20. Geocoded Calibrated Waveform (GCW) Output

GCW output is provided as a new feature of GeocodeWF starting with version 1.1. **GCW** output is provided for users who want to apply their own algorithms to extract relevant information from the waveforms.

The raw waveform sample data is recorded in the SDF file format by the DR560 Data Recorder. This file format is optimized for file size and fast storage speed to optimize efficient data acquisition. However, it is rather difficult to directly handle in post-processing due to the complex file structure. Also, it contains characteristics specific to the individual sensor it was acquired with. Therefore, GeocodeWF provides a possibility to generate waveform data that is calibrated and thus independent of specific system characteristics, and that can be easily and efficiently accessed by users wanting to do their own waveform processing for special applications.

Waveform data is recorded by the LMS-Q560 laser scanner in two sampeling channels with different sensitivity, dynamic range, and timing characteristics. During the calibration process system-specific calibration parmeters are applied to scale and time-correct both data channels and to combine the data to a uniform waveform sample stream of 8 or 16 bits per sample, depending upon the dynamic range of the raw data. Simultaneously, a file is generated that contains geometric and indexing information for each waveform so that the waveform data can easily be queried and accessed by shot number, shot time stamp or geographic location.

GCW data is provided in two files:
1. LWF files containing the calibrated waveform sample data
2. LGC files containing the geocoding and indexing information for each laser shot

Waveform Data

The waveform samples are stored in the LWF files as concatenated byte and ushort arrays. The start position of the waveform data for each laser shot in the LWF file is given by the WFI parameter of the LGC record, as 64 bit (8 byte) integer (__i64 or long long type).

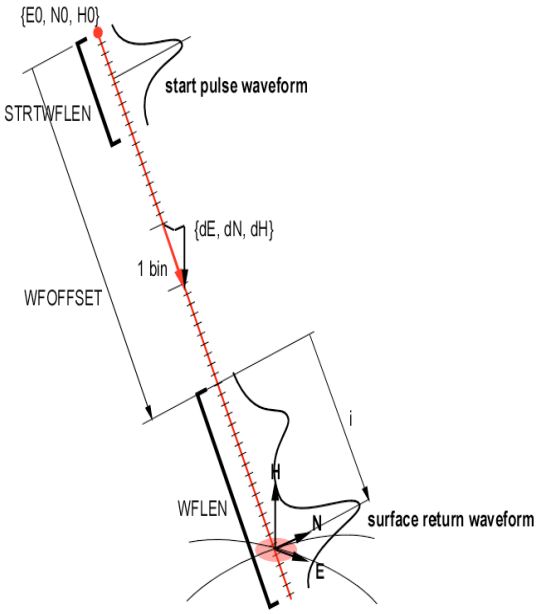
Each waveform consists of a byte array of STRTWFLEN (start waveform length) samples representing the (emitted) start pulse waveform of a laser shot for reference, followed by a byte array or ushort array of WFLEN (waveform length) samples representing the surface return waveform. The type (byte or ushort) is determined by the SAMPDEPTH flag int the LGC record. Waveforms that never exceed a peak value of 255 are stored in a byte array, waveforms containing values larger than 255 are stored in an ushort array.

The waveform data is generated from the two data channels of the LMS-Q560 laser scanner, by scaling, quadratic interpolation, and re-sampling of the values to a common amplitude domain, and applying channel-specific timing and amplitude corrections. A surface return waveform may contain multiple segments (sample blocks) of valid (non-zero) sample values with no-data (zero) areas in between. The inserted empty (zero) samples space the waveform segments at the correct locations within the waveform.

The distance from one sample to the next (1 bin) is 0.149855 m (waveform sampling rate: 1 GHz).

LGC Geocoding Information

The LGC files contain geocoding information for each laser shot, consisting of the 3D position of the origin of the waveform vector (a ray along which the laser pulse travelled through space), the orientation of the waveform vector, indexing information to associate the waveform data in the LWF file with the geocoding information in the LGC file, and timing information.



LGC record format:

Name	Type	Size	Description
WFI	__i64	8 bytes	Offset of first sample of start pulse waveform in LWF file, in bytes from beginning of file
T	DOUBLE	8 bytes	GPS time tag of laser shot [GPS seconds of the week]
E0	DOUBLE	8 bytes	Easting of first sample of start pulse waveform [m]
N0	DOUBLE	8 bytes	Northing of first sample of start pulse waveform [m]
H0	FLOAT	4 bytes	Ellipsoidal height of first sample of start waveform [m]
dE	FLOAT	4 bytes	Easting component of measurement ray (waveform vector) in units of waveform samples [bins] (1 ns ~ 0.15 m)
dN	FLOAT	4 bytes	Northing component of measurement ray [m]
dH	FLOAT	4 bytes	Elevation component of measurement ray [m] (negative, measurement vector points towards the Earth's surface)
WFOFFSET	USHORT	2 bytes	Offset of first sample of surface return waveform in bins, measured from the first sample of the start pulse waveform
WFLEN	USHORT	2 bytes	Number of samples in surface return waveform
STRTWFLEN	USHORT	2 bytes	Number of samples in start pulse waveform
SAMPDEPTH	BYTE	1 byte	0 if waveform samples are 1 byte/sample, 1 if waveform samples are 2 bytes/sample
RES	BYTE	1 byte	reserved (always 0)

The location of any waveform sample in 3D space can be calculated as follows:

$$E_i = E0 + dE * (WFOFFSET + i)$$
$$N_i = N0 + dN * (WFOFFSET + i)$$
$$H_i = H0 + dH * (WFOFFSET + i)$$

with

i : i-th sample of the surface return waveform (first sample: i = 0)

$\{E_i, N_i, H_i\}$: geocoded position of surface return waveform sample i (WGS 84 ellipsoid, UTM projection, ellipsoidal height)