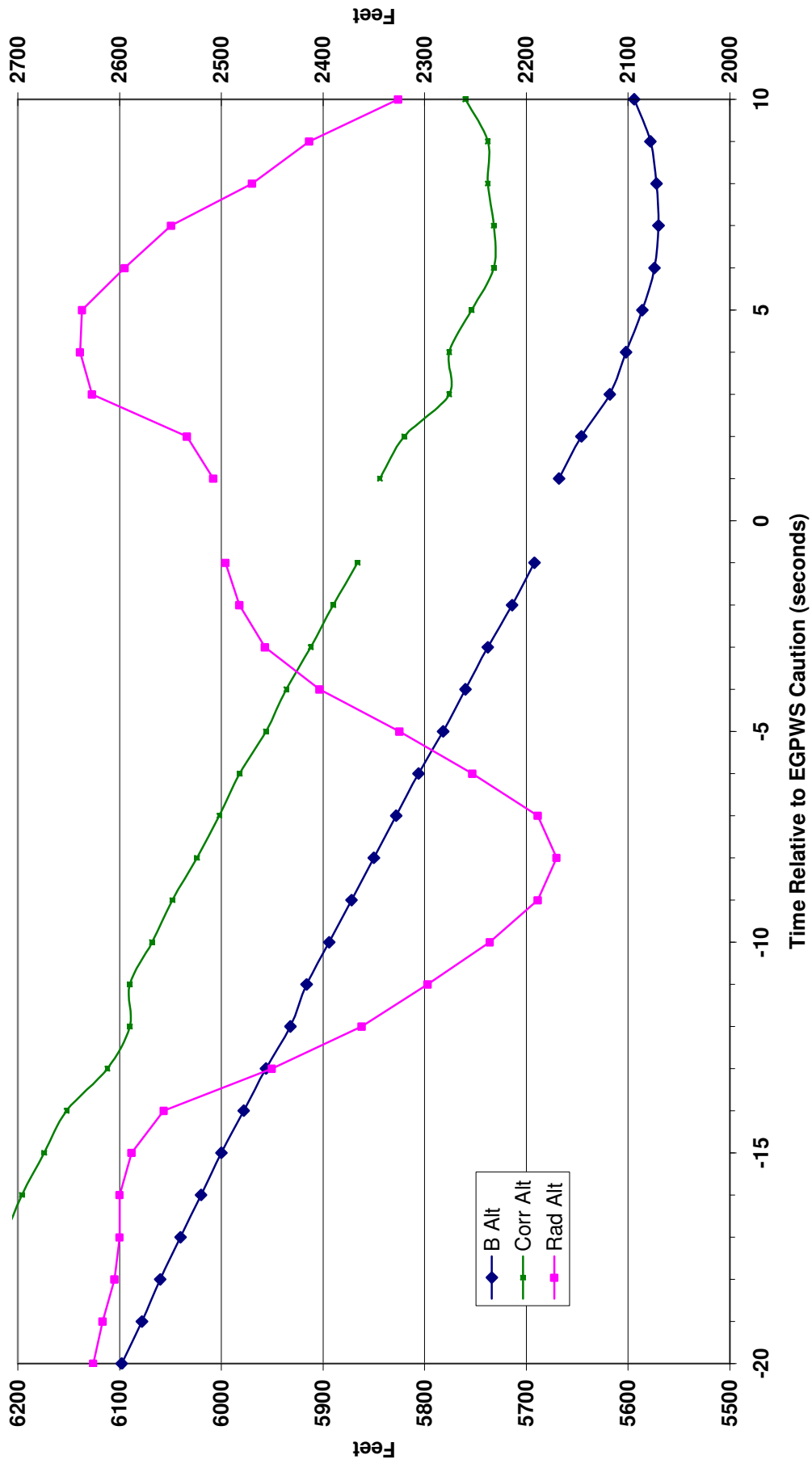
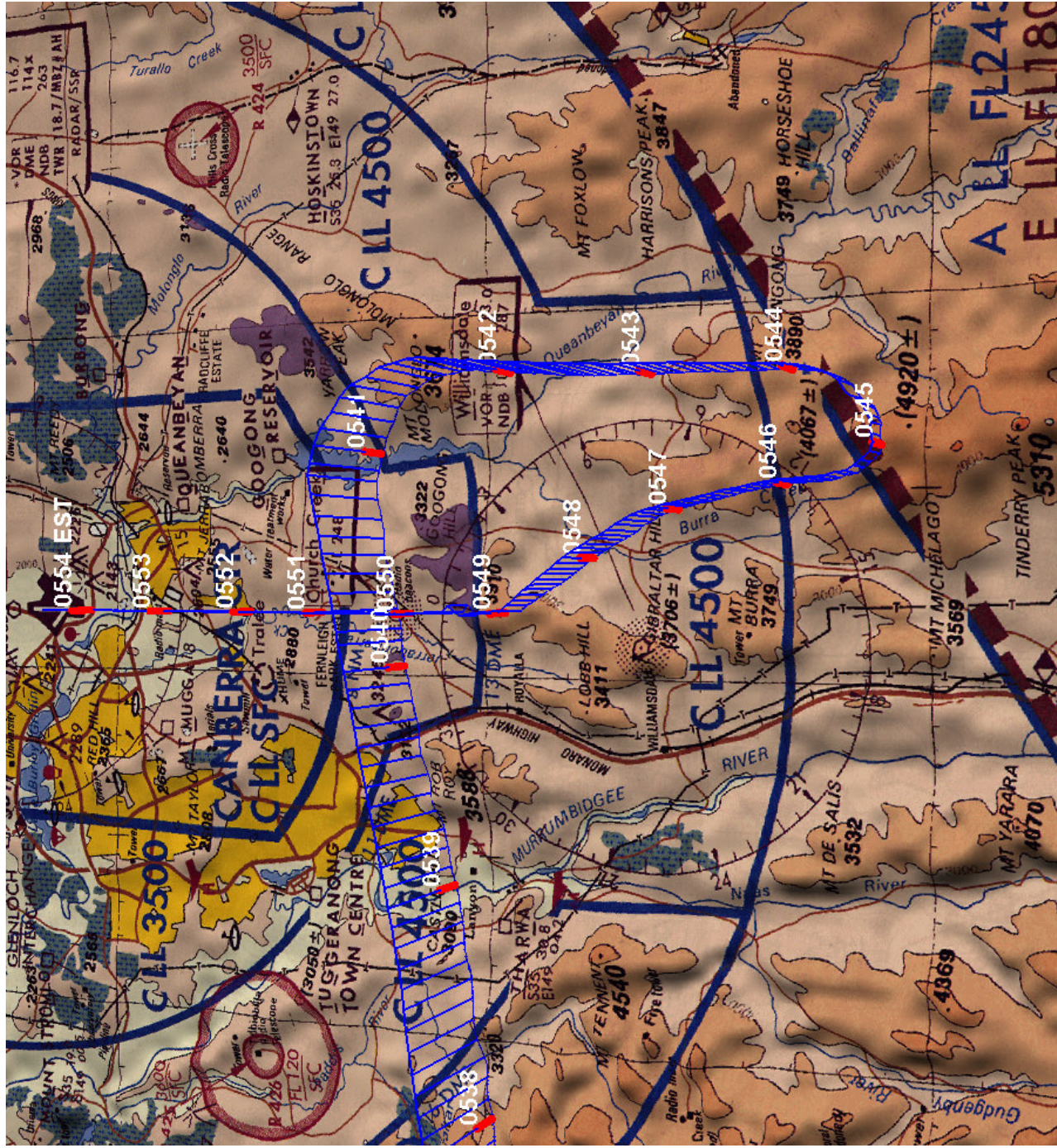EGPWS Data - Plot 2
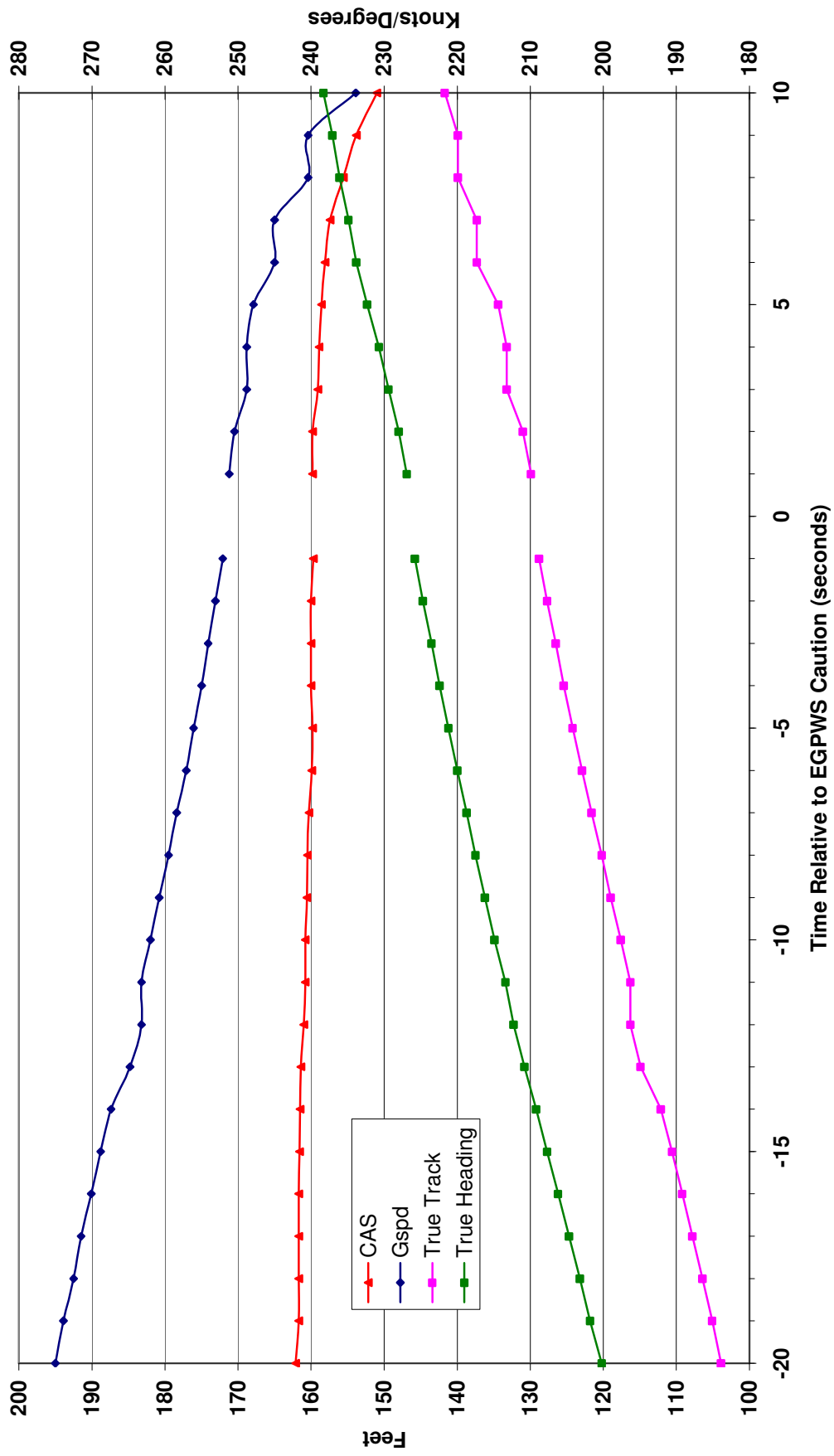
EGPWS Data - Plot 3
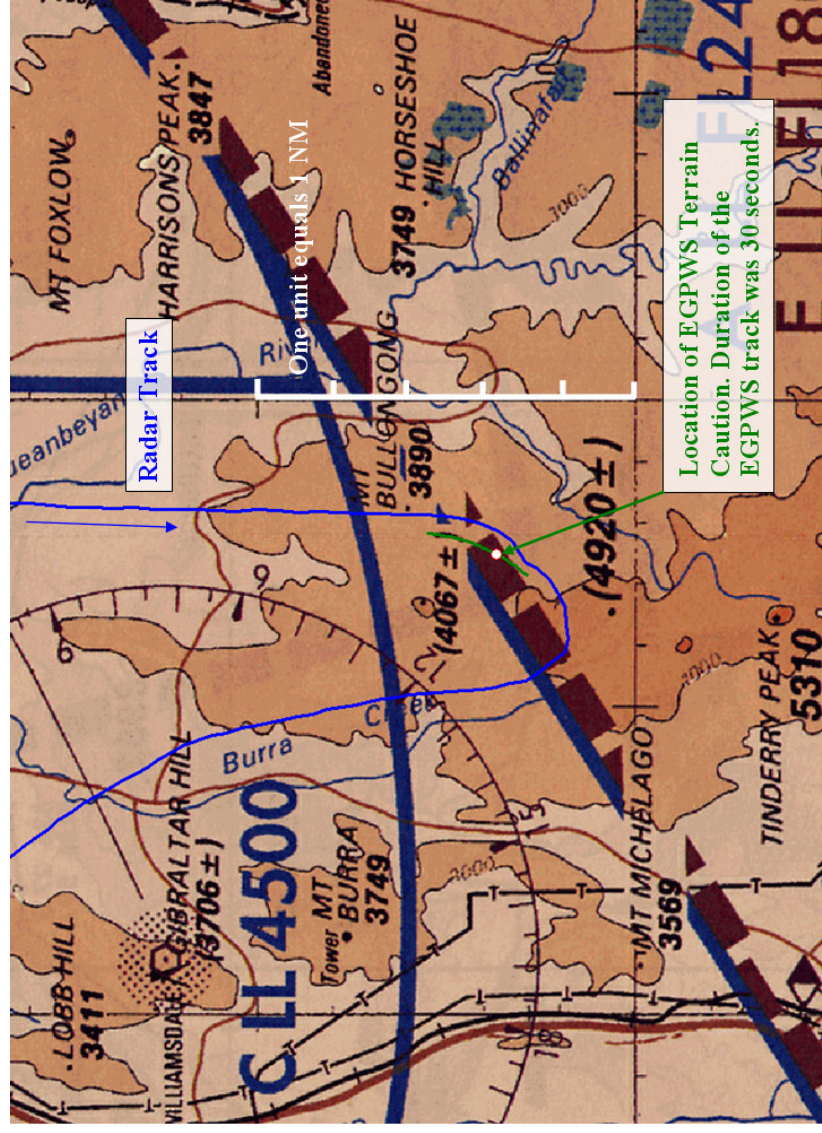
Figure 1 – 3D Representation of Radar Track

Figure 2 – EGPWS Track and Radar Track

7. CONCLUSIONS

The aircraft was equipped with an Enhanced Ground Proximity Warning System (EGPWS). Apart from the basic GPWS functions this system also performed enhanced functions including terrain look-ahead alerting. As no FDR or QAR data was available EGPWS flight history data, obtained from the EGPWS computer, was examined.

Access to the data stored in the EGPWS computer non-volatile memory assisted the investigation significantly. The accessibility of non-volatile memory data has provided another tool for the investigation of accidents and incidents.

8. REFERENCES

8.1   Australian Transport Safety Bureau (ATSB) Report 200402747
(available on the ATSB website: www.atsb.gov.au)

8.2   "Enhanced Ground Proximity Warning System (EGPWS) and Flight History Stored in Non-Volatile Flash Memory" by Don Bateman, Honeywell. Presented at the ANZSASI Conference June 2000 in Christchurch NZ.

9. ABBREVIATIONS

Acronyms may be used in upper case or lower case.

AGL	Above Ground Level
BAOA	Body Angle of Attack
CAS	Computed Airspeed
DME	Distance Measuring Equipment
EGPWS	Enhanced Ground Proximity Warning System
FDR	Flight Data Recorder
FOM	Figure of Merit
FPM	Feet Per Minute
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HFOM	Horizontal Figure of Merit
hPa	Hectopascals
QAR	Quick Access Recorder
QNH	Local Station Pressure Corrected to MSL
MSL	Mean Sea Level
NVM	Non-Volatile Memory (Flash Memory)
SSR	Secondary Surveillance Radar
TAAATS	The Australian Advanced Air Traffic System
UTC	Coordinated Universal Time
VFOM	Vertical Figure of Merit