Australian Government
Geoscience Australia

Eddy Covariance at the Controlled CO_2 Release Facility, Ginninderra:

A tool for emission quantification?

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Acknowledgements

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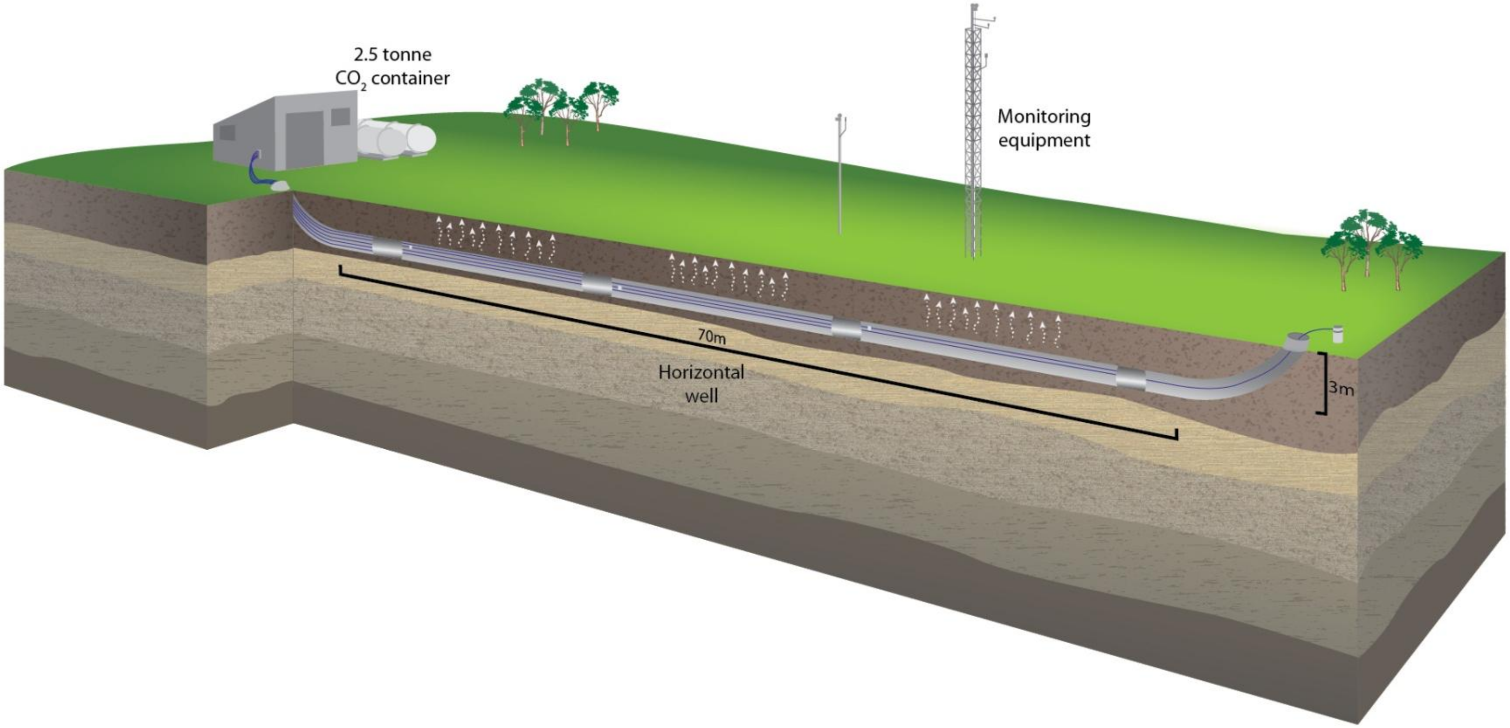
Controlled Release Facility - Ginninderra

Designed to simulate subsurface CO_2 (and CH_4) leaks: from CCS, volcanic gases, CSG wells, natural CH_4 seeps

Goal to develop methodology for detecting and quantifying leaks

In collaboration with the CO2CRC

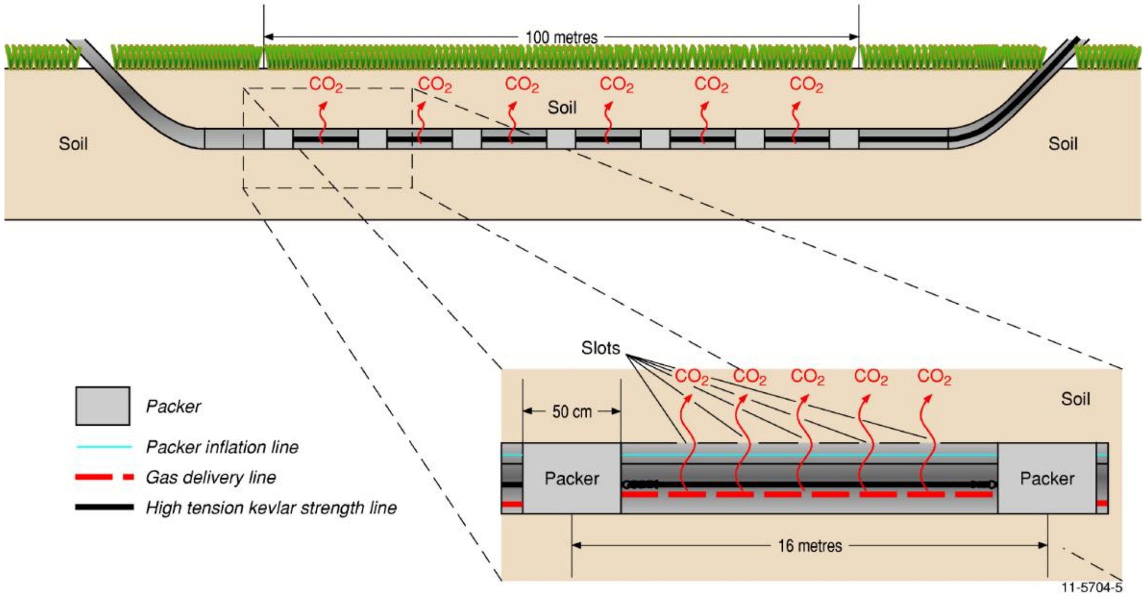


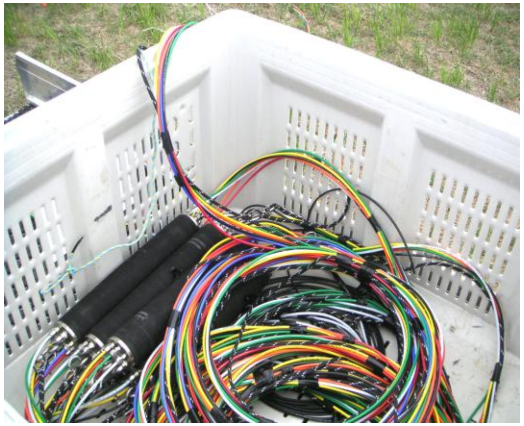
Horizontal well

125 mm ϕ HDPE pipe x 120 m long

Slotted every 0.5 m over 100 m, installed 2 m deep

Six release chambers





Site location and conditions

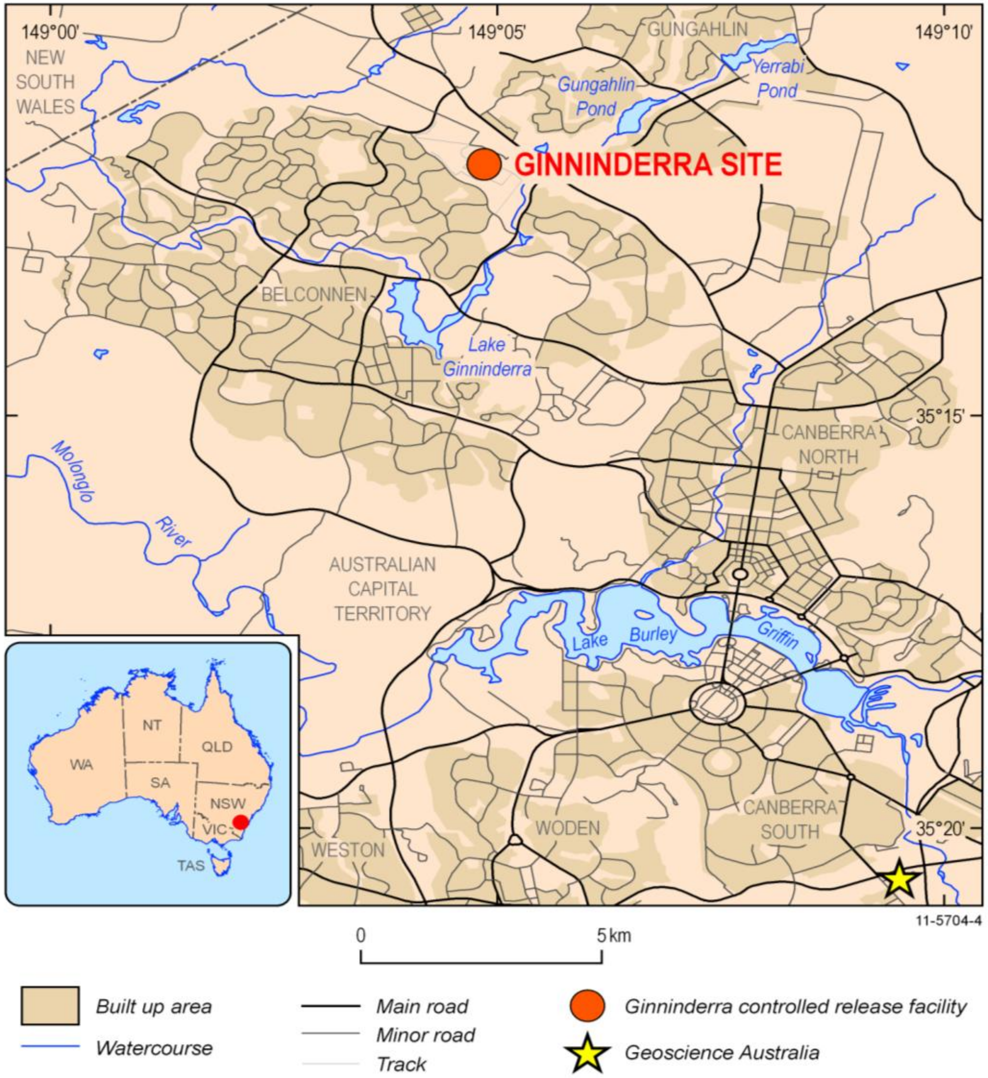
Located in north Canberra

Hosted on the CSIRO Ginninderra Experiment Station

A 1 ha field within 800 ha of cropping/grazing land

Seasonal, dry temperate climate

Cold in winter!!



First experiment

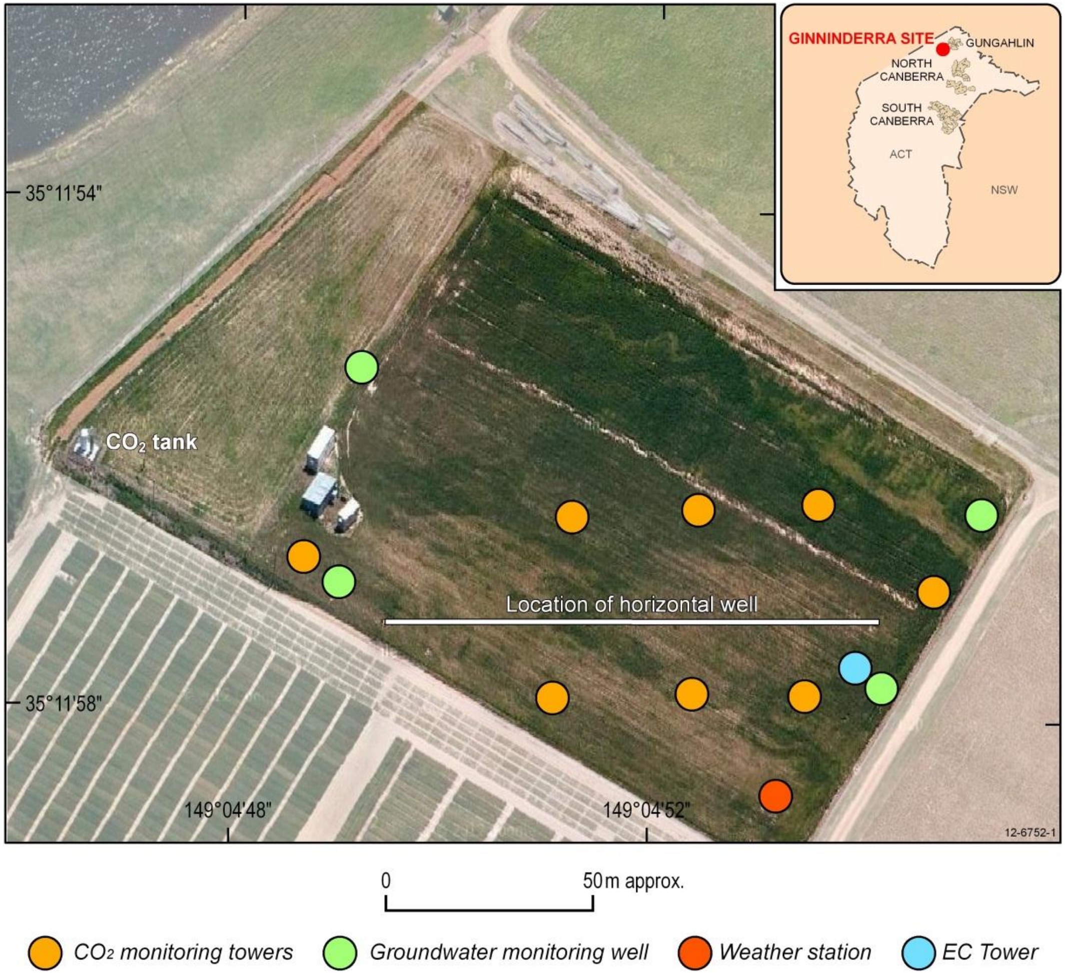
CO_2 released from:
27 March - 28 May 2012

Release rate: 100 kg/day

Released evenly across all sections

A range of techniques were trialled concurrently:

- Eddy covariance
- Soil-flux surveys
- Soil-gas wells
- EM31 and GPR
- Atmospheric tomography
- Kr tracer and sampling
- Groundwater monitoring



Crop conditions

The experiment was conducted over a slashed millet crop

Crop sown late in the season - which meant crop had very little opportunity to grow

Crop height ranged 0.2 - 0.6 m

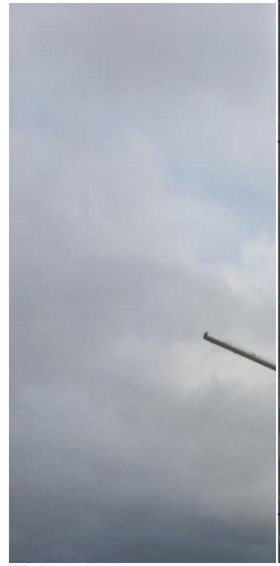
EC flux tower

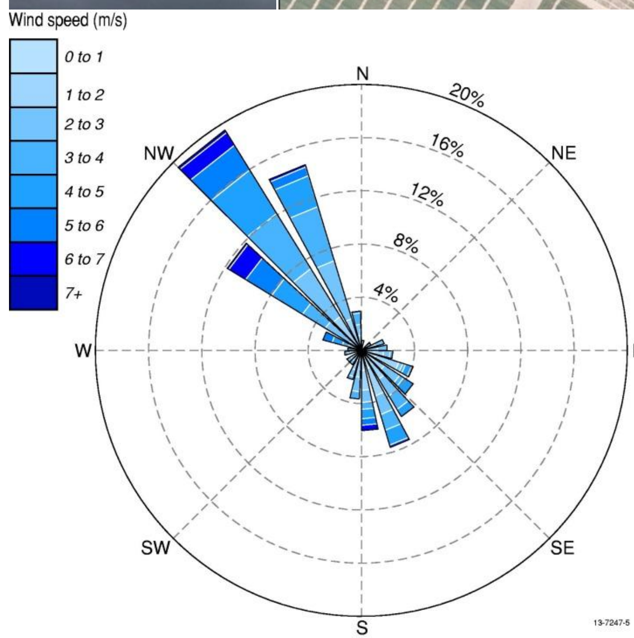
EC tower recorded from:
27 March – 13 June 2012

Dominant wind from NW

Tower positioned 15 m south of east end of pipe

Height of 2.8 m





EC flux tower instruments

Fast Data – 10 Hz

Slow Data – 15 min

Equipment	Variables Measured	Height (m)
Vaisala HMP50 RH & temperature	Relative humidity (RH), Air temperature (Ta)	1.5
CSI CSAT3 sonic anemometer	Wind direction (Wd), 3D wind components (Ux, Uy, Uz), Wind speed (Ws), Virtual air temperature (Tv)	2.8
Li-Cor 7500 IRGA	Absolute humidity (Ah), CO_2 concentration (Cc), Air pressure (ps)	2.8
Kipp and Zonen CNR4 radiometer	Upwelling- and downwelling-longwave radiation (Flu and Fld), Upwelling- and downwelling-solar radiation (Fsu and Fsd)	2.7
Gill WindSonic 2D sonic anemometer	Backup Wind direction and Wind speed	2.9

Data Processing

Data was processed up to L3 using OzFlux v2.1

No direct QC checks on CO_2 conc., σ of CO_2 conc. and Fc

•This could remove anomalous high measurements associated with the leak

L3 data was filtered to exclude time periods with:

•Missing Fc values

•Less reliable measurements associated with night-time and low turbulent conditions:

- Fsd > 50 W/m^2
- u* > 0.11 m/s

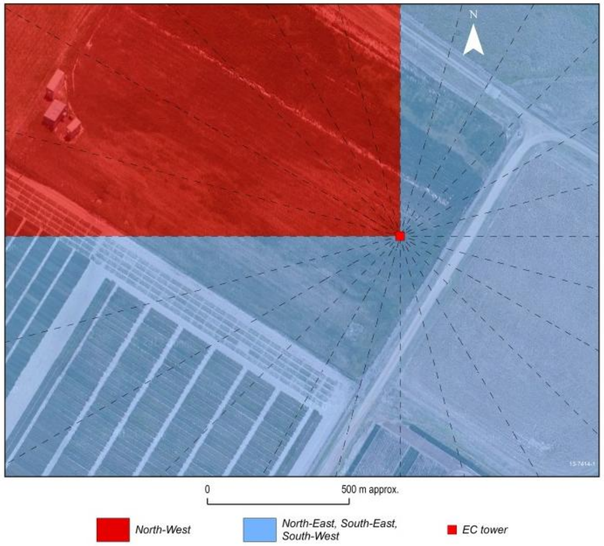
Resulting data was grouped by wind direction into 24 15° bins

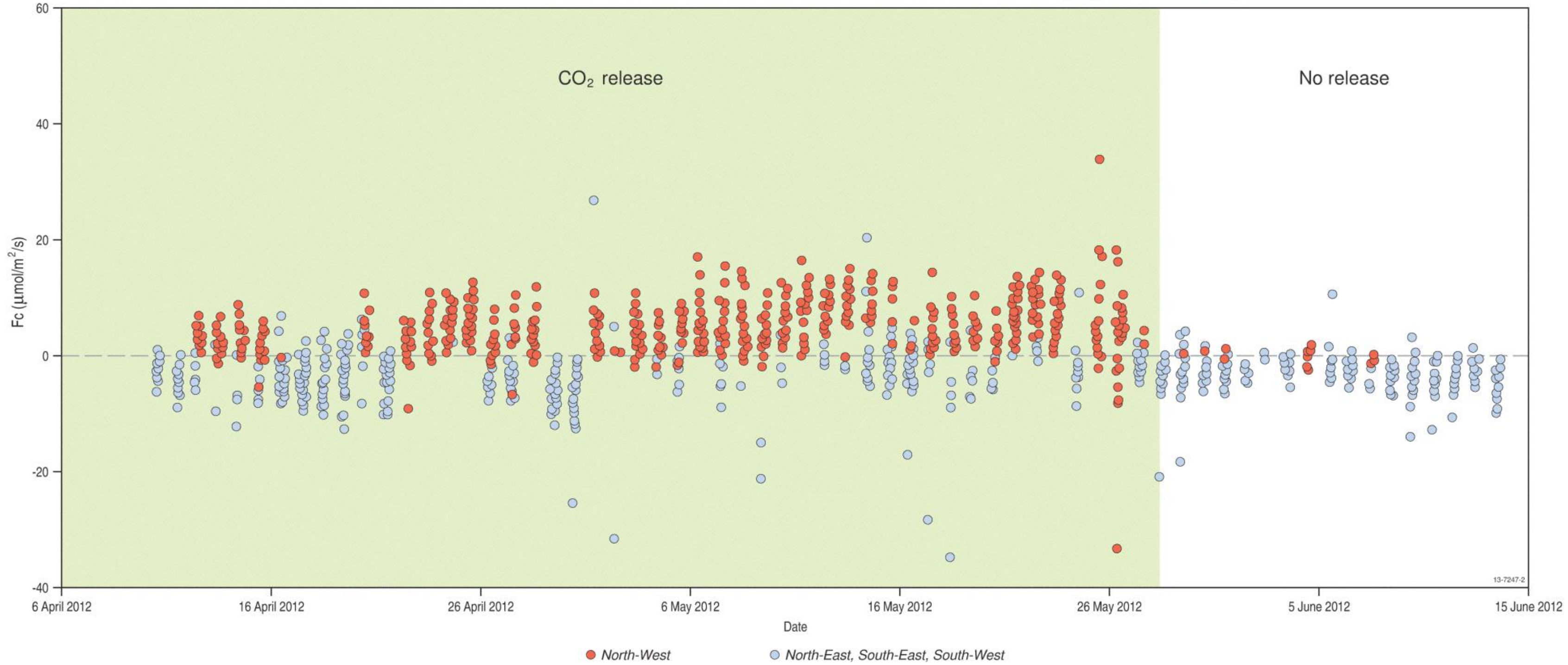
Leak Detection

Can the tower detect the direction of the leak?...Yes

Elevated Fc seen to NW

Drops back to baseline after release





Leak Detection

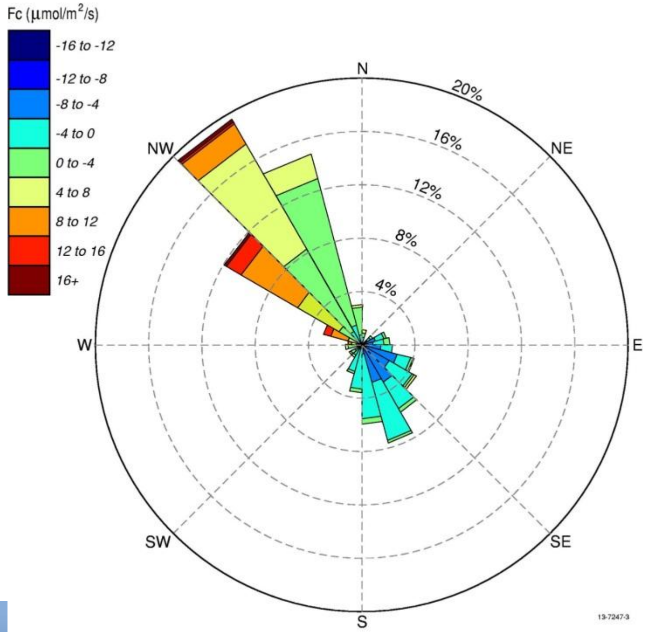
A strong CO_2 leak signal was found within the NW quadrant between 285-315°

However, crop health/type is a confounding variable

- Out of season
- Poor growth & colour

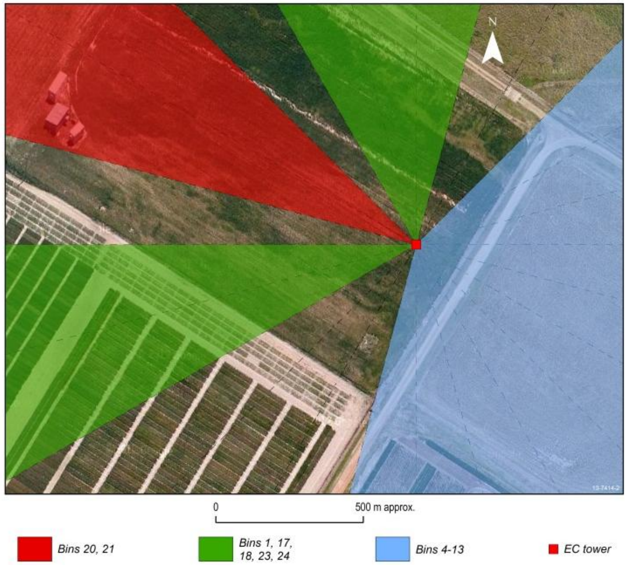
Adjacent fields more photosynthetically active

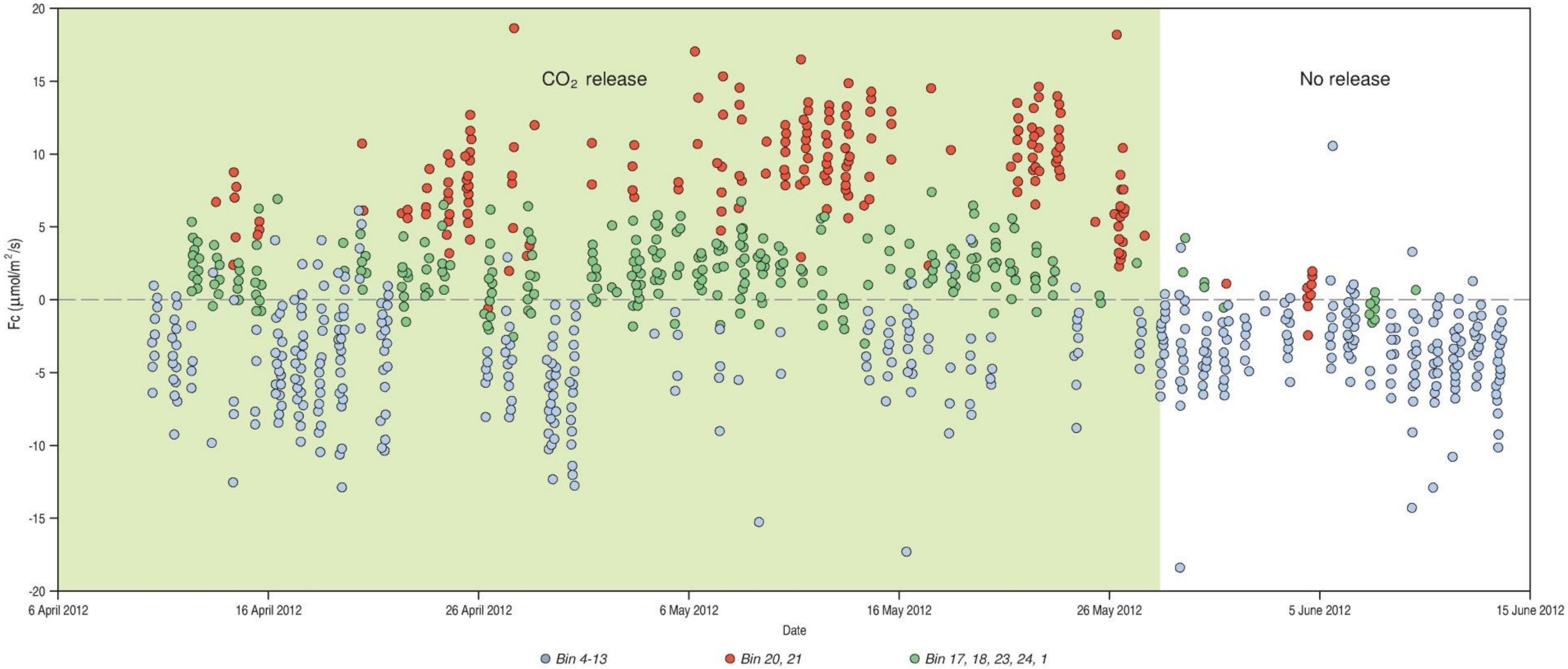
- Greater F_C drawdown



Leak Detection

When split into defined bins, the differences between the leak, the field site, and the surrounding fields become more apparent

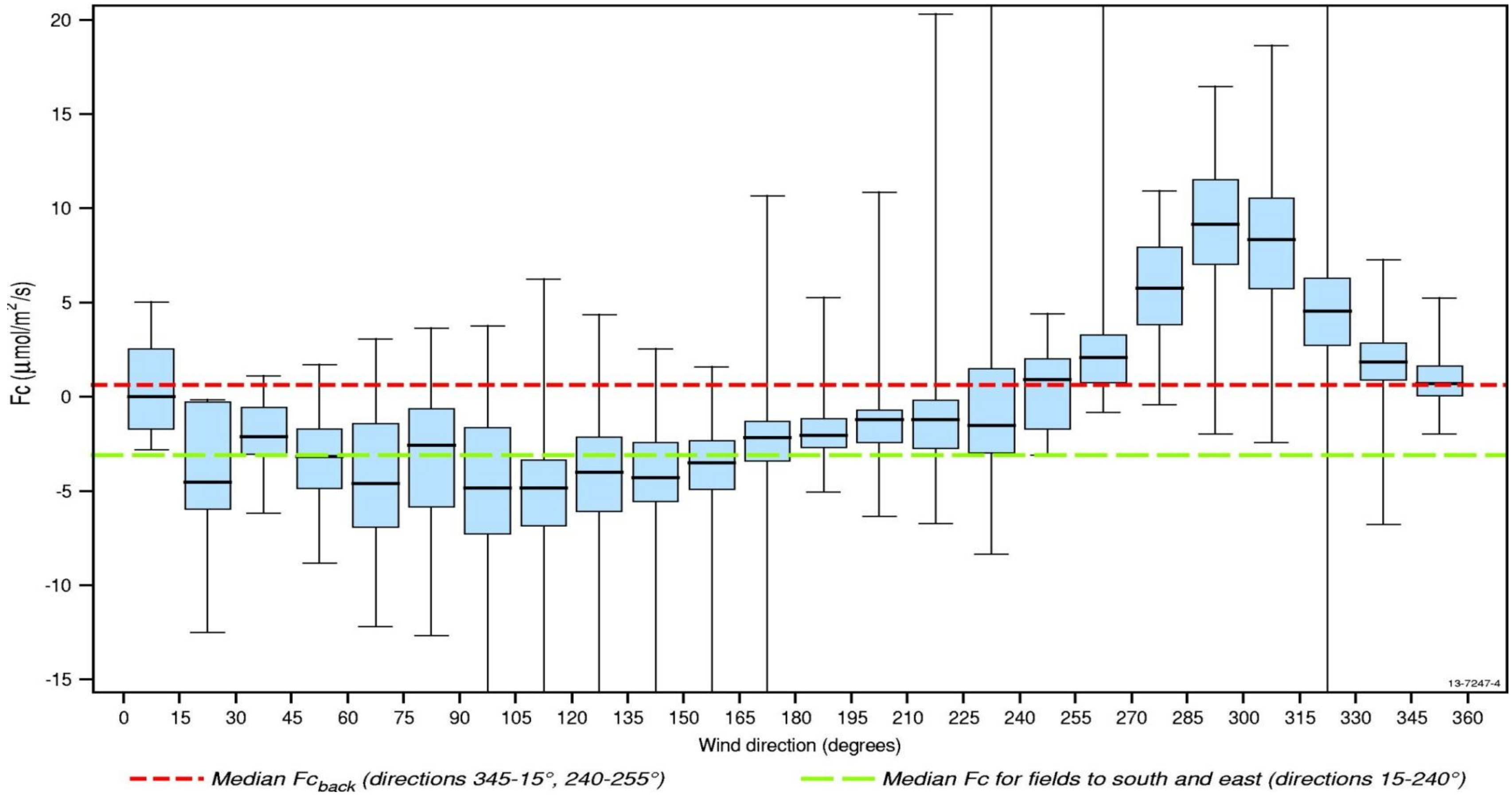




Leak Detection

Median Fc_{back} for the field site = 0.632 µmol/m²/s

Median Fc_{back} for surrounding fields = -3.356 µmol/m²/s



Leak Quantification

The goal is a stand-alone method that could reliably quantify emissions with only a rough idea of a leak's location, and is not too expensive for industry uptake

Very little research into using EC for leak quantification

- ZERT controlled release facility in Montana achieved 7% quantification of leak (Lewicki et al. 2009)

The problem of using EC in leak quantification is two-fold:

- To convert fluxes to a leakage rate, we need to constrain the flux signal to a given area
- We need to separate Fc_{leak} from Fc_{back}

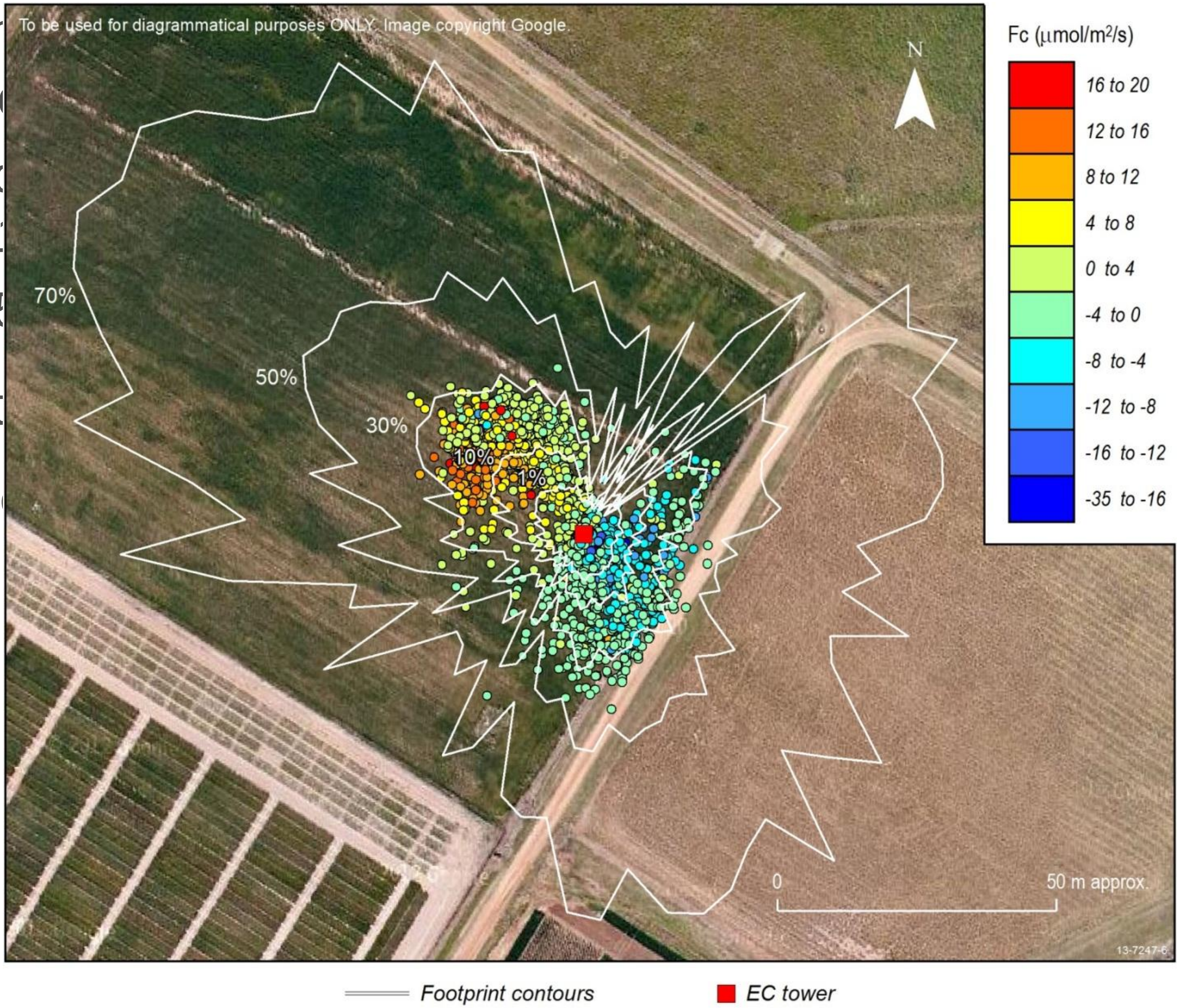
Leak Quantification

To define an area, th
cumulative percentil

- NN% footprint c
  Meixner's (200
  - For each 15

Mean NN% footprint

- In ArcGIS isopl



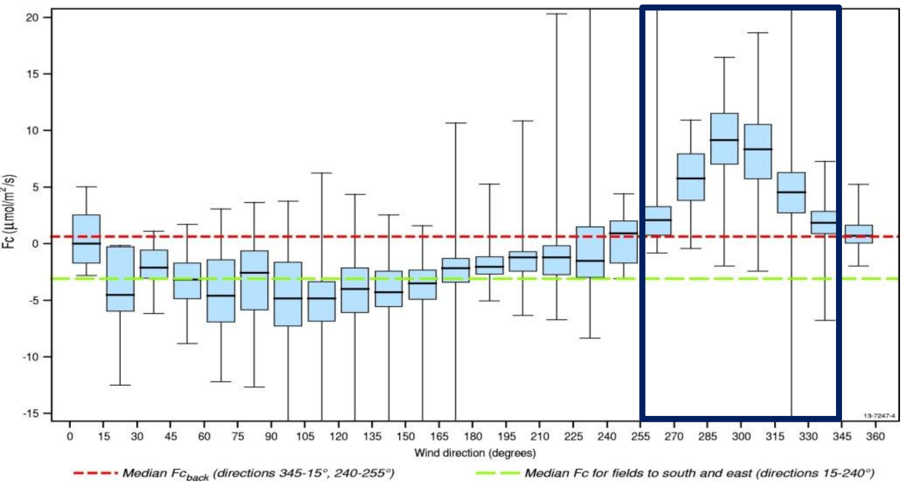
Leak Quantification

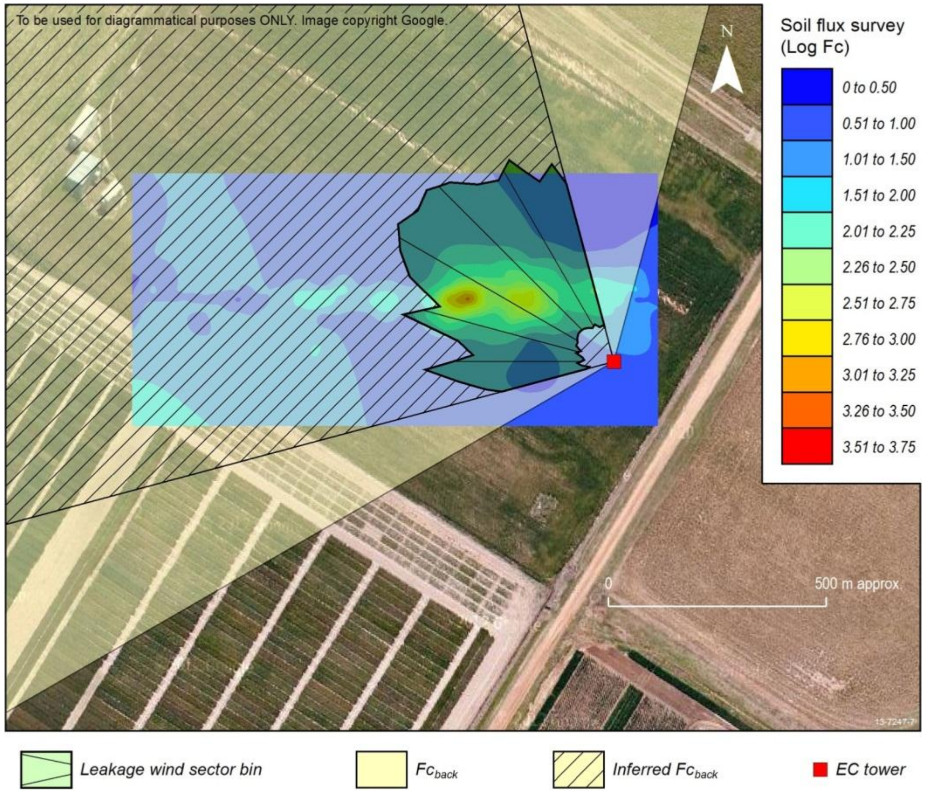
The area contributing to Fc_{leak} was defined as the minimum distance which fully enclosed the leak, for directions with elevated Fc

- Unfortunately, this required a priori knowledge of the leak's distribution
- Determined by soil flux survey

The Fc_{leak} area was identified as:

- The 50% less the 1% footprint
- From 255-345°





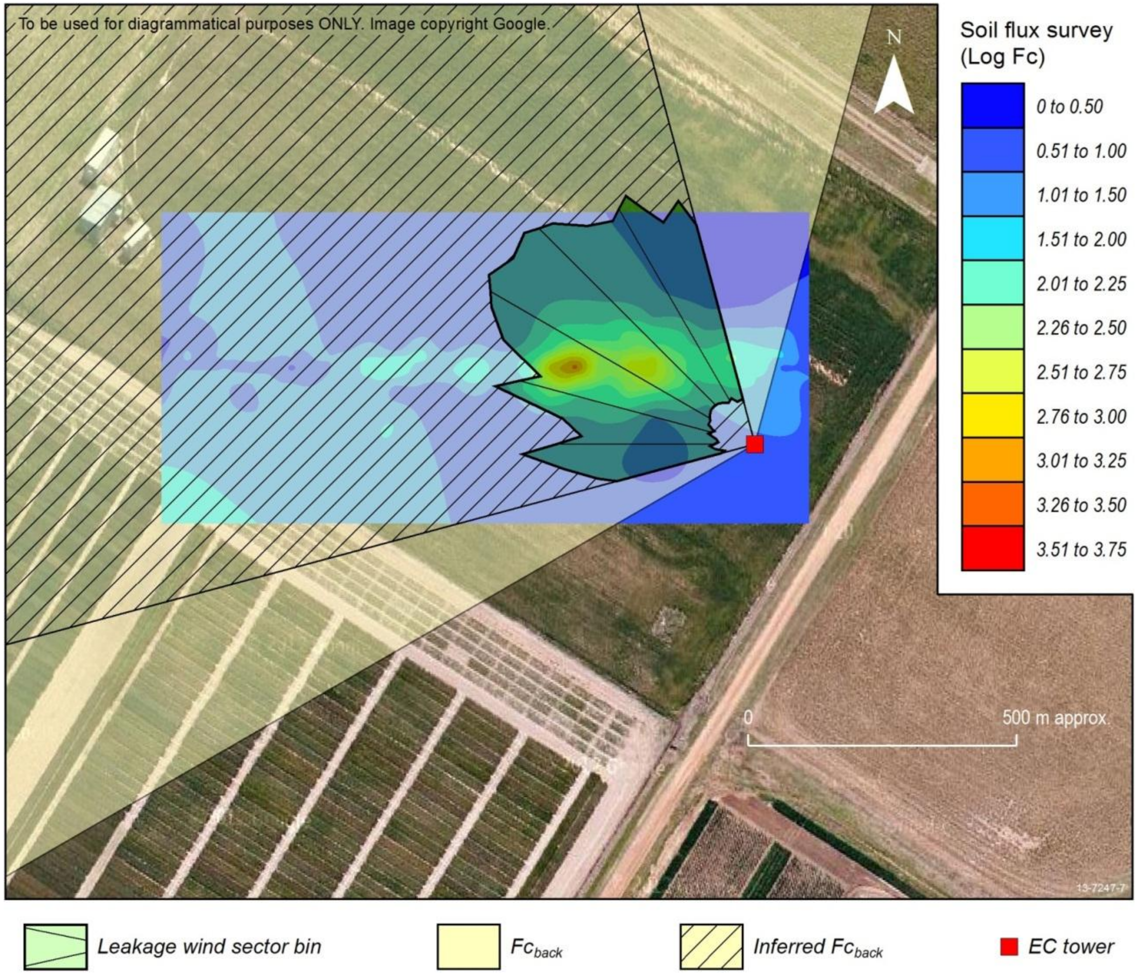
Leak Quantification

A new flux (Fc_{pert}), representative of only the leakage area for each bin (A_{bin}) was calculated:

$$Fc_{tot} = Fc_{pert} * 0.49 + Fc_{back} * 0.51$$

Fc_{tot} = median total CO_2 flux

Fc_{back} = median background CO_2 flux from 240-255° & 345-15°



Assumptions:

- Fc_{leak} was sourced entirely from the area between the mean 50% & 1% footprint isopleths
- The dashed area had a background flux signal (Fc_{back})

Leak Quantification

A leakage rate was then calculated:

$$CO_2\ Leakage\ rate = \Sigma A_{bin} * (Fc_{pert} - Fc_{back})$$

Assumption:

- Each m^2 contributes equally to measured flux signal

Using this method, calculated the leakage rate as 79 kg/day

However, this rate is strongly dependent on the assumptions and decisions made:

		Median Fc_{back} used in calculations	
		240-255° & 345-15° (0.632 μmol/m²/s)	**345-255° (-2.702 μmol/m²/s)**
%NN isopleth used	**50%**	79 kg/day	127 kg/day
	70%	190 kg/day	307 kg/day

Summary

- Novel methodology for EC quantification is in development
- Significant improvement seen in leak quantification (79%) against a known CO_2 release
- Present limitations:
  - Requires leak distribution to be known
  - Doesn't account for non-linear source contributions to flux with distance
  - Fc_{back} is critical variable, yet is based on much less data because of infrequent NE-SW winds
  - Technique reliant on good footprint model.
- Further work is underway to refine the method, test its assumptions and validate against other methods for quantifying CO_2 leaks

Summary

- Another release will be running in August 2013.
  - The field will be split N-S between wheat (E) and snow peas (W)
  - We have access to two flux towers
  - Suggestions for optimal tower placement, instrument height, supporting variables etc. are welcome

Questions and Discussion

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Soil properties

30cm deep topsoil layer (sandy loam)

Sandy loams and clays with occasional coarse gravel

The carbonate content

< 0.3%

predominantly quartz with K and Na feldspars, illite/muscovite, clays and trace amounts of ankerite

Sample Depth (cm)	Soil description	<63µm clay/silt %	63-125µm very fine sand %	125-250µm fine sand %	250-500µm medium sand %	500-1000µm coarse sand %	1000-2000µm very coarse sand %	>2000µm gravel %	CaCO3 %	Total Moisture %	Surface area (m²/g)	Laser particle size d(0.5) µm
0 - 30	Fine brown sandy loam	64	6	7	9	7	4	3	0.0	7.8%	12.1	22.4
30 - 50	Light brown fine sandy loam with occasional coarse sand	49	6	6	9	11	7	12	0.1	8.6%	12.1	21.7
50-70	Light brown fine sandy loam with occasional coarse sand/gravel	35	4	4	5	11	15	26	0.2	7.5%	14.2	44.5
70-85	Mottled orange brown/light brown fine sandy clay	61	7	5	5	6	7	8	0.3	14.1%	22.0	23.3
100-120	Mottled orangey brown fine sandy clay	49	8	11	12	11	7	2	0.3	14.5%	27.4	25.6
150 - 160	Mottled orange-brown, loamy clay	44	7	7	11	14	11	6	0.3	13.3%	35.3	27.5
190-200	Mottled orange-brown, clay fine sand minor coarse sand/gravel	32	6	9	14	17	14	9	0.3	10.8%	8.9	135.4