

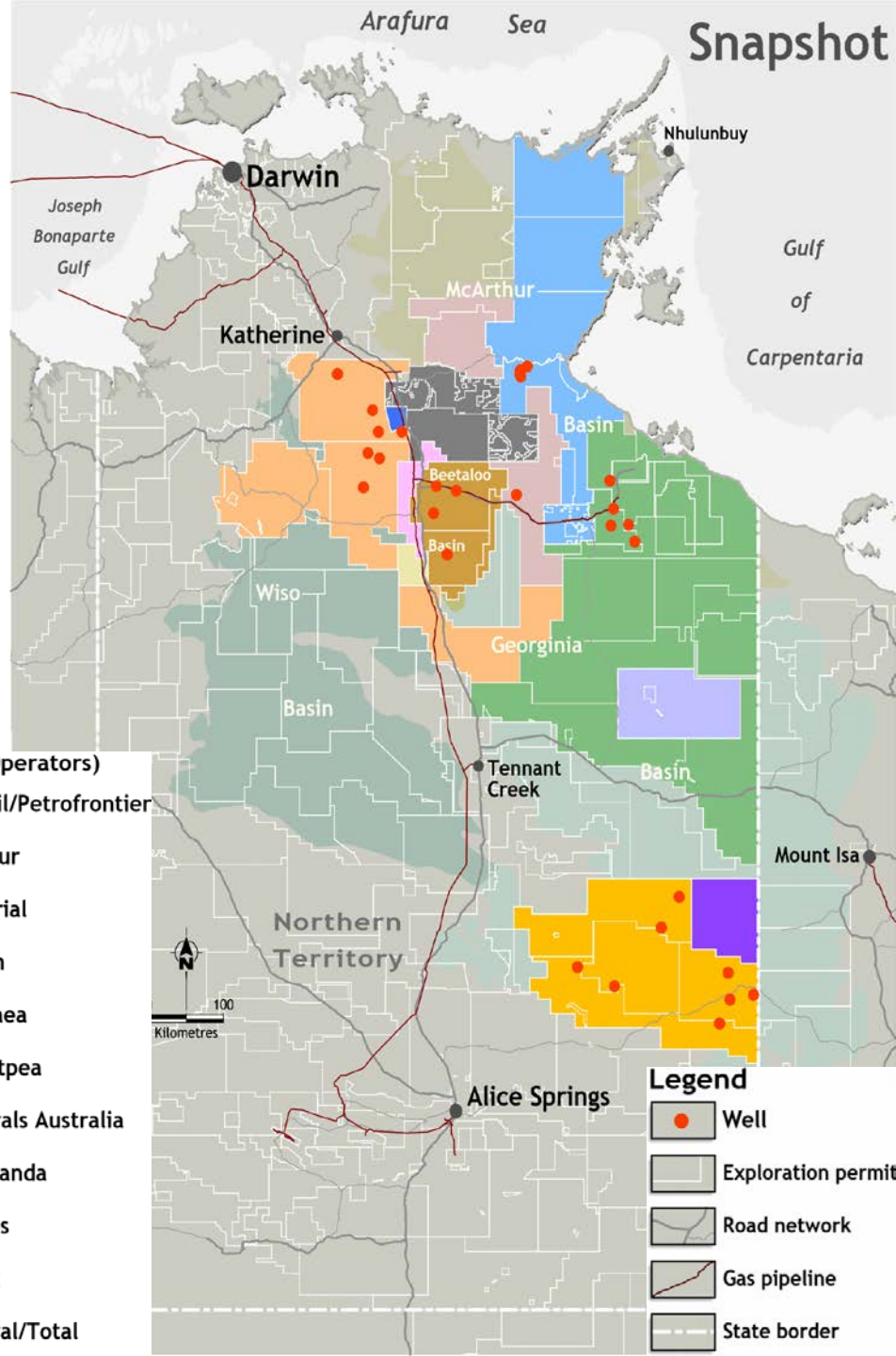
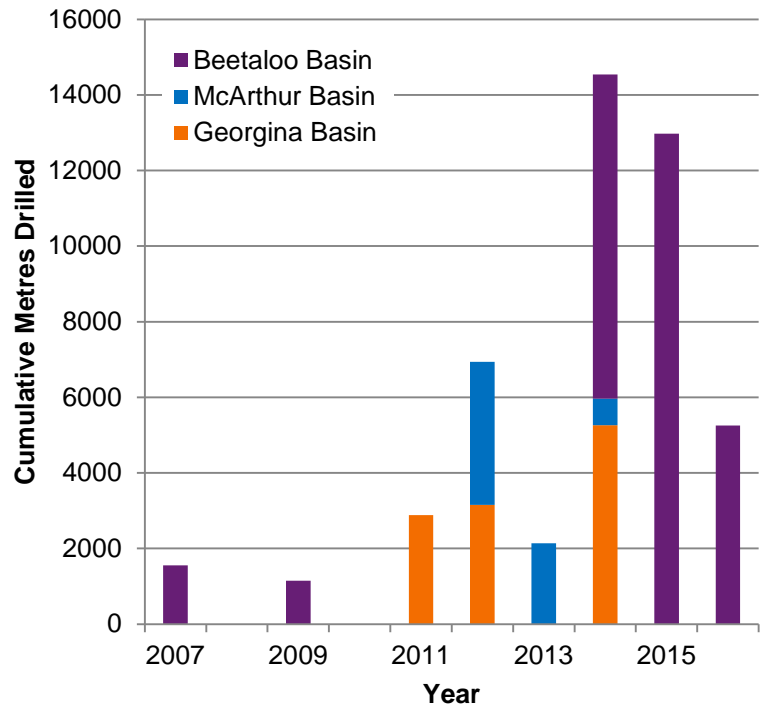


# Presentation to the NT Inquiry into Hydraulic Fracturing

## Katherine, NT

9 August 2017

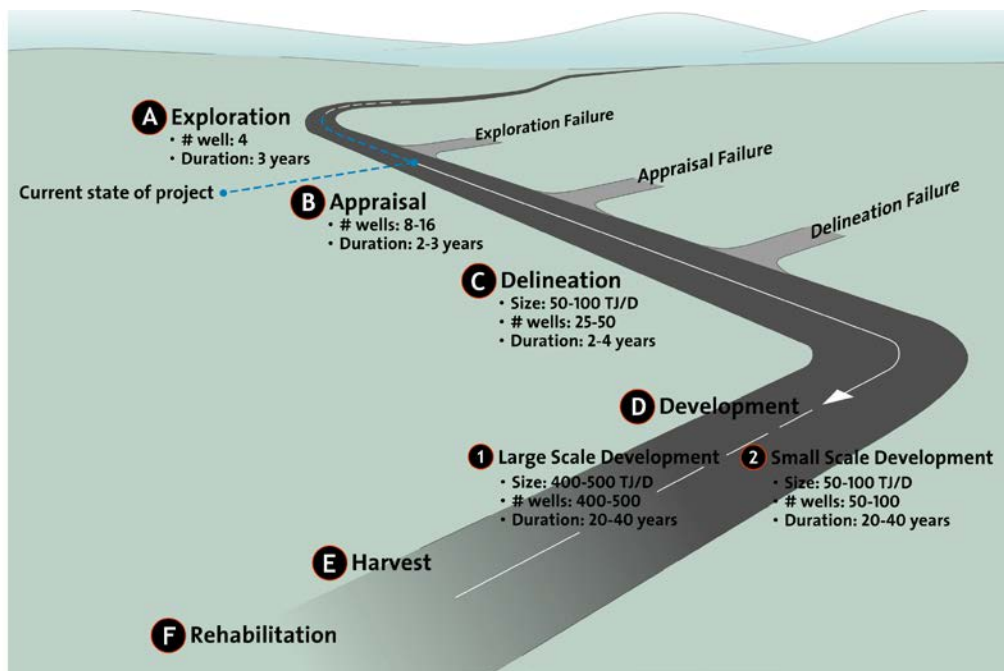
# Unconventional exploration activity in the Northern Territory: 2000s-2010s



- Legend (Operators)**
- Statoil/Petrofrontier
  - Armour
  - Imperial
  - Origin
  - Pangaea
  - Sweetpea
  - Minerals Australia
  - Jacaranda
  - Santos
  - Inpex
  - Central/Total

- Legend**
- Well
  - Exploration permit
  - Road network
  - Gas pipeline
  - State border

# The Beetaloo Project – an exploration phase project with encouraging technical results



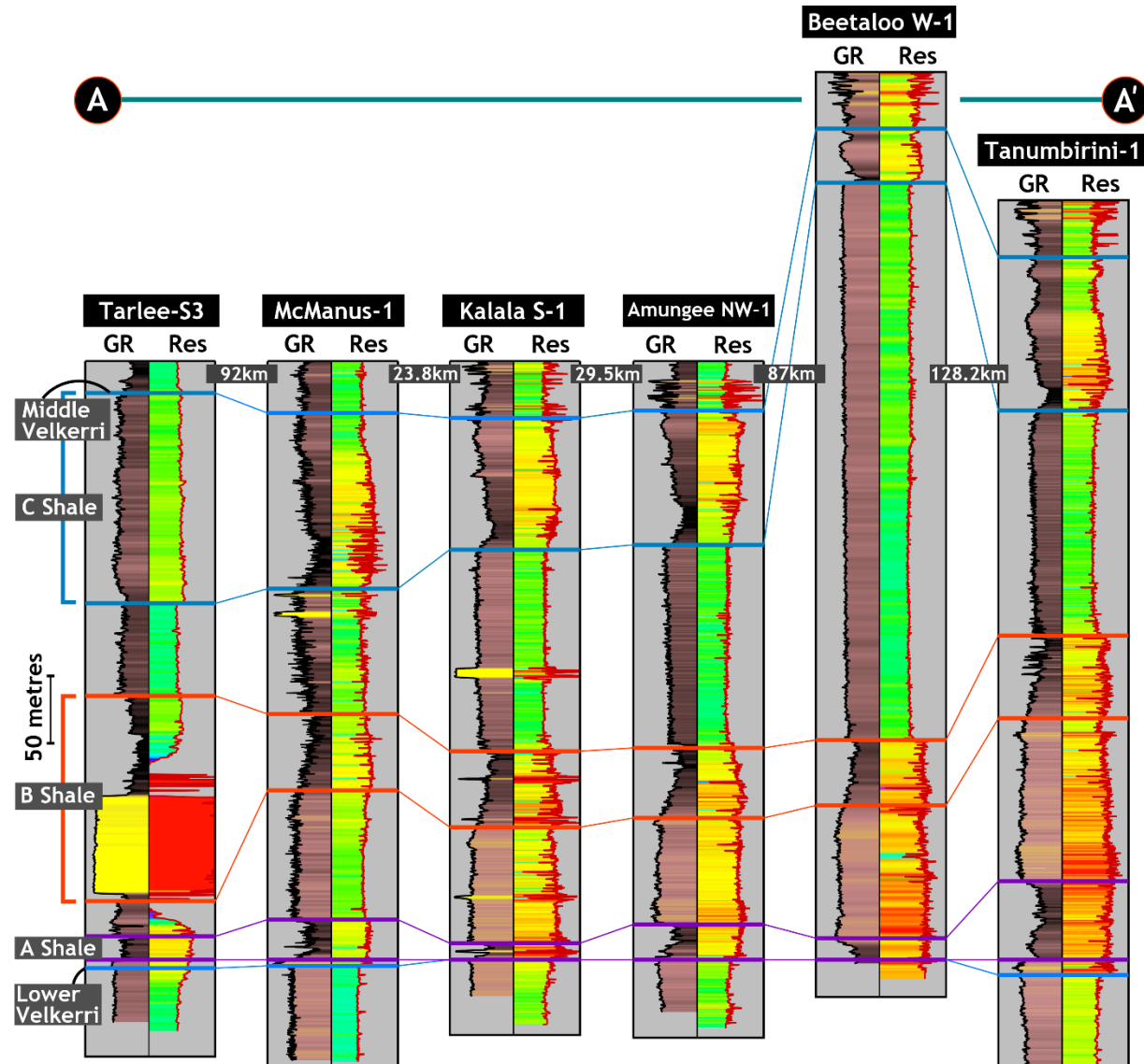
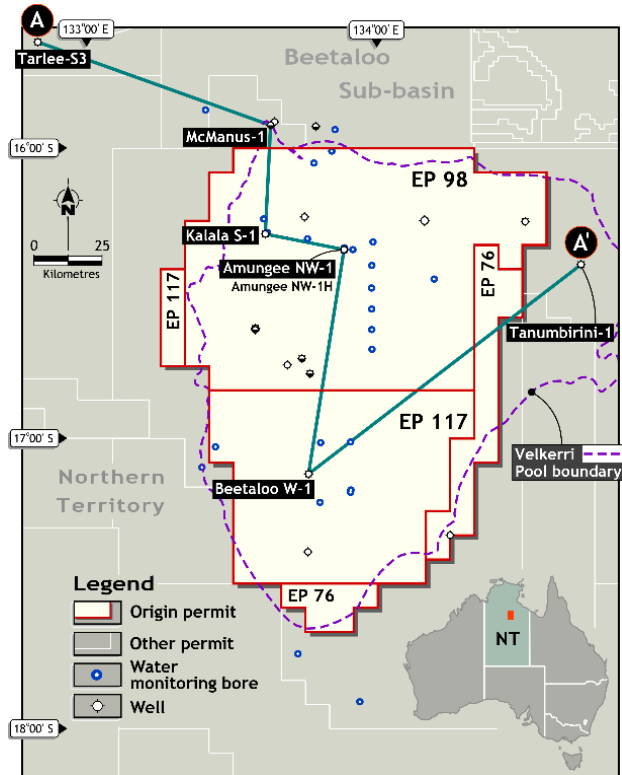
## 5 YEAR WORK PROGRAM

13 July 2017

EP	STAGE 1			Moratorium	STAGE 2	STAGE 3
	2014	2015	2016			
98	Geological and geophysical studies	2 vertical wells, 1 horizontal well	1 HFS horizontal well		1 HFS vertical well	2 HFS horizontal wells
117	Geological and geophysical studies	Geological and geophysical studies	1 vertical well		2 HFS horizontal wells	Geological and geophysical studies
76	Geological and geophysical studies	Geological and geophysical studies	Geological and geophysical studies		Geological and geophysical studies	Geological and geophysical studies

\*HFS  
Hydraulic Fracture Stimulation

# Technical results prove the materiality of the resource volume in the Beetaloo



# Origin's Contingent Resource booking is encouraging but not confirmation of an economic project



## Assessment of 2C Contingent Gas Resource Estimates for the Velkerri B Shale Pool within EP76, EP98, and EP117 as of 14 February 2017<sup>1</sup>

Measured and Estimated Parameters	Units	Best Estimate
Area <sup>2</sup>	km <sup>2</sup>	1,968
Original Gas In Place (OGIP) <sup>3</sup> (Gross)	TCF <sup>6</sup>	61
Contingent Resource <sup>4</sup> (Gross)	TCF	6.6
Contingent Resource <sup>4</sup> (Net) <sup>5</sup>	TCF	2.3

<sup>1</sup> Contingent Resource Estimates have been prepared on a statistical aggregation basis and in accordance with the Society of Petroleum Engineers Petroleum Resource Management System (SPE-PRMS). Contingent Resource Estimates are those quantities of gas (produced gas minus carbon dioxide and inert gasses) that are potentially recoverable from known accumulations but which are not yet considered commercially recoverable due to the need for additional delineation drilling, further validation of deliverability and original gas in place, and confirmation of prices and development costs

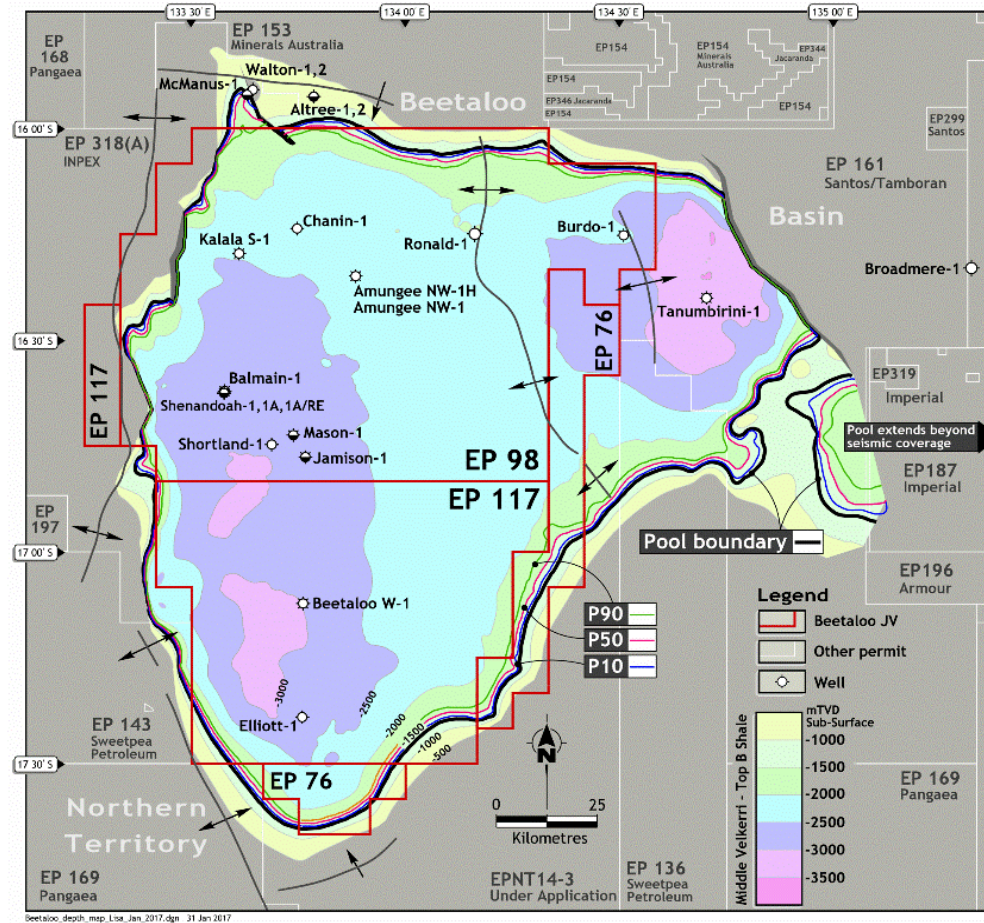
<sup>2</sup> P50 area from the Contingent Resource area distribution

<sup>3</sup> OGIP presented is the product of the P50 Area by the P50 OGIP per km<sup>2</sup>

<sup>4</sup> Estimated Gas Contingent Resource category of 2C

<sup>5</sup> Net to Origin's 35% interest in EP76, EP98, and EP117

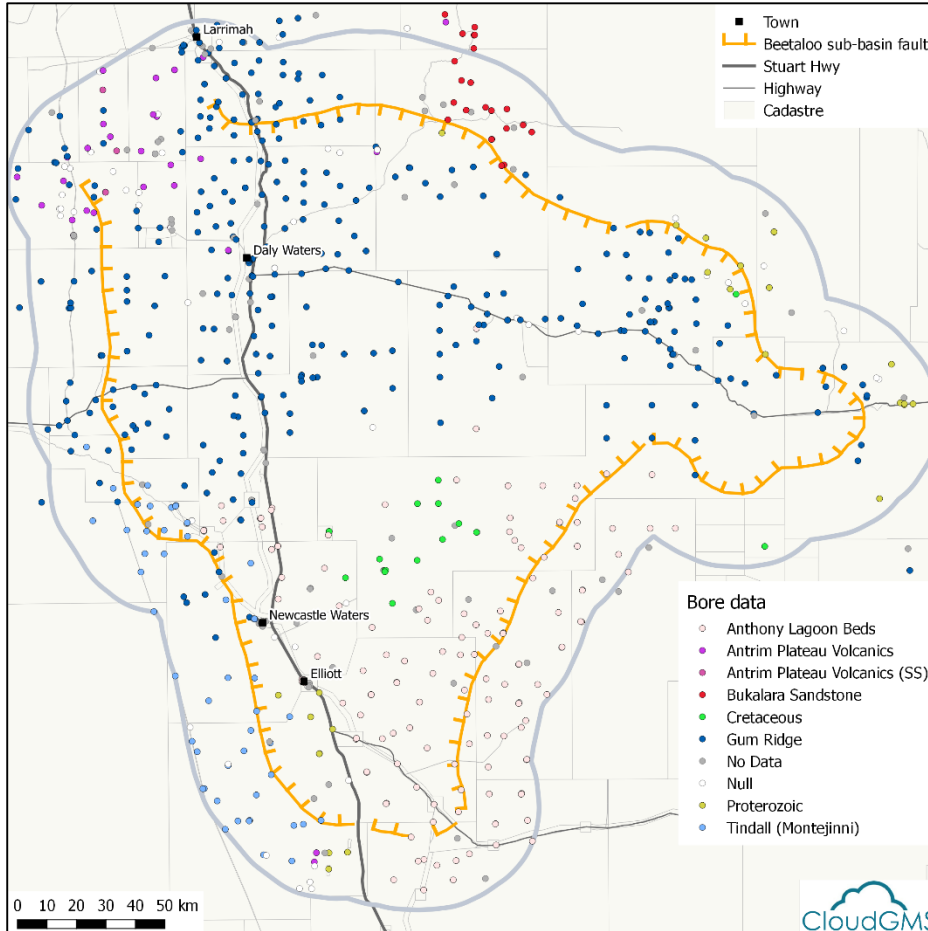
<sup>6</sup> TCF: trillion cubic feet



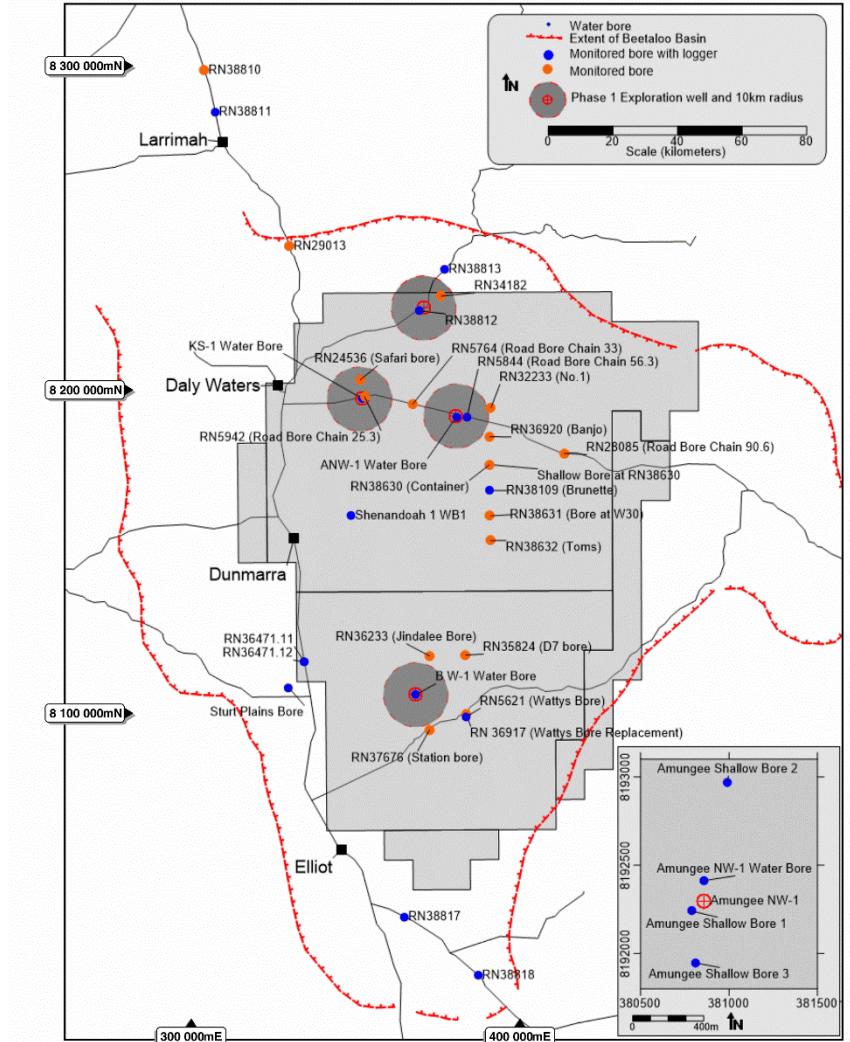
# Environmental monitoring: groundwater baseline



## Cloud GMS – desktop study



## Origin GMP





## Beetaloo Basin Water Study

Baseline Characterisation of Groundwater

Damian Barrett

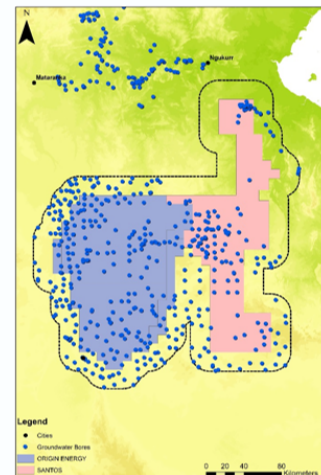
19 July 2017

ENERGY BUSINESS UNIT  
www.csiro.au

WWW.GISERA.ORG.AU



## Progress - Groundwater Bores



Analysis of data from NT DLRM HYDRSTA database in July 2017

Sampling September/early October 2017

Observations:

- 579 bores within 20 km buffer
- Depth range: 15.2 m – 1767m
- Water level: 0.3 m – 150 m below ground level

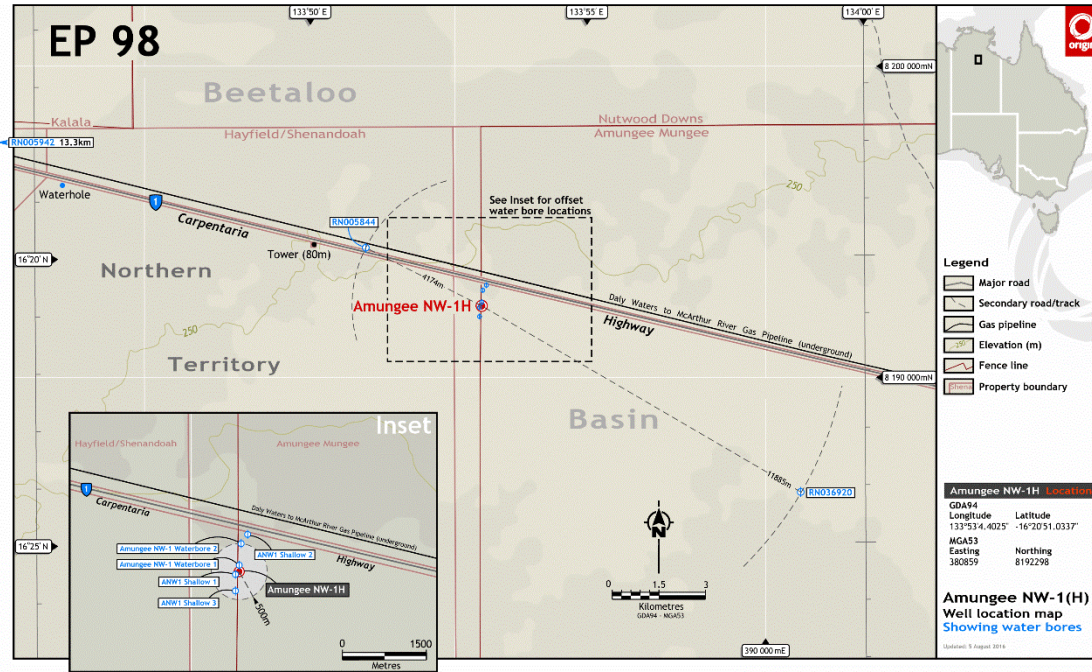
Relevance to project:

- Sufficient coverage for EP 161 permit area
- Planning to monitor some of these wells as part of project

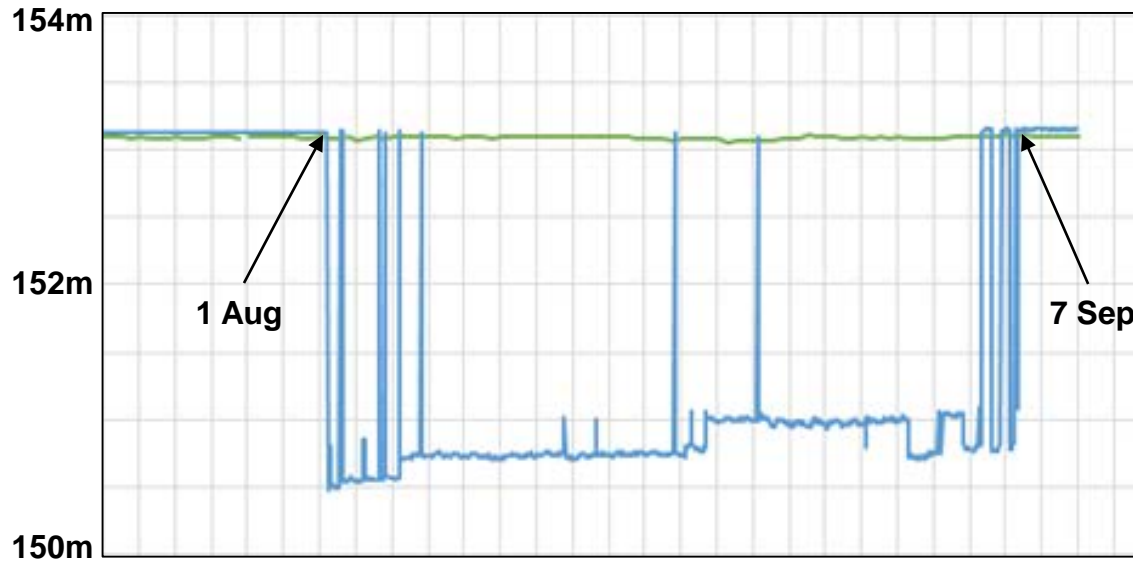
Location of groundwater bores (Source: DLRM, 2016)

# Localised supply baseline data

BORE ID/RN	OWNER	FORMATION	ESTIMATED VOLUME WITHDRAWN
Amungee NW-1 Waterbore 1	Origin	Cambrian Limestone Aquifer	3,758 m <sup>3</sup>
Amungee NW-1 Waterbore 2	Origin	Cambrian Limestone Aquifer	4,666 m <sup>3</sup>
RN 5942	NTG Roads and Highways Department	Cambrian Limestone Aquifer	1,576 m <sup>3</sup>



Water level: RN5844 and Amungee NW-1 WB1



# Baseline data: methane (fugitives), air quality, terrestrial ecology



ENERGY FLAGSHIP  
www.energysubsidy.gov.au

## Characterisation of Regional Fluxes of Methane in the Surat Basin, Queensland

Phase 2: A pilot study of methodology to detect and quantify methane sources

Stuart Day, Cindy Ong, Andrew Rodger, David Etheridge, Mark Hibberd, Eva van Gorsel, Darren Spencer, Paul Krummel, Steve Zegelin, Robyn Fry, Mark Dell'Amico, Stephen Sestak, David Williams, Zoë Loh and Damian Barrett

EP 15369  
May 2015

Report for the Gas Industry Social and Environmental Research Alliance (GISERA), Project No GAS1315

Queensland Government  
Department of Environment and Heritage Protection

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Air quality [Live air data](#)

### Hourly Air Quality data

Latest measurement: 04 August 2017, 1:00pm - 2:00pm

Related information  
[Get all data here](#)

Search

Day: 04 Month: 08 Year: 2017 Hour: 01:00PM - 02:00PM

Display:  Air Quality  Meteorological  DOAS  Metals  Historical

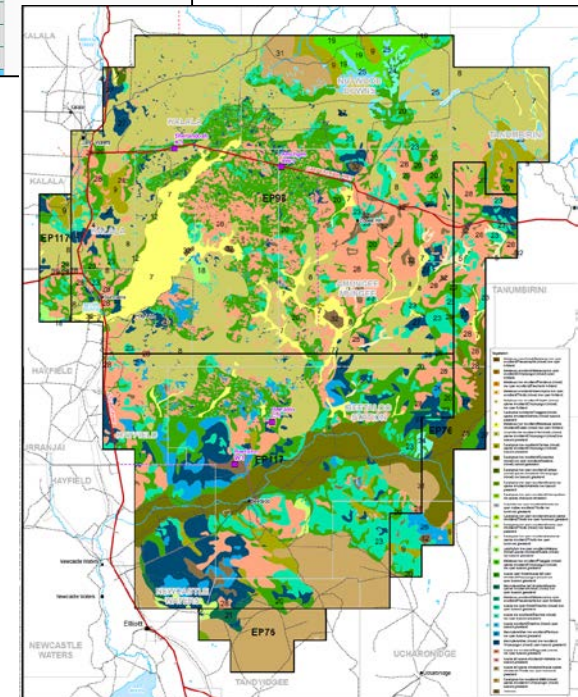
Show:  data readings  index values

Region	Station	Carbon Monoxide (8hr Au) (ppm)	Nitrogen Dioxide (1hr Au) (ppm)	Ozone (1hr Au) (ppm)	Sulfur Dioxide (1hr Au) (ppm)	Particles TSP (24hr Au) (µg/m³)	Particle PM10 (24hr Au) (µg/m³)	Particle PM2.5 (24hr Au) (µg/m³)	Visibility (1hr Au) (km)
South East Queensland	Mountain Creek		0.004	0.04			15.3		3
	Deception Bay		0.002	0.023					
	Wynnum		0.006		0.007		12	3.8	
	Wynnum West				0.006		15.4	3.8	
	Lutton				0		12.6	3	
	Cannon Hill			0.032		23.6	16	8.6	

Department of Natural Resources and Mines

## Code of Practice for coal seam gas well head emissions detection and reporting

Version 2 – June 2011



# Shale gas development in the Beetaloo will not stress ground water resources in the Cambrian Limestone Aquifer (CLA)



**CLA annual sustainable yield ~  
100,000ML**

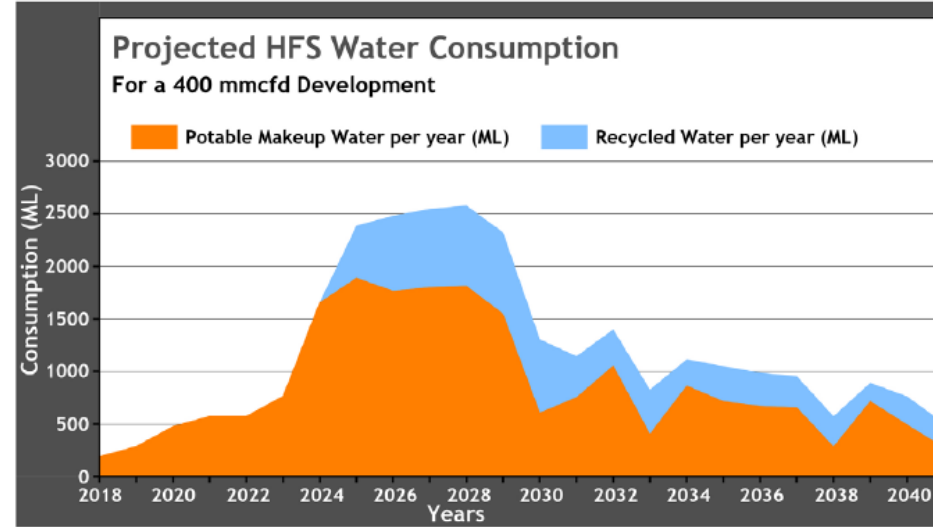
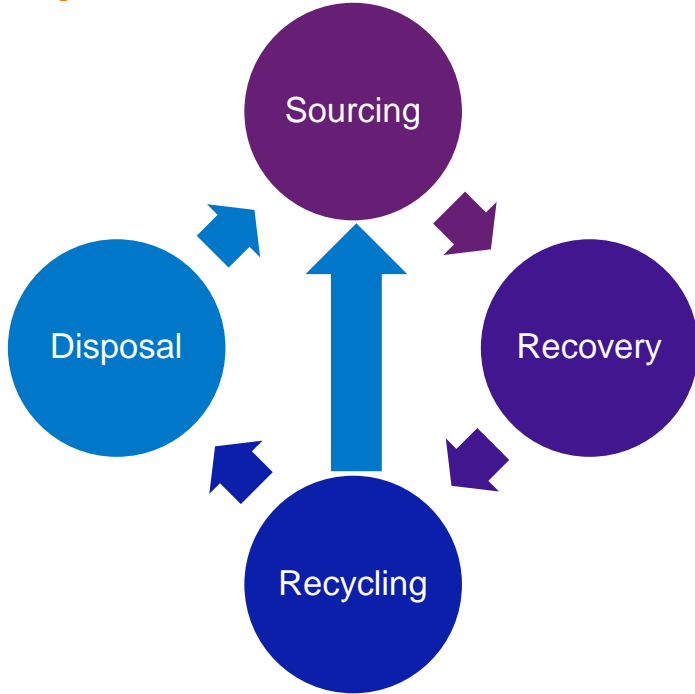
**Max Shale Development  
Consumption  
(5,000 ML/year)**

**Existing  
Consumption  
(6,000 ML/year)**



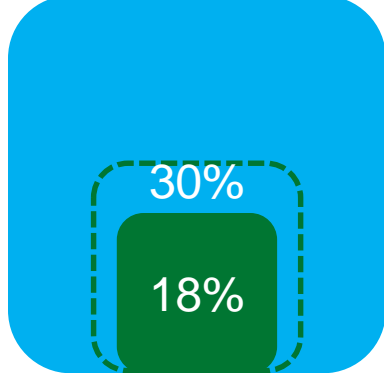
**TOTAL =  
11,000 ML/year  
(11% of  
sustainable  
yield)**

# Recycling of flowback fluids reduces sourcing and disposal requirements



## Amungee NW-1H flowback summary

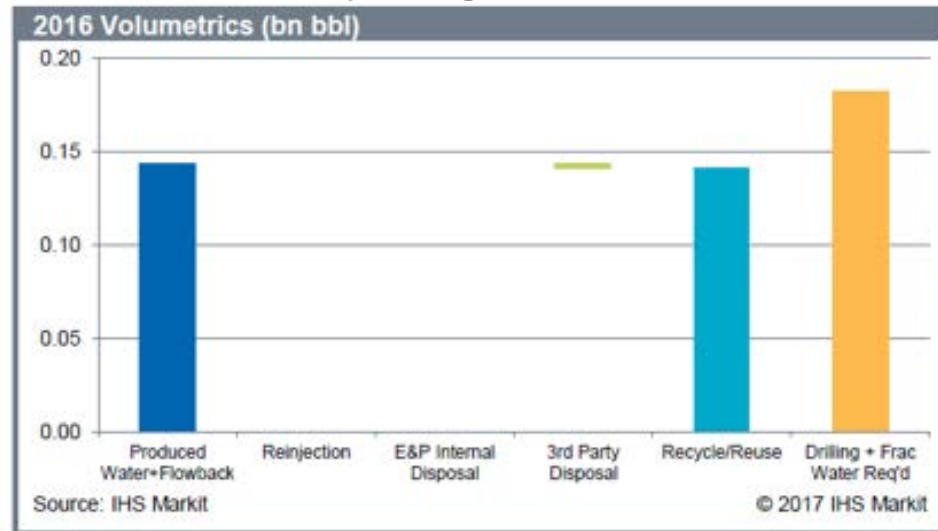
Pumped = 10,640 m<sup>3</sup>

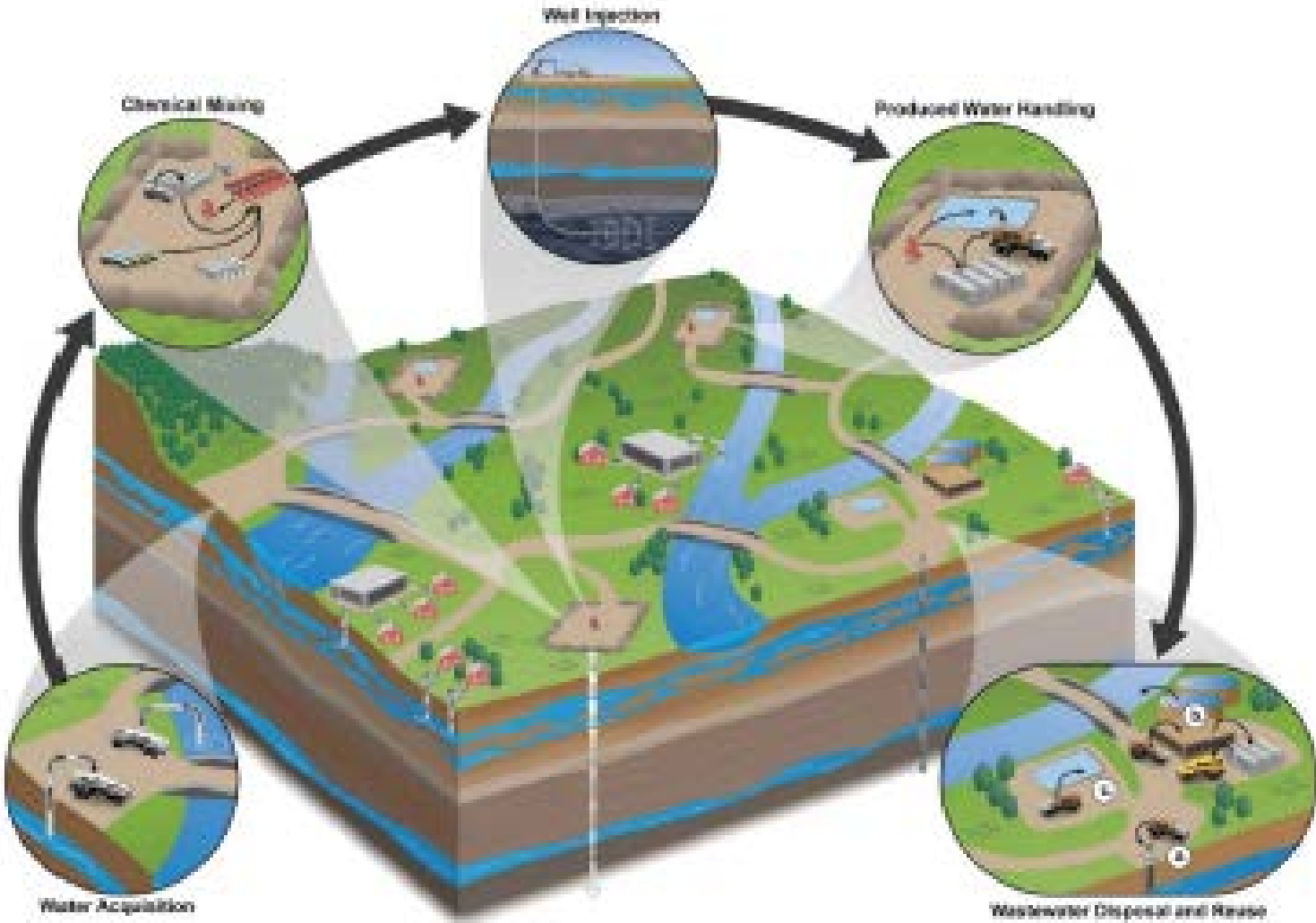


**Flowback (actual) = 18% (1,915 m<sup>3</sup>)**

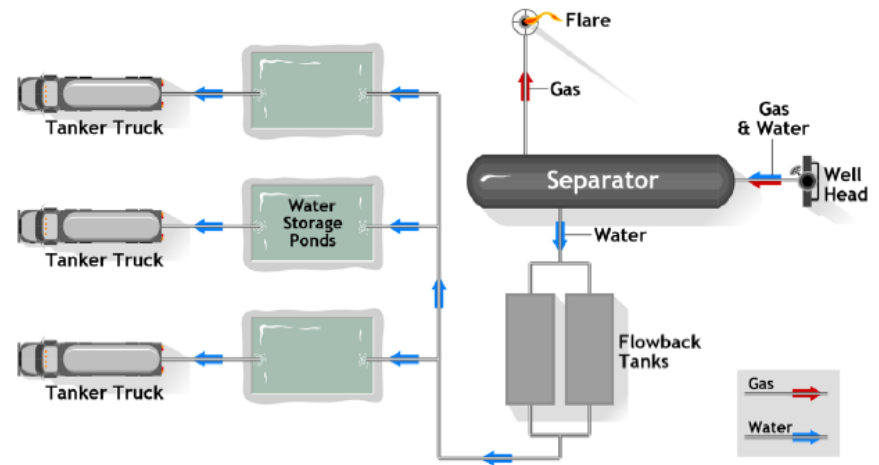
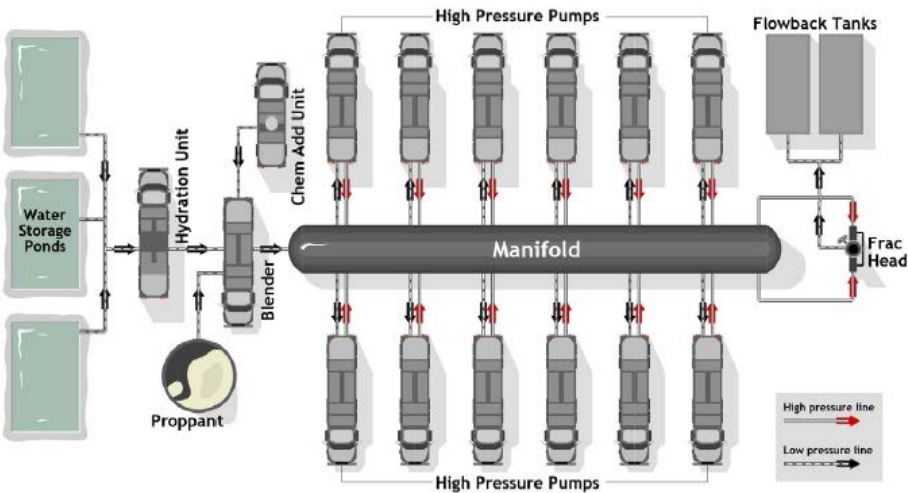
**Flowback forecast = 30% (3,200 m<sup>3</sup>)**

## Marcellus recycling





# Chemical mixing and surface handling



# EPA factors affecting the frequency and severity of ground water impacts associated with fluid migration

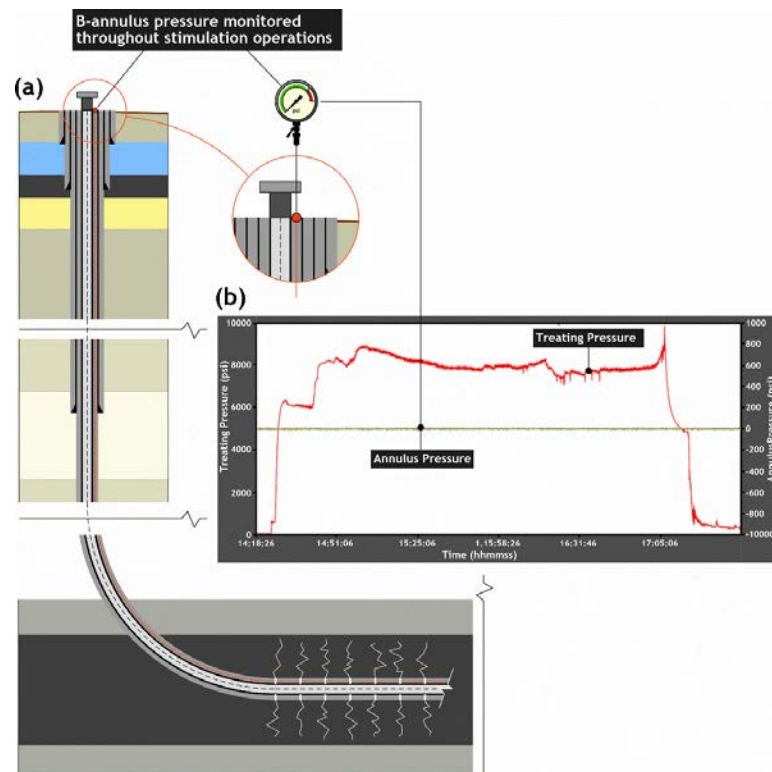
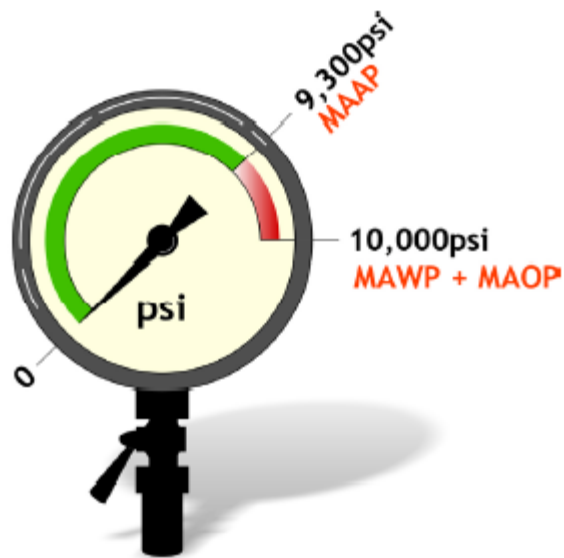
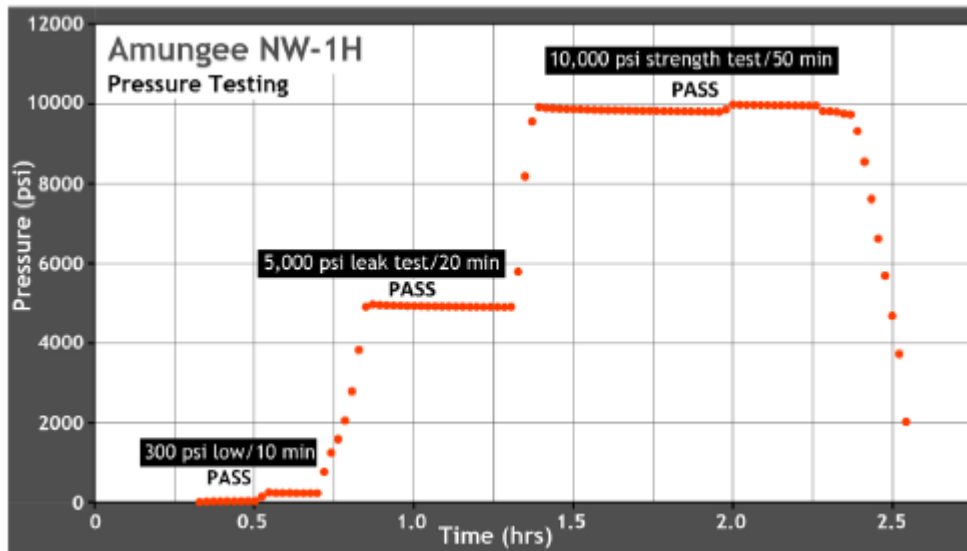


Construction and condition of the well being HFS

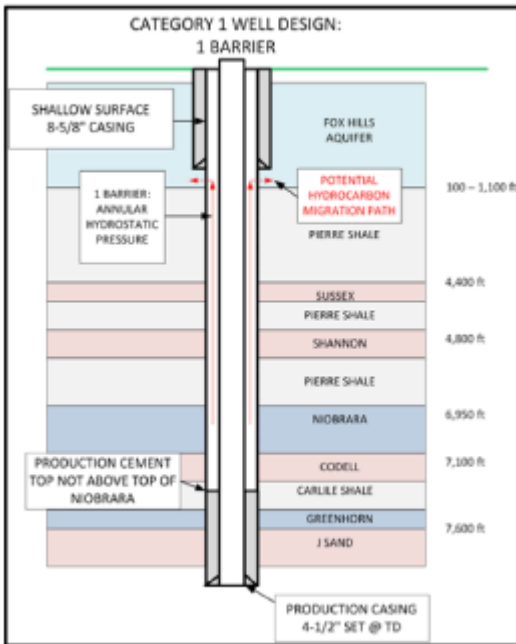
Vertical separation

Location, depth and condition of nearby wellbores and faults

# EPA Review: loss of mechanical integrity during pumping operations (Killdeer, North Dakota)



# EPA: Well construction and stray gas migration

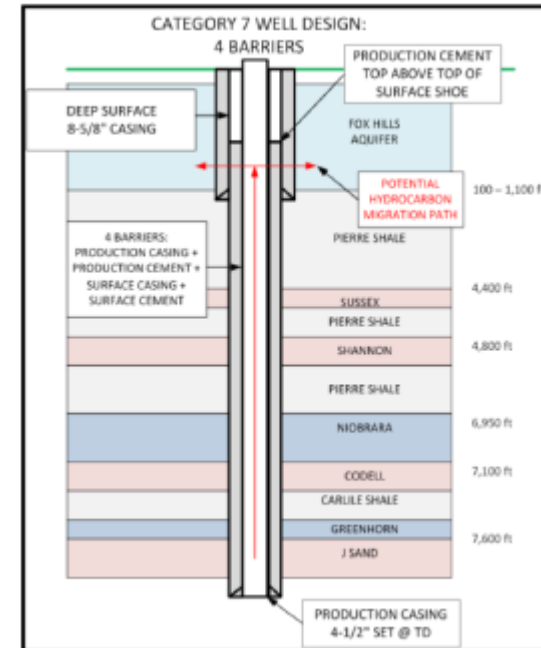


Origin's minimum design requirement for a producing well

Origin's minimum design requirement for a P&A well

Origin's Beetaloo wells

Category	Description	Risk
1	Shallow surface casing + top of production casing cement below over pressured hydrocarbon reservoir	High
2	Shallow surface casing + top of production casing cement below under pressured hydrocarbon reservoir	
3	Shallow surface casing + top of production casing cement above top of gas	
4	Shallow surface casing + top of production casing cement above surface casing shoe	
5	Deep surface casing + top of production casing cement below under pressured hydrocarbon reservoir	
6	Deep surface casing + top of production casing cement above top of gas	
7	Deep surface casing + top of production casing cement above surface casing shoe	
8	Deep surface casing + 1 intermediate casing + top of production casing cement below top of gas	
9	Shallow surface casing + 1 intermediate casing + top of production casing cement above casing shoe	
10	Deep surface casing + 1 intermediate casing + top of production casing cement above top of gas	
11	Deep surface casing + 1 intermediate casing + top of production casing cement above casing shoe	
12	Deep surface casing + 2 intermediate casing strings + top of production casing cement above casing shoe	Low



# EPA: Well construction and stray gas migration



## (a) Vertical and deviated wells

CATEGORY	ORIGINAL WELL COUNT	POTENTIAL BARRIER FAILURES	POTENTIAL BARRIER FAILURES %	CATASTROPHIC BARRIER FAILURES	CATASTROPHIC BARRIER FAILURES %	AVG COMPLETION DATE	P&A WELL COUNT	CURRENT WELL COUNT	ORIGINAL AVG SURFACE CASING DEPTH (FT)	ORIGINAL AVG TOP OF PRODUCTION CEMENT (FT)
Category 1	166	100	60.24%	3	1.81%	1979	57	15	253	7,334
Category 2	621	219	35.27%	5	0.81%	1983	138	301	306	6,566
Category 3	46	16	34.78%	1	2.17%	1987	14	31	321	4,008
Category 4	7	0	0.00%	0	0.00%	1982	1	15	222	125
Category 5	8,789	77	0.88%	1	0.01%	1995	782	6,140	559	6,111
Category 6	5,433	6	0.11%	0	0.00%	2007	105	7,181	712	2,816
Category 7	1,766	0	0.00%	0	0.00%	2009	8	2,040	719	534
<b>TOTAL</b>	<b>16,828</b>	<b>418</b>	<b>2.48%</b>	<b>10</b>	<b>0.06%</b>		<b>1,105</b>	<b>15,723</b>		
D&A	147									

## (b) Horizontal wells

CATEGORY	ORIGINAL WELL COUNT	POTENTIAL BARRIER FAILURES	POTENTIAL BARRIER FAILURES %	CATASTROPHIC BARRIER FAILURES	CATASTROPHIC BARRIER FAILURES %	AVG COMPLETION DATE	P&A WELL COUNT	CURRENT WELL COUNT	ORIGINAL AVG SURFACE CASING DEPTH (FT)	ORIGINAL AVG TOP OF PRODUCTION CEMENT (FT)
Category 1	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 2	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 3	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 4	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 5	0	0	0.00%	0	0.00%	NA	0	0	NA	NA
Category 6	269	0	0.00%	0	0.00%	2012	1	268	789	2,153
Category 7	704	0	0.00%	0	0.00%	2012	2	702	929	442
<b>TOTAL</b>	<b>973</b>	<b>0</b>	<b>0.00%</b>	<b>0</b>	<b>0.00%</b>		<b>3</b>	<b>970</b>		
D&A	0									

# EPA: Stray gas migration and surface casing depth and depth of cement top

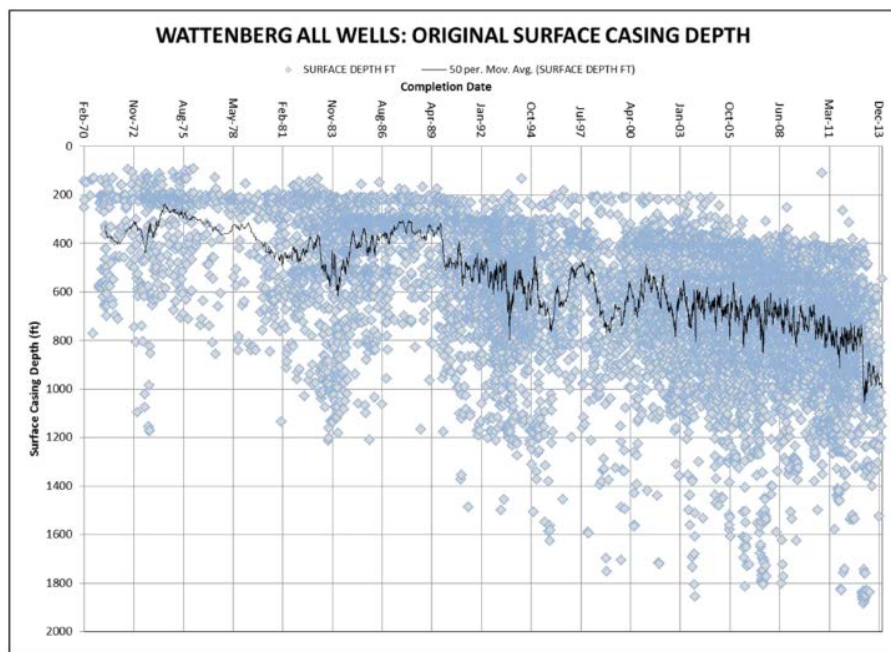


Figure 5—Chronologic original surface casing setting depths in the Wattenberg Field.

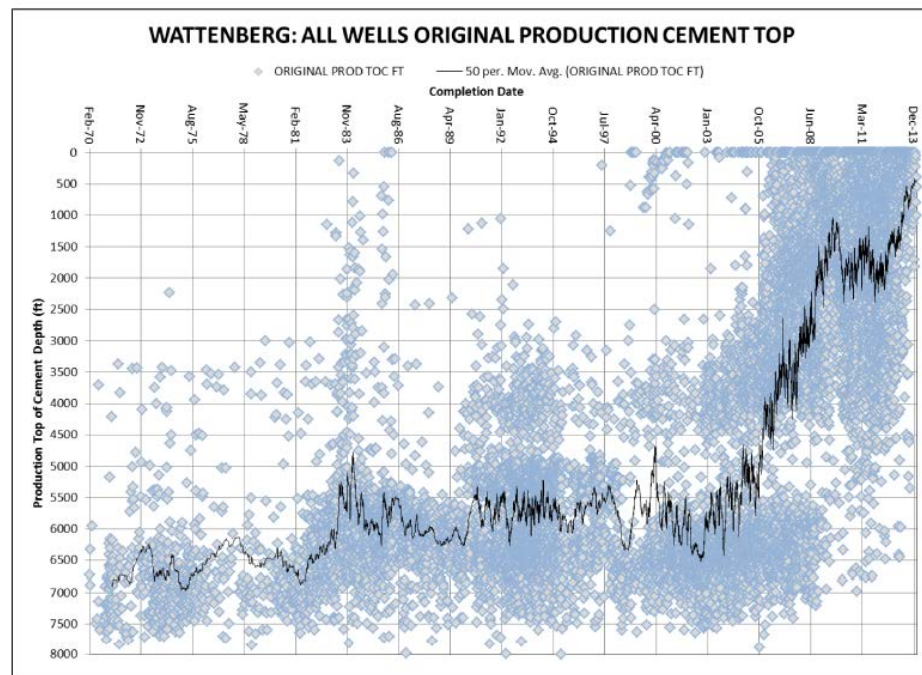
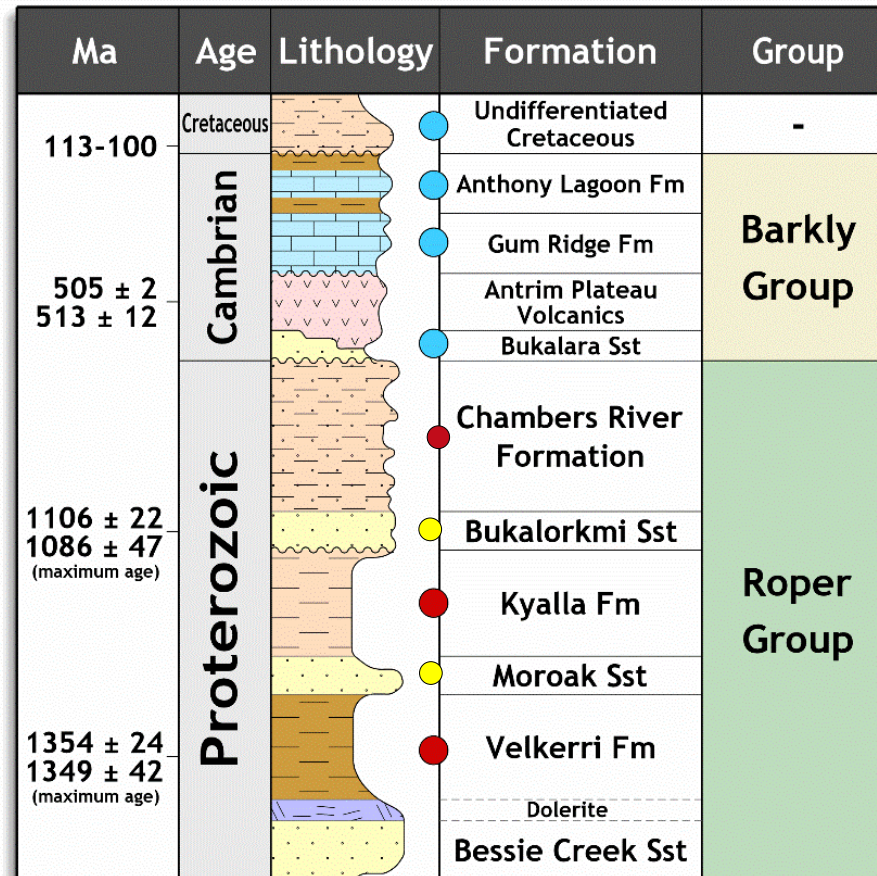


Figure 7—Chronologic original top of production cement depths in the Wattenberg Field.

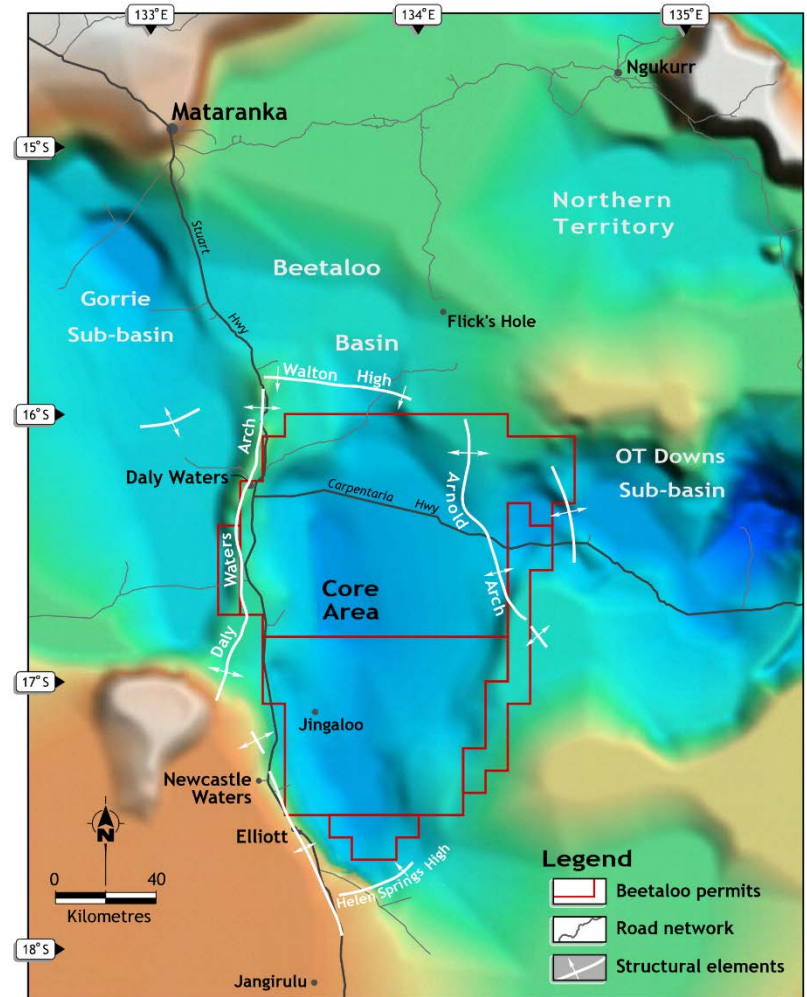
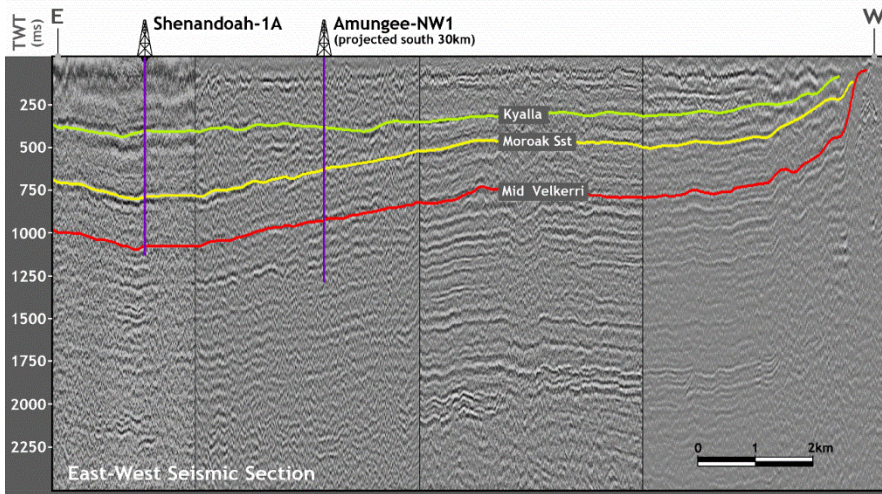
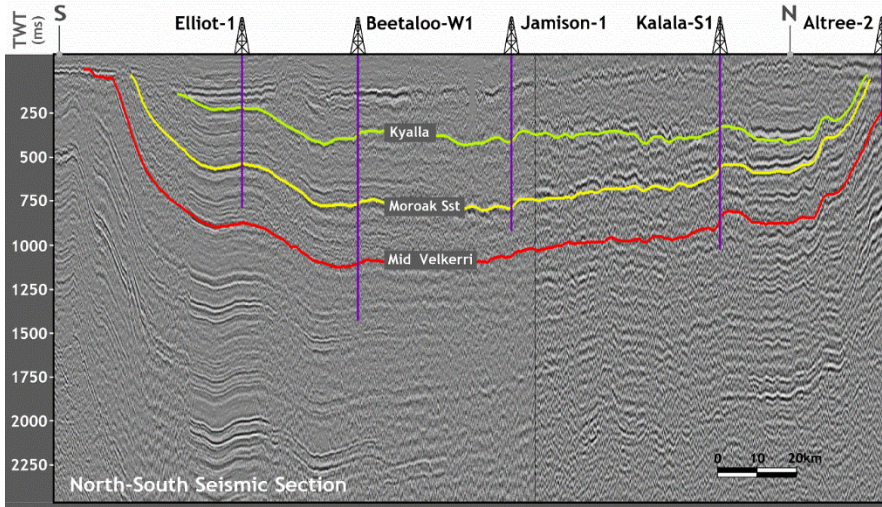
# Potential for gluid migration in the Beetaloo is low at virgin conditions



- Potable Acquifer
- Hydrocarbon Bearing Zone
- Non Potable Aquifer



# EPA: migration pathways via faults and structures



## Well failure and barrier failure



### Ingraffea Study Well Failure Rates

**1,609 wells drilled in 2010**

- 111 well failures
- 6.9% rate of failure

**1,979 wells drilled in 2011**

- 142 well failures
- 7.2% rate of failure

**1,346 wells drilled in 2012**

- 120 well failures
- 8.9% rate of failure

### Origin Review Well Failure Rates

**1,600 wells drilled in 2010**

- 7 well failures
- 0.4% rate of failure

**1,975 wells drilled in 2011**

- 0 well failures
- 0.0% rate of failure

**1,351 wells drilled in 2012**

- 0 well failures
- 0.0% rate of failure



YEAR	UNCONVENTIONAL WELLS DRILLED	NOV's ASSOCIATED WITH POTENTIAL WELL FAILURE*		NOV's ASSOCIATED WITH POTENTIAL WELL FAILURE* WITH A CONFIRMED RELEASE TO THE ENVIRONMENT**		UN REMEDIATED*** NOV's ASSOCIATED WITH POTENTIAL WELL FAILURE* WITH A CONFIRMED RELEASE TO THE ENVIRONMENT**	
		TOTAL	AS A PERCENTAGE OF WELLS DRILLED	TOTAL	AS A PERCENTAGE OF WELLS DRILLED	TOTAL	AS A PERCENTAGE OF WELLS DRILLED
2002	1	0	0.00%	0	0.00%	0	0.00%
2003	4	0	0.00%	0	0.00%	0	0.00%
2004	2	0	0.00%	0	0.00%	0	0.00%
2005	9	0	0.00%	0	0.00%	0	0.00%
2006	37	1	2.70%	0	0.00%	0	0.00%
2007	114	2	1.75%	0	0.00%	0	0.00%
2008	332	1	0.30%	0	0.00%	0	0.00%
2009	818	4	0.49%	1	0.12%	1	0.12%
2010	1,600	13	0.81%	7	0.44%	2	0.13%
2011	1,957	5	0.26%	0	0.00%	0	0.00%
2012	1,351	2	0.15%	0	0.00%	0	0.00%
2013	1,214	3	0.25%	1	0.08%	0	0.00%
2014	1,371	1	0.07%	0	0.00%	0	0.00%
2015	784	5	0.64%	2	0.26%	2	0.26%
2016	504	0	0.00%	0	0.00%	0	0.00%
2017	185	0	0.00%	0	0.00%	0	0.00%
<b>Total</b>	<b>10,283</b>	<b>37</b>	<b>0.36%</b>	<b>11</b>	<b>0.11%</b>	<b>5</b>	<b>0.05%</b>

\* NOV categories included: 78.73(a), 78.73A, 78.73(b), 78.81(a)2 and 207B

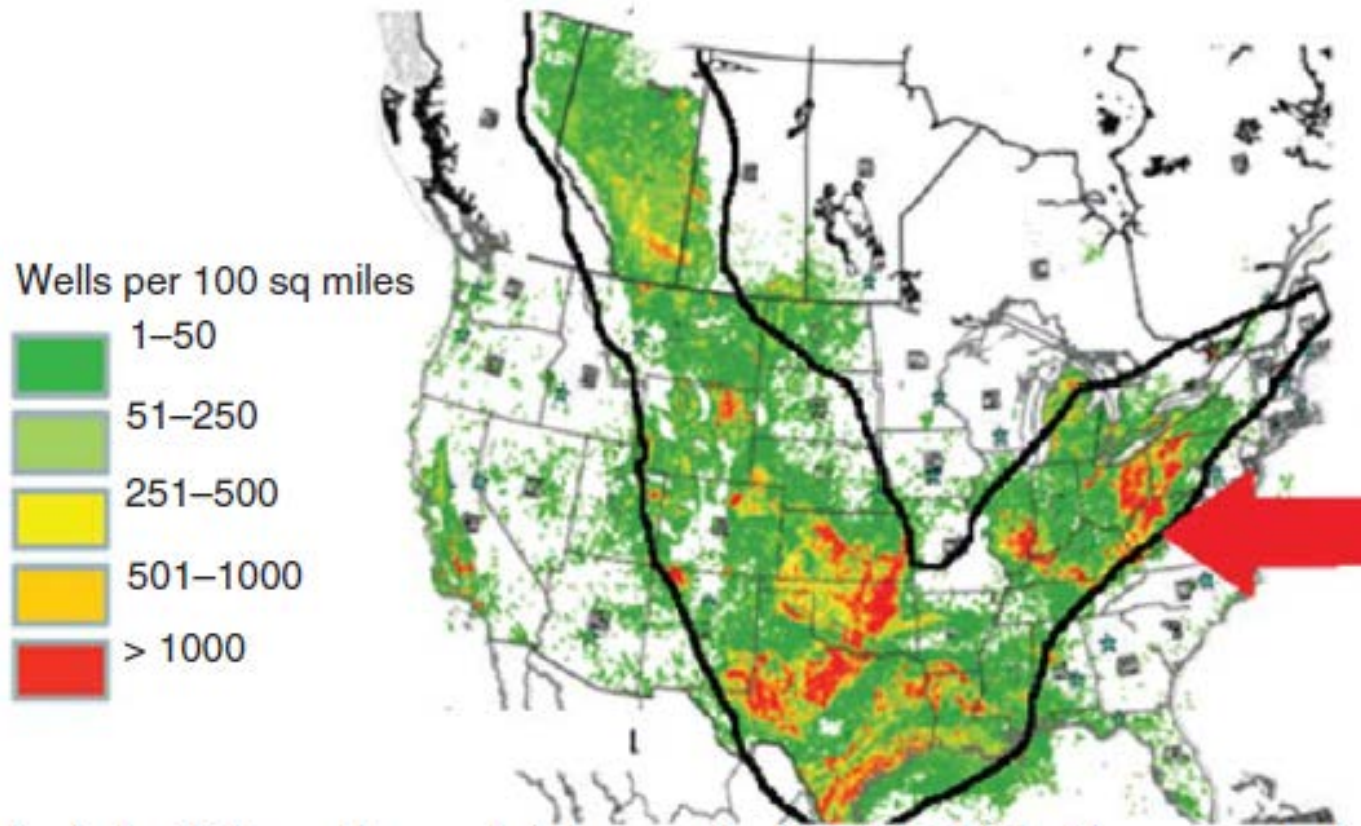
\*\* PADEP NOV's where the comments indicated that no well integrity failure had occurred (i.e. pre-emptive NOV's, and NOV's associated to surface equipment such as separators) were removed

\*\*\* NOV's have not been confirmed as corrected, fixed, or remediated by the PADEP

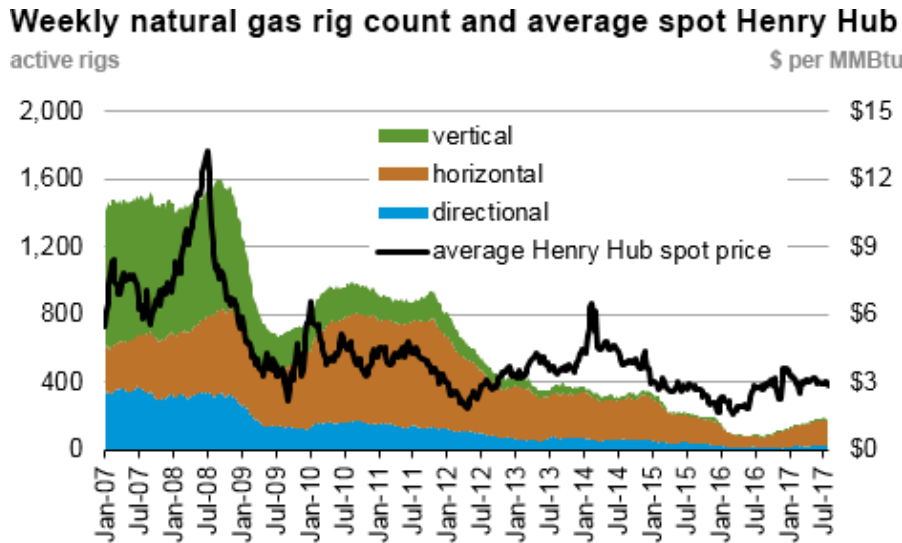
# Abandoned wells



Total: 4.3 Million Wells



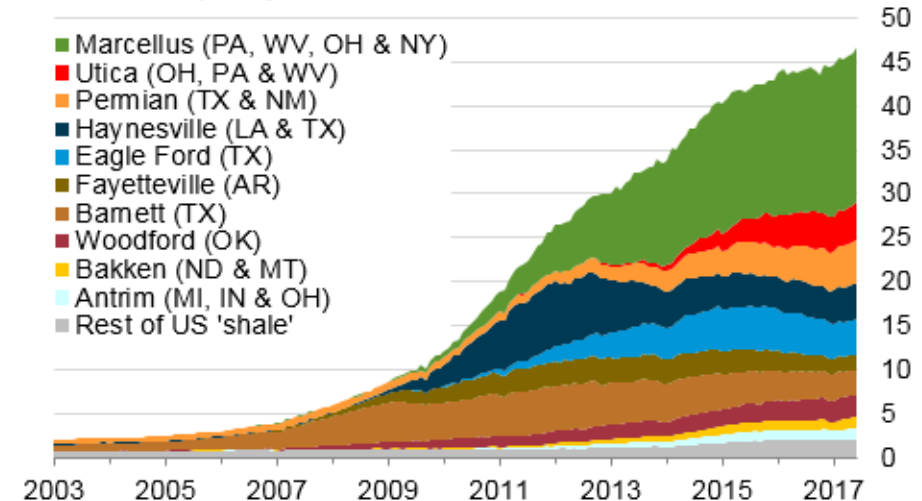
# Shale gas and North American experience – reserves, gas prices and rig count



eia Source: Baker Hughes

The US has experienced sustained low gas prices with lower rig activity...

**Monthly dry shale gas production**  
billion cubic feet per day



Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through June 2017 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).



...because shale gas operators have become efficient

In 2005 no economic analysis forecast this – too much uncertainty

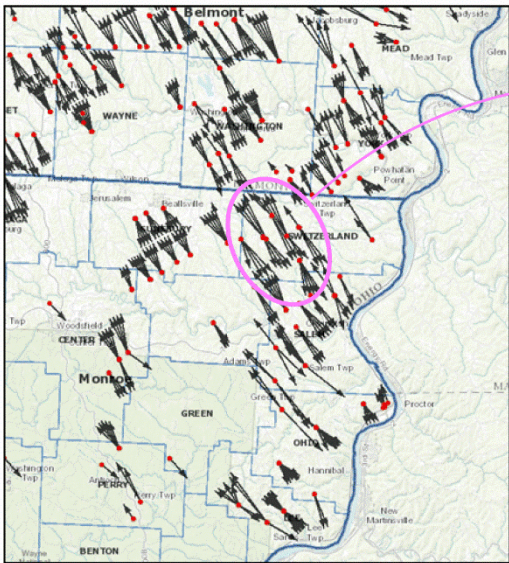
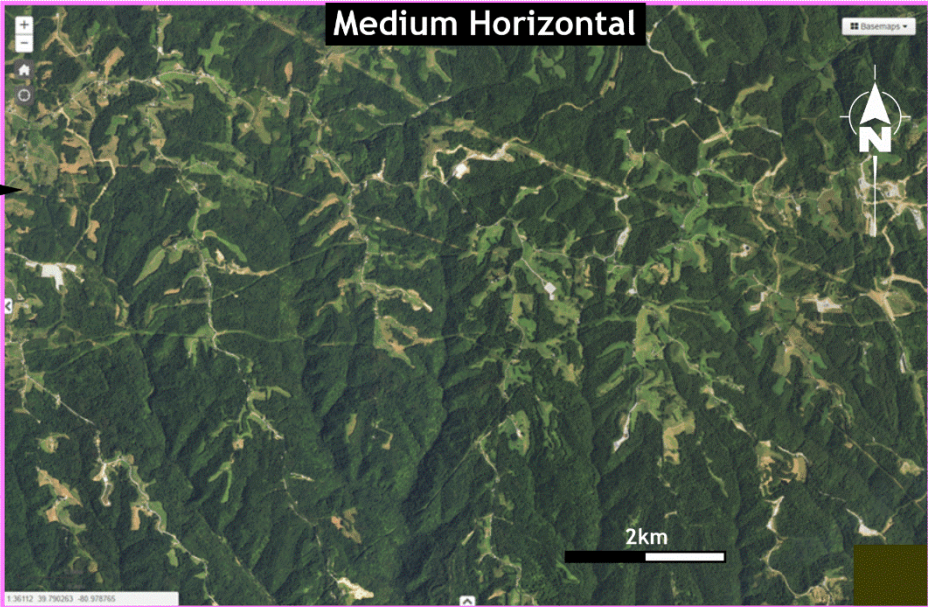
Horizontal drilling and multi-well pads provide almost infinite scope for efficiency improvements and decreased surface impact

# Pad developments are efficient and minimise surface impact

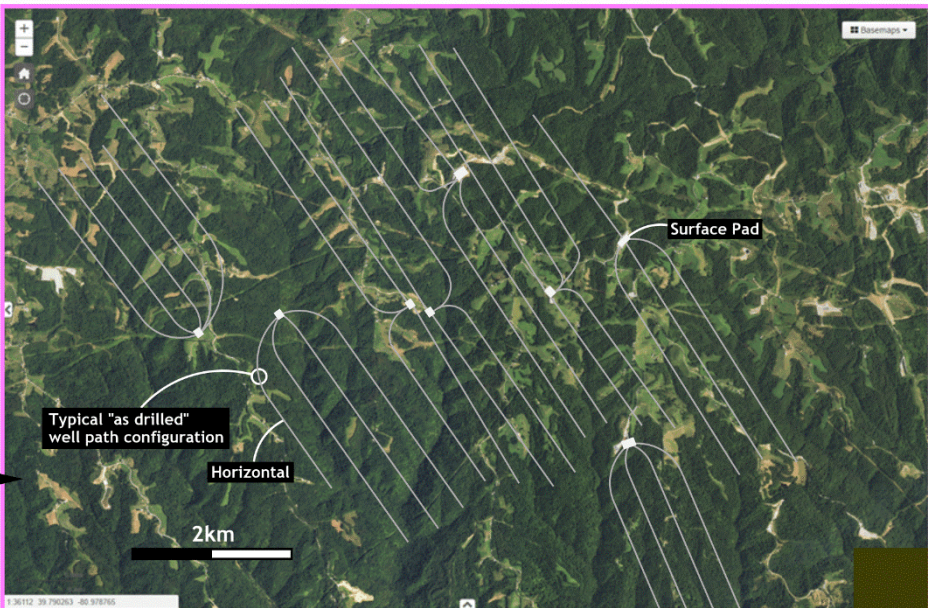


Utica Shale Play: eastern Ohio

Surface Footprint



Sub-surface Footprint



# Photos of US oil or gas fields are typically a poor analogy for the NT where there is not a history of conventional production

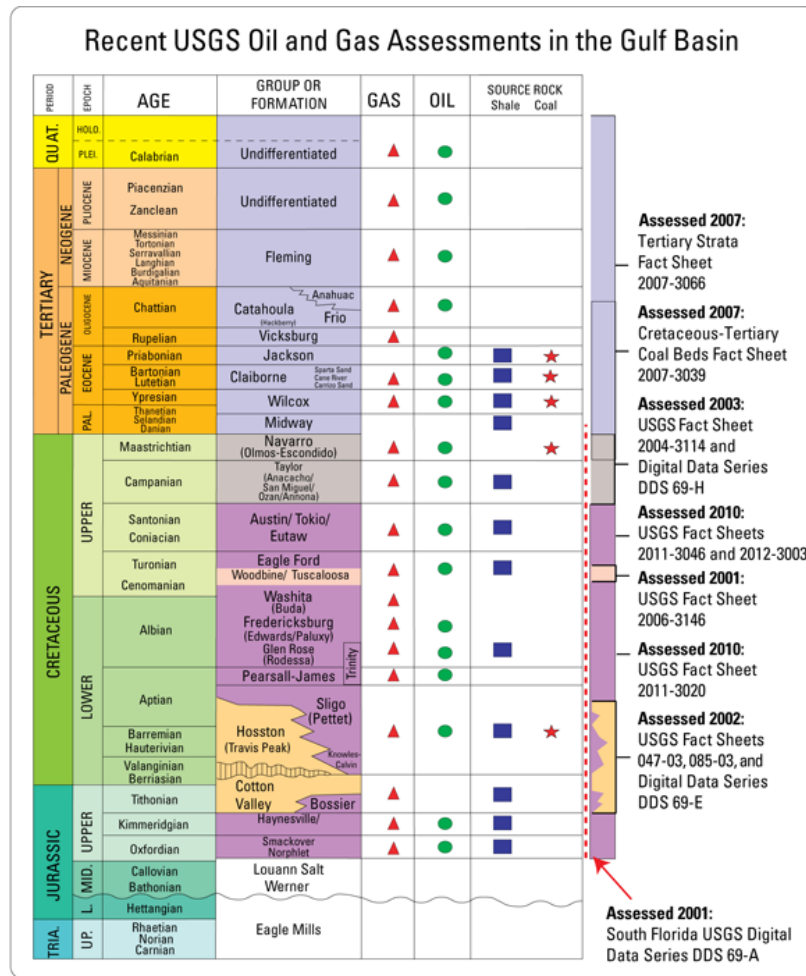


South Texas “example” introduced to this Inquiry by LTG in March



Decades of conventional oil and gas production prior to development of any shale gas

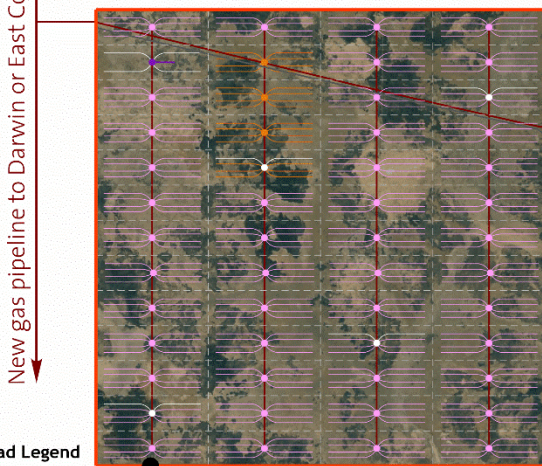
South Texas stratigraphic column (USGS)



# Velkerri or Kyalla shale plays could only be economically developed with horizontal wells from multi-well pads

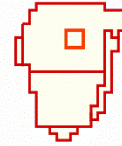


## Large Development



- Well/Pad Legend**
- Exploration
  - Appraisal
  - Delineation
  - Development

**Notional Development Area: approx. 500km<sup>2</sup>**

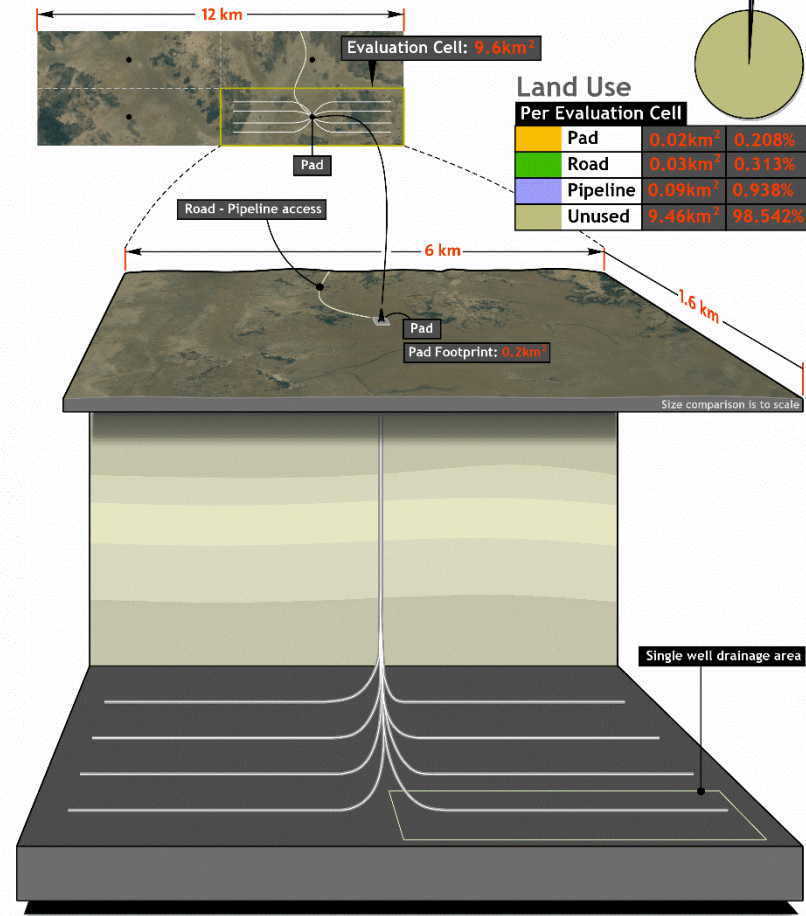


## D Large Scale Development Phase

- Duration: 20-40 years
- # wells drilled and HFS: 300-500
- # rigs: 3-6
- Production: 400-500 TJ/D
- Water consumption: 18,000-30,000 ML

### Infrastructure\*

- Facilities: Expand gas plant
  - # pads: 40-65
  - Roads: 40-130 km
  - Pipeline: 80-130 km
  - Surface footprint: 3-10 km<sup>2</sup>
- \* Constructed during the phase within the notional development area



## Economic drivers:

1. Expected Ultimate Recovery (EUR) per well
2. Natural Gas Liquids (NGLs) in gas stream
3. Costs
  - i. All drilling and hydraulic fracturing during one pad operating sequence:
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# The Velkerri Formation is technically comparable to successful North American plays in many critical aspects



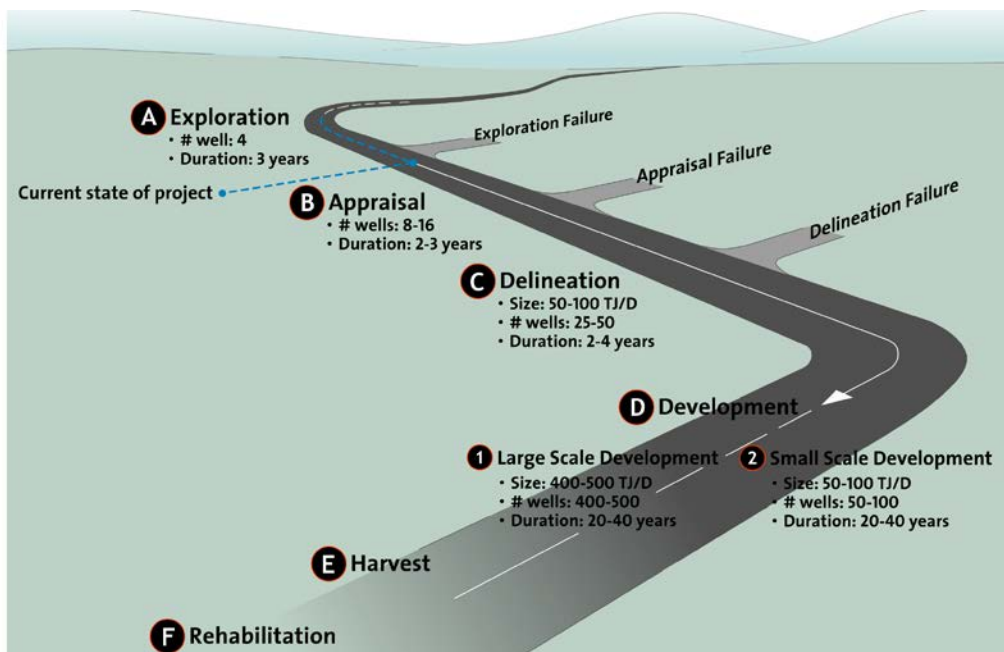
Shale	Marcellus <sup>1</sup>	Barnett <sup>1</sup>	Fayetteville <sup>1</sup>	Middle Velkerri Member	B Shale (Amungee NW-1)
Basin/area	Appalachian Basin	Fort Worth Basin Texas	Arkoma Basin Arkansas	Beetaloo Basin Northern Territory	Beetaloo Basin Northern Territory
Age	Devonian	Mississippian	Mississippian	Mesoproterozoic	Mesoproterozoic
Estimated basin area (km <sup>2</sup> )	246,050	12,950	23,310	17,070	17,070
Typical depth for shale gas (m)	1220 - 2590	1980 - 2590	1,735	1000 - 2500	2418
Gross Thickness (m)	60	60 - 305	15 - 100	45 - > 420	30
<b>Net Thickness (m)</b>	<b>15 - 105 (45)</b>	30 - 215 (90)	5 - 60 (40)	60 - 86 (73) <sup>2</sup>	<b>30</b>
Reported Gas contents (scf/ton)	60 - 150	300 - 350	60 - 220	100 <sup>2</sup>	148
Adsorbed gas (%)	45	55	50 - 70	50 <sup>2</sup>	45
Free gas (%)	55	45	30 - 50	50 <sup>2</sup>	55
Porosity (%)	4.0 - 12.0 (6.2)	4.0 - 6.0 (5.0)	2.0 - 8.0 (6.0)	2.0 - 8.0	7.0 - 7.1
Permeability range (average) (nD)	0 - 70 (20)	0 - 100 (50)	1 - 100 (50)	10 - 100 (50)	10 - 100 (50)
Pressure Gradient (psi/ft)	0.61	0.48	0.44	0.53 <sup>2</sup>	0.53
<b>Gas-filled porosity (%)</b>	<b>4.0</b>	5.0	4.5	2.5 <sup>2</sup>	<b>3.6 - 4.1</b>
Water Saturation (%)	43	38	70	58 <sup>2</sup>	43
Oil saturation (%)	1.0	10.0	< 1.0	0	0
Reported Silica Content (%)	37	45	35	49 (1.0 - 77)	54 (48 - 59)
<b>Reported Clay Content (%)</b>	<b>35</b>	25	38	35 (1.1 - 80)	<b>29 (27 - 32)</b>
Reported Carbonate Content (%)	25	15	12	Tr (Tr - 12.3)	1 (Tr - 4)
Chlorite (%)	20 (0 - 50)	2 (0 - 20)	20 (5 - 40)	3 (Tr - 40)	3 (3 - 4)
%Ro (average-range)	1.5 (0.9 - 5.0)	1.6 (0.85 - 2.1)	2.5 (2.0 - 4.5)	1.5 - > 2.5 <sup>3</sup>	2.0 - 2.3 <sup>3</sup>
HI present-day	20	45	15	20	22
TOC present-day (average in wt%)	4.01 (2.0 - 13.0)	3.74 (3.0 - 12.0)	3.77 (2.0 - 10.0)	3.74 (1.0 - 10)	4.05 (3.8 - 4.1)
S1 present-day + S2 present-day (mg/g)	1.23	1.95	0.35	0.89	1.04
GIP from gas contents (average bcf/section)	130	150 - 200	55	126 <sup>2</sup>	31

<sup>1</sup>Source: Jarvie, D.M., 2012, AAPG Memoir 97, p. 69-87

<sup>2</sup>Origin Energy Ltd estimated average values from C, B, and A shale in Kalala S-1 and Amungee NW-1

<sup>3</sup>Value represent Equiv. %Ro estimated from alginite reflectance

# The Beetaloo Project – an exploration phase project with encouraging technical results



## 5 YEAR WORK PROGRAM

13 July 2017

EP	STAGE 1			Moratorium	STAGE 2	STAGE 3
	2014	2015	2016			
98	Geological and geophysical studies	2 vertical wells, 1 horizontal well	1 HFS horizontal well		1 HFS vertical well	2 HFS horizontal wells
117	Geological and geophysical studies	Geological and geophysical studies	1 vertical well		2 HFS horizontal wells	Geological and geophysical studies
76	Geological and geophysical studies	Geological and geophysical studies	Geological and geophysical studies		Geological and geophysical studies	Geological and geophysical studies

\*HFS  
 Hydraulic Fracture Stimulation

# Origin stakeholder interaction(s) during exploration



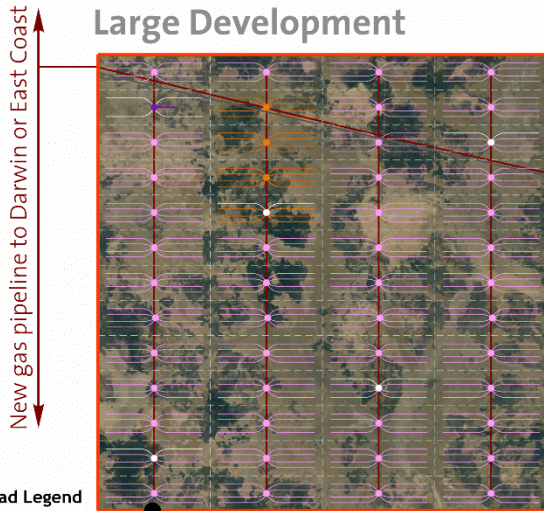
**Communication**  
‘push process’

**Consultation**  
‘two-way’

**Engagement**  
‘active involvement’



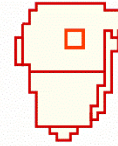
# Velkerri or Kyalla shale plays could only be economically developed with horizontal wells from multi-well pads



## Large Development

- Well/Pad Legend**
- Exploration
  - Appraisal
  - Delineation
  - Development

**Notional Development Area: approx. 500km<sup>2</sup>**

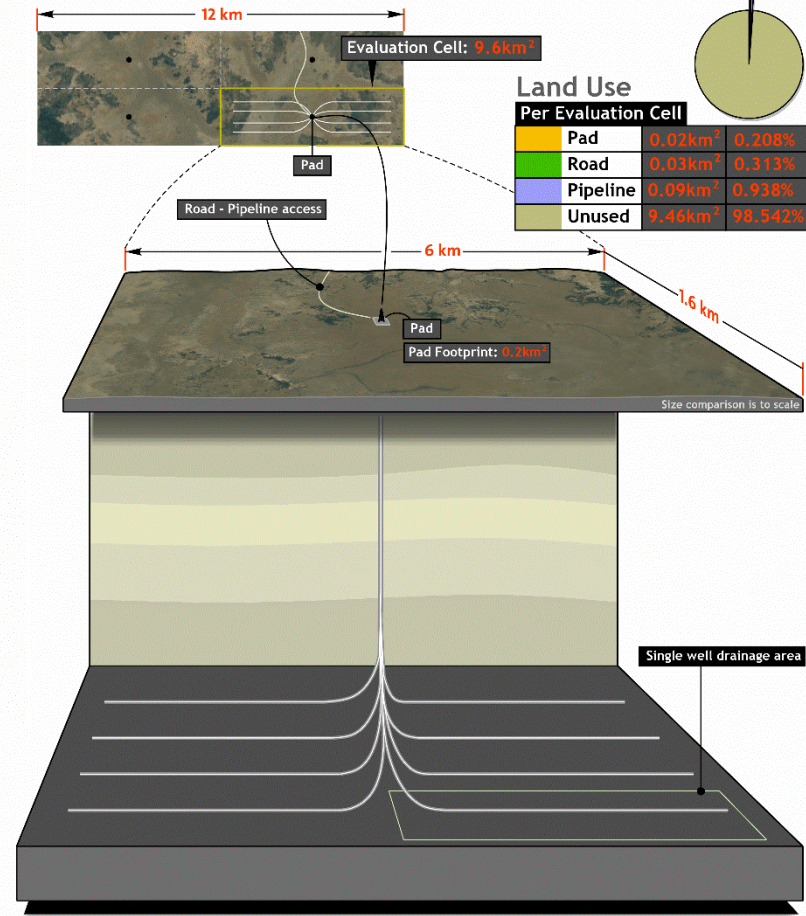


## D Large Scale Development Phase

- Duration: 20-40 years
- # wells drilled and HFS: 300-500
- # rigs: 3-6
- Production: 400-500 TJ/D
- Water consumption: 18,000-30,000 ML

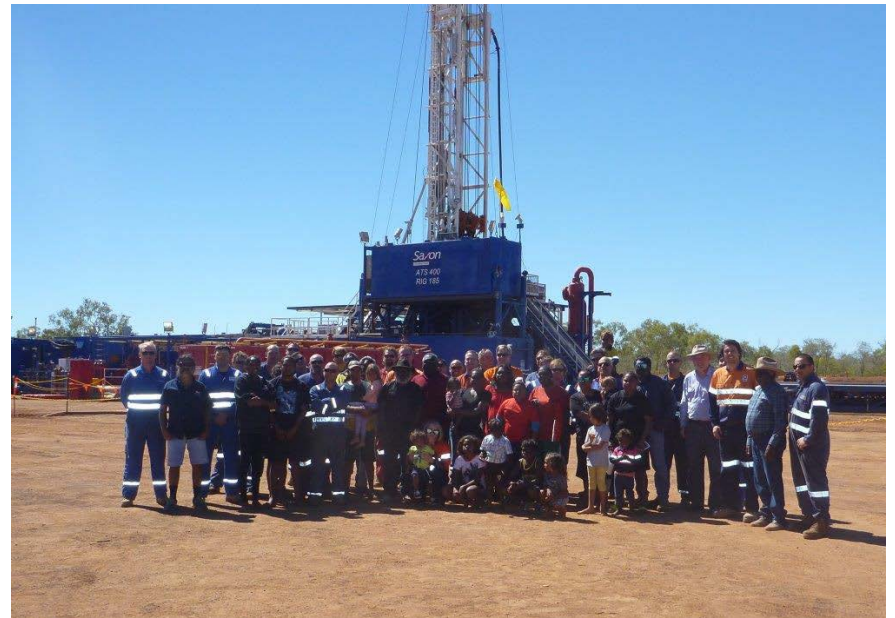
### Infrastructure\*

- Facilities: Expand gas plant
  - # pads: 40-65
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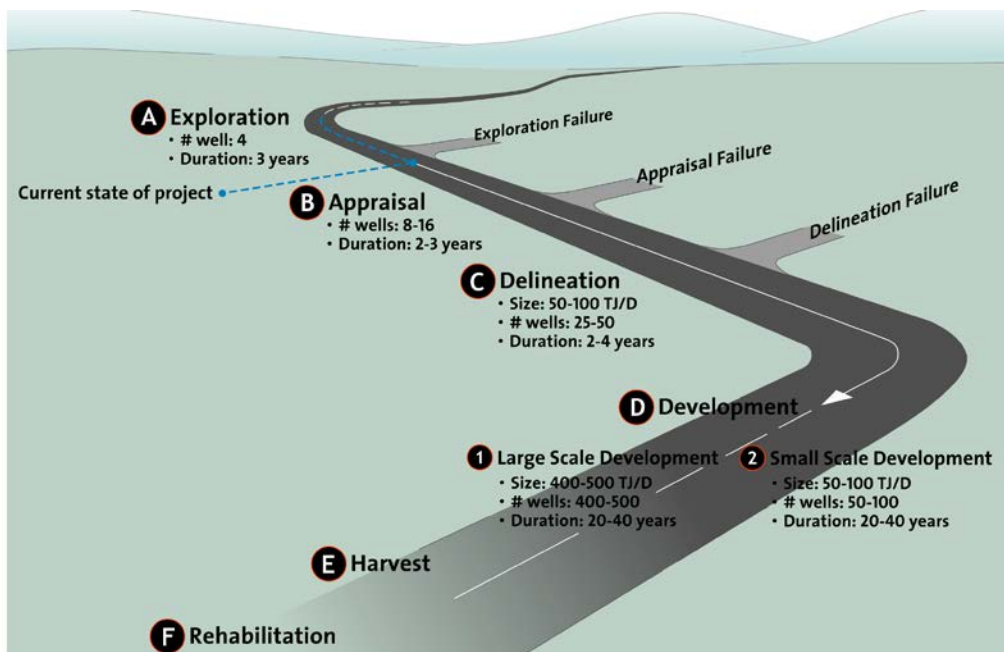


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 Hydraulic Fracture Stimulation

