PEGASUS
AIRBORNE SYSTEMS

NORFOLK METALS

EL20-2020 UAV MAGNETICS

17/05/22

PREPARED BY PEGASUS AIRBORNE SYSTEMS

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SURVEY INFORMATION & SPECIFICATIONS

In May 2022 Pegasus Airborne Systems conducted a low-level UAV magnetic survey of the EL20-2020 project for Norfolk Metals. The area surveyed was adjacent to the villages of Nabageena and Trowutta in North West Tasmania[Figure 1].

The survey was flown using the WGS84 UTM coordinate system (a Universal Transverse Mercator projection derived from the World Geodetic System of 1984) and was contained within zone 55 with a central meridian of 147 degrees. Details of the datum and projection system are provided in Appendix B of this report. Survey boundary coordinates are listed in Appendix C.

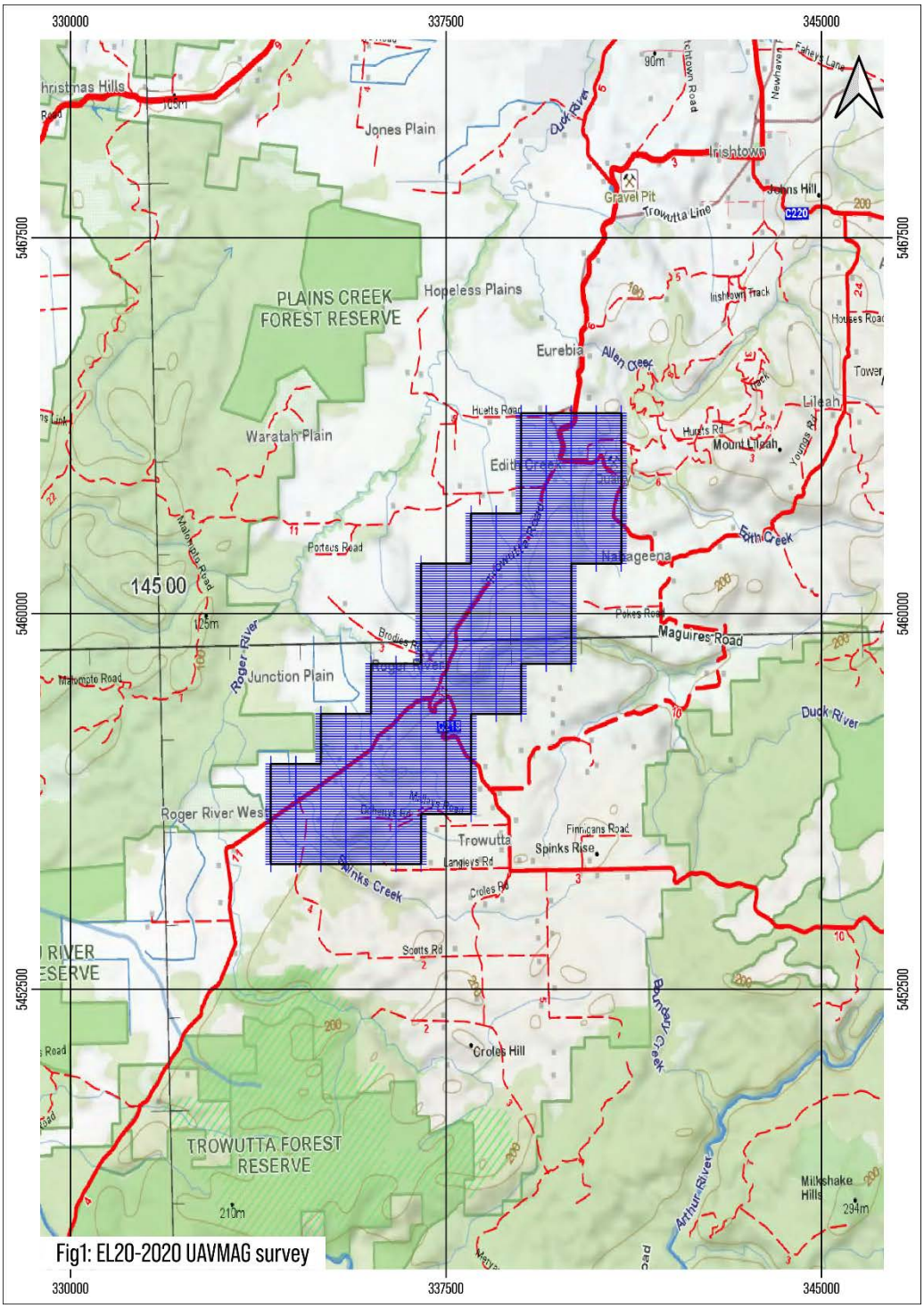
Table 1 contains acquisition specifications for each survey area. Sensor height may be varied where topographic relief or laws pertaining to built up areas do not allow this altitude to be maintained, or where the safety of the aircraft and equipment is endangered.

Grid Name	Line Spacing	Line Direction	Tie-Line Spacing	Tie-Line Direction	Sensor Height	Total Line km
EL20-2020	50	090-270	500	000-180	75m	595

Table 1

Data acquisition commenced on the 9th of May 2022 and was completed on the 12th of May with the final data delivered promptly after.

FIGURE 1 – EL20-2020 PROJECT



AIRCRAFT AND SURVEY EQUIPMENT

A specialised unmanned rotary wing geophysical survey aircraft was equipped with a Pegasus autonomous flight control and terrain following system. This aircraft was used to tow a Pegasus designed and built magnetometer bird which housed the geophysical sensors and Pegasus data acquisition system.

The list of geophysical and navigation equipment used for the survey is as follows:

Survey Aircraft

The PAS-H100 was selected for deployment to this project due to its portability, agility, and responsive handling. Due to its excellent power to weight ratio, the helicopter has exceptional climb rates making it ideal for low level geophysical surveys. Under survey, the relatively slow acquisition speed and tuning of the autopilot to make smooth transitions between climb/descent make for an extremely stable platform for the sensor payload, resulting in optimal signal to noise over the survey area.

HELICOPTER	PAS H100 Rotary Wing
ENGINE	Brushless Electric Motor
AUTOPILOT	Pegasus FC-100
FUEL TYPE	LiPo Battery
ENDURANCE	1 hours with reserve
SURVEY SPEED	15m/s
MAX LATERAL DEVIATION	5m
MAX VERTICAL DEVIATION	5m
SURVEY HEIGHT AIRCRAFT	95m AGL (Terrain drape enabled)
SURVEY HEIGHT SENSOR	75m AGL (Terrain drape enabled)

Towed Bird Assembly

- Designed by Pegasus Airborne Systems using CAD with lightweight and strong composite Kevlar construction
- 3.9kg assembled weight with battery
- Aerodynamic design with stable characteristics in cross wind
- Magnetic sensor located at distance from the electronics and GNSS receiver
- Low power consumption at < 18W
- Towed 20m below survey aircraft

Magnetic Sensor

- Scintrex CS-VL Cesium vapour magnetometer
- Sensitivity 0.0006nT sq rt RMS
- Noise envelope 0.002nT peak to peak
- Heading error ± 0.25nT
- https://scintrexltd.com/wp-content/uploads/2017/03/CS-VL-Brochure.pdf

Data Acquisition System

- Designed by Pegasus Airborne Systems to be extremely lightweight with small form factor
- Dedicated O/S for real time acquisition
- GNSS PPS time synchronised
- IEEE 802-11 Wifi module for monitoring

Magnetometer Counter

- Designed by Pegasus Airborne Systems to interface with Scintrex CS-VL square wave output
- Sample frequency 260Mhz
- Counter resolution 0.1pT

GNSS Receiver

- uBlox GNSS receiver with multi constellation tracking
- 10Hz output (20Hz capable)
- Operating in autonomous mode
- Sub metre accuracy

Laser Altimeter

- Lightweight, small form factor laser with fast, accurate measurements.
- 20g weight
- 100m range
- 1cm resolution
- 10cm accuracy
- Update rate maximum 360 readings per second
- Class 1M or class 1, eye safe.

Other Sensors

- Inertial measurement unit (IMU)
- Pitch, roll, yaw error of < 0.1 degrees

Autopilot and Ground Control Station

- Industry leading autopilot with custom Pegasus firmware for terrain draping
- Dual GNSS receivers, IMU, barometric altimeter and laser rangefinder
- Fuel consumption and level monitoring, battery monitoring, altitude, main rotor and engine RPM
- Automated alarms and fail safes
- 400Mhz radio link with Iridium satellite backup
- Display of flight path over satellite imagery or client maps
- Return to home using terrain follow mode.

Diurnal Magnetometer

- GEM Systems GSM19-F Overhauser Magnetometer
- GNSS time stamped data
- 0.01nT resolution
- 0.1nT accuracy
- 1Hz sample rate

http://www.gemsys.ca/rugged-overhauser-magnetometer/

PROJECT MANAGEMENT

Norfolk Metals	Leo Pilapil
Pegasus/PEGAIR Perth Office	Leon Mathews
Geophysicist/Data Processor	Adam Schubert
Chief UAV Pilot	Andre Lua
UAV Pilot	Reilly Williamson
UAV Pilot	Garth Thompson

DATA PROCESSING

Data Quality Control and Pre-Processing

At the end of each flight the raw data was downloaded from the acquisition system and delivered to the data processor.

Initial data quality control procedures were then implemented which included checking to ensure line navigation specifications had been met, the data was trimmed to the correct survey boundary extents, and further data quality control measures were performed, these included visual inspection of magnetic and ancillary data channel profiles and preliminary grids, measurement and analysis of magnetic noise levels, and closer inspection of various horizonal and vertical navigation parameters.

The diurnal base station data was checked to ensure survey flight coverage and for magnetic storm activity and cultural noise.

Any out of specification sections of data were flagged and marked for re-flight.

The trimmed and checked survey and diurnal data was then exported to a cumulative master processing database for further processing.

Magnetic data processing

No editing or filtering of the recorded raw TMI data is carried out. This is because the data are inherently clean due to the large separation between the bird and aircraft.

The base station diurnal data were suitably filtered to remove any high frequency content and then subtracted from the survey data using the common GNSS derived UTC time. A base datum value was applied during this process.

After diurnal subtraction, the regional magnetic gradient was removed using the IGRF for a given date and interpolated position and time. Tie line levelling was carried out using the intersection points between tie and survey lines. Where required, the tie line levelled data was selectively microlevelled to remove any residual acquisition artefacts.

Digital Terrain Model (DTM) Data Processing

A Digital Terrain Model (DTM) was calculated by subtracting the laser altimeter height from the GNSS recorded height. It should be noted that the accuracy of the DTM is governed by the accuracy of the GNSS altitude and may also be inaccurate where laser returns are recorded from dense tree canopy. The DTM should only be used as an approximation of the terrain height.

APPENDIX A – DATA FORMATS

Final located magnetic data was supplied in Geosoft .gdb and ASEG-GDF2 format, with grids of the following products in ERMapper format.

ER Mapper Grids

- TMI
- TMI 1VD 2VD
- TMI Reduced to Pole
- TMI Reduced to Pole 1VD 2VD
- TMI Reduced to Pole Tilt Derivative
- Digital Terrain Model

Located Magnetic Data Format

	FIELD FORMAT	DESCRIPTION	UNITS
1	F10.1	LINE NUMBER	
2	F7.0	FID	
3	F9.1	TIME	hhmmss.s
4	F12.3	EASTING (WGS84)	metres east
5	F13.3	NORTHING (WGS84)	metres north
6	F13.8	LATITUDE (WGS84)	degrees south
7	F13.8	LONGITUDE (WGS84)	degrees east
8	F8.1	GPS ALTITUDE	metres ASL
9	F8.2	LASER HEIGHT	metres AGL
10	F12.4	DIURNAL	nT
11	F12.4	IGRF	nT
12	F12.4	MAG RAW	nT
13	F11.4	MAG DIURNALLY CORRECTED	nT
14	F11.4	MAG DIURNALLY AND IGRF CORRECTED	nT
15	F11.4	MAG TIE LINE LEVELLED	nT
16	F11.4	MAG FINAL	nT
17	F8.2	DIGITAL TERRAIN MODEL	metres ASL

APPENDIX B – COORDINATE SYSTEMS

Locations for the survey data are provided in both geographical latitude and longitude and Universal Transverse Mercator metric projection coordinate systems.

WGS84	World Geodetic System 1994
Coordinate Type	Geographical
Semi Major Axis	6378137m
Flattening	1/298.257223563

APPENDIX C – SURVEY BOUNDARY DETAILS

SURVEY AREA COORDINATES

Project ID: 2147

Area Name: EL20-2020

WGS84 UTM Grid Zone 55 south

341000.000	5461000.000
340000.000	5461000.000
340000.000	5459000.000
339000.000	5459000.000
339000.000	5458000.000
338000.000	5458000.000
338000.000	5456000.000
337000.000	5456000.000
337000.000	5455000.000
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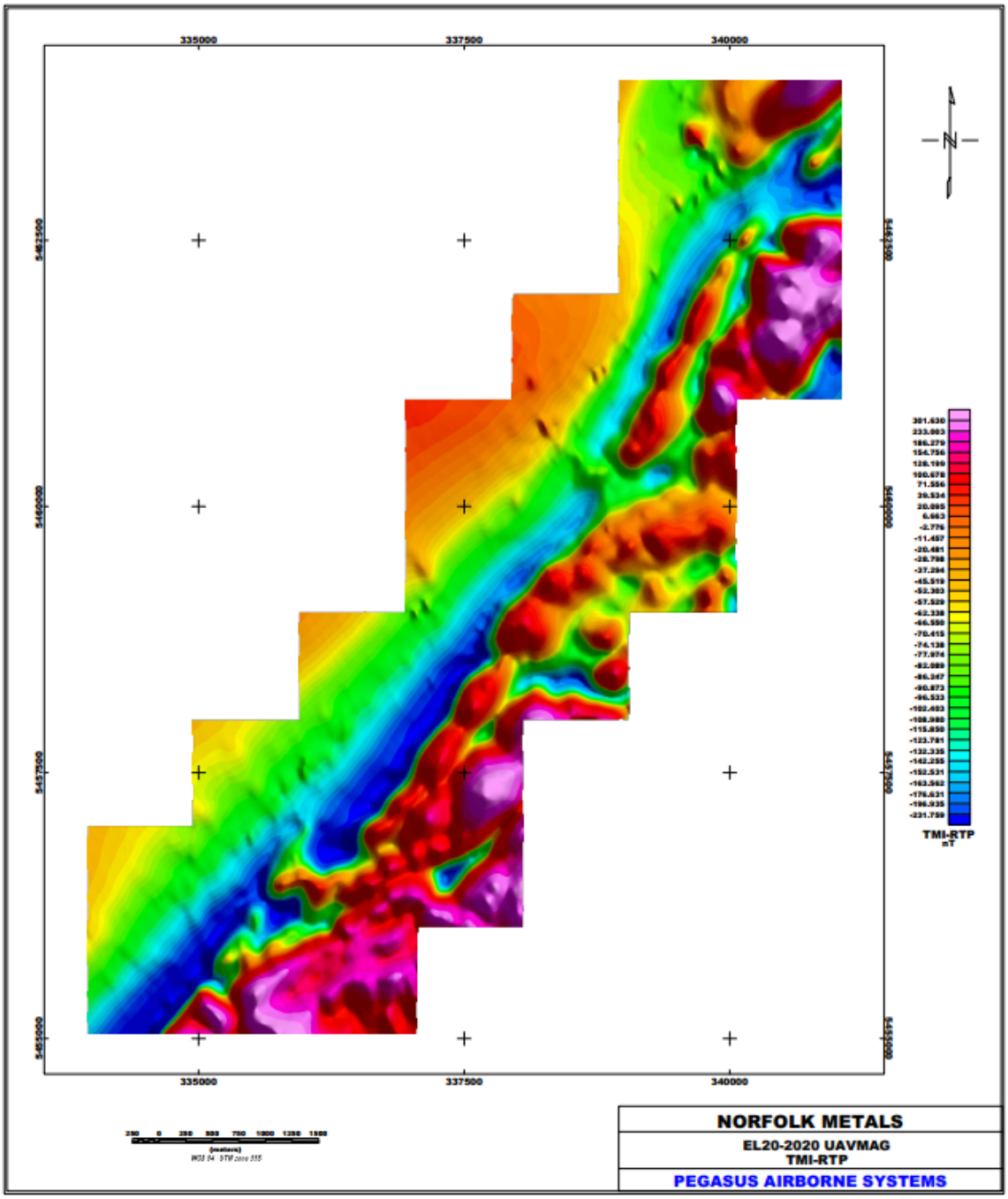
335000.000	5458000.000
336000.000	5458000.000
336000.000	5459000.000
337000.000	5459000.000
337000.000	5461000.000
338000.000	5461000.000
338000.000	5462000.000
339000.000	5462000.000
339000.000	5464000.000
341000.000	5464000.000
341000.000	5461000.000

APPENDIX D – PROJECT DATA OVERVIEW

Project - EL20-2020

Total Magnetic Intensity Reduced to Pole



APPENDIX E – MAGNETIC PROCESSING PARAMETERS

IGRF Date:	IGRF 2022.335
Average Declination:	13.221 degrees
Average Inclination:	-71.419 degrees
Average IGRF Field:	61477.4503nT
Average diurnal:	61311.3874nT