USING A SOIL GAS SURVEY TO DETERMINE METHANE FLUX AROUND A PLUGGED GAS EXPLORATION WELL

SOIL EMISSION

+

WATER EMISSION

=

TOTAL EMISSION

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BACKGROUND

- During drilling a blow out occured and it was brought under control with drilling relief wells and pumping seawater in
- In 2015 gas was observed to bubble from the abandoned plugged gas exploration well

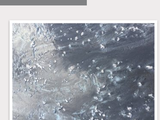
Based on field observations, water was also flowing from the subsurface in the vicinity of the standpipe

AREAS OF EMISSION

Was it only from the areas where bubbling is observed in the water?

Does gas emission from the soil contribute?

- Safety personnel reported bubbling from the surrounding soil during rainfall events
- Site visit determined bubbling from wet soil away from the stand pipe



SOIL VAPOUR SURVEY

The project team decided on a soil vapour survey to determine the area of possible impact

Using a predefined grid, a probe was inserted into the soil and the soil gas was extracted for analyses in the field

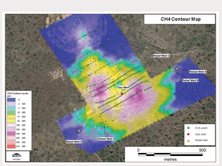
Ecoprobe 5® instrument provides in field:

TPH | Methane | VOC | CO2 | Oxygen

DATA PROCESSING

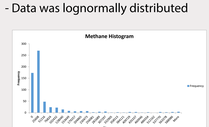
- Daily capturing of field data in onsite database
- Analyses indicated that the soil vapour survey had to be extended
- This allowed immediate decision making increased data integrity and conclusions
- Project spend optimized by adapting field schedule and scope and preventing remobilization

INITIAL SCOPE TOO LIMITED

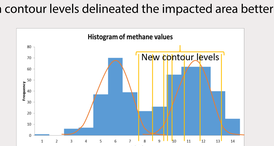


METHANE RESULTS

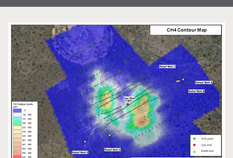
- Little to no methane found in ambient air
- Widespread methane was found in the subsurface
- The range of the values was large:
  0 – 590,000 ppm
- Data was lognormally distributed



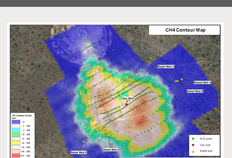
- Contouring with linear intervals masked subtle changes in data and only highest areas showed up visually
- Transforming data yielded a bi-modal normal distribution
- Custom contour levels delineated the impacted area better



LINEAR CONTOUR LEVEL SCALE



CUSTOM CONTOUR LEVEL SCALE



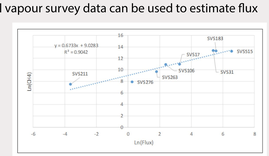
FLUX MEASUREMENTS

- Using a sweeping nitrogen gas to flush emissions from the flux chamber

$$EF = \frac{16}{24.05} * \frac{1}{A} * \frac{C.Q_s}{1-C}$$

EF - Emission Flux
C - Measured methane concentration
Q_s - Sweeping gas flow rate
A - Area of the flux chamber

- Direct relationship between ln (CH4) and ln (Flux)
- Soil vapour survey data can be used to estimate flux

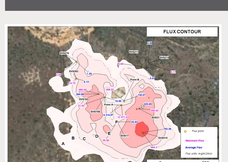


FLUX MEASUREMENTS

- The results from the soil vapour survey were used to identify positions for flux measurements
- On the soil the Scentroid S450 flux chamber was buried and wetted on the outside to seal it
- Gas samples were collected from the flux chamber in Isotech® bags

- Water methane flux was measured in areas where visible bubbling was observed
- A floating Scentroid S450 flux chamber and TR8 Odotracker® was used to determine the flux
- Gas samples from the water were collected in IsoJar® containers

SOIL METHANE FLUX



Region	Contour level	Area (m2)	Flux midpoint (mg/m2/min)	Average Flux (mg/day)
A	1700	93600	0.352	4.74E+07
B	10000	51493	2.539	1.05E+08
C	20000	70992	7.245	7.41E+08
D	50000	84260	30.733	3.73E+09
E	140000	57200	137.906	1.13E+10
F	>277500	4764	411.899	2.84E+09
			Total	**1.88E+10**

1.88E+10 mg/day

WATER METHANE FLUX

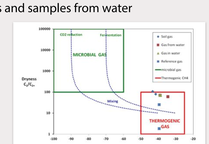
- Flux rates vary over time with occasional bursts
- Position 2 at some distance from the standpipe had two orders of magnitude higher emissions than Position 1 at the standpipe
- Visible bubbling from the water had three orders of magnitude less emission than from the soil

Region	Radius (m)	Area (m2)	Flux midpoint (mg/m2/min)	Average Flux (mg/day)
A	2	12.57	4214.87	7.87E+07
B	1	3.14	750.07	3.88E+06
			Total	7.87E+07

7.87E+07 mg/day

ORIGIN OF GAS

- Composition mostly methane (>80%)
- Composition between soil gas samples and samples from water bubbling is isotopically similar



Isotope analyses confirm the gas source to be thermogenic

ORIGIN OF WATER

- The water chemistry of the community boreholes is a low salinity (EC <160 mS/m) water typical of freshly recharged, shallow groundwater
- The stable isotope contents of the community boreholes are typical of a local rainfall type
- The stable isotope content (δ18O and δD) of the gas well flow water are typical of a local rainfall type
- The low radiocarbon (14C) content of 10.6 pmc in the gas water flow is far below that of present-dayseawater (110 pmc) and suggests that any recent seawater contribution to the gas water flow is less than 10%

Isotope analyses confirm the water source to be old rain water

CONCLUSIONS

- Ambient measurements were not able to detect methane or indicate flux from soil
- Soil gas survey found the large footprint of emission
- Flux chamber measurements directly proportional to soil vapour survey values (both log-normal distributions)
- Emission from soil is three orders of magnitude higher than from water where bubbling is observed
- Isotopic analyses correlated soil gas and bubbling gas
- Gas is of thermogenic origin indicating leaking from gas reservoir at depth
- Water is old rain water and not sea water