Mitigation of an Orphan Well Leaking Methane in a Residential Area

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October 15, 2021

Orphan Well Association

GOLDER
MEMBER OF WSP

01 Gas Migration

02 Well Location & History

03 Investigation

04 Gas Extraction

05 Downhole Intervention

06 Next Steps

General Overview

FUGITIVE GASES AND ABANDONED WELLS IN THE NEWS

Abandoned Texas oil wells seen as "ticking time bombs" of contamination

Texas is among several states grappling with a surge of abandoned drilling sites and dwindling funds to clean them up.

BY JIM MALEWITZ DEC. 21, 2016 12 PM

REPUBLISH

REGULATORY OIL & GAS MARKETS & INVESTMENT DRILLING & COMPLETIONS

B.C. faces possible $90 million tab for one company's orphan wells

By Glacier Media | Feb. 27, 2019, 7:15 a.m. | Share:

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Group cleaning up old oil wells says Alberta government rules inadequate

BOB WEBER Updated: January 18, 2020

PENNSYLVANIA

Pennsylvania orders gas well plugged in fight over methane

AP ASSOCIATED PRESS | Monday, January 13, 2020 7:41 p.m.

Home / News / Energy & Environment / Climate change / Abandoned wells pump thousands of tonnes of 'fugitive' emissions into North Sea

Abandoned wells pump thousands of tonnes of 'fugitive' emissions into North Sea

By Sam Morgan | EURACTIV.com Sep 5, 2017

The study was limited to abandoned offshore wells but so-called fugitive emissions could also be a problem for onshore and working offshore wells. [Shutterstock]

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Business · CBC Investigates

Alberta's looming multibillion-dollar orphan wells problem prompts auditor general probe

There are 3,406 deserted oil and gas wells in the province, with growing concern about more joining the list

Inayat Singh · CBC News · Posted: Jan 23, 2020 4:00 AM ET | Last Updated: January 23

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General Overview

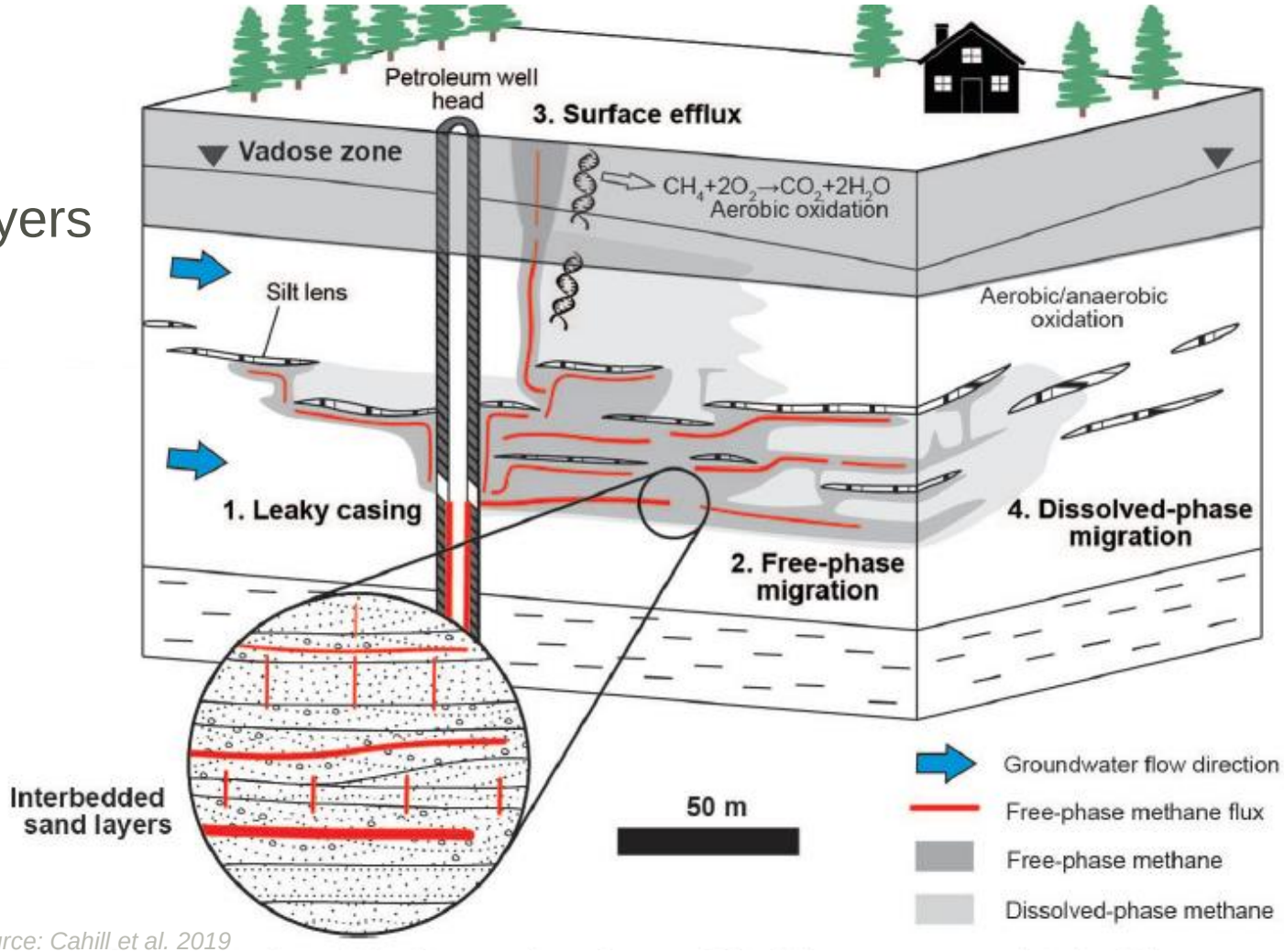
CONCEPTUAL MODEL: GAS MIGRATION AND FUGITIVE GAS

- Vertical gas migration and lateral migration below low permeability layers
- Potential impacts to:

  Groundwater (drinking water quality)

  Soil gas (explosive risk)

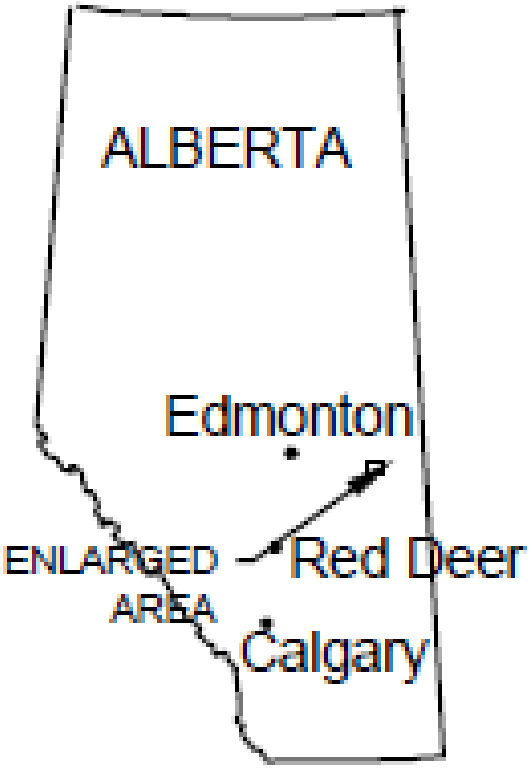
  Atmospheric air (explosive risk, greenhouse gas)



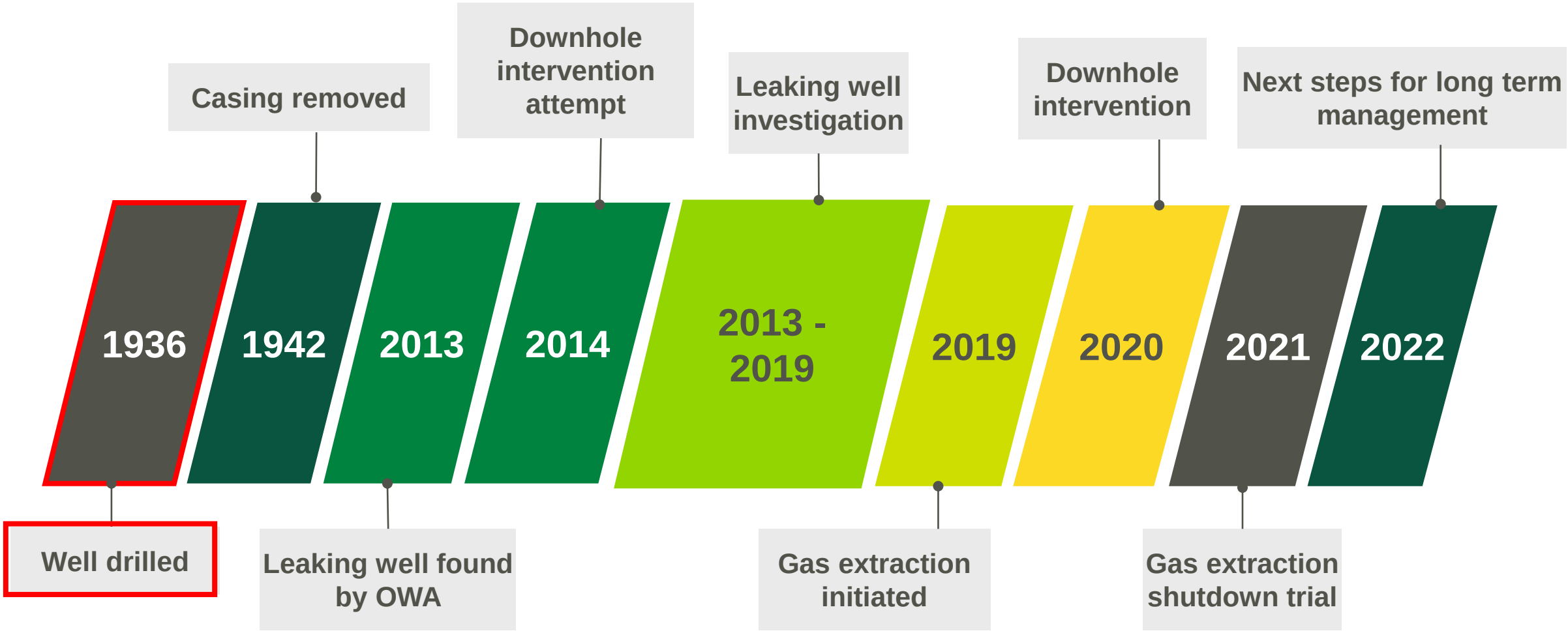
Source: Cahill et al. 2019

Well Location

TENWELL NO. 1

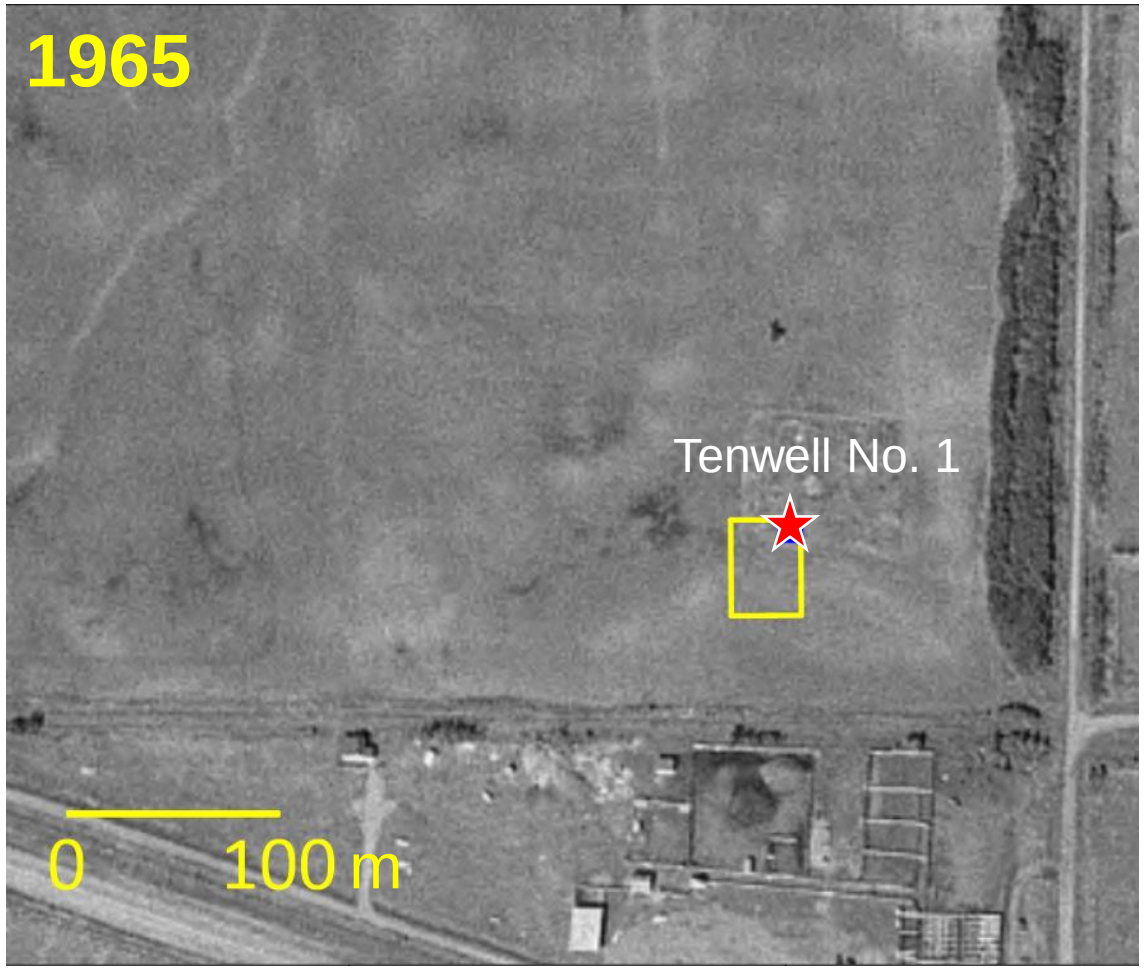


Tenwell No.1 Well Timeline



Well Location – Site Development

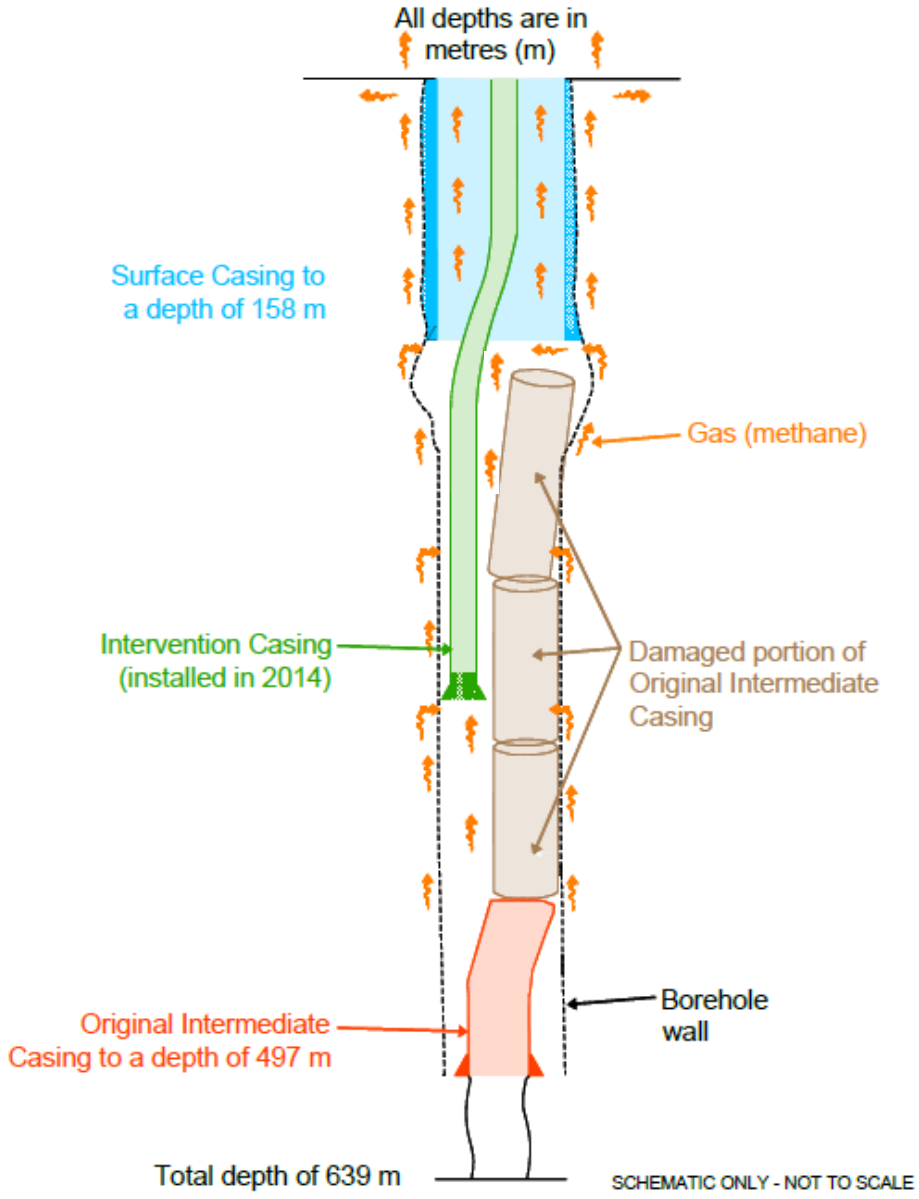
AGRICULTURAL LAND TO RESIDENTIAL SUBDIVISION



Well History

TENWELL NO. 1

- Drilled in 1935-1936 to a depth of 639 m
- Surface casing to 158 m, intermediate casing to 497 m, open hole to 639 m. Annulus not fully cemented.
- In 1942, intermediate casing partially removed, wellbore damaged
- OWA found the leaking well in 2013
- OWA attempted to seal the well in 2014



Well History

STRATIGRAPHY

Stratigraphic Unit			From (m)	To (m)	Lithology
Quaternary Till			0	54	Till
Quaternary Sand			54	56	Sand
Belly River Group			56	59	Siltstone
Lea Park Formation			59	265	Shale
Colorado Group	Niobrara Formation	First White Speckled Shale	265	336	Carbonaceous Shale
		Medicine Hat	336	352	Shale
		Verger	352	357	Shale
	Carlile Formation		357	371	Shale
	Second White Speckled Shale		371	390	Carbonaceous Shale, Sandy Sh
	Belle Fourche		390	413	Shale
	Fish Scales		-	-	Shale
	Westgate		413	457	Shale
	Viking		457	473	Sandy Sh and Ss
	Joli Fou		473	506	Shale
Mannville Group			506	639	Sandstone

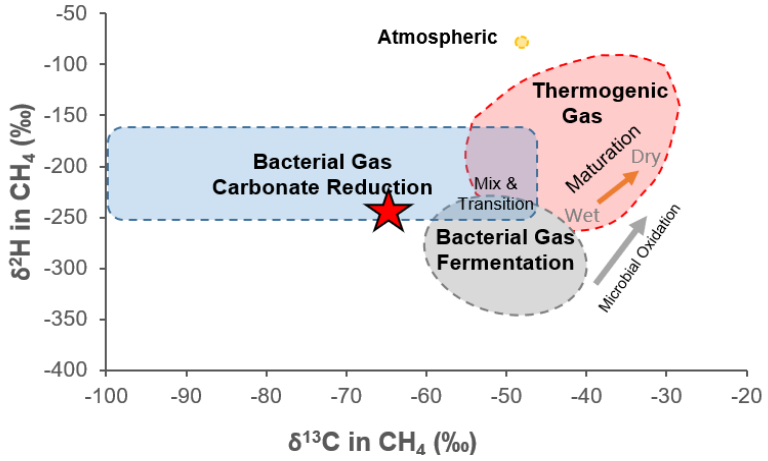
Groundwater Aquifer
(Neighborhood uses municipal water supply)

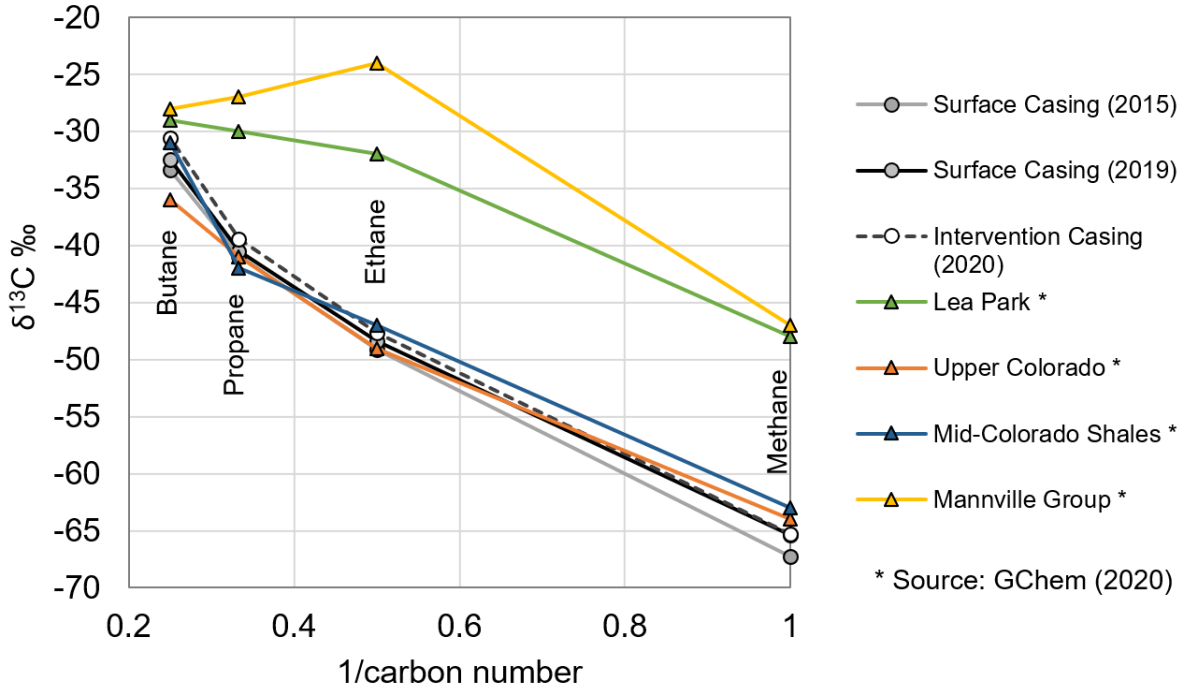
★ Potential Gas Source, based on regional production records

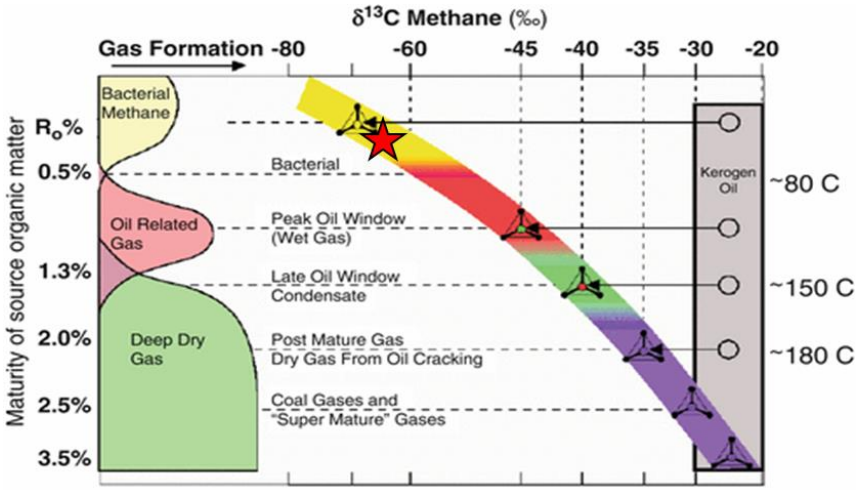
Original Oil and Gas Target Production Zone
(Heavy oil reservoirs)

Well History

GAS LEAK FORENSICS: ISOTOPES







- Stable isotopes of C and H in methane suggest a bacterial source, using traditional methods
- But isotopes of C in ethane and propane indicate low-maturity thermal gas (e.g., Rowe and Muehlanbachs 1999)
- Isotopic fingerprints from regional drilling indicate the source of the gas leaking from Tenwell No. 1 is likely 300 to 390 m deep, in the Upper to Middle Colorado Group

Well History

SITE PHOTOGRAPHS – 2013 LOCATING AND 2014 SURFACE CASING VENT

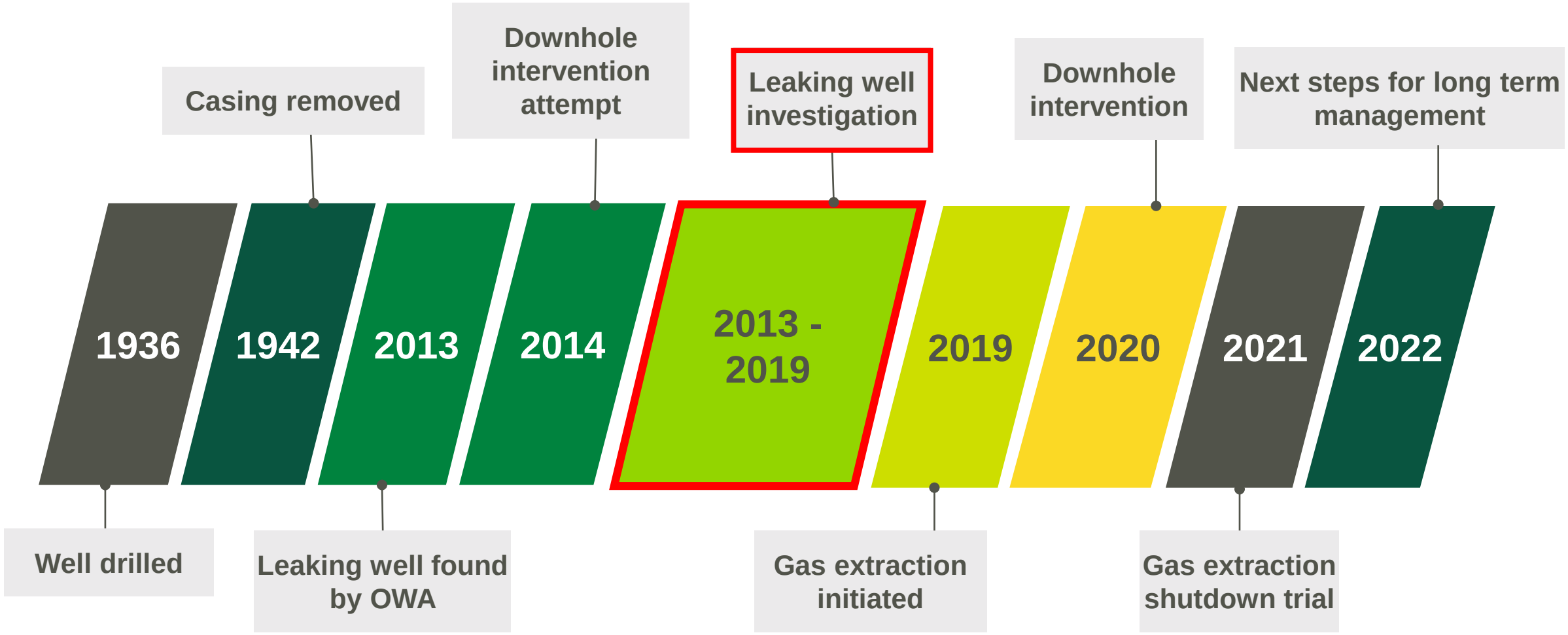
Well location with surface casing below grade and apparently stressed vegetation when first found by the OWA in 2013

Intervention casing, wellhead, and surface casing vent (SCV) installed by the OWA in 2014

Well History

SITE PHOTOGRAPHS – 2014 DOWNHOLE INTERVENTION

Tenwell No.1 Well Timeline

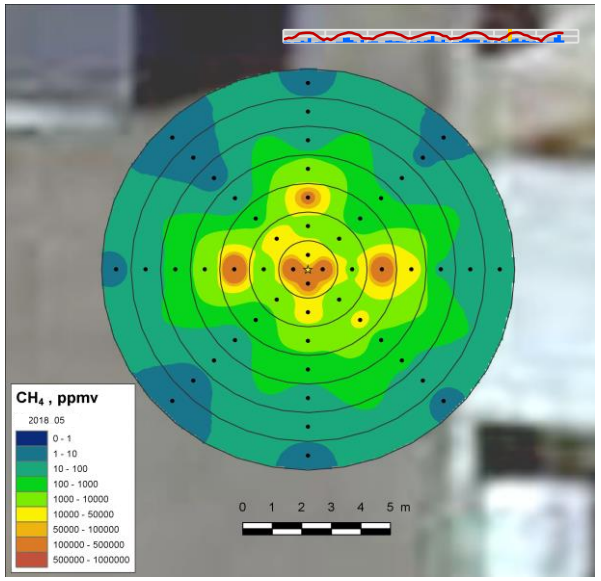


Site Investigation

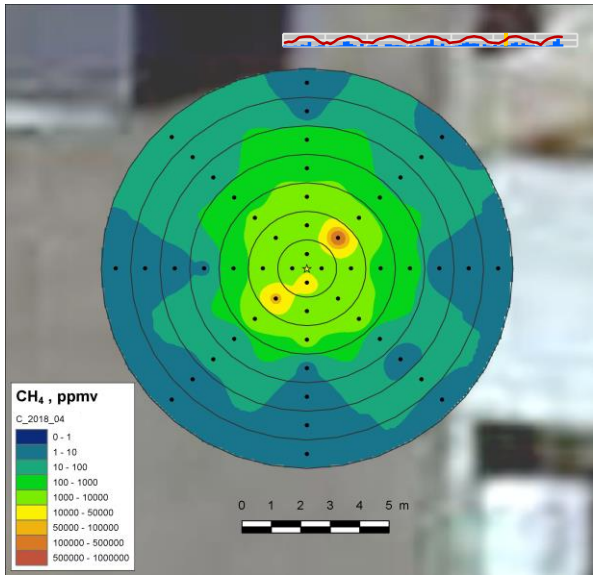
SURFACE GAS CONCENTRATION MEASUREMENTS

- Measure methane concentrations in shallow soil with handheld meter
- Measurements in radial pattern around well
- Efficient method, done monthly 2014-2019
- Methane highly variable in concentration and location (e.g., Forde et al. 2019 study of 15 well pads in BC)
- Assessed data for 50 months of surface gas measurements around well: no correlation with ***temperature, barometric pressure, precipitation, or season***

APRIL 2018

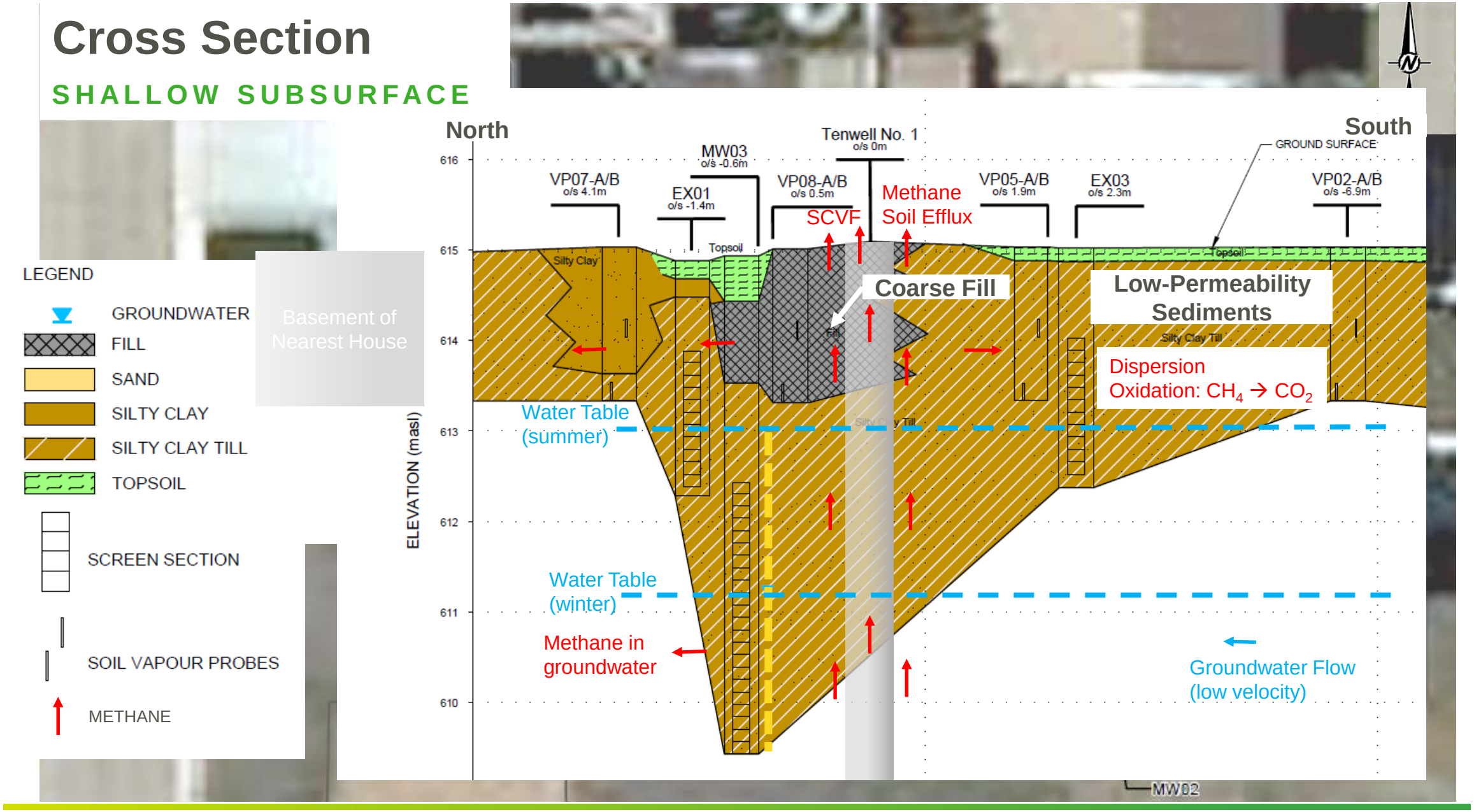


MAY 2018



Cross Section

SHALLOW SUBSURFACE



Site Investigation

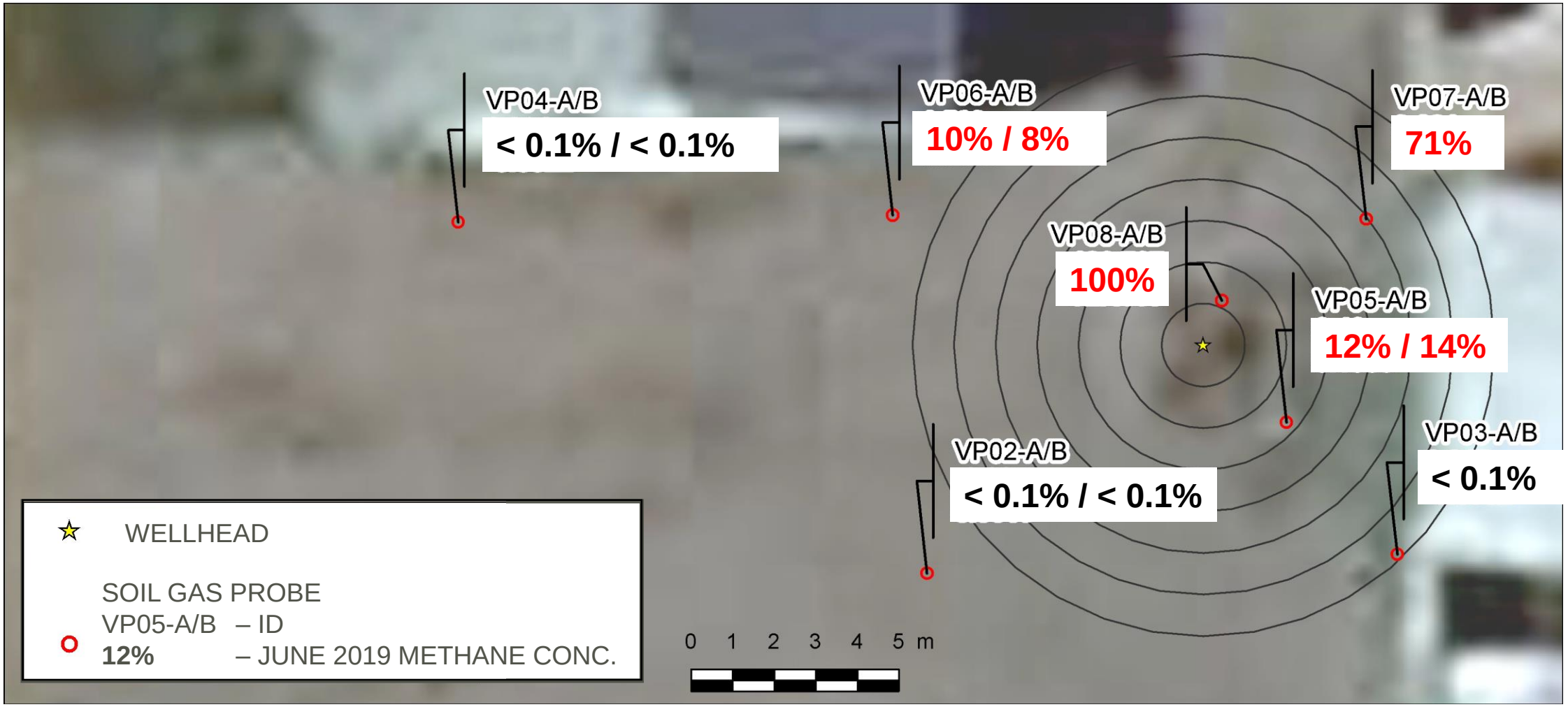
SOIL GAS CONCENTRATIONS

- 8 multi-depth soil gas probes around well
  - Within 1 m of well
  - Background location 35 m from well
- Soil gas probes leak tested and purged
- Field and laboratory measurements of fixed gas concentrations

Soil Gas Methane Concentrations

JUNE 2019

Units: percent by volume



Site Investigation

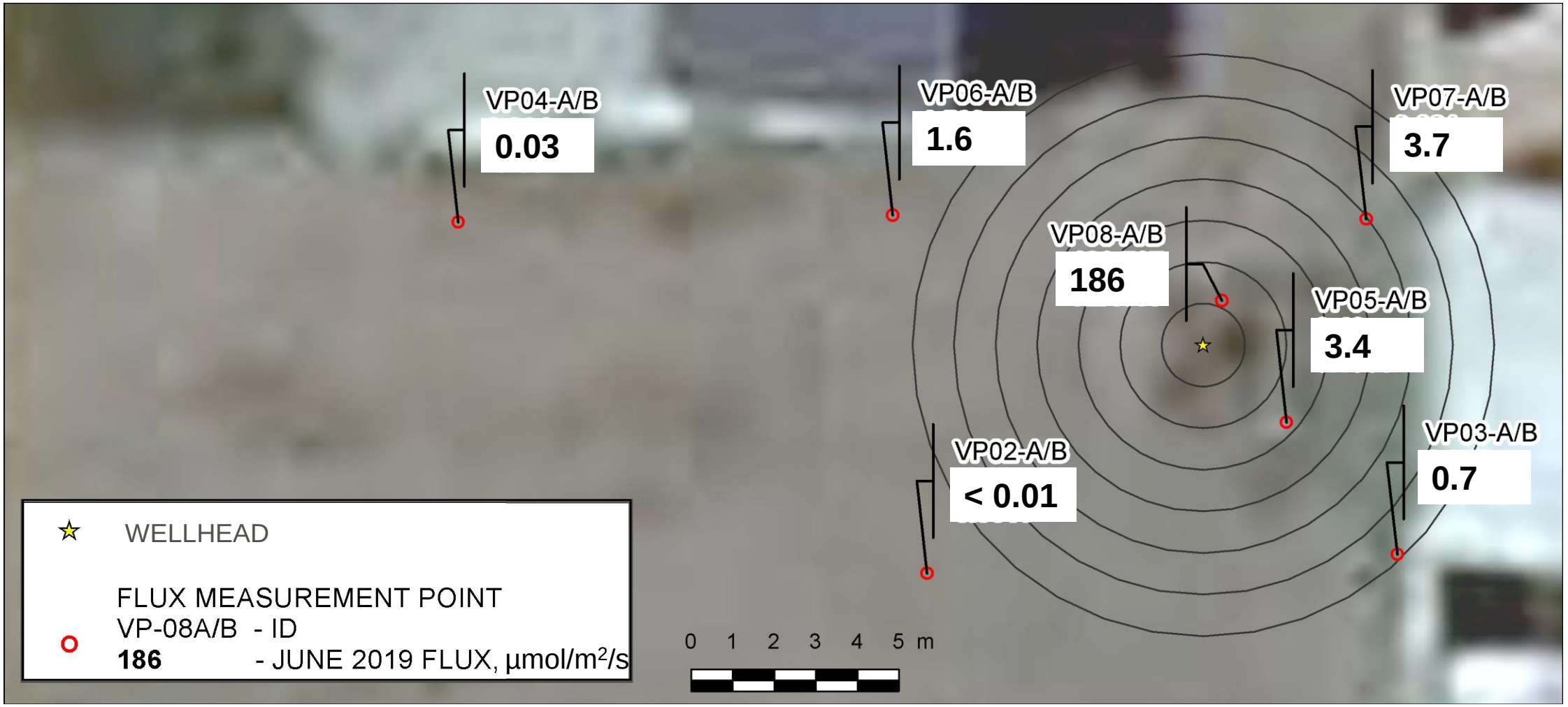
SOIL GAS EFFLUX MEASUREMENTS

- LI-COR soil gas flux chamber with Los Gatos Ultraportable Greenhouse Gas Analyzer
- Soil gas efflux measurements made at surface in radial pattern around well head
- Estimates methane flux at surface
- Methane flux range for study of 15 well pads in BC: **0.017 to 180 µmol/m²/s** (Forde et al. 2019)
- Methane flux CFB Borden controlled gas release: **up to 220 µmol/m²/s** (Cahill et al. 2017)
- Background for agricultural soils: <0.01 µmol/m²/s, wetlands up to 0.1 µmol/m²/s

Soil Gas Efflux Measurements

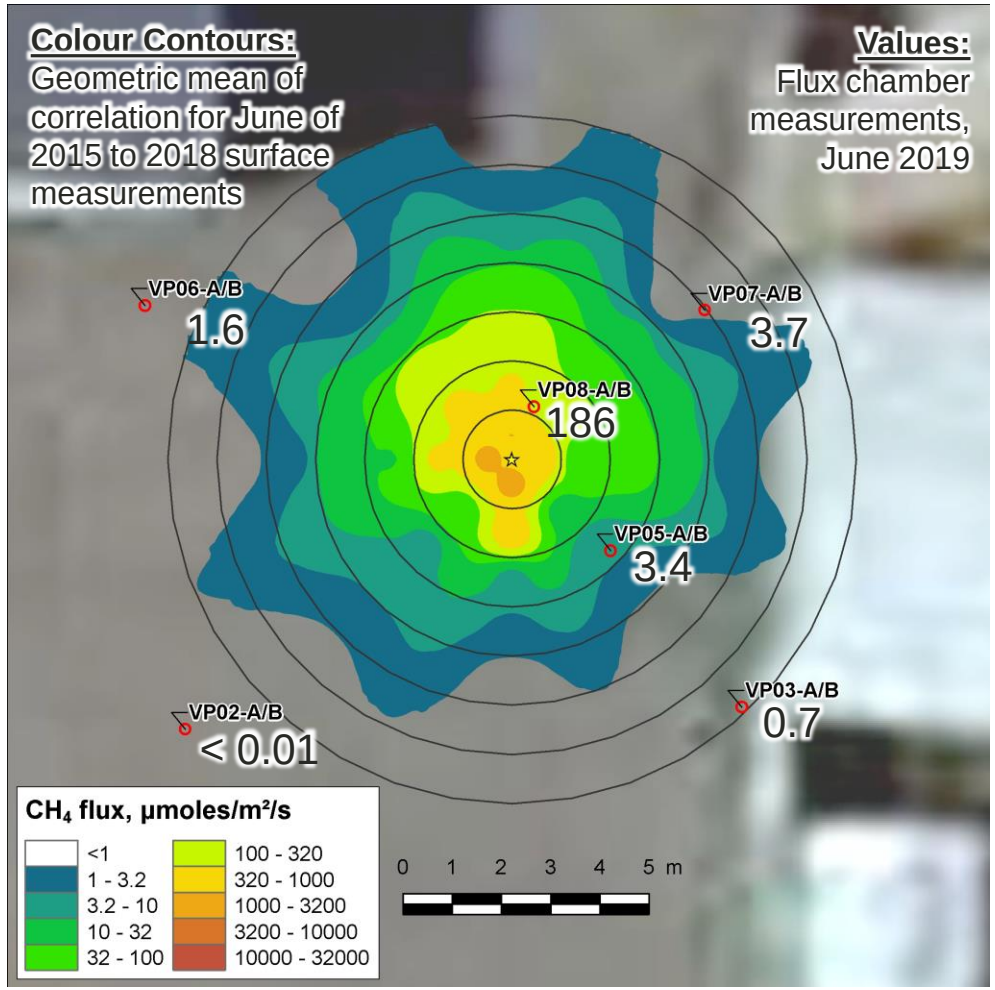
JUNE 2019 (BASELINE)

Units: µmol m^{-2} s^{-1}



Soil Gas Efflux Measurements

JUNE 2019 (BASELINE)



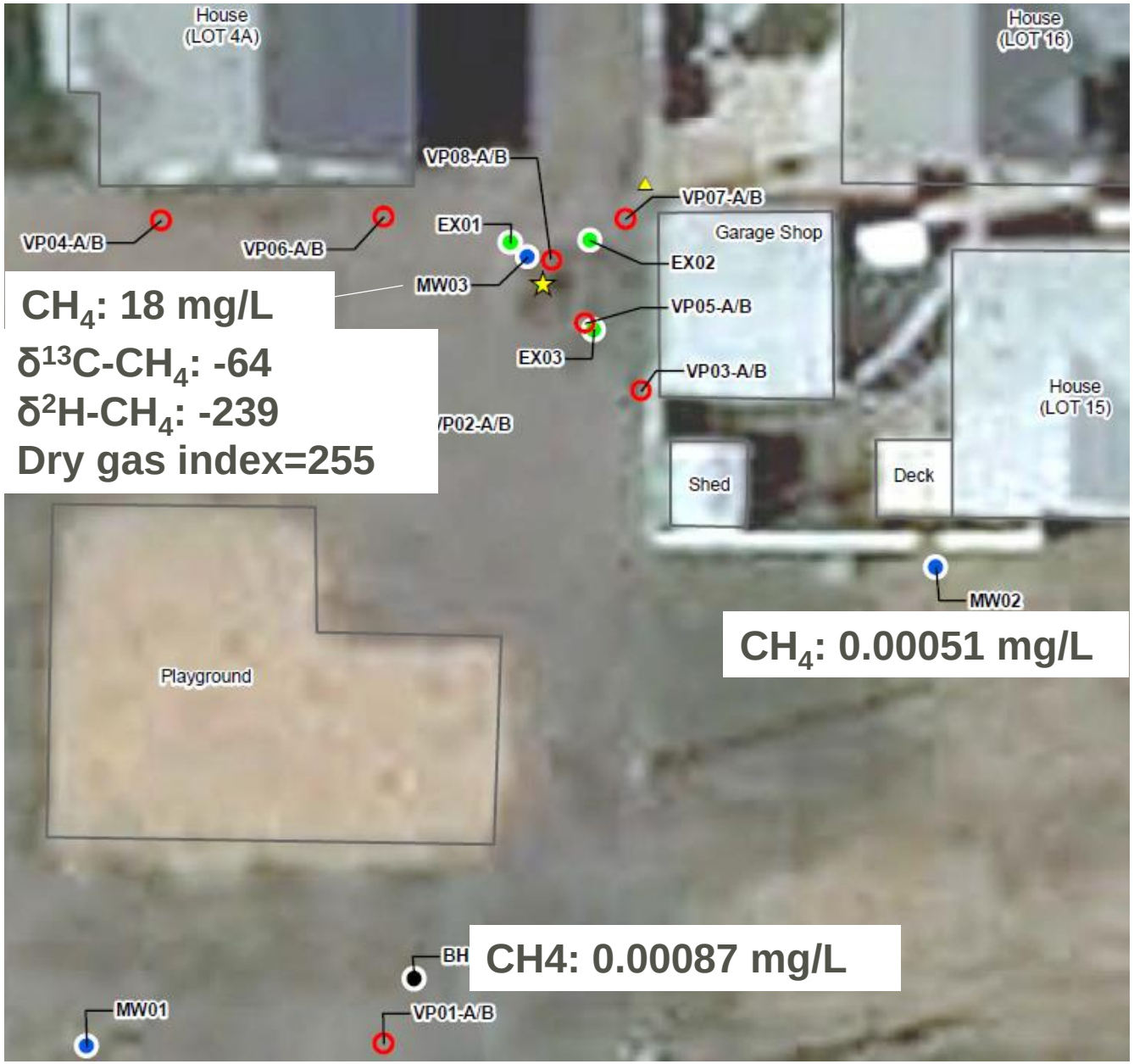
- Correlated surface gas measurements with soil gas efflux measurements to develop estimate of flow through soil
- Total methane flow through soil: **5 to 10 m³/day**
  - Methane flow range for studies of abandoned wells in Pennsylvania: **< 0.2 to 15 m³/day** (Kang et al. 2014; Pekney et al. 2018)
  - Mean methane flow for study of 100 decommissioned wells in UK: **1 m³/day** (Boothroyd et al. 2016)
- Flux through soil for this well is an order of magnitude greater than surface casing vent flow of **1 m³/day**
- Total methane flow equivalent to running a barbecue 6 to 8 hours per day, or 12 to 22 cattle
- Majority of gas migration reporting to soil surface is within 2 m of well (but measured up to 18 m from well)
- Strong trend of decreasing flux from soil with distance from well

Notes: Colour contours represent the mean distribution of methane at ground surface for Junes from 2013 to 2018, which was then converted to estimates of methane flux using correlation.

Groundwater Results

2019

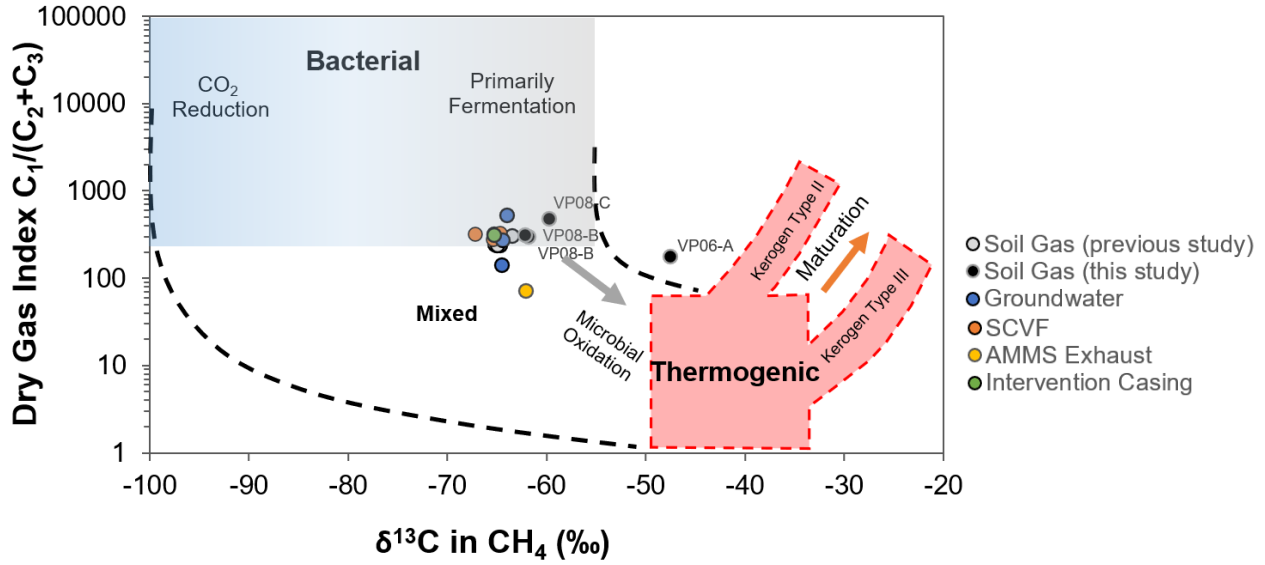
- Elevated dissolved methane in groundwater at MW03 prior to gas extraction
- Methane at MW03 is isotopically similar to the gas from the surface casing, production casing, and soil gas near the well

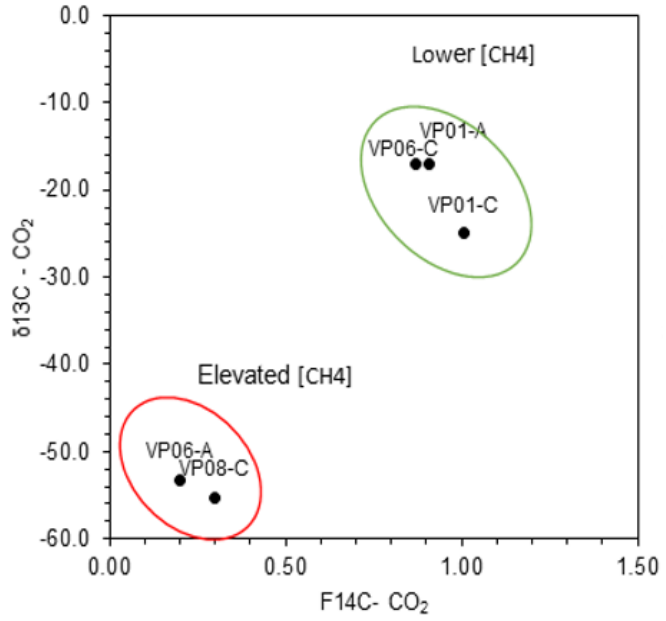


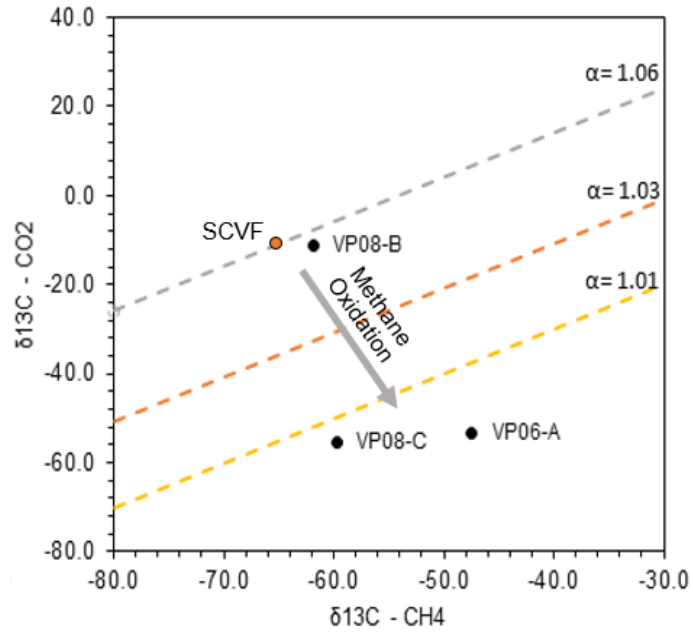
Site Investigation

SOIL GAS SOURCE

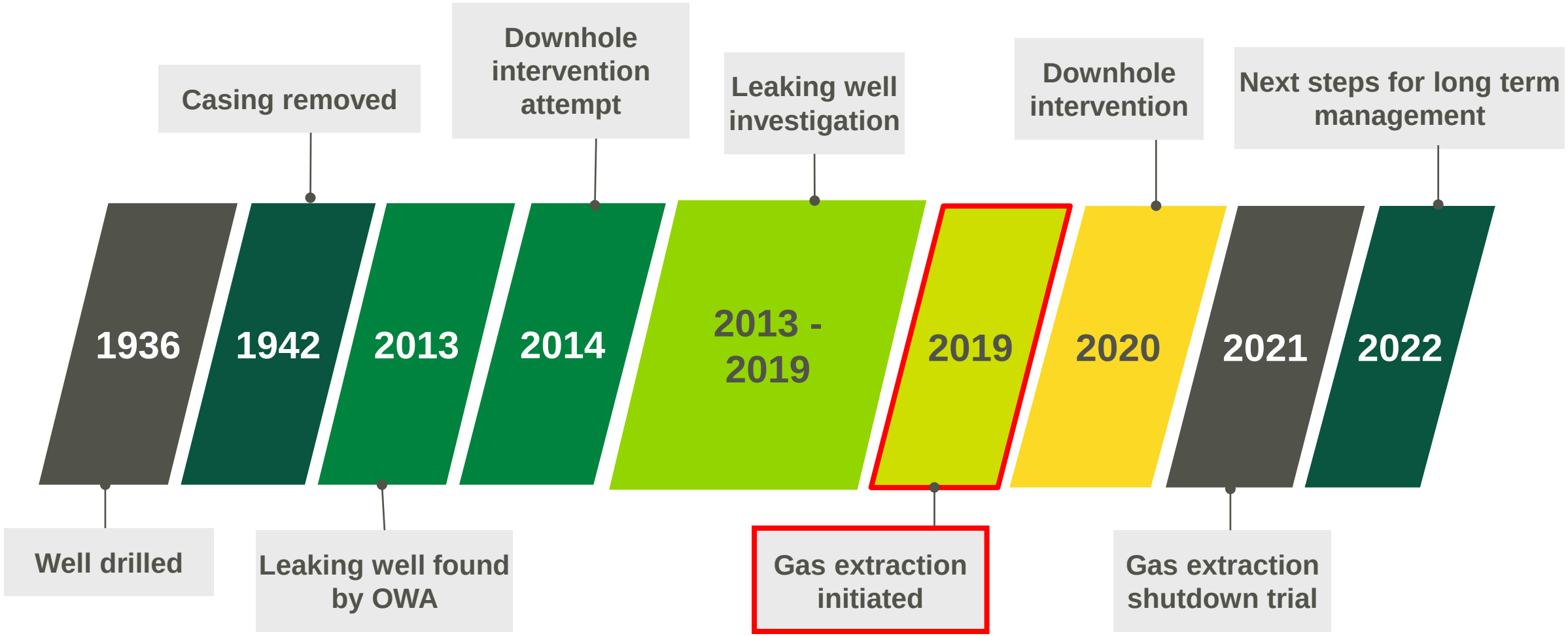
- Isotopes confirm that the source of the gas in the soil and groundwater is from the Tenwell No. 1 well
- Some soil gas has signature of oxidation of methane from Tenwell No. 1 to form CO_2 with low radiocarbon ($F^{14}C < 0.3$)
- Microbial oxidation in the <10 m of soil between the well and nearest house was important







Tenwell No.1 Well Timeline



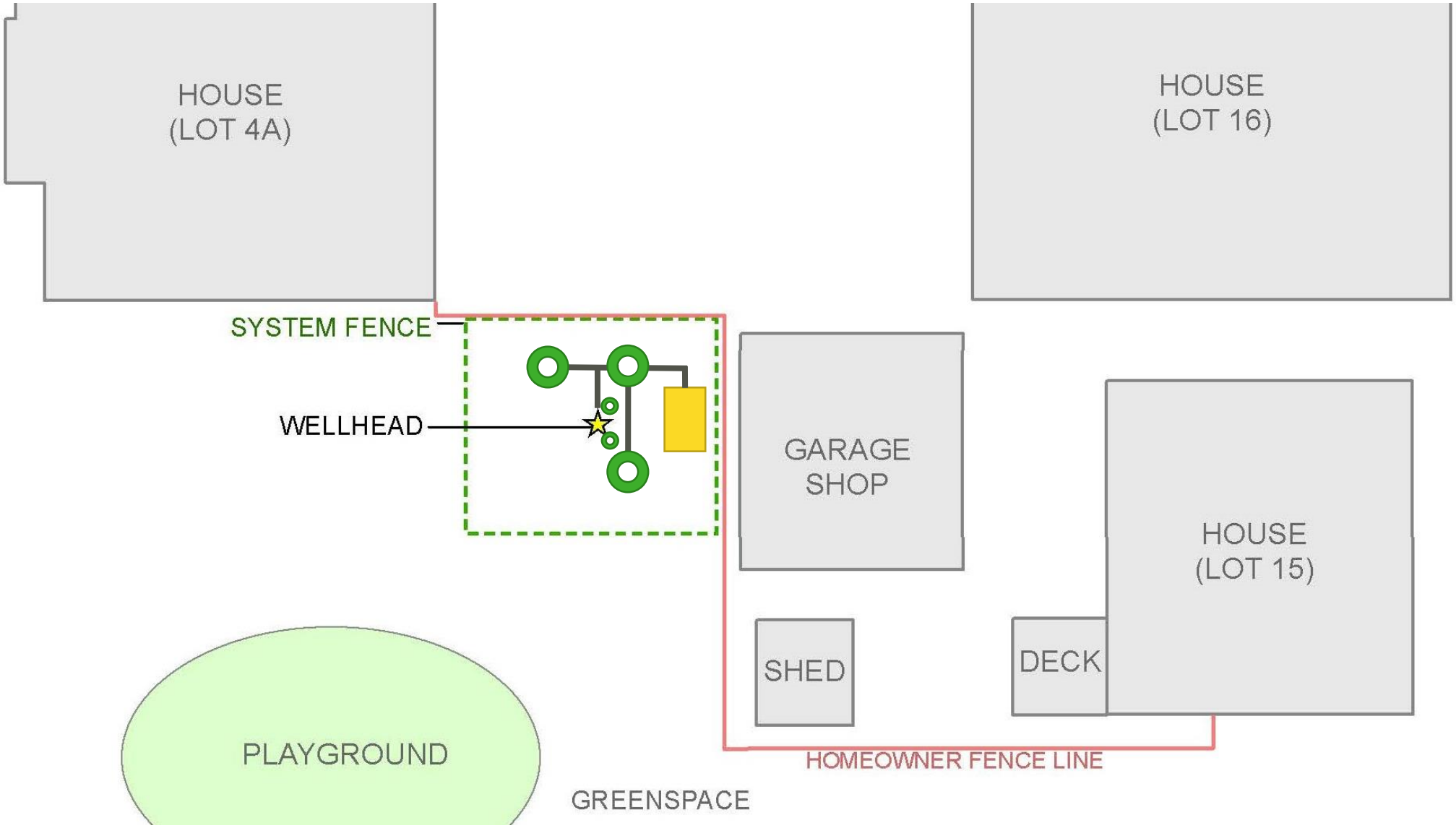
Temporary Surface Mitigation – Gas Extraction

ACTIVE METHANE MITIGATION SYSTEM

- **Objective:** extract methane gas from the shallow subsurface around the well to prevent migration towards nearby houses
- Extraction points: 3 vertical extraction wells + 2 riser pipes + surface casing vent
- Continuous operation of active blower within fan-ventilated enclosure
- Discharge to atmosphere through a riser stack
- Call-out alarm system in event of system shut-down

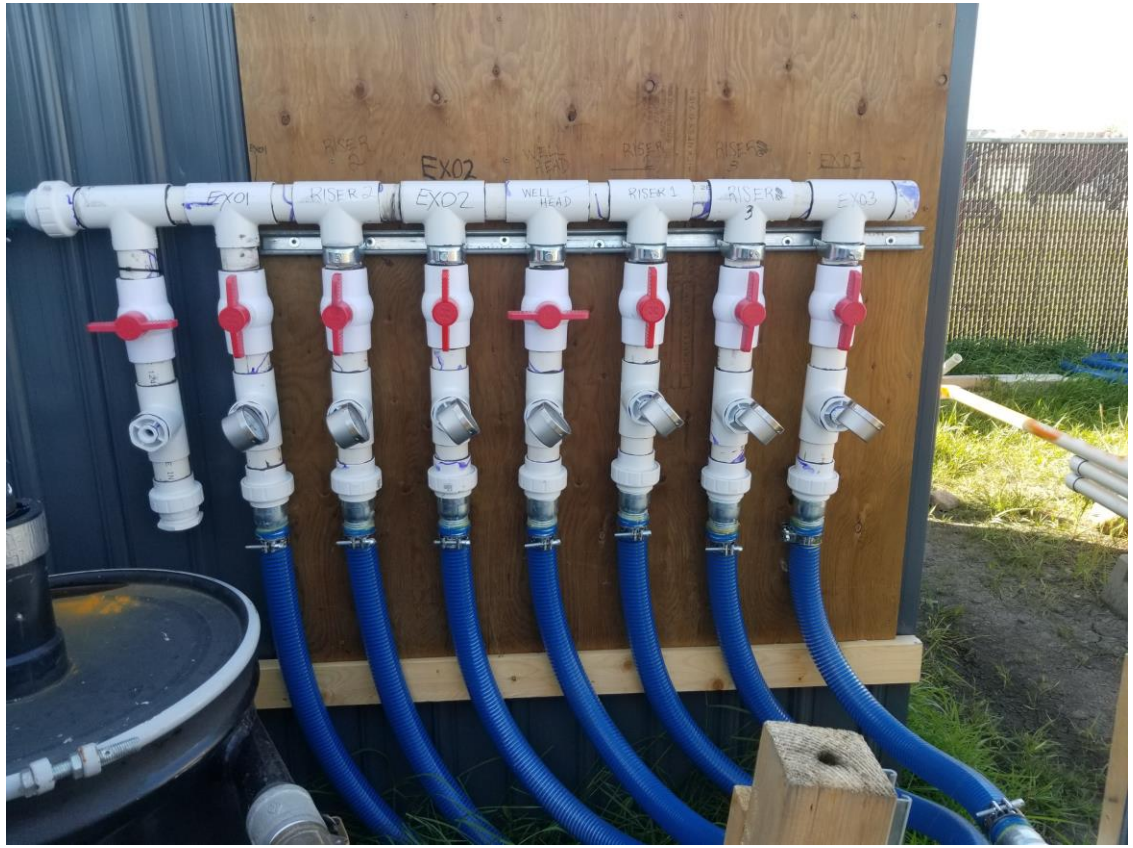
Temporary Surface Mitigation – Gas Extraction

ACTIVE METHANE MITIGATION SYSTEM



Temporary Surface Mitigation – Gas Extraction

ACTIVE METHANE MITIGATION SYSTEM

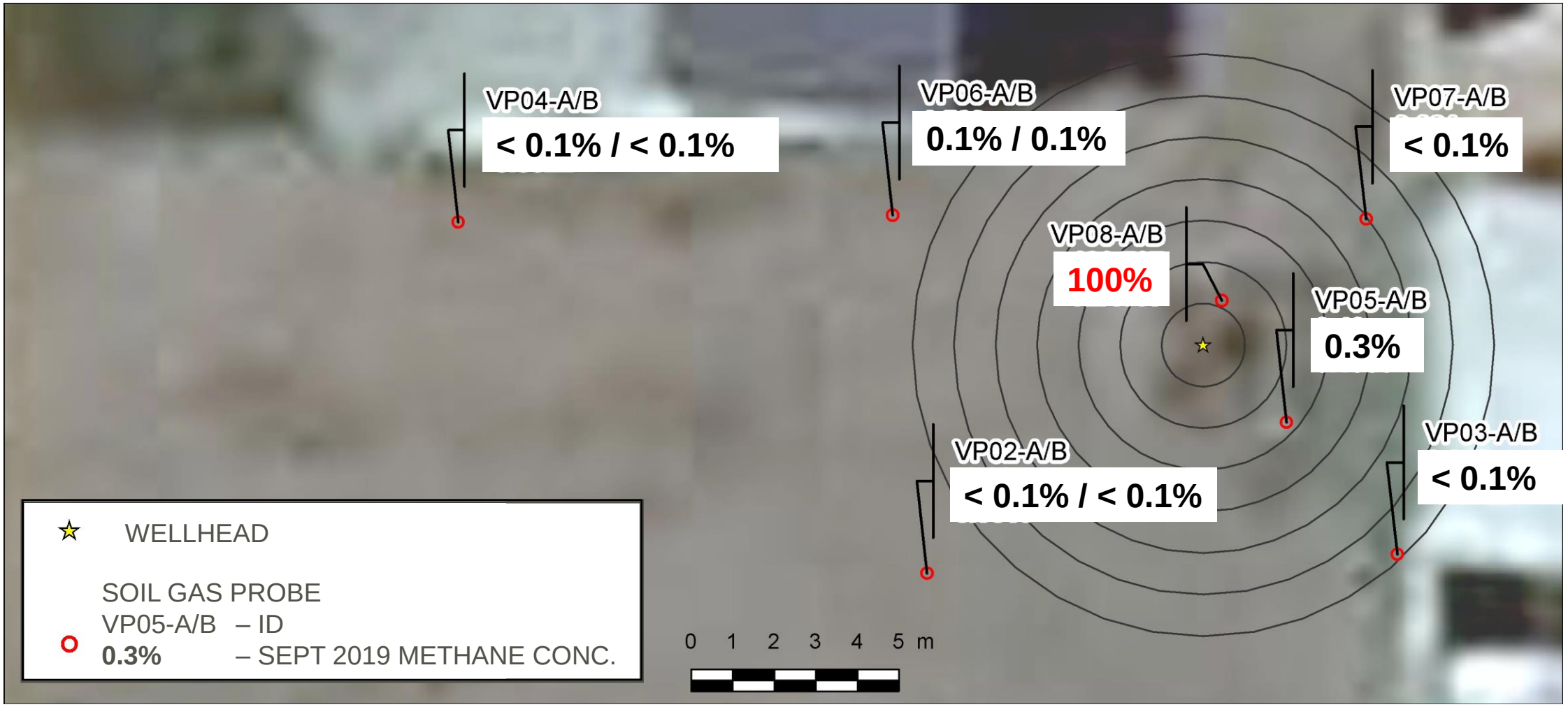


- System operation began in July 2019 and ran continuously for 1.5 years
- Methane gas extraction rate between 5 and 19 m^3/day
- 7 m radius of influence
- Reduction in soil gas methane concentrations and soil gas efflux

Soil Gas Methane Concentrations

SEPTEMBER 2019 (2 MONTHS GAS EXTRACTION)

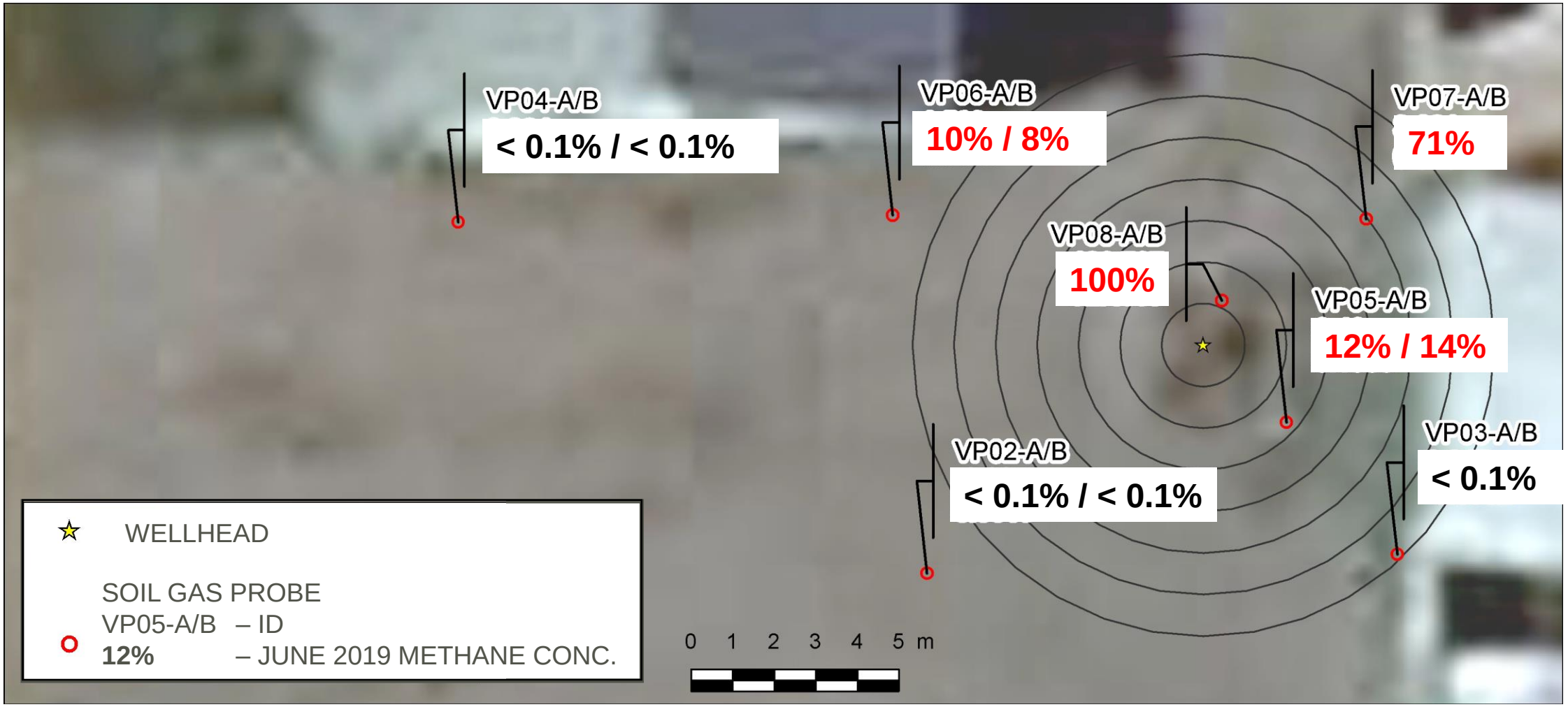
Units: percent by volume



Soil Gas Methane Concentrations

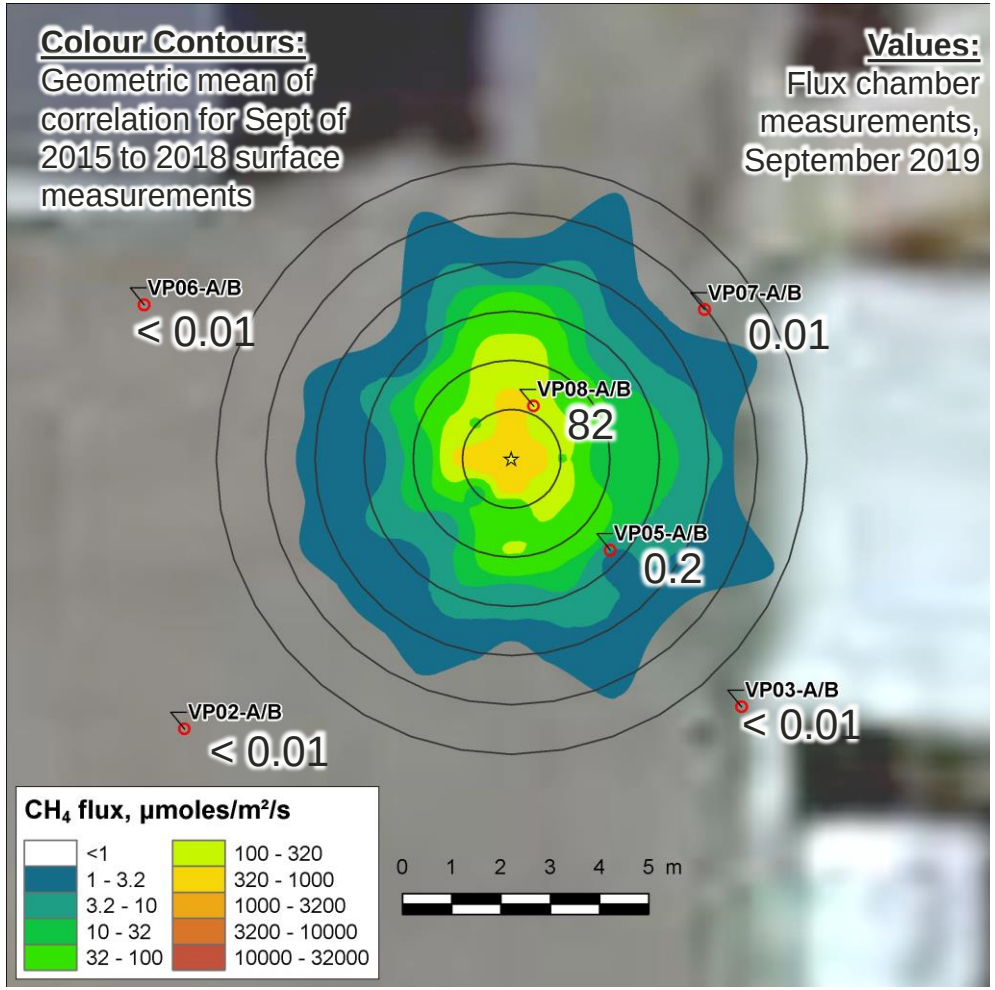
JUNE 2019 (BASELINE)

Units: percent by volume



Soil Gas Efflux Measurements

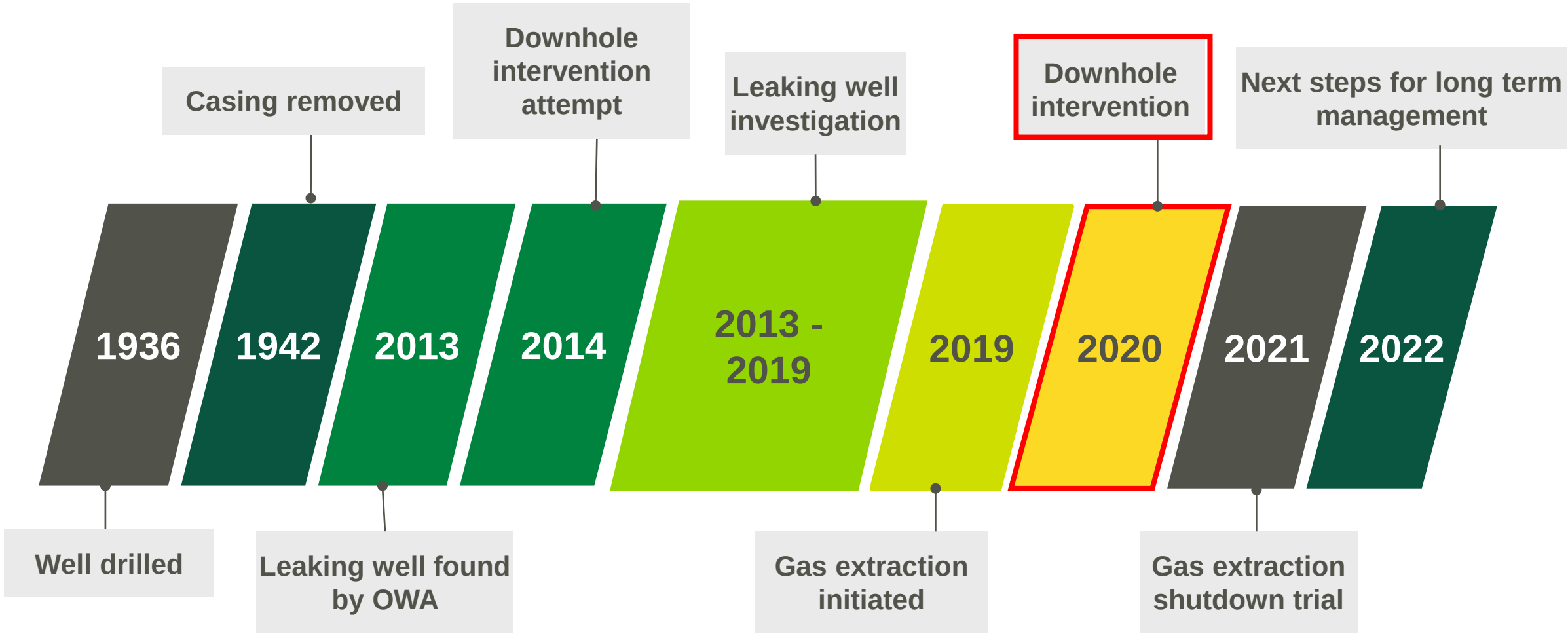
SEPTEMBER 2019 (2 MONTHS GAS EXTRACTION)



- Correlated surface gas measurements with soil gas efflux measurements to develop estimate of flow through soil
- Total methane flow through soil:
  - June 2019: **5 to 10 m^3/day** (pre-mitigation)
  - September 2019: **2 to 5 m^3/day** (post-mitigation)
- Gas migration reporting to soil surface only within 2 m of well during operation of mitigation system

Notes: Colour contours represent the mean distribution of methane at ground surface for Septembers from 2013 to 2018, which was then converted to estimates of methane flux using correlation.

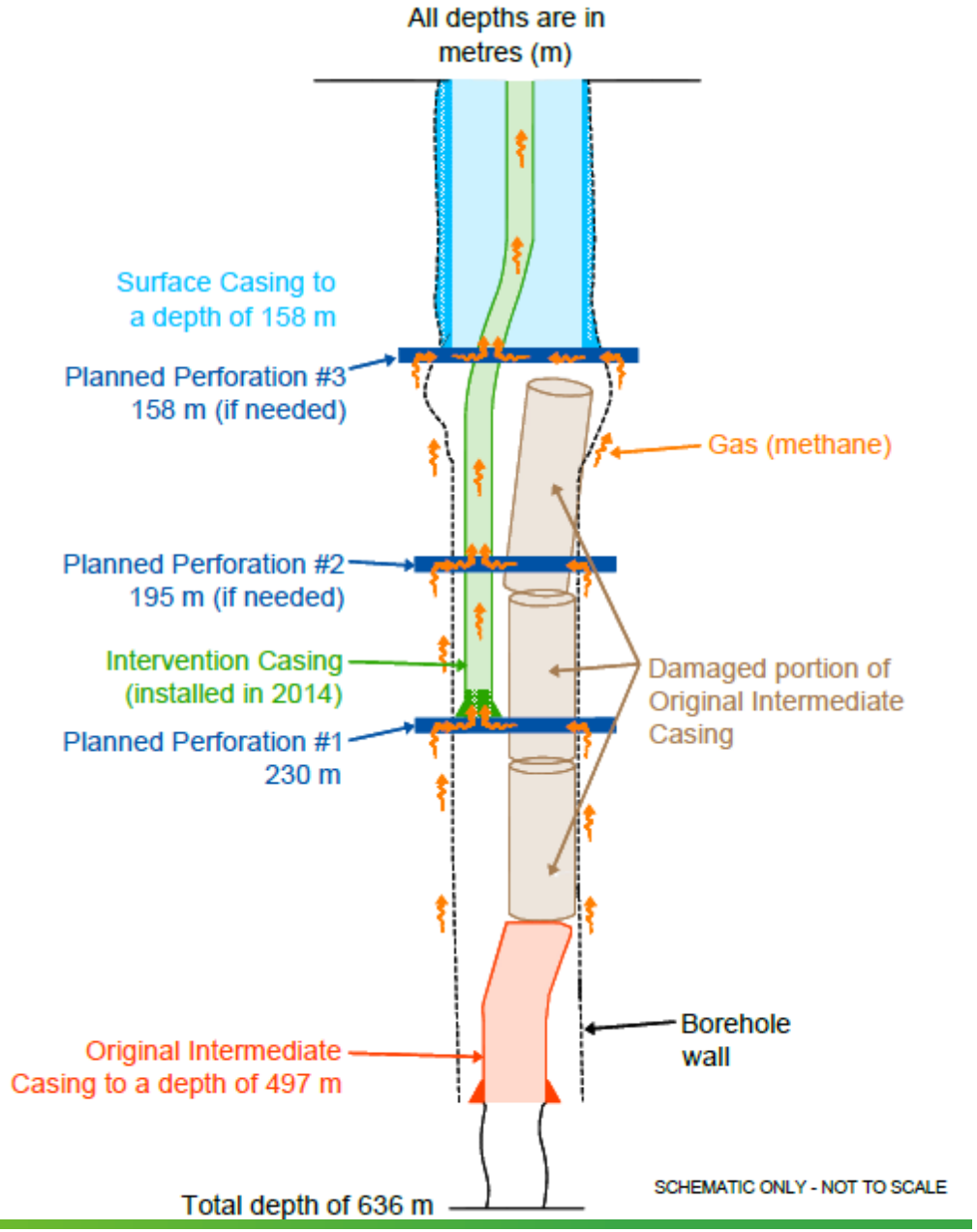
Tenwell No.1 Well Timeline



Well Perforation and Diversion

DOWNHOLE INTERVENTION

- **Objective:** perforate up to 3 intervals of the well casing to encourage gas flow into the wellbore and reduce gas migration through soil around well
- Need for 2nd and 3rd perforations based on gas flow rate through casing following 1st perforation



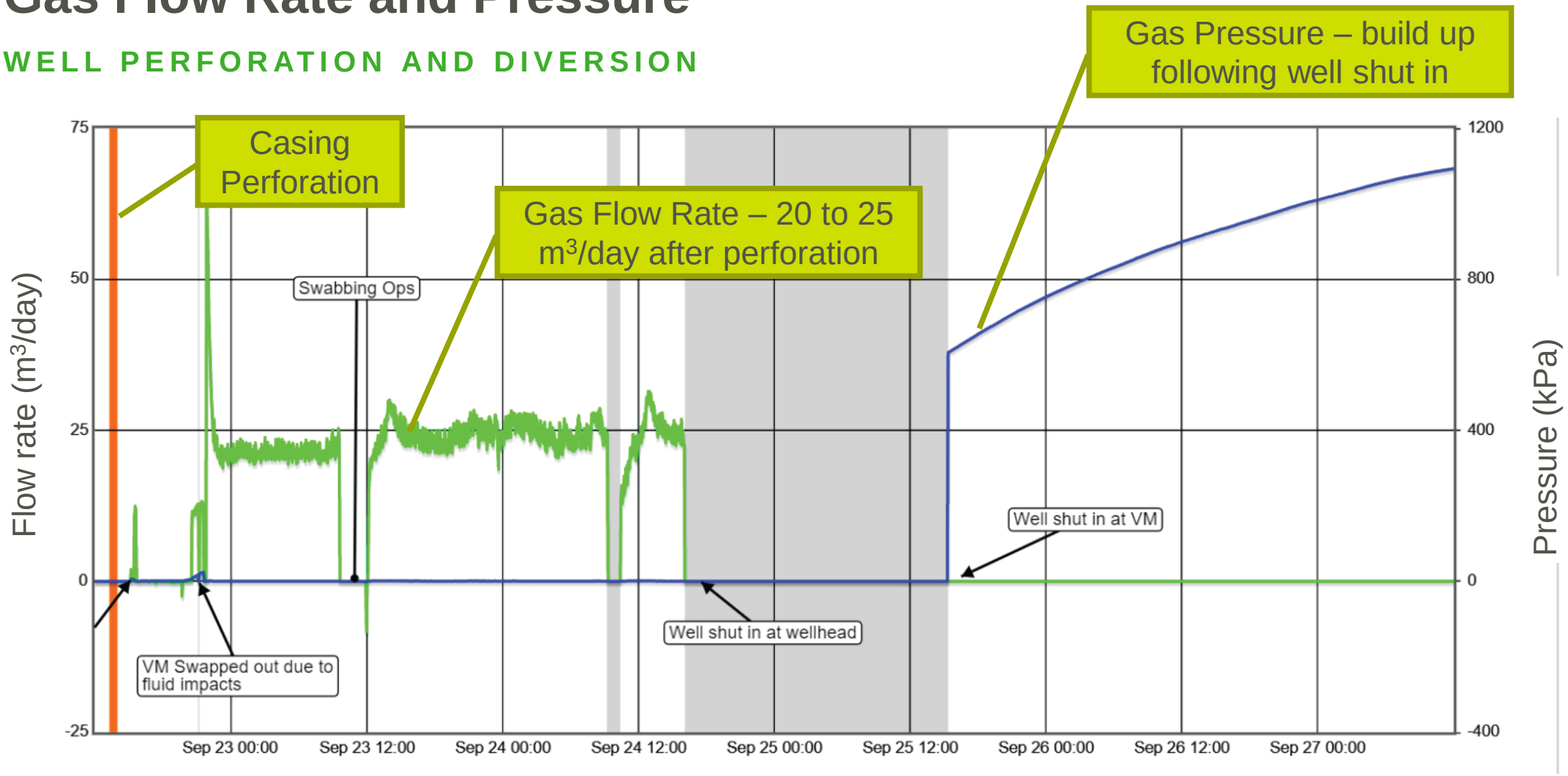
Well Perforation and Diversion

DOWNHOLE INTERVENTION

- Extensive community consultation by OWA
- 13 houses evacuated for 2 hours during well perforation
- Nearby residential roads barricaded and playground area closed
- Incinerator present in event of high gas flow rates following perforation
- Continuous monitoring of ambient gas concentrations and gas flow rates

Gas Flow Rate and Pressure

WELL PERFORATION AND DIVERSION



Vent Stack and Well Venting

WELL PERFORATION AND DIVERSION

- Single well perforation completed
- Gas flow rate through casing stabilized at 20 m^3/day
- Well temporarily shut in during construction of 6 m vent stack
- Air dispersion modelling completed
- Controlled well blowdown to initiate gas flow from well to 6 m vent stack
- Monitoring of air quality

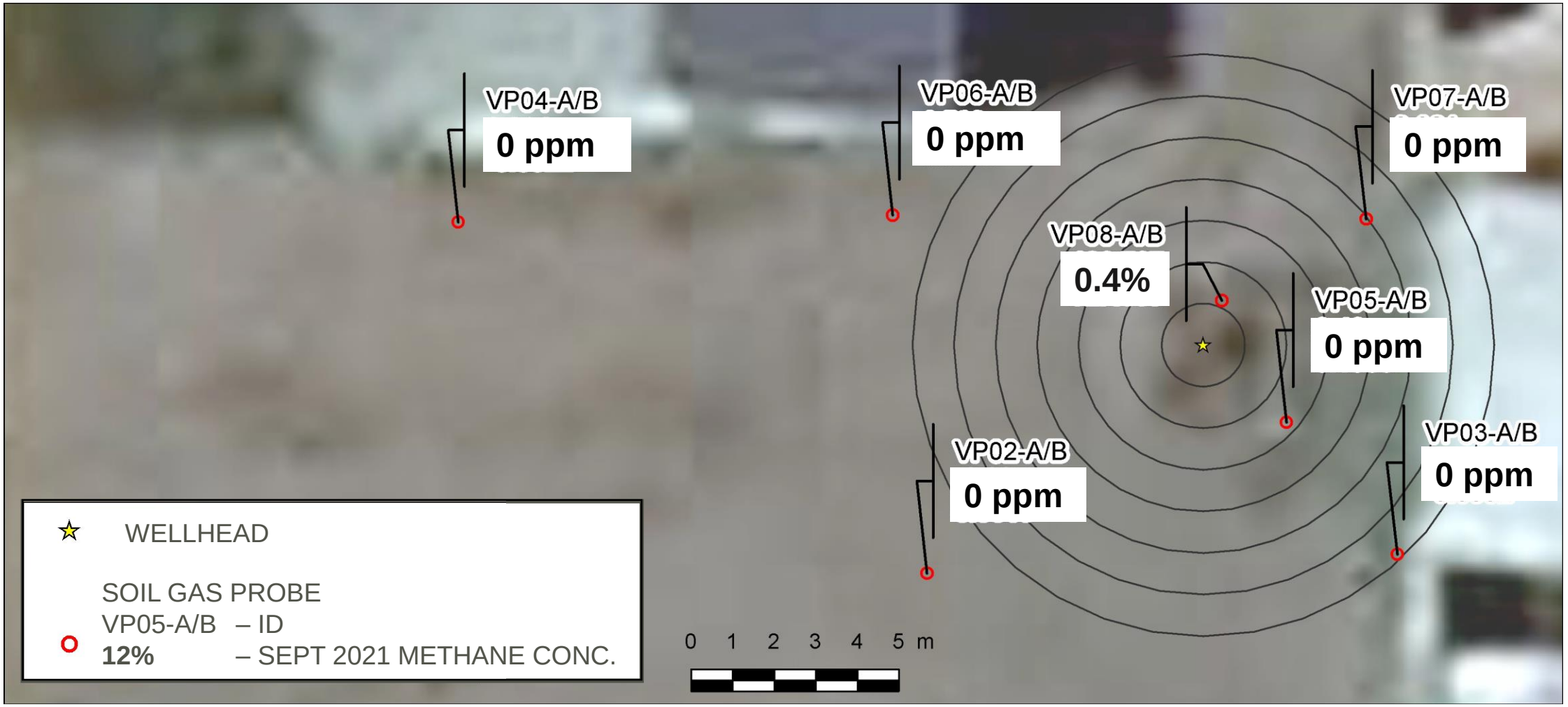
Active Methane Mitigation System Shutdown Trial

POST-WELL PERFORATION AND DIVERSION

- Methane mitigation system operated for 4 months following intervention program
- Shutdown trial completed to evaluate gas migration post-intervention
- Before gas extraction and intervention:
  - High methane concentrations in soil gas
  - High efflux of methane from soil
- After gas extraction and intervention:
  - Low methane concentrations in soil gas, approaching detection limit
  - Low methane efflux from soil, approaching detection limit

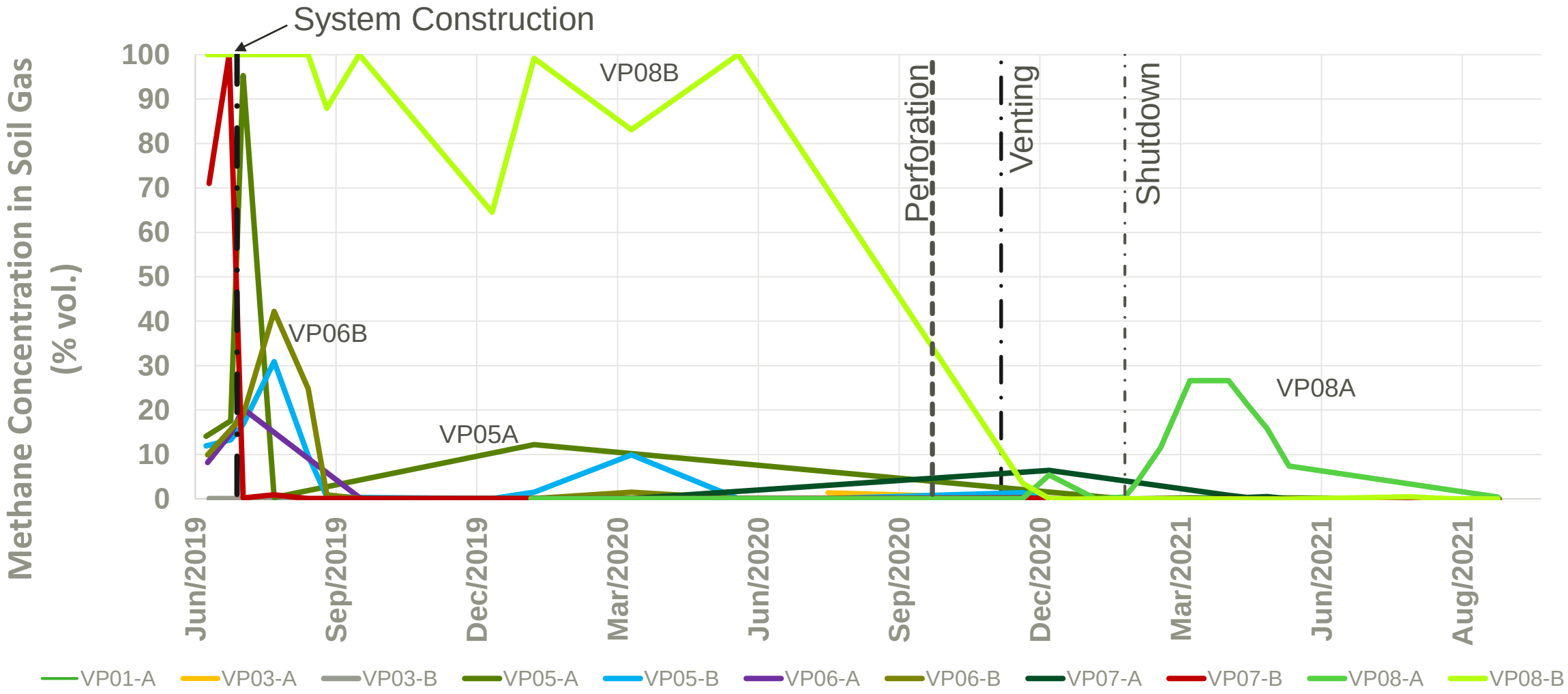
Soil Gas Methane Concentrations

SEPTEMBER 2021



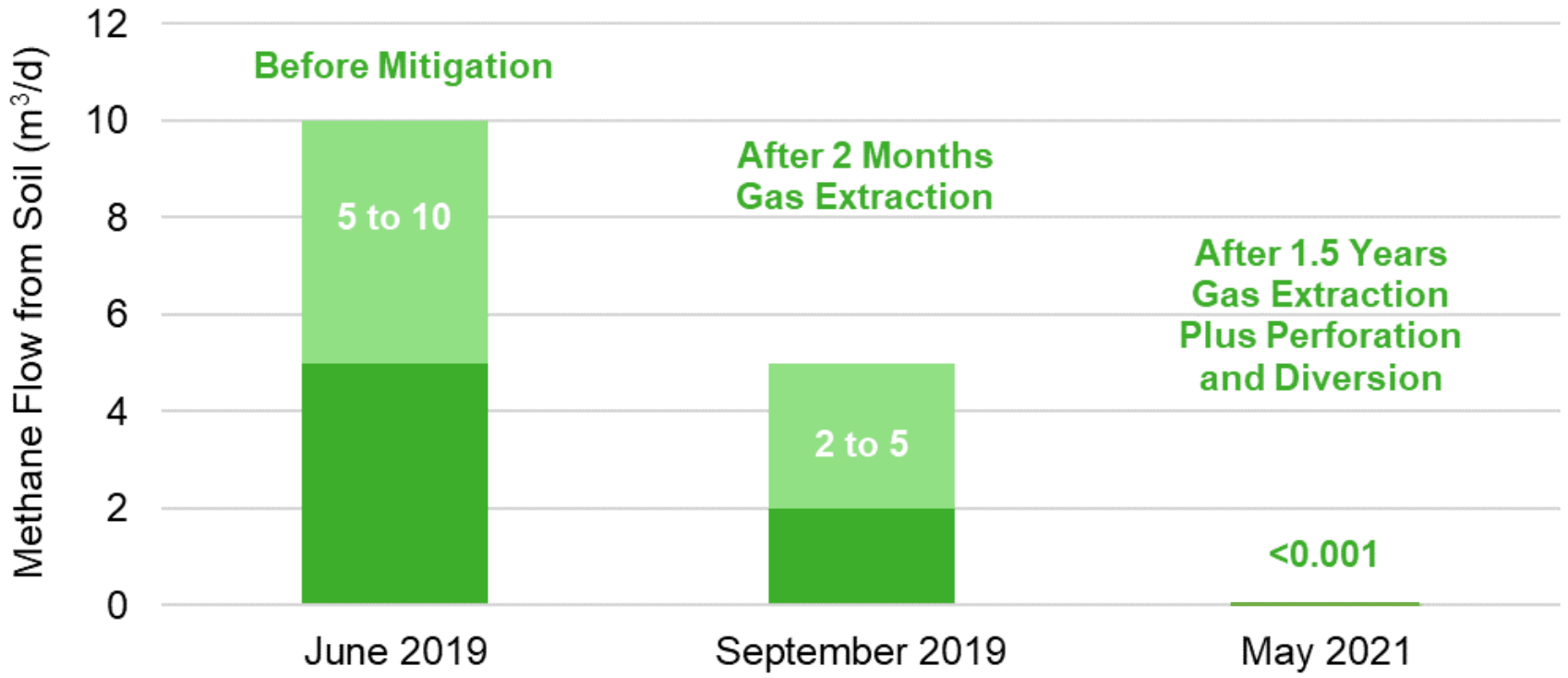
Soil Gas Methane Concentrations

SHUTDOWN TRIAL FOLLOWING WELL PERFORATION AND DIVERSION



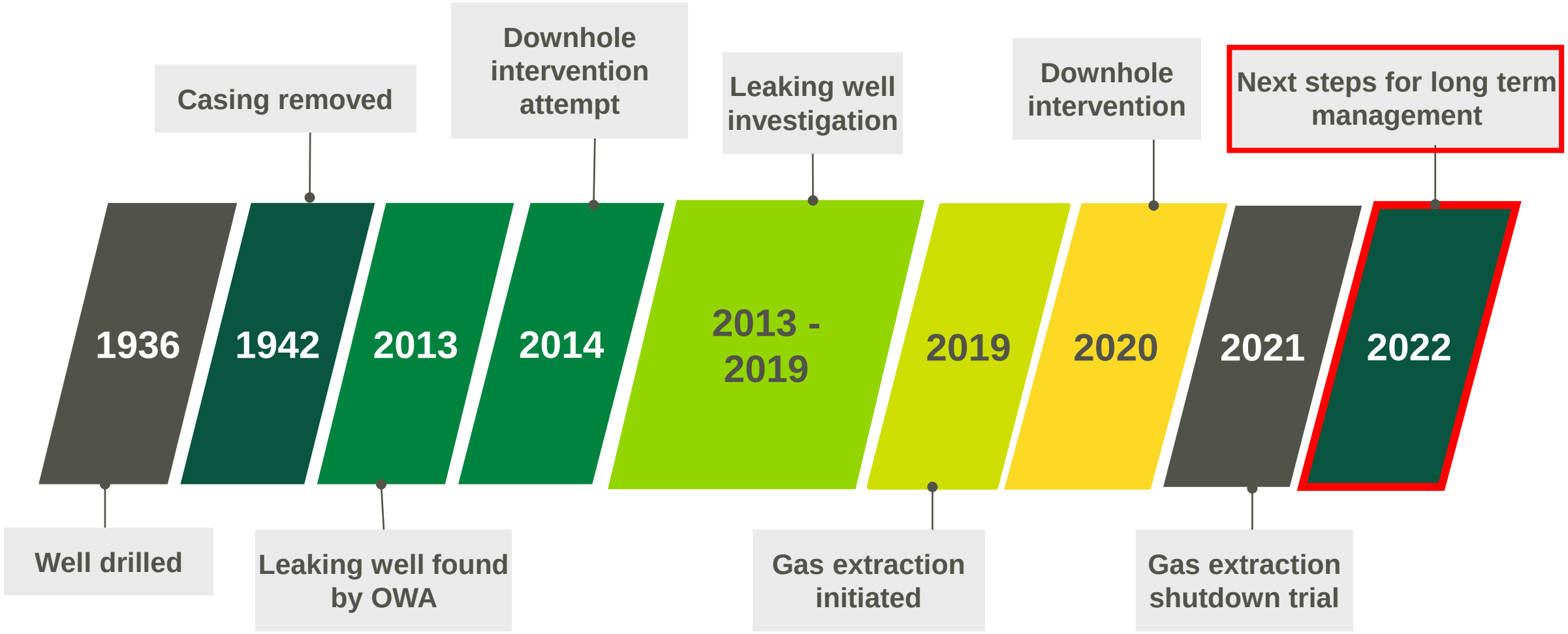
Soil Gas Efflux Measurements

METHANE FLOW THROUGH SOIL



- May 2021: Negligible gas migration reporting to soil surface, but possibly influenced by high soil moisture

Tenwell No.1 Well Timeline



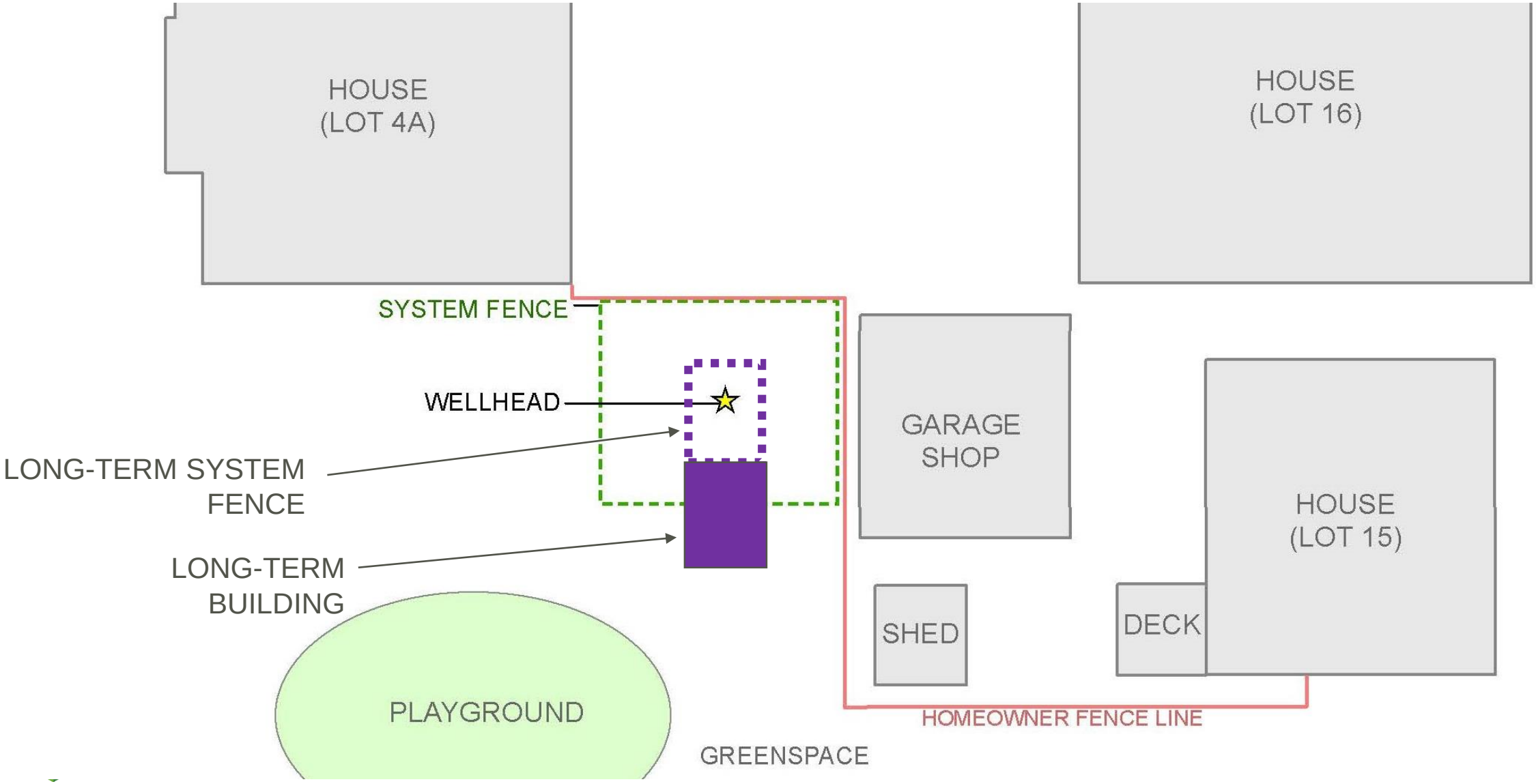
Next Steps for OWA's Management of Tenwell No. 1 Well

WWW.ORPHANWELL.CA/COMMUNITY

- Continue venting of well to atmosphere
- Construction of long-term surface mitigation system infrastructure
  - Soil gas extraction system to be operated on contingency basis
  - Quieter and smaller footprint
- Monitoring of soil gas, groundwater, and ambient air quality
- Further evaluation of well abandonment options and methane capture options by OWA

Long-Term Surface Mitigation Infrastructure

NEXT STEPS



Acknowledgments

COLLABORATION

The Orphan Well Association is an industry-funded collaboration among the Alberta Government, provincial regulators, and oil and gas producers

OWA project leads: Dave Marks and Gerry May

We thank the Town of Vermilion for their ongoing assistance in managing the well site

Other contractors who have supported the OWA at the Tenwell No. 1 well site include Doull Site Assessments, Frontier Project Solutions, GChem, and Chemistry Matters

Many thanks to other Golder team members including Lexya Hansen, Janelle Track, Jeff Rogers, Carol Yan, Anne Wozney, and Lenz Haderlein

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Questions