SHARED LANDSCAPES

INDUSTRY TRENDS

GasFields Commission Queensland

AUGUST 2019

Shared Landscapes captures the key trends and footprint of two industries sharing the regional Queensland landscape – agriculture and gas.

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- Queensland Rural and Industry Development Authority
- Queensland Treasury
- Santos
- Senex Energy
- Shell's QGC

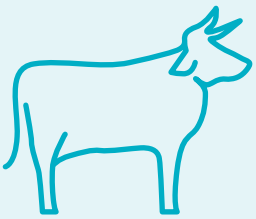
DISCLAIMER

CSG well surrounded by oat crop

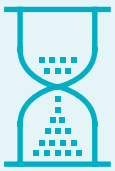
IN THIS REPORT

INTRODUCTION

CSG well on property near Dalby, Queensland

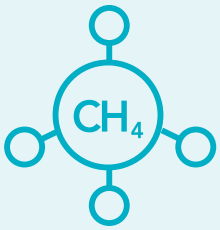


Queensland is Australia's **largest producer** and **exporter** of **beef**



Queensland's **first gas field** was discovered in Roma in

1900



Queensland gas is used for **cooking**, **heating**, **manufacturing** and **electricity** generation

SHARED LANDSCAPES

Queensland has a long and pioneering history with agriculture and natural gas.

The two industries have been sharing the Queensland landscape since the first gas was discovered by chance in Roma in 1900.

The gas industry has since grown to become an $8.2 billion industry creating thousands of jobs, underpinning the development of Queensland industry and creating a thriving export industry.

Liquefied natural gas (LNG) has become Queensland's second largest commodity export after coal with a rise in exports from 2015 onwards.

At the same time and despite the significant effects of widespread drought, Queensland agricultural exports contributed $10.3 billion to the Queensland economy in 2016/17.

Agriculture, fisheries and forestry employs 54,300 people full time in Queensland while the coal seam gas industry employs approximately 24,000 people.

Agriculture occupies 88.4 percent of the Queensland landscape, while less than two percent of the state is under petroleum production tenure and a further 13.9 percent is under exploration tenure.

Land used for agriculture is primarily leasehold or freehold land and underground resources remain the property of the state with resource companies allowed to access them under government permit.

There is an estimated total of 390,000 megalitres of groundwater taken from Queensland's gas producing areas each year, with 141,158 megalitres of that used in agriculture, 148,445 megalitres used for stock and domestic consumption and 66,000 megalitres produced as part of the petroleum and gas extraction process.

Queensland's natural gas is used to cook our locally produced food, power industry, manufacture fertiliser and generate electricity – it has become an everyday part of our shared lives.

The GasFields Commission gathers and collates the most up to date and relevant information to provide an accurate representation of industry trends.

This information can be used by policy makers, educators, planners and stakeholders to make informed decisions.

It's part of our vision to create informed and self-reliant communities, based on respectful and balanced relationships between landholders, communities, and the onshore gas industry in Queensland.

This report captures the key trends of the two main industries sharing the regional Queensland landscape.

PETROLEUM AND GAS GLOSSARY

Access agreement – a negotiated agreement between a resource company and private landholder relating to the rights over designated 'access land' (see below).

Access land – this is land **outside** a declared resource authority area, over which it is reasonably necessary for a resource company to travel in order to access land subject to their resource authority.

Access right – a resource company's right to cross access land where reasonably necessary or carry out activities on the access land.

Advanced activity – an authorised activity for the resource authority that is not a preliminary activity.

Alluvial aquifer – an aquifer that is not completely confined by an aquitard and usually located adjacent to a river. Alluvial aquifers are generally composed of silt, clay, sand, gravel or similar unconsolidated material deposited by running water. An example is the Condamine Alluvium.

Aquifer – an underground geological layer with high permeability which means it can store and allow water movement.

Aquitard – an underground geological layer with low permeability. Sometimes called a confining layer. Examples include siltstone, shale and mudstone.

Associated water – sometimes referred to as 'CSG produced water'. Groundwater that is produced as a result of gas production. This water can be treated and used beneficially for a range of purposes.

ATP – authority to prospect also commonly known known as an exploration permit or tenure.

Authorised activity – an activity permitted for the resource authority by the particular Act under which it is granted.

bcf – billion cubic feet (of gas).

boe – barrels of oil equivalent – a unit of energy approximating the energy released by burning one barrel (158 litres) of crude oil.

Conduct and Compensation Agreement – a legal agreement between a landholder and a resource company relating to proposed activities or conduct and, where there is impact on the landholder, compensation arrangements for those activities.

Coal seam gas (CSG) – natural gas contained in coal seams.

Conventional gas – *also see natural gas*. Conventional gas reservoirs largely consist of porous sandstone formations capped by impermeable rock, with the gas stored at high pressure.

Deferral agreement – a legal agreement in which a landholder and resource company agrees to defer the negotiation of Conduct and Compensation Agreement until a later date and after the resource company has accessed the land to undertake advanced activities.

Fracking or fraccing – see hydraulic fracturing (below).

GWh – a gigawatt hour is a unit of energy representing one billion (1,000,000,000) watt hours and is equivalent to one million kilowatt hours.

Hydraulic fracturing – an established method used by the petroleum and gas industry since the late 1940s to increase the rate and total amount of petroleum and gas extracted from reservoirs. Water and sand (99 percent) and additives (1 percent) are pressure pumped into steel-encased wells to stimulate the opening of cracks in gas-bearing formations.

Hydrocarbons – are organic compounds comprising hydrogen and carbon. Hydrocarbons are the principal constituents of oil and gas.

Landholder – owner/occupier/lessee (e.g. rental tenant) of private land.

LNG – liquefied natural gas. Natural gas that is cooled to -161 degrees celcius to reduce its volume to 1/600th for the purpose of transport. To unload LNG from a vessel no processing is required as conversion back to gaseous form occurs as the temperature increases.

Methane – molecules comprised of hydrogen and carbon (CH_4) – the primary constituent of natural gas.

Natural gas – is comprised primarily of methane and is extracted from gas-bearing underground reservoirs.

Opt-Out Agreement – a legal agreement in which the landholder chooses to 'opt-out' of the requirement to enter into a Conduct and Compensation Agreement or Deferral Agreement.

Petroleum – liquid, gaseous and solid hydrocarbons including oil, gas, condensate, ethane, propane, butane and pentane.

Petroleum well – for the purposes of this report, 'petroleum wells' refers to conventional, tight gas and shale wells.

Permeability – the degree to which gas or fluids can move through a porous material, such as rock.

Petajoule – one petajoule (PJ) is enough energy to power 42,000 average Australian households for one year.

Preliminary activity – an activity that will have no impact or only a minor impact on the business or land use activities of a landholder on which the activity is to be carried out. (N.B. These activities are not considered preliminary activities if they are carried out on land that is being used for intensive farming or broadacre agriculture that is less than 100 ha in size or if they affect organic or bioorganic farming.)

Private land – is freehold land or an interest in land less than fee simple held from the State under another Act. However, land is not private land to the extent of an interest in a resource authority under a resource Act.

PL – petroleum lease also commonly known as a production licence or tenure.

Proppant – a solid material, typically sand, treated sand or man-made ceramic materials, designed to keep an induced hydraulic fracture open during or following a fracturing treatment.

Proven reserves (1P) – petroleum that can be estimated with reasonable certainty (at least 90 percent) to be commercially recoverable. Also known as 1P/P90 reserves.

Proven and probable reserves (2P) – proven petroleum reserves plus reserves deemed probable (at least 50 percent likely) to be commercially recoverable. Also known as 2P/P50 reserves.

Proven, probable and possible reserves (3P) – proven and probable reserves plus reserves deemed possible (at least 10 percent) to be commercially recoverable. Also known as 3P/P10 reserves.

Resource Act – the *Petroleum and Gas (Production and Safety) Act 2004, Petroleum Act 1923, Mineral and Energy Resources (Common Provisions) Act 2014.*

Resource authority – an authorisation (permit/licence) from the Queensland Government for a resource company to carry out specified activities over an area of land, including privately owned land.

Resource company – a resource authority holder or their agents or representatives.

Restricted land – land around particular buildings, farming infrastructure and areas that a resource company cannot enter without written permission from the landholder(s).

Shale gas – natural gas that is contained within shale formations under high pressure. Having extremely low porosity makes it difficult for gas to flow to wells. Hydraulic fracturing is commonly used in shale gas wells to increase the flow of gas from the reservoir.

tcf – trillion cubic feet (of gas).

Unconventional gas – *also see CSG, shale and tight gas.* Unconventional gas is found in complex geological systems, with some trapped in reservoirs with poor permeability or porosity. The gas is often difficult to produce and techniques for production vary and may require innovative technological solutions for extraction.

Tight gas – a natural gas field that can be made economic with horizontal wells and/or fracture stimulation *(see hydraulic fracturing).*

1 LAND USE

Overlapping land uses – agriculture with gas production

IN THIS CHAPTER

Agricultural footprint

Gas industry footprint

173M
hectares is the **total land area** of Queensland

150M
hectares of Queensland is used for **agricultural production**

3.1M
hectares of Queensland is under **petroleum production** tenure*

24.1M
hectares of Queensland is under **exploration** tenure*

9.3%
of Queensland's dryland agriculture **overlaps** with petroleum tenure*

3.4%
Queensland's **intensive land use area** overlaps with petroleum tenure*

*this area does not reflect the actual surface footprint of petroleum and gas development activities

AGRICULTURAL FOOTPRINT

Agricultural production covers 88.4 percent of Queensland's land base with the majority used for livestock grazing (see Table 1.1 and Figure 1.1).[1]

There are approximately 24,200 agricultural businesses spread across Queensland.[2]

Table 1.1: Agricultural land uses in Queensland[1]

Agricultural Activity*	Area (ha)	% of Queensland's Land Base
Grazing	147,926,860	85.87%
Sown Pastures	16,041,166	9.31%
Broadacre Cropping	3,547,778	2.06%
Sugar Cane	565,162	0.33%
Perennial Horticulture	87,829	0.05%
Annual Horticulture	47,166	0.03%
Intensive Livestock	37,856	0.02%
Aquaculture	4,548	0.00%

*not mutually exclusive activities – some overlap may exist between two or more agricultural activities

1 Department of Agriculture and Fisheries, Queensland Agriculture Snapshot 2018
2 Department of Environment and Science, Queensland Land Use Mapping Program, retrieved June 2019 and Department of Natural Resources, Mines and Energy, Queensland Spatial Catalogue, retrieved April 2019

Land use types and petroleum tenure

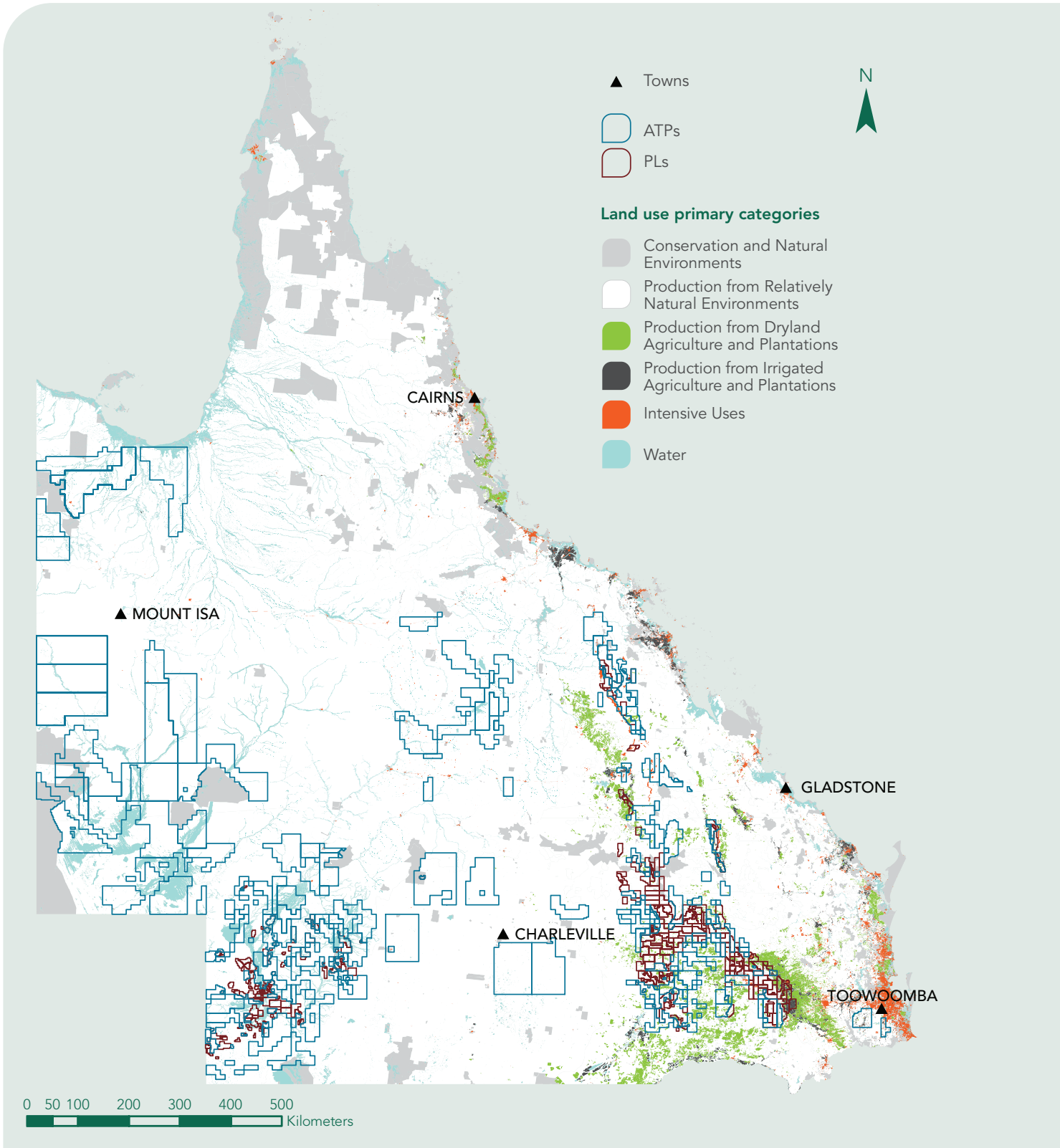


Figure 1.1: Land uses in Queensland including petroleum leases (PL) and authorities to prospect (ATP) that have been granted or applied for as at June 2019.[2]

2 Department of Environment and Science, Queensland Land Use Mapping Program, retrieved June 2019 and Department of Natural Resources, Mines and Energy, Queensland Spatial Catalogue, retrieved April 2019

GAS INDUSTRY FOOTPRINT

Agricultural businesses are typically either leasehold or freehold property whereas petroleum and gas resources in Queensland are owned by the state and managed by the state government on behalf of the people of Queensland.

That means that petroleum and gas tenures often overlap with other land uses.

Satellite imagery verified by local and regional authorities is used to make and update land use maps.

INSIGHTS

Gas companies must obtain the appropriate resource authority from the Queensland Government before they conduct any exploration or production activities on the land.

Exploration – an authority to prospect (ATP) is granted to allow a resource company to explore for petroleum and gas. A potential commercial area (PCA) may be granted to allow additional time to explore areas that show some potential but still require further exploration.

Production – a petroleum lease (PL) is granted once exploration activities have been completed and a commercial petroleum/gas resource is known to exist.

Generally speaking, a PL covers a much smaller area than an ATP because a PL targets specific petroleum and gas resources that are considered commercially viable.

Table 1.2: Queensland land use types and proportion covered by petroleum lease[3]

Land use type	Examples of related land use	% of Queensland mainland area	% overlapping a petroleum lease*
Production from relatively natural environment	Grazing native vegetation (e.g. in a state forest and on state owned land)	82.0%	2.4%
Conservation and natural environments	National parks, stock routes and natural areas of defence land	10.9%	0.6%
Water	Lakes/dams, rivers, estuaries and wetlands	4.1%	1.8%
Production from dryland agriculture and plantations	Cropping, non-irrigated pastures and plantation forests	2.1%	9.3%
Production from irrigated agriculture and plantations	Irrigated cropping, irrigated fruits and vegetables	0.6%	8.0%
Intensive uses	Residential and industrial areas, as well as intensive agricultural production such as feedlots and greenhouses	0.6%	3.4%

*this doesn't reflect the actual surface footprint of petroleum and gas infrastructure over these land use types

3 Department of Natural Resources, Mines and Energy, Queensland Spatial Catalogue, retrieved April 2019 and ABARES, Australian Land Use and Management Classification, Australian Government, retrieved 2019

New exploration areas are offered by the Queensland Government for competitive tender through its Queensland Exploration Program (QEP).

The petroleum and gas exploration tenders scheduled for released in 2019 include 18 areas totaling 36,604 km^2 across the Bowen, Surat, Drummond, Millungera, Adavale and the Cooper/Eromanga Basins.[4]

Table 1.3: Queensland's petroleum and gas exploration program for 2019[4]

Program No.	Tender No.	Size	Basin	Commodity
PLR2019–1* (see Figure 1.2)	PLR2019–1–1	1425 km^2	Bowen and Drummond	Conventional Gas and CSG
	PLR2019–1–2**	450 km^2	Bowen and Drummond	Conventional Gas and CSG
	PLR2019–1–3**	568 km^2	Bowen and Drummond	Conventional Gas and CSG
	PLR2019–1–4	77 km^2	Surat and Bowen	CSG
	PLR2019–1–5	37 km^2	Surat	CSG
	PLR2019–1–6	24 km^2	Surat	CSG
	PLR2019–1–7	154 km^2	Surat	CSG
	PLR2019–1–8	753 km^2	Surat and Bowen	CSG
	PLR2019–1–9	12 km^2	Surat	CSG
	PLR2019–1–10	89 km^2	Surat	CSG
	PLR2019–1–11	153 km^2	Surat	CSG
PLR2019–2*** (see Figure 1.3)	PLR2019–2–1	7976 km^2	Millungera	Conventional and unconventional gas (shale or tight gas)
	PLR2019–2–2	4970 km^2	Millungera	Conventional and unconventional gas (shale or tight gas)
	PLR2019–2–3	7338 km^2	Millungera	Conventional and unconventional gas (shale or tight gas)
	PLR2019–2–4	7796 km^2	Adavale	Conventional oil & gas
	PLR2019–2–5	2038 km^2	Cooper/Eromanga	Conventional oil & gas
	PLR2019–2–6	337 km^2	Cooper/Eromanga	Conventional and unconventional oil & gas (shale or tight gas)
	PLR2019–2–7	2407 km^2	Cooper/Eromanga	Conventional oil & gas

* competitive non-cash tender for program PLR2019–1 closed (Australian Eastern Standard Time) on Thursday 8 August 2019
** Australian market supply condition applies to these tenures – gas produced from these tenures must be supplied exclusively to the domestic gas market
*** call for tenders to commence following the award of program PLR2019–1 tenders – estimated date for call for tenders is November 2019

4 Department of Natural Resources, Mines and Energy Queensland Exploration Program, June 2018

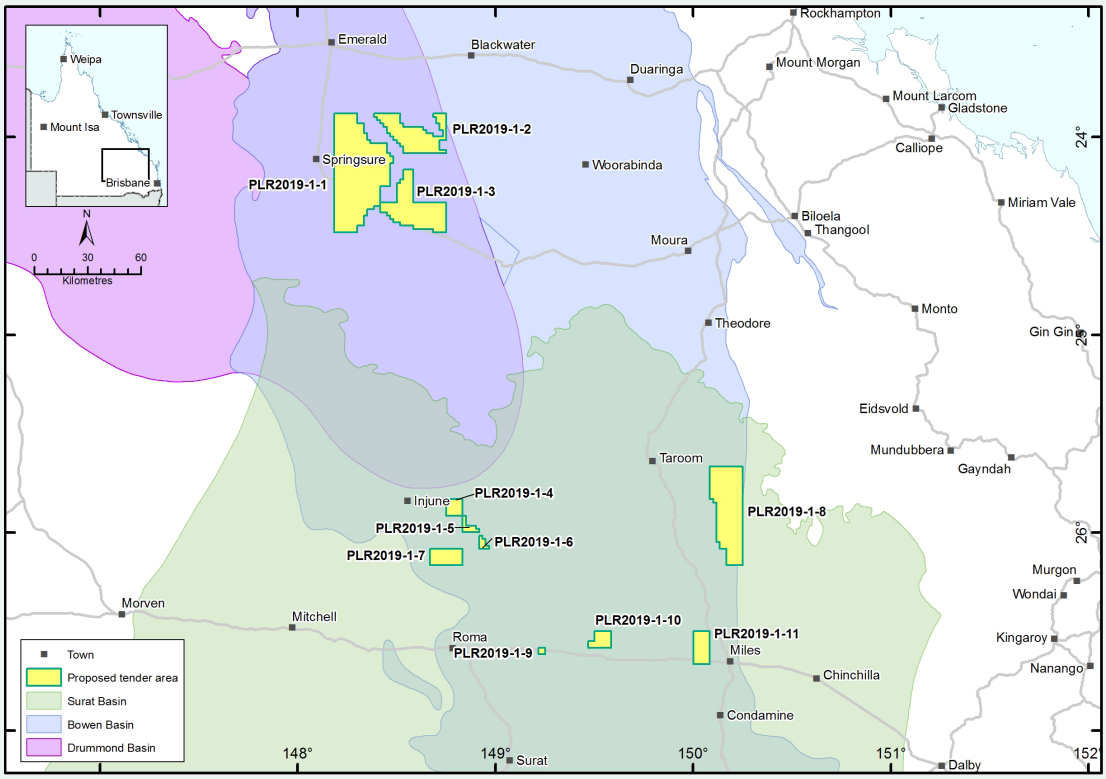


Figure 1.2: Map of petroleum and gas exploration program PLR2019–1 tender releases.[4]

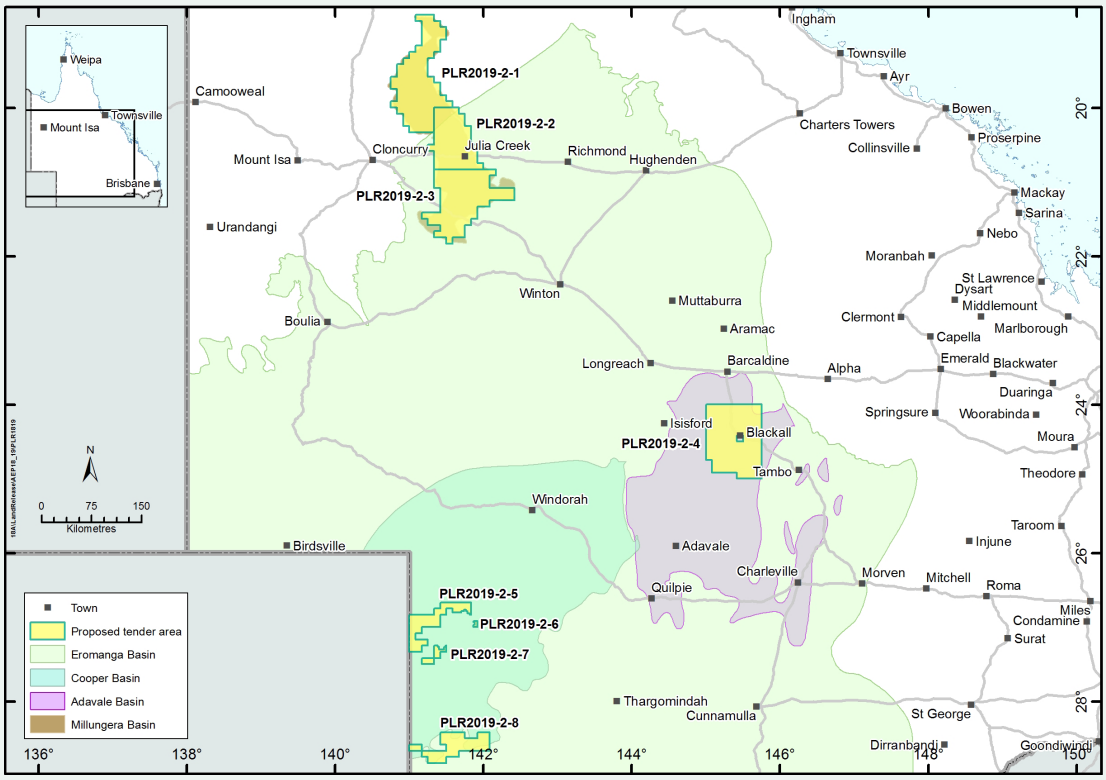


Figure 1.3: Map of petroleum and gas exploration program PLR2019–2 tender releases.[4]

4 Department of Natural Resources, Mines and Energy Queensland Exploration Program, June 2018

Petroleum and gas tenure and facility areas in Queensland

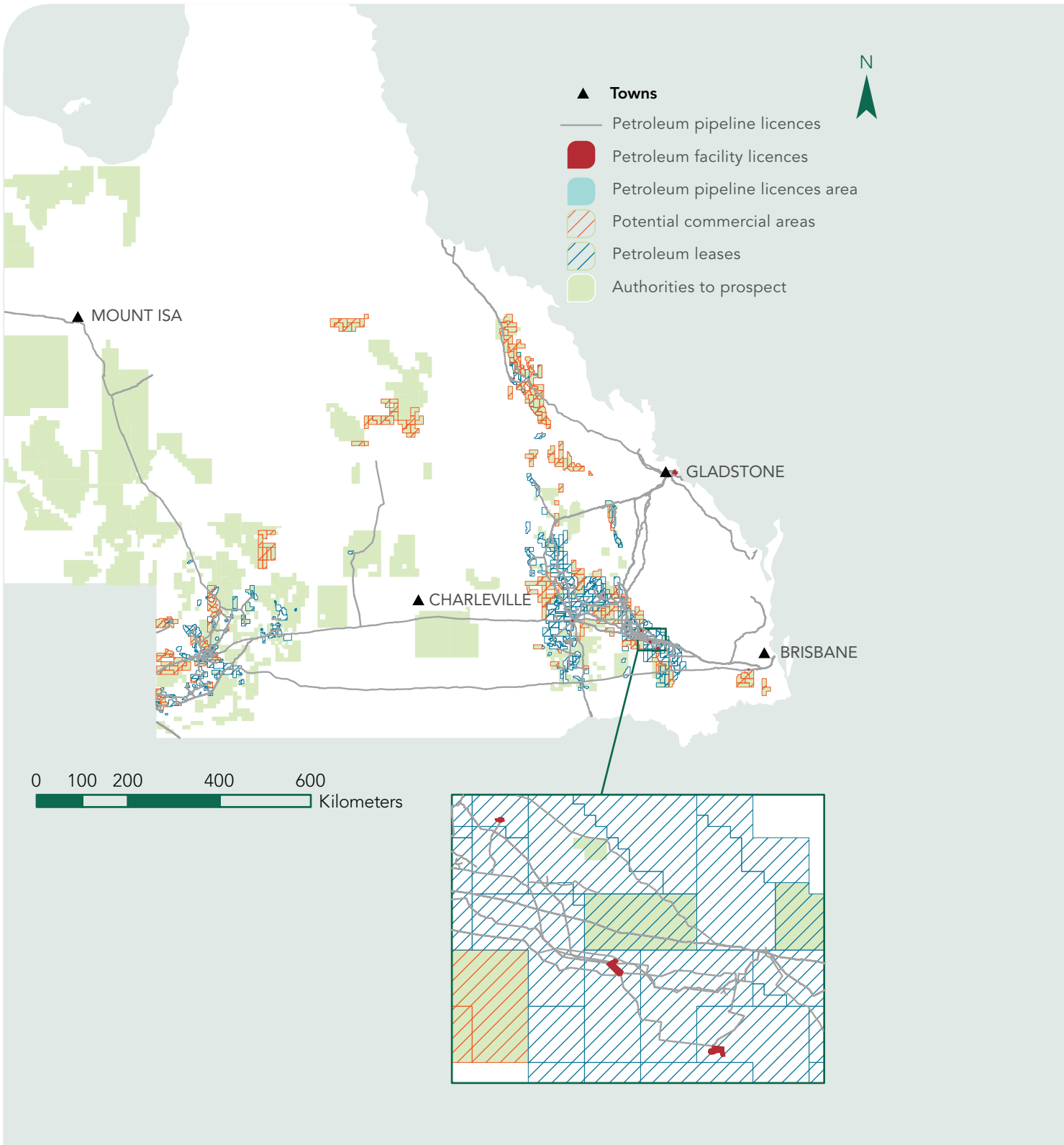


Figure 1.4: Representative illustration of the petroleum and gas tenure and facility areas in Queensland. This map represents authorities granted and under application.[5]

5 Department of Natural Resources, Mines and Energy, Queensland Spatial Catalogue, retrieved April 2019

The extent of areas under tenure change regularly as government releases tenure, companies are granted new authorities and relinquish old ones.

Petroleum and gas tenures apply to the sub-surface petroleum and gas resources and do not grant exclusive use of the surface land area.

The land covered by an ATP must be reduced over time through a process of compulsory relinquishment. The process requires the holder of an ATP to relinquish 50 percent of the area after six years if it has not been converted to a PL prior to the six year anniversary.[6]

Total Queensland Land Area = 173,064,800 ha.

Table 1.4: Land area under petroleum and gas tenures as at December 2018[7]

	Area (Ha)	% Qld land area
ATP granted	**24,117,827**	**13.9%**
ATP application	4,718,646	2.7%
PL granted	**3,146,540**	**1.8%**
PL application	1,127,725	0.7%

Petroleum and gas tenures that have been granted cover approximately 15.7 percent of Queensland.

12,815 km^2 of Petroleum Pipeline Licenses has been granted to construct and operate major high pressure pipelines across Queensland, with an additional 114 km^2 under application.

6,740 km^2 (674,000 ha), or 2.5 percent of the total petroleum and gas tenure area in Queensland has been awarded with a domestic only market supply condition attached i.e. gas produced from these areas must be supplied exclusively to the domestic market.[8]

ATPs often overlap with PL applications because the ATP is not cancelled until the PL is granted.

Currently, 33 local government areas have active (granted) ATPs while 11 have active (granted) PLs.

6 Queensland Legislation, Petroleum and Gas (Production and Safety) Act 2004
7 Department of Natural Resources, Mines and Energy, personal communication, Dec 2018
8 Department of Natural Resources, Mines and Energy, personal communication, 2019

Petroleum tenure within local government areas

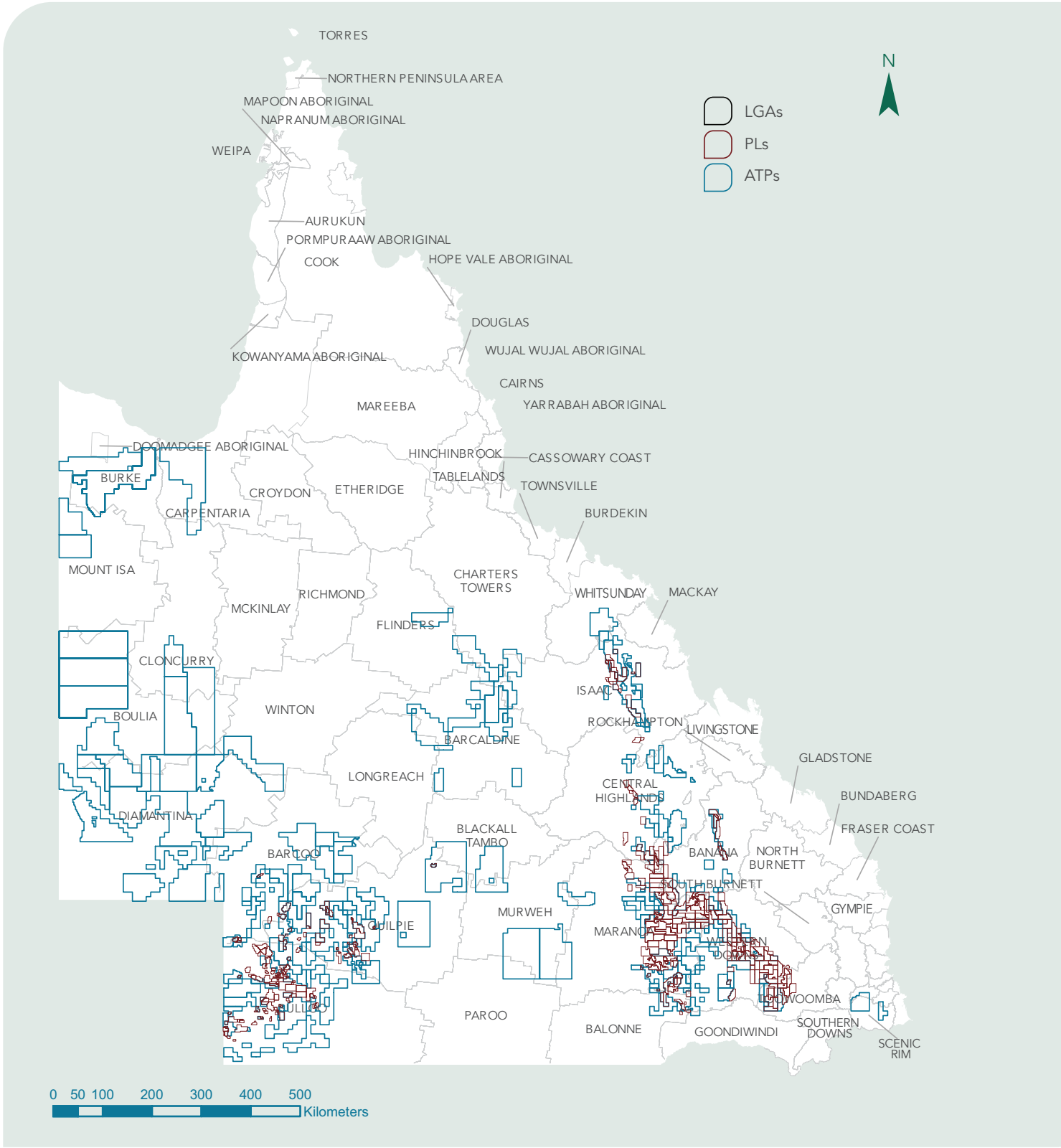


Figure 1.5: Petroleum leases and authorities to prospect (both granted and applied for) within Queensland local government area boundaries.[9]

9 Department of Natural Resources, Mines and Energy, Queensland Spatial Catalogue, retrieved April 2019

Local government areas under petroleum lease tenure

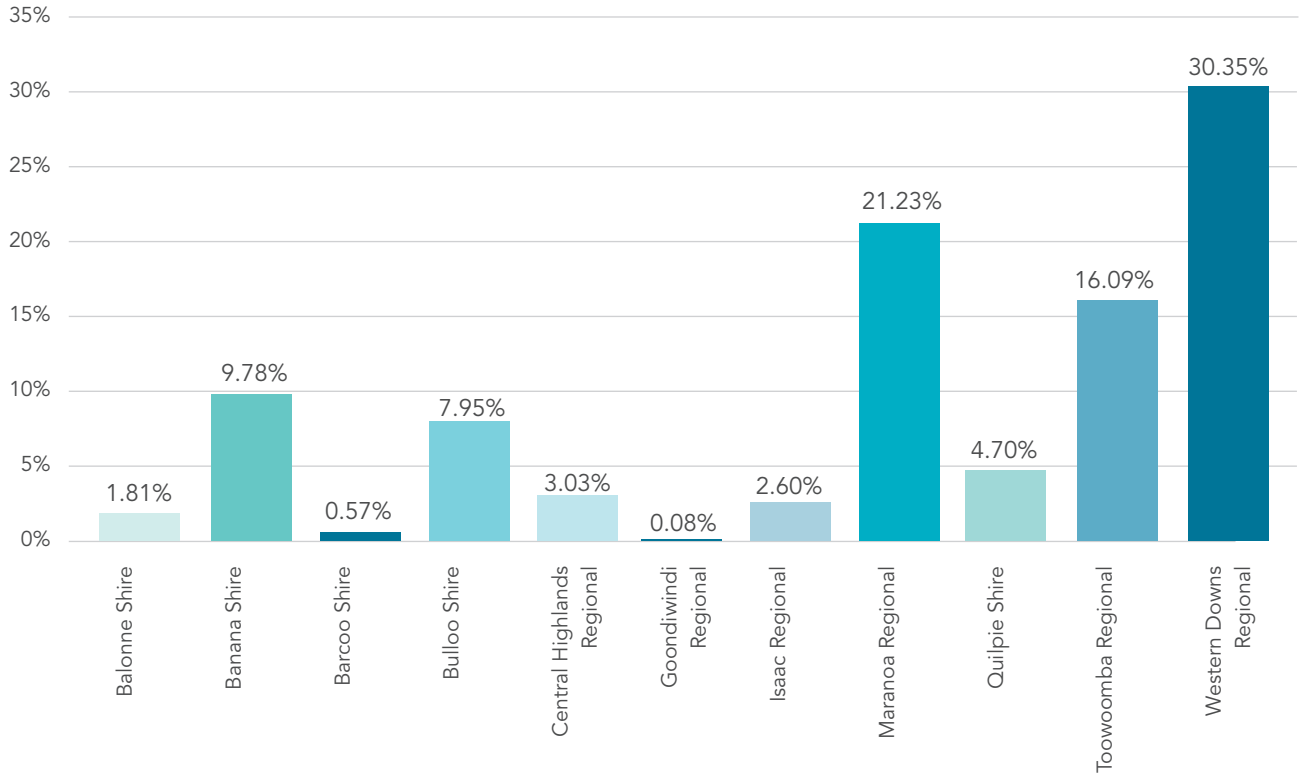


Figure 1.6: Percentage of Queensland local government areas under petroleum lease tenure (granted and under application).[10]

10 Department of Natural Resources, Mines and Energy, personal communication, 2019

Exclusive and non-exclusive possession native title exists over approximately 29 percent of Queensland. 4 percent of the native title land overlaps a petroleum lease (Figure 1.7).

Native title land in Queensland

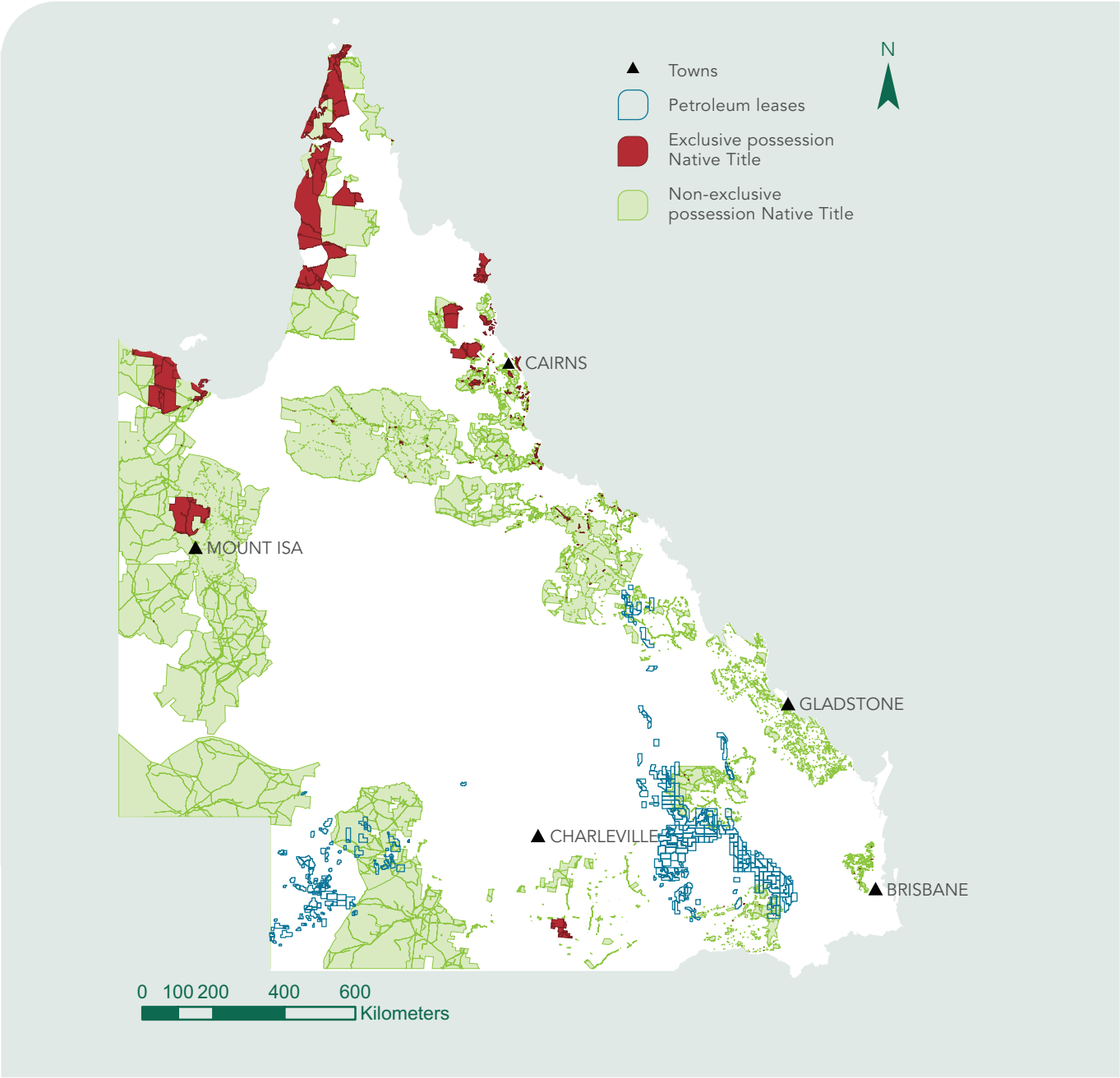


Figure 1.7: Exclusive possession native title and non-exclusive native title possession overlapping petroleum leases that had been granted or were under application as of April 2019.[11]

11 National Native Title Tribunal dataset, retrieved April 2019

Indigenous Land Use Agreements (ILUAs) cover approximately 222,000 km^2 of Queensland (Figure 1.8).

Indigenous land use agreements

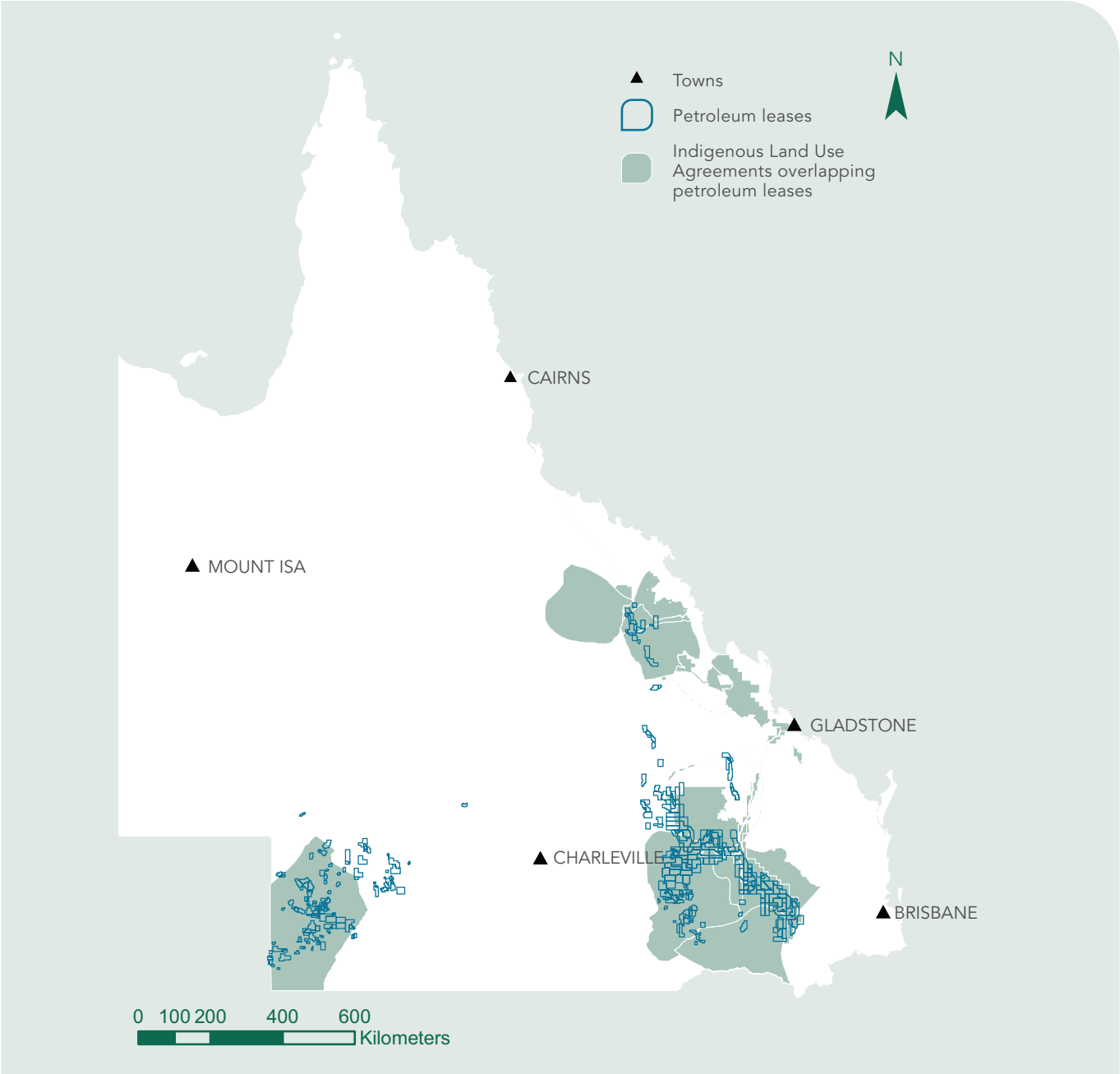
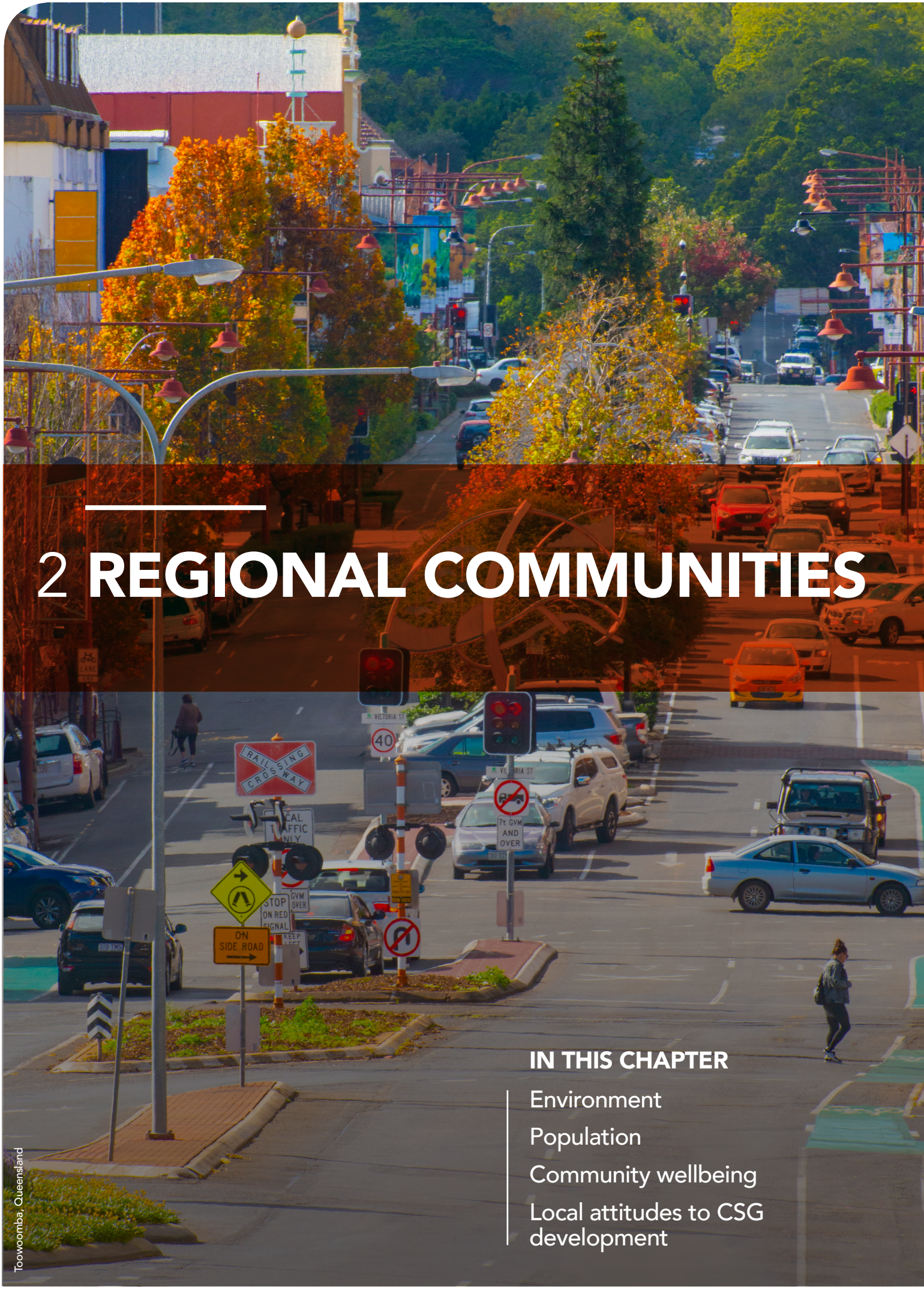


Figure 1.8: Indigenous Land Use Agreements (ILUAs) overlapping petroleum leases that were under application as of April 2019.[12]

12 Department of Natural Resources, Mines and Energy, Queensland Spatial Catalogue, retrieved April 2019

2 REGIONAL COMMUNITIES



Toowoomba, Queensland

IN THIS CHAPTER

65.2%
of Queensland was drought declared as of **1 April 2019**

30
local government areas were fully **drought declared** on 1 April 2019

3%
population growth occurred in the Western Downs during the construction phase in 2011

2011 & 2013
construction phases **created population growth** in the Maranoa but this has been slowly declining since

2016
showed a sharp increase in **non-resident workers** in Wandoan

38%
of people in Eastern Maranoa said they **accepted CSG development** in a 2018 survey

ENVIRONMENT

Queensland's regional communities experience a diverse, variable and changing climate.

Weather is the fundamental consideration for agricultural producers when making decisions about planting, harvesting, increasing or decreasing herd/flock numbers.

In Western Queensland annual rainfall can be less than two millimetres.[1]

Climate change models suggest that rainfall will decrease over most of Queensland. Climate variability is also increasing in the form of increased severity of major weather events which cause significant economic costs and social impact to regional communities.

The effects of the floods and cyclones in 2011 were still being felt in Queensland communities more than 18 months later.[2]

More recently, flood warnings were issued in many areas of Queensland associated with ex-tropical cyclone Trevor at the end of March 2019. Major flooding events continued across Western and Central Queensland throughout the following months.[3]

Most of regional Queensland has been in drought since 2011. As of 1 April 2019, 65.2 percent of Queensland was drought declared with 30 fully declared local government areas (see Figure 2.1).

1 Queensland Agriculture Snapshot, Department of Agriculture and Fisheries, 2018
2 Queensland Rural Debt Survey, Queensland Rural and Industry Development Authority, Queensland Government, 2017
3 Monthly climate summary, Bureau of Meteorology, Australian Government, 2019

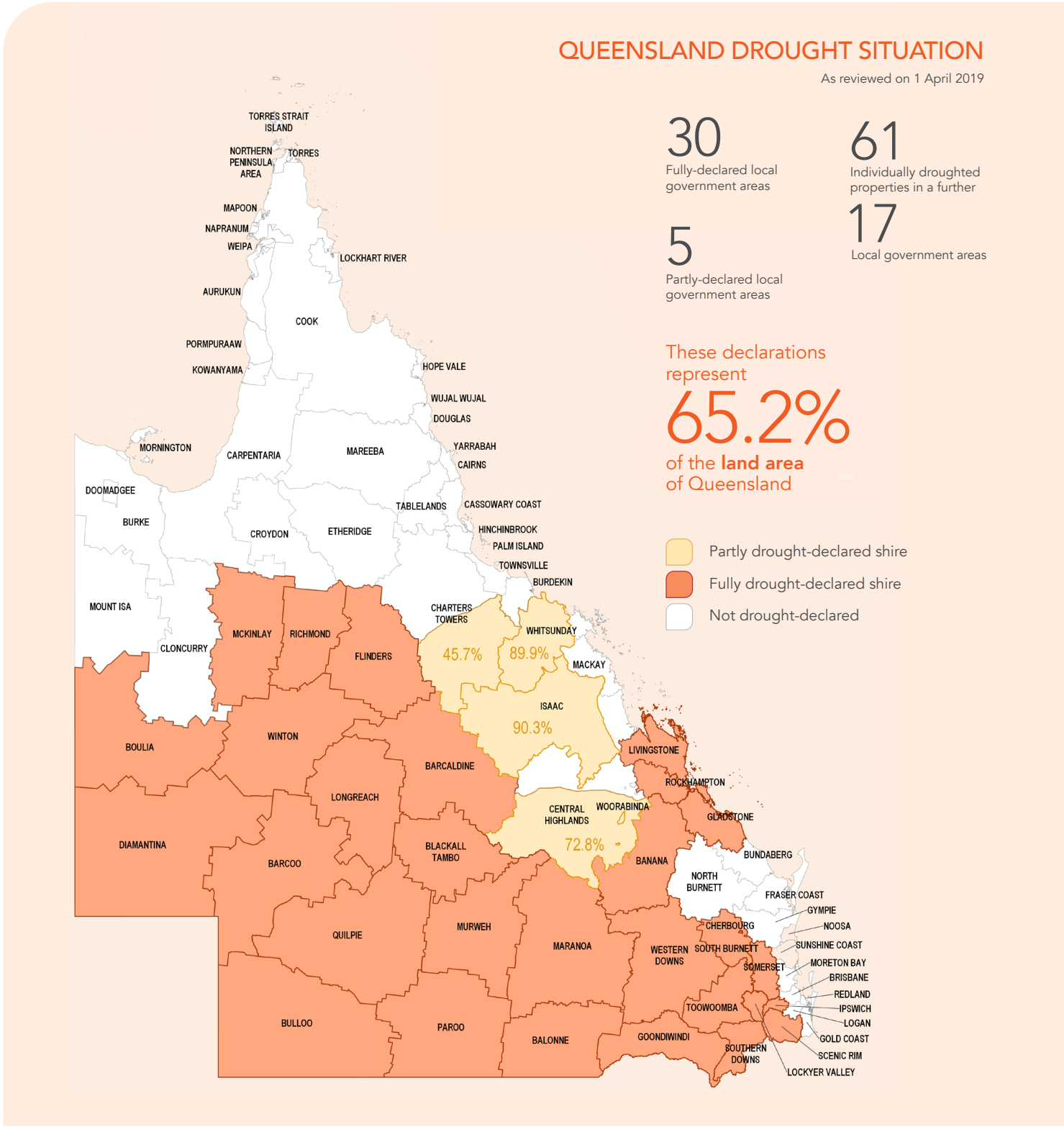


Figure 2.1: Map of drought declared regions of Queensland as at 1 April 2019.[4]

4 The Long Paddock, Drought Declarations, Queensland Government, 2019

Climate summary, Queensland 2011–2018

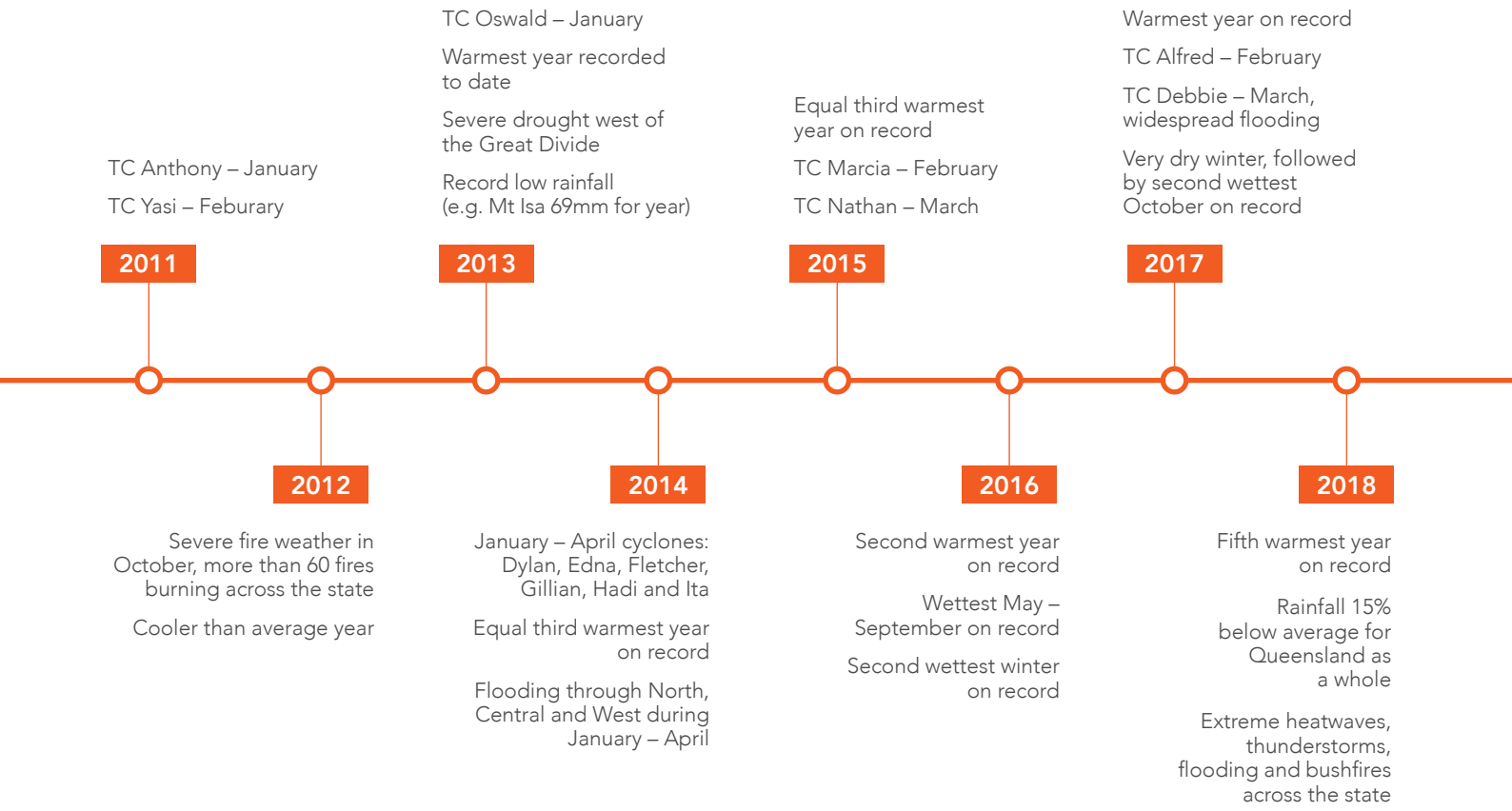


Figure 2.2: Queensland's natural disasters from 2011 – 2018. [5]

POPULATION

Population is declining in many regional Queensland communities, however population trends in communities living in the Surat Basin have remained relatively stable for the past decade.[6]

The Western Downs local government area experienced rapid population growth of around three percent in 2011 coinciding with the expansion of the gas industry and has continued to grow slowly in the following years.

The Maranoa region experienced population growth in 2011 and again in 2013 but the trend has been a slow decline since.

Toowoomba is also experiencing steady population growth of around one percent or greater each year since 2011.

Gas activity in the Bowen Basin is relatively small and communities such as Moranbah are affected more by peaks and troughs in the mining industry.

The Isaac region has experienced consistent decline in population since 2014.

5 Queensland Rural and Industry Development Authority, Rural Debt Survey 2017 AND Australian Bureau of Meteorology, Climate Summaries Archive, retrieved May 2019
6 University of Queensland's Annual Reports on Queensland Gasfields Communities, retrieved 2019

Regional populations

Figure 2.3: Populations for regional communities in gas development areas.[6]

6 University of Queensland's Annual Reports on Queensland Gasfields Communities, retrieved 2019

The number of non-resident workers in a community fluctuates and can become a large proportion of the total population particularly during the construction phase of a gas project.

A sharp increase in non-resident workers in Wandoan in 2016 can potentially be attributed to the commencement of construction of Shell's QGC Charlie Project (see Figure 2.3).

Figure 2.4 shows the timing of peak construction periods differs slightly for different regions.

Numbers of non-resident workers living within the towns have more impact on local businesses and housing pressure than workers living outside of the towns in workers camps.

Non-resident workers living in regional communities

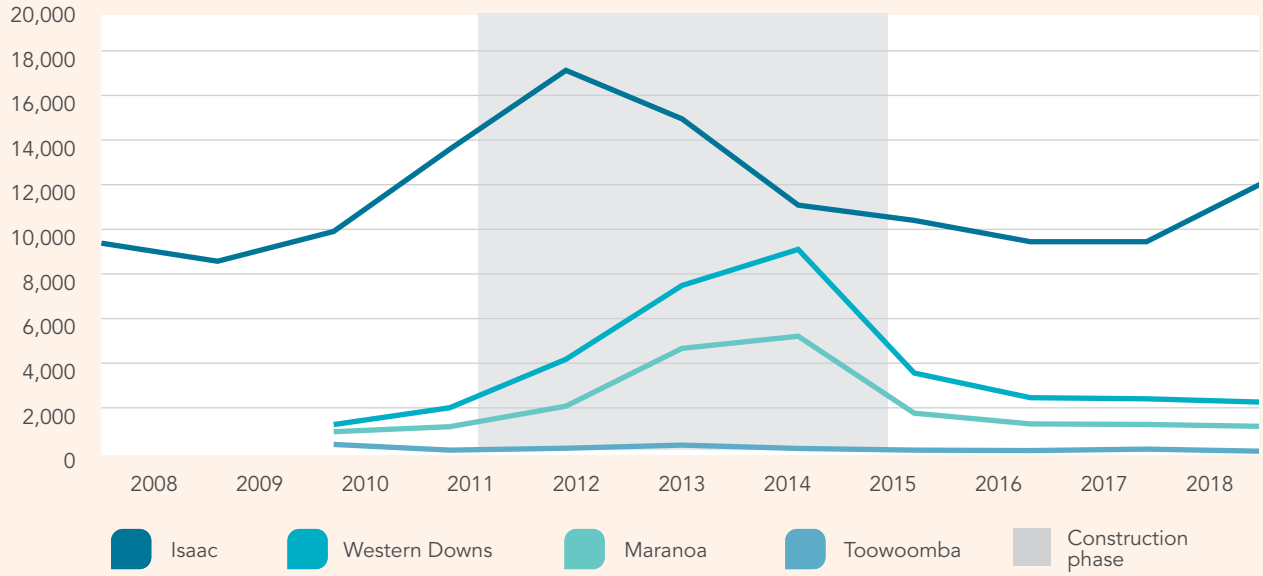


Figure 2.4: Numbers of non-resident workers living in local government areas each year from 2008–2017. Gas field communities compared with a predominantly mining community (Isaac).[6]

6 University of Queensland's Annual Reports on Queensland Gasfields Communities, retrieved 2019

COMMUNITY WELLBEING

CSIRO researchers[7] have been monitoring community wellbeing in the Surat Basin since 2014.

Residents were asked their views on a range of dimensions of community wellbeing including physical infrastructure and services, social, environmental, health, political, and economic aspects of the community.

Figure 2.5 shows that despite the economic fluctuations of the construction phase, post-construction phase, and operations phase of gas development, there was a robust level of community wellbeing between 2014 and 2018 in the Western Downs.

The key drivers of community wellbeing over the three periods were **community cohesion, trust, social interaction and the level of services and facilities**.

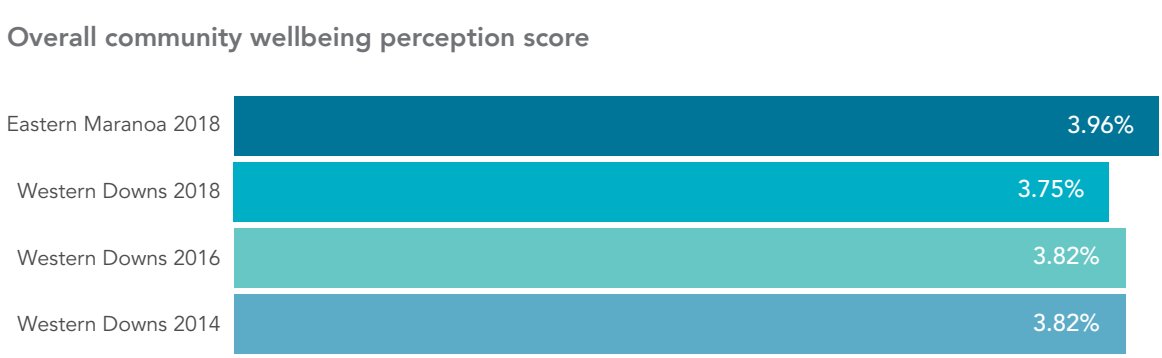


Figure 2.5: Mean scores of overall community wellbeing in Western Downs region from 2014–2018 and Eastern Maranoa in 2018. Perception scores: 1 = lowest, 5 = highest, >3 = favourable, <3 = unfavourable.[7]

The key drivers of community wellbeing over the three periods were **community cohesion**, **trust**, **social interaction** and the level of services and facilities.

7 Walton, A. and McCrea, R. (2018) Trends in community wellbeing and local attitudes to coal seam gas development, 2014–2016–2018: Western Downs and Eastern Maranoa regions, Queensland. Survey report. CSIRO Australia. ISBN 978–1–4863–1177–4 (Online version)

LOCAL ATTITUDES TO CSG DEVELOPMENT

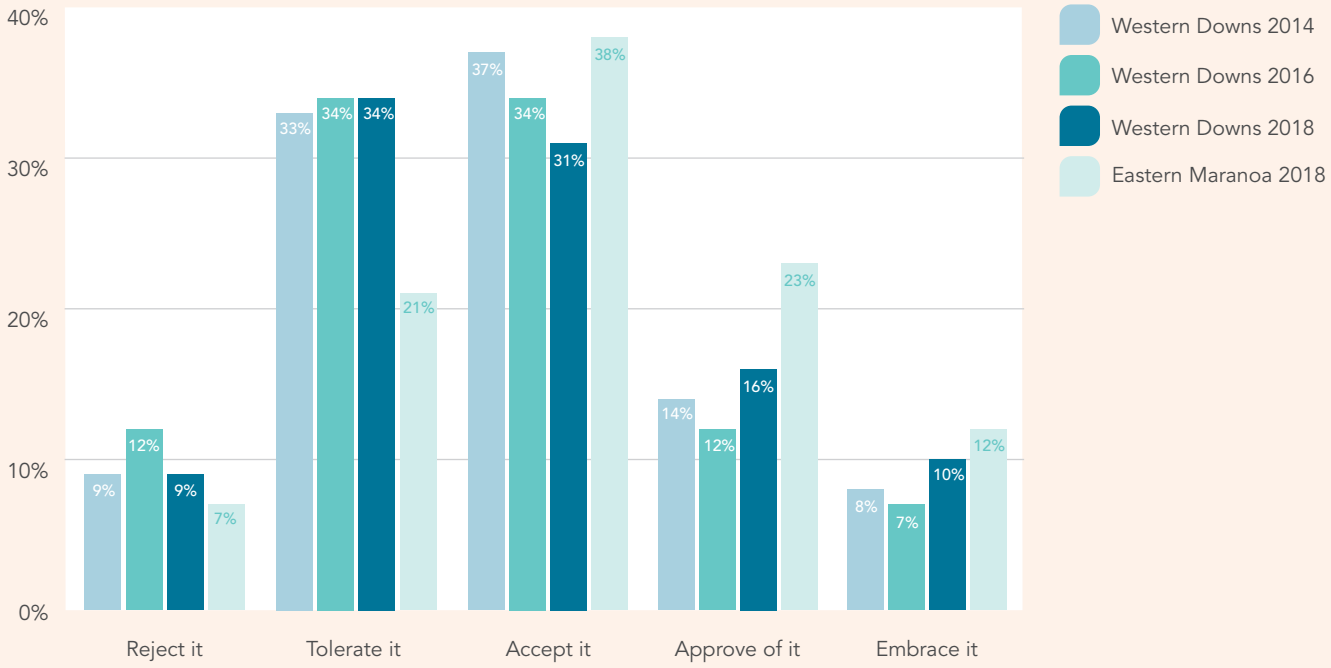
CSG development covers extensive areas and affects many people, especially people who live out of town.

In the Surat Basin, the placement of gas wells can impact many different types of properties from broad acre cattle farming to more intensive agriculture to lifestyle blocks.

CSIRO surveys have found that there is no single community view towards CSG development but rather a spread of attitudes that range from 'reject' CSG to 'embrace' CSG.

Feelings toward CSG development are generally more favourable for residents living in-town compared to those living out of town.

Local attitudes towards coal seam gas



Note: Percentages rounded to the nearest whole percent.

Figure 2.6: Attitudes towards coal seam gas development: Western Downs 2014–2016–2018 and Eastern Maranoa 2018.[7]

7 Walton, A. and McCrea, R. (2018) Trends in community wellbeing and local attitudes to coal seam gas development, 2014 – 2016 – 2018: Western Downs and Eastern Maranoa regions, Queensland. Survey report. CSIRO Australia. ISBN 978–1–4863–1177–4 (Online version)

3 ECONOMIC TRENDS

IN THIS CHAPTER

- Rural debt
- Incomes and employment
- Residential trends, land valuations and property sales
- Economic contributions
- Land access and compensation

Industry employees operating a drilling rig

$17.24B

was the **total rural debt** in Queensland as at 31 December 2017

2011–2015

generally showed **higher average personal incomes** for people living in regional centres with gas development

14.1%

of employment in the Maranoa region is in beef production

141,246

full-time jobs were supported during the peak construction period for the gas industry in 2013/14

$186.70M

was **paid to the state** as oil and gas royalties in 2017/18

$78M

in compensation was **paid to landholders** in the 2018/19 financial year for the impacts of petroleum and gas

RURAL DEBT

As at 31 December 2017, total rural debt in Queensland was $17.24 billion up 1.6 percent from 31 December 2011.

The Queensland Rural Debt Survey 2017 shows that the rating of rural debt in Queensland improved between 2011 and 2017 with 94.41 percent of the total value of the debt rated either viable – rating A – or potentially long term viable – rating B+.

That's up from 85.89 percent in 2011.

Grazing accounts for 86 percent of the land use in Queensland and the majority of Queensland rural debt is carried by the cattle industry.

> "Rural debt is defined as the total indebtedness of all farmers/ rural enterprises throughout Queensland, where the servicing of the rural debt relies primarily on rural generated income."
>
> QRIDA 2017

Total regional rural debt ($M)

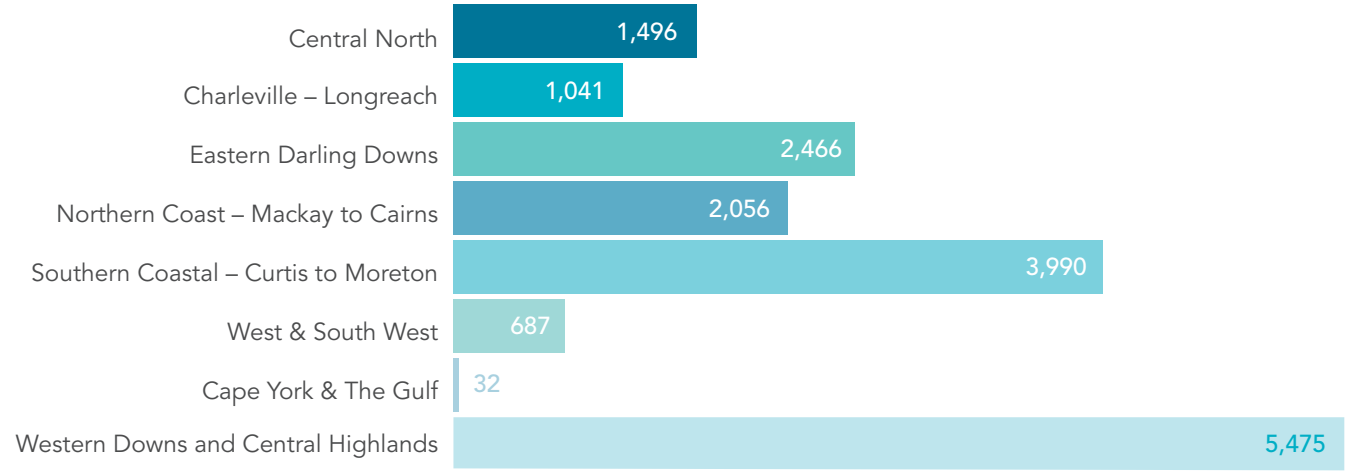


Figure 3.1: Total rural debt in 2017 in Queensland by region.[1]

Total regional rural debt by industry

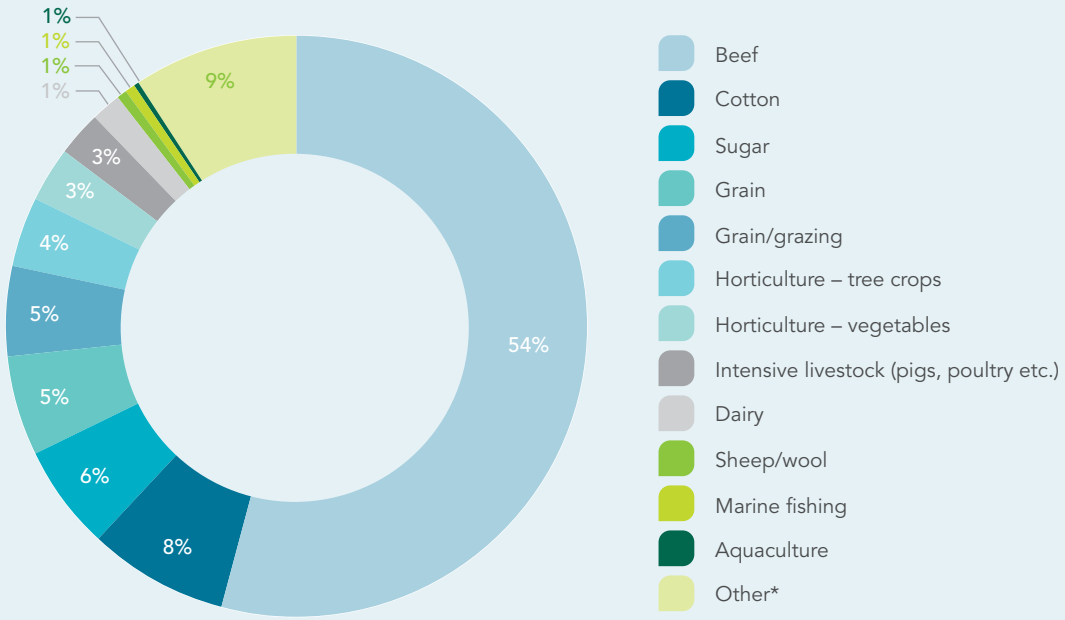


Figure 3.2: Total rural debt in 2017 in Queensland by industry.[1]

*Other includes services to agriculture, forestry, logging, hunting and trapping

1 Queensland Rural and Industry Development Authority, Rural Debt Survey 2017


"The Commission has regular discussions with landholders about their experiences in the regions and it is clear that compensation has provided benefits to landholders in a variety of ways including diversification of income, debt reduction, purchase of additional property for expansion and succession planning."
RUTH WADE, former Chair, GasFields Commission Queensland, 8 May 2018

INCOMES AND EMPLOYMENT

Personal incomes

Average personal incomes for people living in regional centres with gas development have generally been the highest at times when construction activity was at its highest (2011–2015, or in earlier years depending on the town).

In terms of landholder compensation received for gas field development on private land, this is not necessarily captured in the personal income figures as much of it is non-taxable.

Personal incomes – low income and taxable individuals (ATO)

Figure 3.3: Yearly personal incomes for low income and taxable individuals in regional towns and the Queensland average from 2001–2016.[2]

2 The University of Queensland's Centre for Coal Seam Gas, Boomtown Indicators, retrieved 2019

Non-primary production businesses

The number of non-primary production businesses operating in towns with gas development has remained relatively stable over the years.

From 2009–2018, Chinchilla had an increase of 153 non-primary production businesses and the Miles-Wandoan area increased by 57 businesses.

Dalby had an overall increase of 85 businesses during this period but has been experiencing a decline in recent years.

Roma had large increases in business numbers from 2009–2012 then a decline following a major flooding event. After a stable period, business numbers declined again in 2016 but started to rise in 2018.

Trends in Moranbah business numbers reflect mining activity in the area with large increases from 2009–2011. Overall, the number of businesses in Moranbah has grown by 43 between 2009–2018.

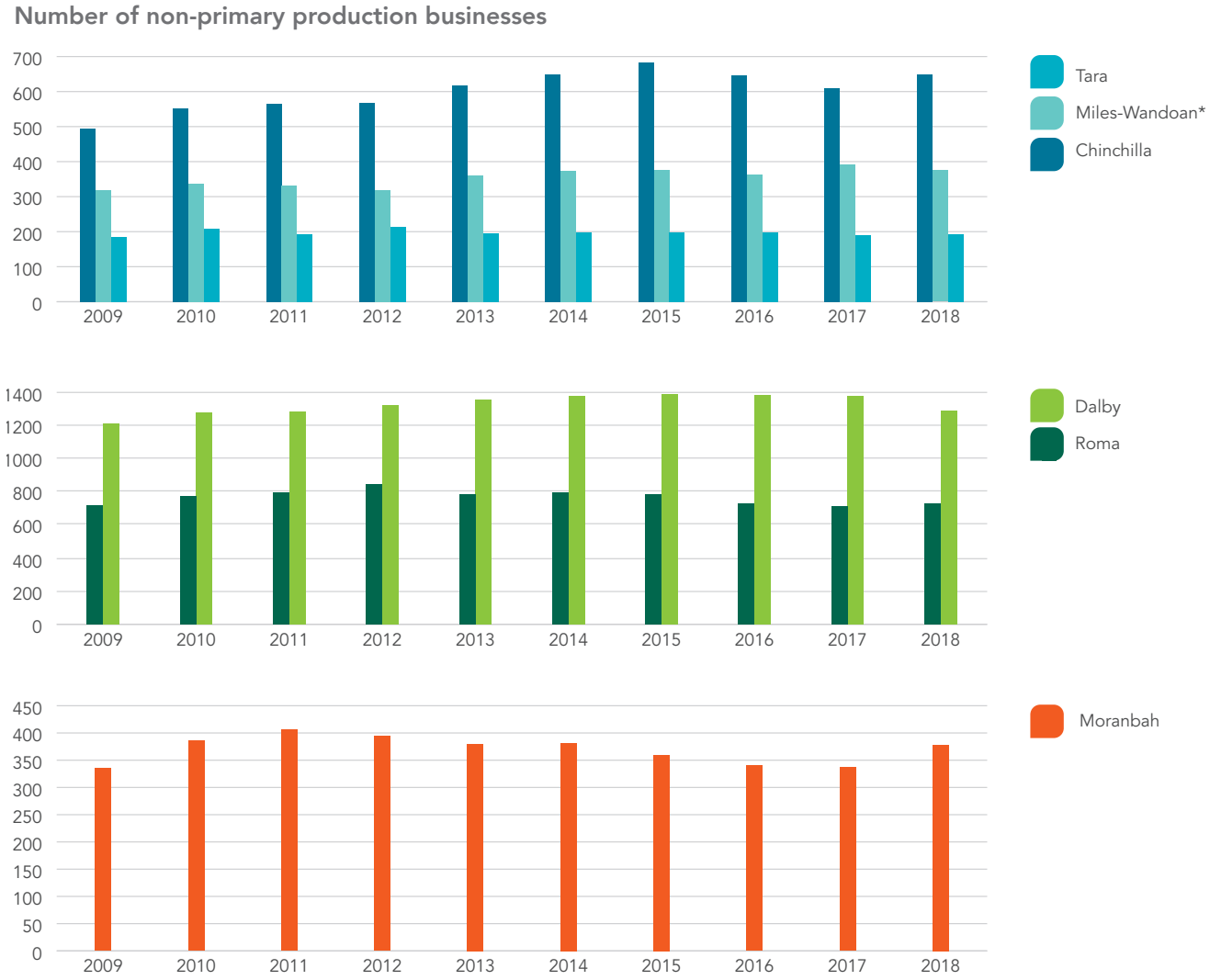


Figure 3.4: Number of non-primary production businesses in regional towns from 2009–2018.[3]

*Miles and Wandoan are located in the same ABS statistical area level 2 (SA2) and therefore have the same data above.

3 Australian Bureau of Statistics, 8165.0 – Counts of Australian Businesses 2009–2018, compiled by The University of Queensland's Centre for Coal Seam Gas

Employment

Agricultural industries are the main drivers and influencers on local economies. However, the oil and gas sector is now also a significant contributor.

Table 3.1 shows increased economic diversification with agriculture, oil and gas and government as major employers.

Table 3.1: Employment by industry[4]

Western Downs Regional Council	Number	%
OVERALL		
Beef cattle farming (specialised)	1,067	7.5
Local government administration	511	3.6
Other grain growing	500	3.5
Primary education	424	3
Supermarket and grocery stores	354	2.5
CHINCHILLA		
Beef cattle farming (specialised)	-	6.2
Oil and gas extraction	-	5.1
Primary education	-	3.1
Supermarket and grocery stores	-	2.9
Secondary education	-	2.9
WAMBO		
Other grain growing	-	4.4
Beef cattle farming (specialised)	-	3.7
Local government administration	-	3.7
Primary education	-	2.8
Secondary education	-	2.5
MILES (SSC)		
Local government administration	-	6.4
Supermarket and grocery stores	-	5.3
Secondary education	-	5
Hospitals	-	4.8
Oil and gas extraction	-	4.5
WANDOAN		
Beef cattle farming (specialised)	-	19.9
Oil and gas extraction	-	6.7
Site preparation services	-	6.4
Log sawmilling	-	6.1
Accommodation	-	6.1
TARA		
Beef cattle farming (specialised)	-	16.2
Grain-sheep or grain-beef cattle farming	-	8.9
Local government administration	-	6
Other grain growing	-	4.5
Combined primary and secondary education	-	4.3

Maranoa Regional Council	Number	%
OVERALL		
Beef cattle farming (specialised)	884	14.1
Local government administration	327	5.2
Hospitals (except psychiatric hospitals)	322	5.2
Oil and gas extraction	161	2.6
Road freight transport	144	2.3
ROMA TOWN		
Hospitals	-	6
Local government administration	-	5.4
Oil and gas extraction	-	3
State government administration	-	2.8
Accommodation	-	2.6
ROMA REGION		
Beef cattle farming	-	28
Local government administration	-	5
Hospitals	-	4.4
Grain-sheep or grain-beef cattle farming	-	3.3
Combined primary and secondary education	-	2.6

Isaac Regional Council	Number	%
OVERALL		
Coal mining	3,527	35.4
Beef cattle farming (specialised)	701	7
Local government administration	315	3.2
Primary education	304	3.1
Accommodation	213	2.1
DYSART (SCC)		
Coal mining	-	48.6
Beef cattle farming (specialised)	-	4.2
Building and other industrial cleaning services	-	3.3
Primary education	-	3.2
Accommodation	-	2.5
MORANBAH		
Coal mining	-	39.3
Local government administration	-	3.3
Primary education	-	3.3
Explosive manufacturing	-	2.5
Takeaway food services	-	2.3

4 ABS Census 2016

During the peak construction period for the industry overall in 2013/14, **the total number of full-time jobs supported was**

141,246[5]

INSIGHTS

For long distance export, gas is chilled to -161°C, at which temperature it becomes a liquid.

Liquefied natural gas (LNG) occupies 1/600 of the space it does as a gas, making it economical to export.

LNG is exported in purpose-built tanker ships and then re-gasified on delivery.

As the majority of gas produced in Queensland is CSG (more than 95 percent), Queensland's gas export chain is often referred to as the CSG-LNG sector.

This term refers to the whole supply chain and includes onshore production of the gas through to the compression and export facilities.

In Shared Landscapes, we refer to this whole supply chain as simply 'the gas industry'.

For more information on where Queensland gas is used, refer to Chapter 6 – Supply and Demand.

5 Queensland Resources Council 2018. Economic Contribution Data. Yearly Economic Impact of the Mineral & Energy Sector on the Queensland Economy Reports

Direct oil and gas employment averaged less than 4,500 people in the year to May 2019 (Figure 3.5).

Queensland mining employment by type (year to May – four quarter average) ('000)

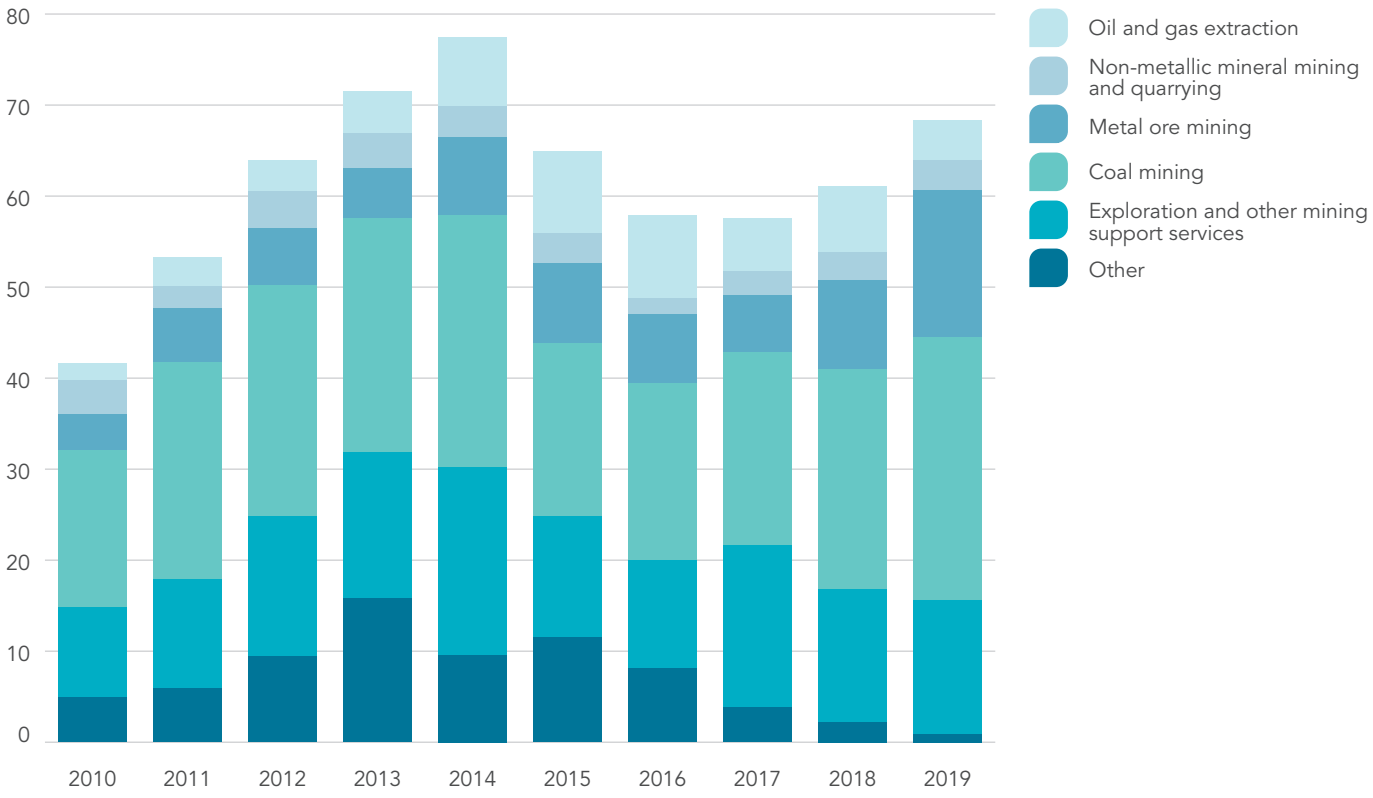


Figure 3.5: Employment by Queensland's resource industries.[6]

54,300 PEOPLE were employed full-time and **24,400** PEOPLE were employed part-time in Queensland's agriculture, forestry and fisheries sectors as at February 2019.[6]

6 Australian Bureau of Statistics Labour Force, Australia, Detailed, Quarterly, Feb 2019

Since 2016 there has been an increase in unemployment in the Maranoa region, while increases in the Western Downs and Toowoomba regions stabilised in 2017 and 2018.

Figure 3.6 shows how unemployment was low in the Surat Basin during the gas industry construction period (from 2012–2014 or earlier depending on the town).

Unemployment rates – regional communities with gas development compared to QLD average

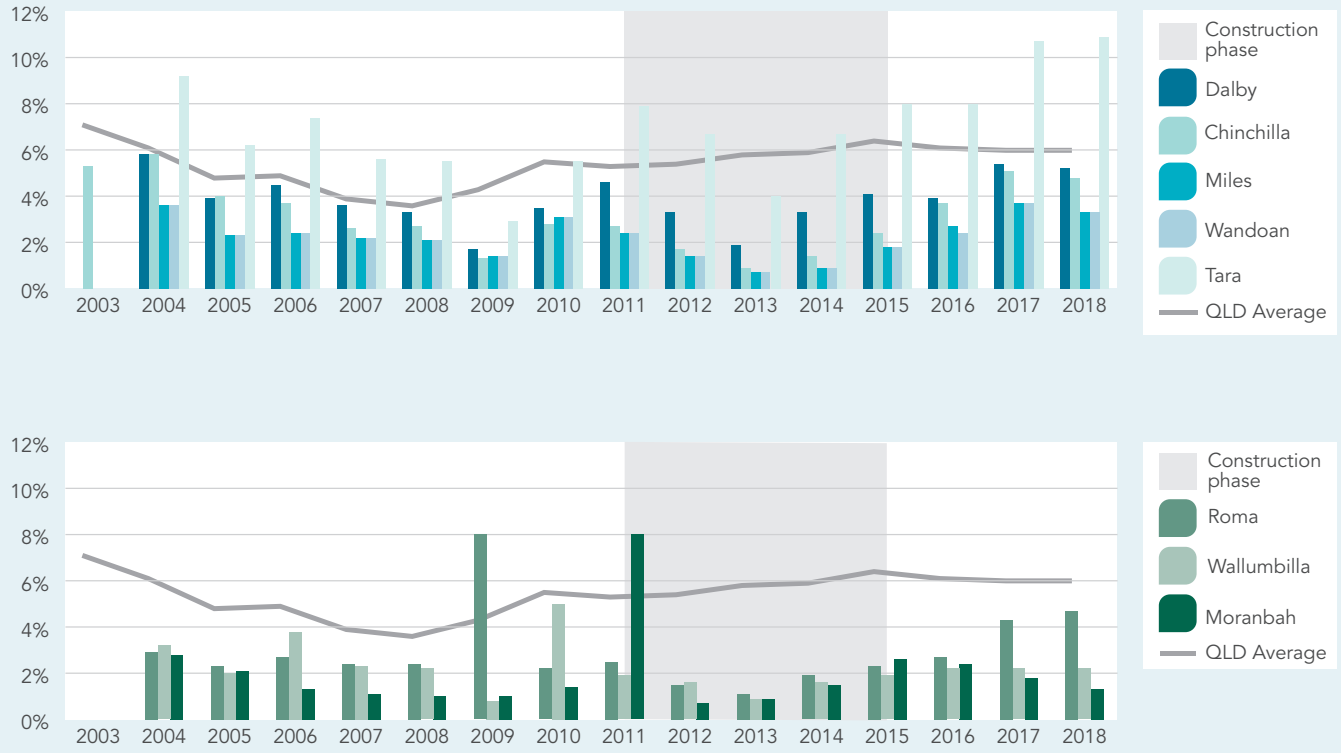


Figure 3.6: In most cases, unemployment rates in the Surat and Bowen Basin communities are much lower than the rate for Queensland.[7]

7 The University of Queensland's Centre for Coal Seam Gas, Boomtown Indicators, retrieved 2019

RESIDENTIAL TRENDS, LAND VALUATIONS AND PROPERTY SALES

Housing

With the arrival of an increased workforce to carry out gas construction projects in Queensland's Surat Basin communities, there came an increase in residential construction to provide the necessary housing.

Figure 3.7 shows the spike in residential building approvals occurred earlier in Dalby (2010) than some of the other Surat Basin towns.

Residential building approvals

Figure 3.7: Trends in residential building approvals in regional towns from 2001–2017.[7]

*Miles and Wandoan are located in the same ABS statistical area level 2 (SA2) and therefore have the same data above.

7 The University of Queensland's Centre for Coal Seam Gas, Boomtown Indicators, retrieved 2019

There was also a noticeable spike in residential rental prices during this time, after which prices returned to normal for these towns and are generally below rental prices for Queensland as a whole.

Median rent for three bedroom house

Figure 3.8: Trends in median rent for a 3 bedroom house in regional towns from 2001–2017, compared with the Queensland average.[7]

*Miles and Wandoan are located in the same ABS statistical area level 2 (SA2) and therefore have the same data above.

7 The University of Queensland's Centre for Coal Seam Gas, Boomtown Indicators, retrieved 2019

Property values and sales

The Valuer-General's 2018 Property Market Movement Report shows a general increase in property sales activity in rural areas.[8]

The Valuer-General attributes property value increases to strong rural commodity prices, low interest rates and a generally renewed confidence within rural markets.

The report acknowledges that the gas industry continues to influence the market.

Figure 3.9 shows the increase in land values by local government area by comparing trends using a consistent starting value of $100,000. For example, a parcel of land worth $100,000 within the Maranoa Regional Council area in 2010 would be worth $141,900 in 2018.

Actual property sales prices are determined by a number of factors.

Land value trend

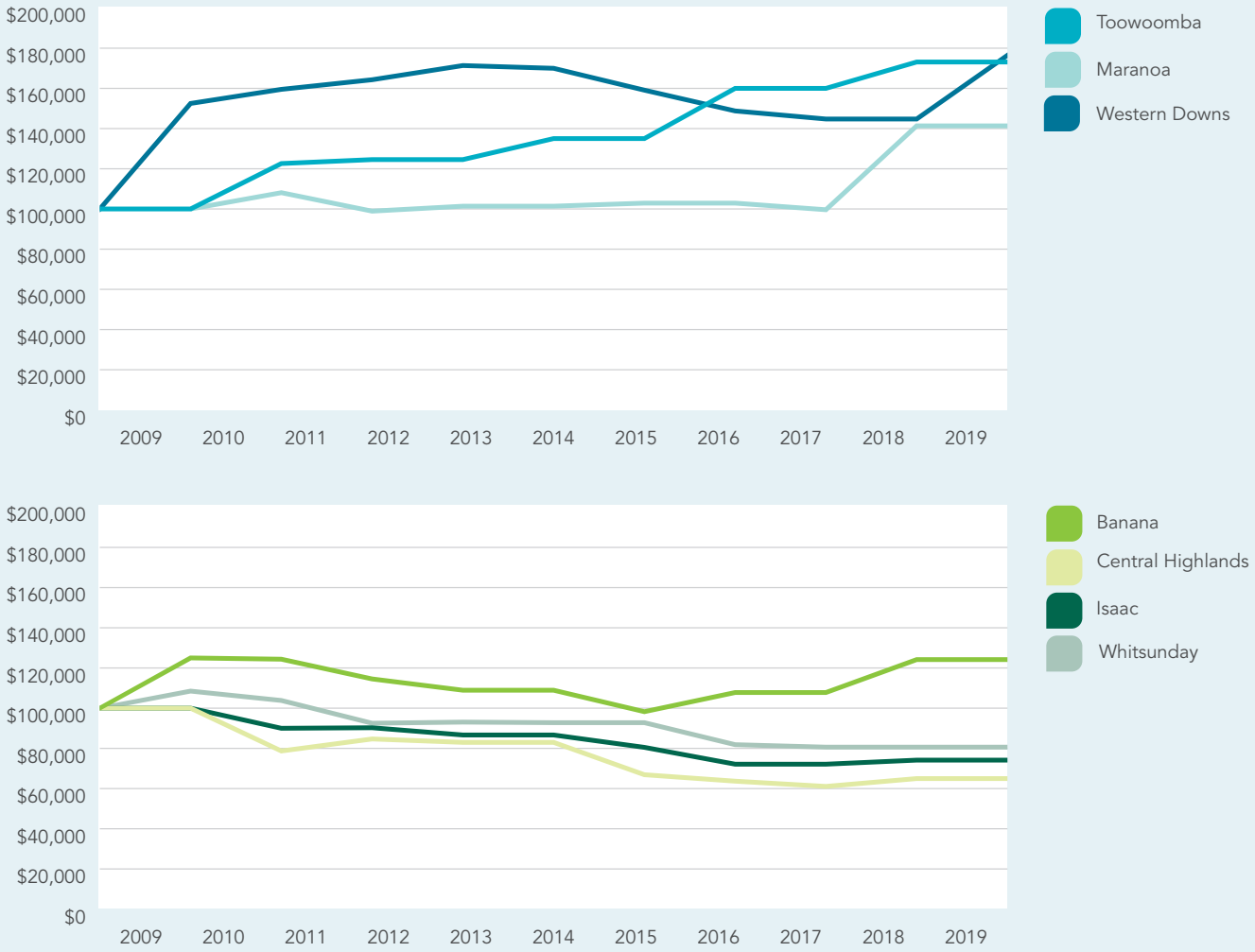


Figure 3.9: Rural land valuations in local government areas in the Bowen and Surat Basins from 2009–2017. These comparison graphs were generated using a consistent starting value of $100,000.[9]

8 Department of Natural Resources, Mines and Energy (DNRME). State Valuation Service. Valuer-General's 2018, Property Market Movement Report

9 Graphs generated using Queensland Government, Historical Trends in Land Valuations, retrieved May 2019

Residential house prices in these towns show a different trend. House prices increased in many Western Downs and Maranoa areas during 2012 and 2013. This was followed by a sharp decline from 2014–2016 before stabilising in 2017 and a slight recovery in 2018.[10]

Recent residential house prices in these Surat Basin towns are all significantly higher than before gas development began.

Toowoomba has shown a steady increase in house prices since 2012.

The changes in house prices seen in the Surat Basin are not as significant as those seen in the Isaac and Central Highlands local government areas. These Bowen Basin areas are influenced primarily by coal mining.

Median house sale price

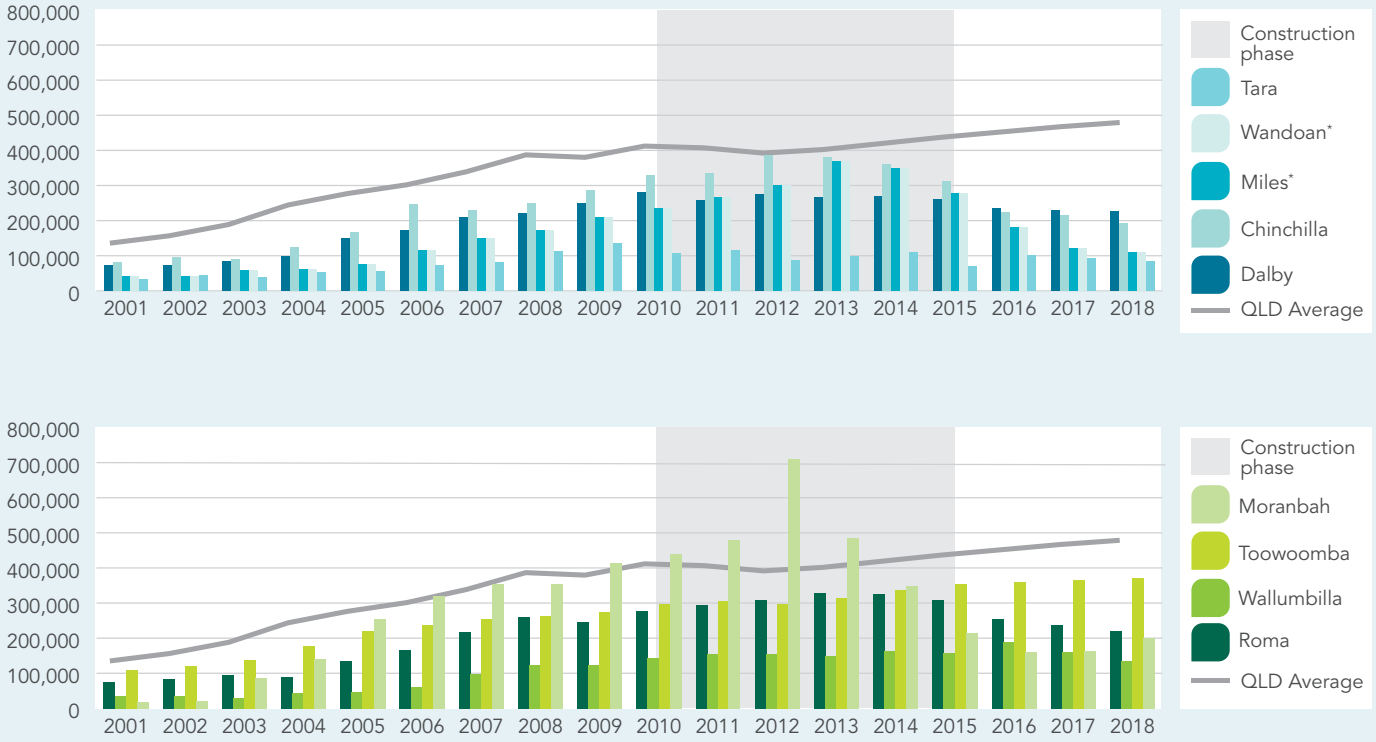


Figure 3.10: Median house sale prices for Surat and Bowen Basin towns compared to Queensland as a whole.[10]

*Miles and Wandoan are located in the same ABS statistical area level 2 (SA2) and therefore have the same data above

10 The University of Queensland's Centre for Coal Seam Gas, Boomtown Indicators, retrieved 2019

House sales have generally been on the decline since 2005 in Surat Basin towns. Slight increases in the number of house sales occurred in the early years of peak gas industry construction activity (2012–2013).

Annual number of house sales

Figure 3.11: Annual number of house sales has been declining in many towns in the Surat and Bowen Basins.[10]

*Miles and Wandoan are located in the same ABS statistical area level 2 (SA2) and therefore have the same data above.

10 The University of Queensland's Centre for Coal Seam Gas, Boomtown Indicators, retrieved 2019

ECONOMIC CONTRIBUTIONS

Agriculture

Agriculture continues to be a key economic driver in Queensland. The agricultural sector's contributions to regional economies and the overall Queensland economy are expected to continue indefinitely, whereas resource projects such as CSG have a shorter timeframe.

The total value of Queensland's agriculture industry commodities, comprising gross value of production (GVP) at the farm gate and first-stage processing, is forecast to be $18.54 billion in 2018–19.[11]

For a breakdown of agricultural production and exports by commodity, refer to Chapter 6: Supply and Demand.

Petroleum and gas

The gas industry's direct contribution to the Queensland Gross State Product (GSP) was 1.2 percent in the 2017/18 financial year.[12]

When economic flow-on effects are added, this contribution to GSP becomes 2.5 percent.

The figures reflect a period of heightened economic activity during the initial construction period of the gas industry with a lessening trend in wages and purchases as the gas projects became operational (Figure 3.12).

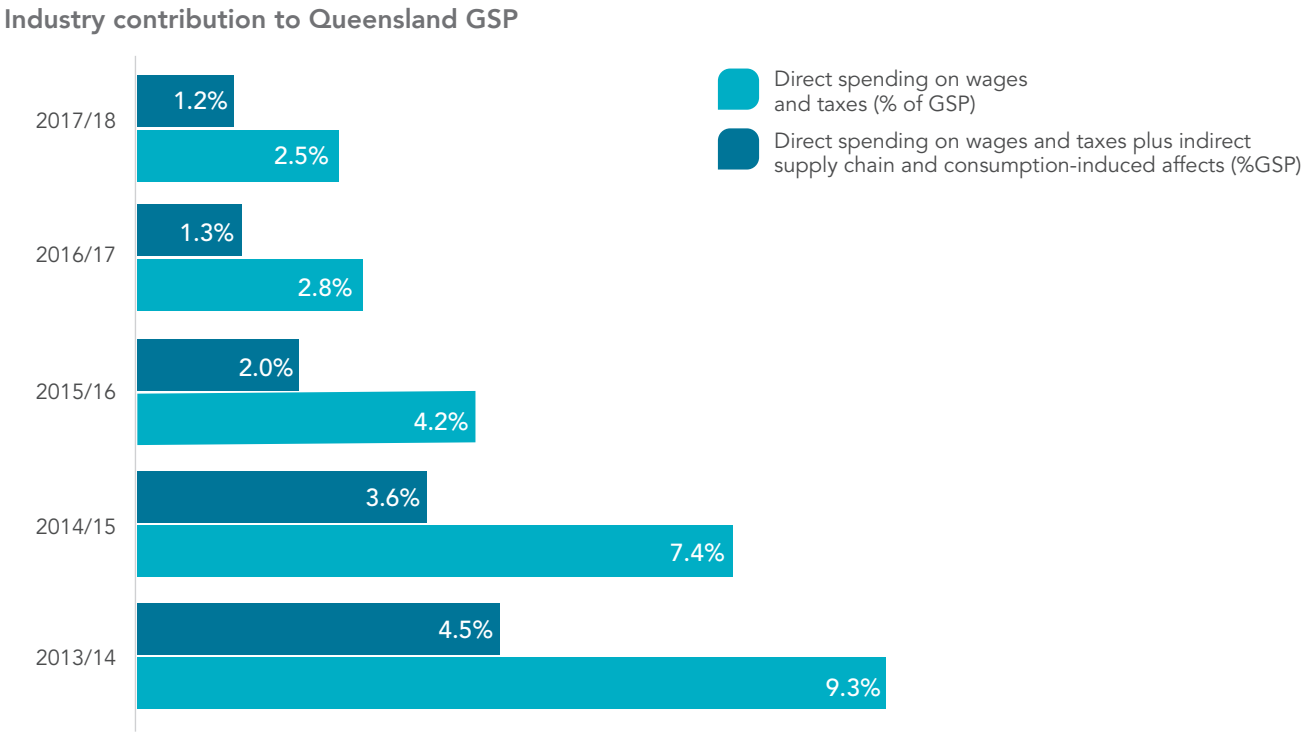


Figure 3.12: Gas industry yearly percentage contribution to the Queensland Gross State Product.[13]

The gas industry added **$8.2 billion** to the Queensland economy, supporting **2,926 businesses** and **325 regional community organisations**[13] in the 2017/18 financial year.[12]

11 Queensland AgTrends 2018–19, April 2019 update, DAF
12 Queensland Resources Council 2018. Economic Contribution Data. Yearly Economic Impact of the Mineral & Energy Sector on the Queensland Economy Reports, retrieved May 2019
13 The Australian Petroleum Production and Exploration Association (APPEA), personal communication 2019

This includes the sector's contribution through added value, which is calculated using economic modelling of company data to estimate the flow-on effects of consumption and investment for the region.

The gas industry contributes to regional economies through direct payments made to:

- community organisations through community grants schemes, sponsorship and social investment
- local government including rates, infrastructure charges and partnerships for development
- state government payments including resource rents and royalties, stamp duty, payroll tax and land tax.

Figure 3.14 shows the direct regional community contributions and contributions to the overall Queensland economy.[12]

While contributions to the state government have increased with an increase in gas production since 2016, local government payments have decreased over the same period.

This decrease is mostly due to less demand for local government services and infrastructure following the peak construction period.

Direct contribution to the Queensland economy

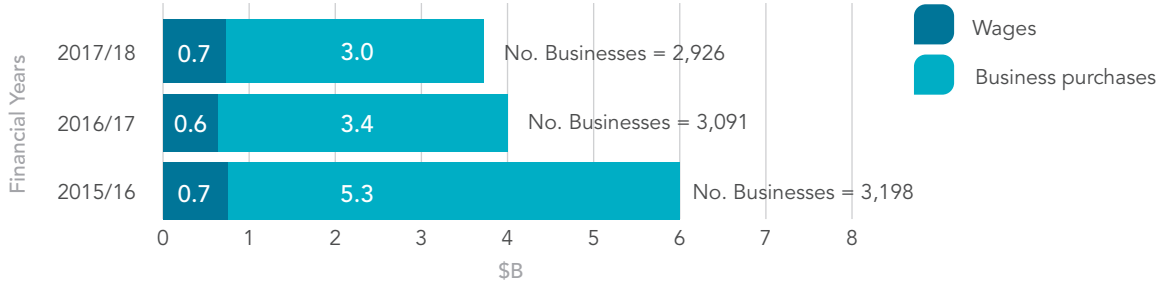


Figure 3.13: Gas industry value contribution to the Queensland economy for the latest 3 financial years.[12]

* Purchases: goods & services purchased locally, community contributions and local govt. payments

** Value Added (Added Value) "The value added measures the addition of consumption, investment and government expenditure, plus exports of goods and services, minus imports of goods and services for a region"

Petroleum and gas direct regional contribution

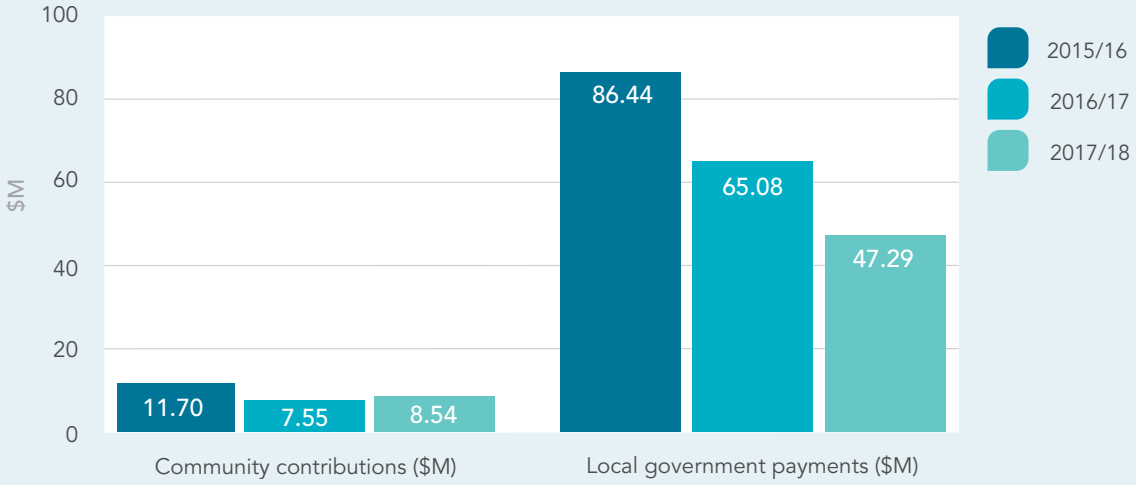


Figure 3.14: Petroleum and gas industry direct contributions to regional communities.[13]

12 Queensland Resources Council 2018. Economic Contribution Data. Yearly Economic Impact of the Mineral & Energy Sector on the Queensland Economy Reports, retrieved May 2019

13 The Australian Petroleum Production and Exploration Association (APPEA), personal communication 2019

The five local government areas that have benefitted most from the gas industry in Queensland have changed over time although Brisbane, Toowoomba and Western Downs areas have consistently been in the top five since 2014.

While Brisbane received the most direct spending in the 2017/2018 financial year, Maranoa, Western Downs, Gladstone and Toowoomba received more direct spending on a per capita basis with $14,377, $4,790, $3,849 and $2,518 respectively compared to Brisbane's $1,740 per capita.[14]

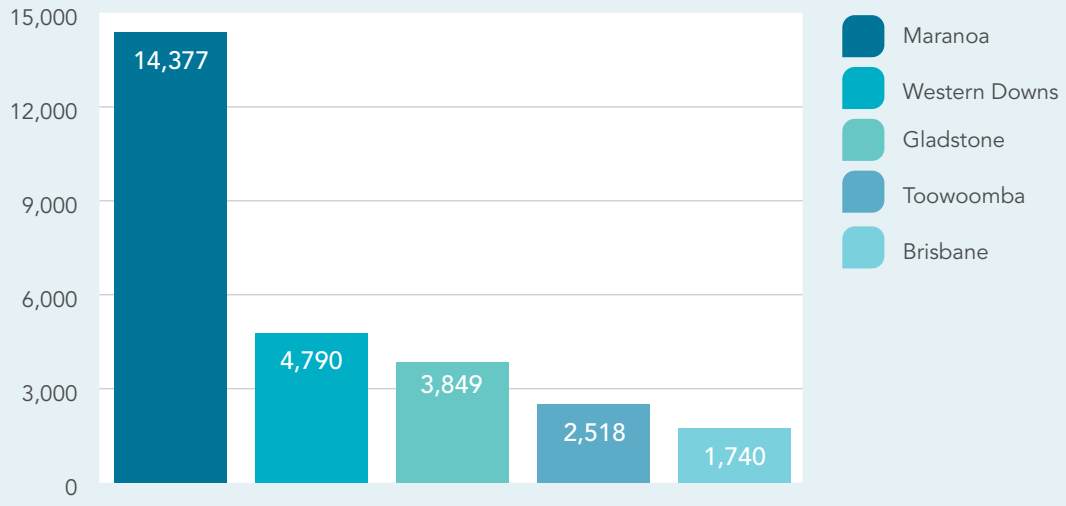


Figure 3.15: Direct spending by the gas industry per capita in LGAs in 2017/18.[14]

Table 3.2: Gas industry contributions to regional economies in 2018[15]

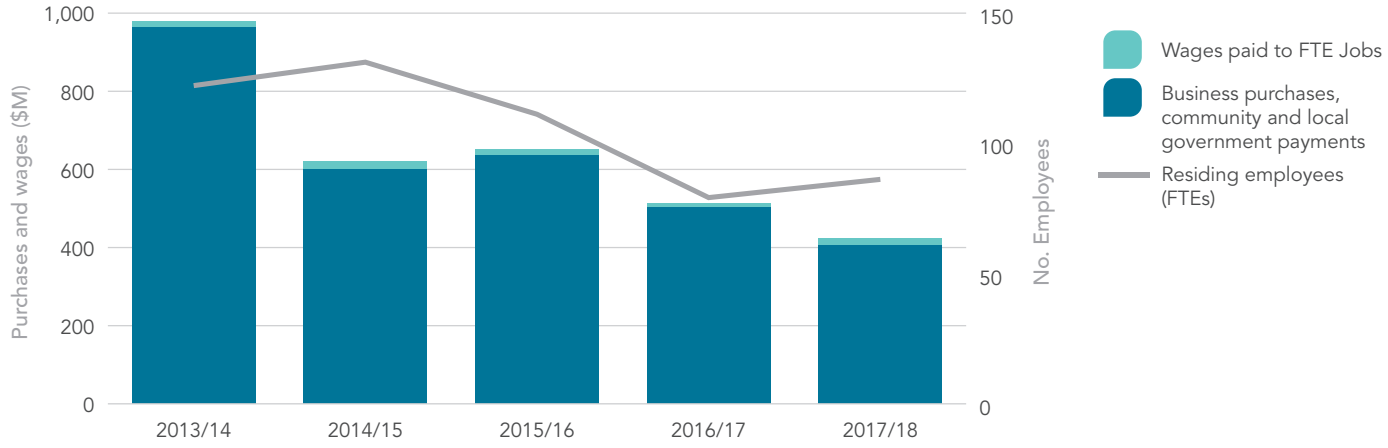
2017/2018 LGA	Wages paid to FTE Jobs ($M)	Residing Employees FTE	Business Purchases, Community and Gov't Contributions ($M)	Total Direct Spending ($M)
Brisbane	372.8	2,017	1,770.7	2,143.5
Toowoomba	15.6	90	406.6	422.2
Gladstone	69.0	432	173.3	242.4
Maranoa	16.4	97	167.5	183.9
Western Downs	49.5	343	115.6	165.1

Since the initial construction period of the CSG-LNG industry in Queensland, the total direct spend by the gas sector has been declining and is now starting to stabilise as the industry moves into a sustained production phase (Figure 3.16).

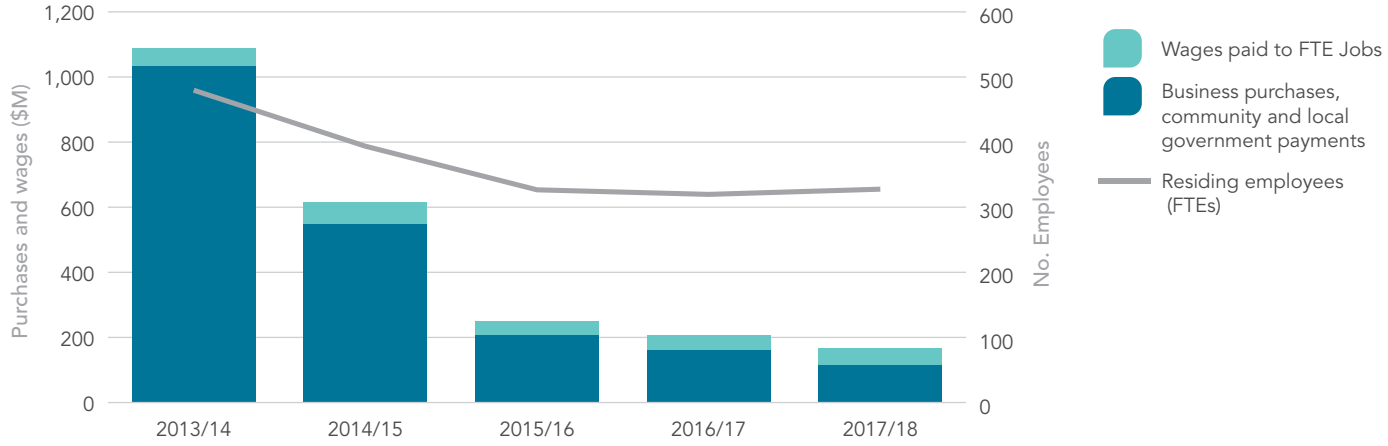
This includes a reduction in full-time employment numbers and associated wages as well as reduced business purchases, community contributions and payments for local government services.

14 Queensland Government's Statistician's Office, Estimated resident population by local government area, retrieved 2019
15 Queensland Resources Council, Economic Contribution of the Mineral & Energy Sector on the Queensland Economy 2017/18

Gas industry contribution to Toowoomba



Gas industry contribution to Western Downs



Gas industry contribution to Brisbane

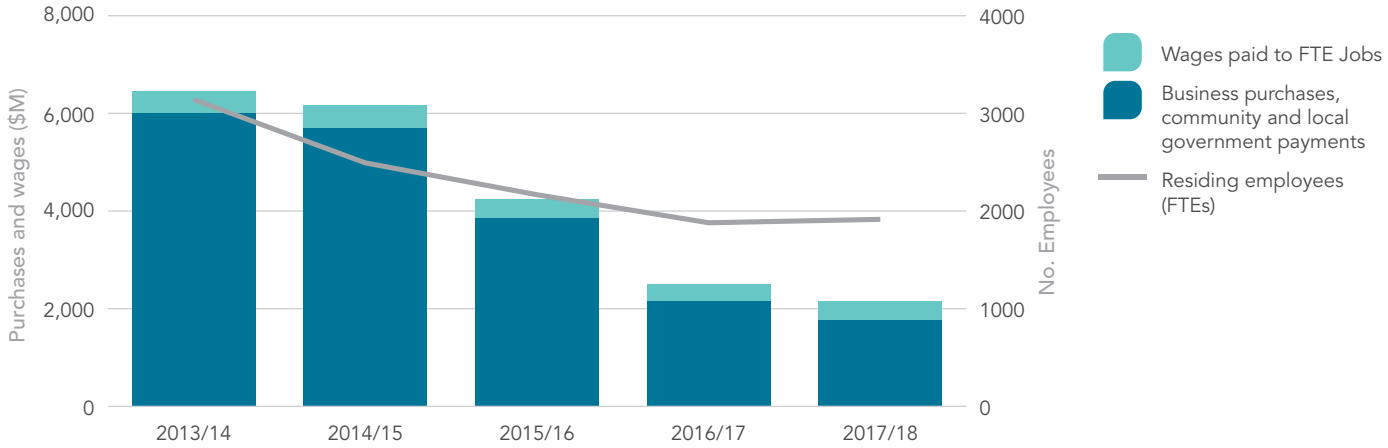


Figure 3.16: Gas industry contributions to regional economies by local government area. These three local government areas were consistently in the top five for highest direct industry spend.[16]

16 Queensland Resources Council, 2018. Economic Contribution Data. Yearly Economic Impact of the Mineral & Energy Sector on the Queensland Economy Reports

Purchases and payments still form the major component of gas industry spend in local government areas although wages spending increased, particularly in the Maranoa local government area in 2017/18.

This reflects the life cycle of the industry as the production phase requires specialised skills with wage packages designed to attract and retain skilled workers in regional areas.

Exploration expenditure

The annual spend on petroleum and gas exploration activities in Queensland is illustrated in Figure 3.17.

There was a total of $188.5 million spent by exploration companies in Queensland in the 2018 calendar year.

Exploration activity doesn't necessarily lead to further development of the gas field into a production phase so peaks in exploration aren't always followed by peaks in production.

Technological advances are continuing to increase for gas industry operations and this means that efficiencies are leading to lower costs in many cases and perhaps less exploration expenditure.

Petroleum and gas exploration expenditure in Queensland

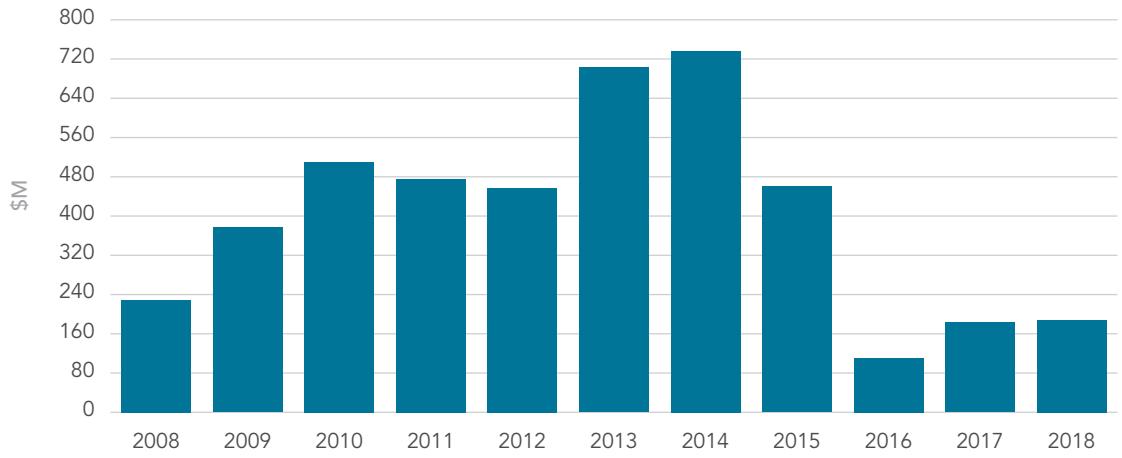


Figure 3.17: Petroleum and gas exploration expenditure by calendar year in Queensland.[17]

INSIGHTS

Resource companies pay royalties on oil and gas that is produced in Queensland. As at 1 July 2019, royalties in Queensland are calculated by taking 12.5 percent (previously 10 percent) of well head value.

Well head value is the profit margin on the gas – the amount the petroleum and gas company could reasonably be expected to realise if it were sold on a commercial basis (i.e. its market value) less production, processing and transportation expenses.[18]

Royalty payments are spent by government on behalf of taxpayers across the entire community towards shared services such as health, education, police, community services and roads.

17 Australian Bureau of Statistics, 8412.0 – Mineral and Petroleum Exploration, Australia, Mar 2019, retrieved 2019
18 Queensland legislation, Petroleum and Gas (Royalty) Regulation 2004, accessed June 2019

The gas industry's royalty payments have increased significantly in recent years due to the increased volume of CSG now being produced in Queensland for export as LNG.

Oil and gas royalty payments

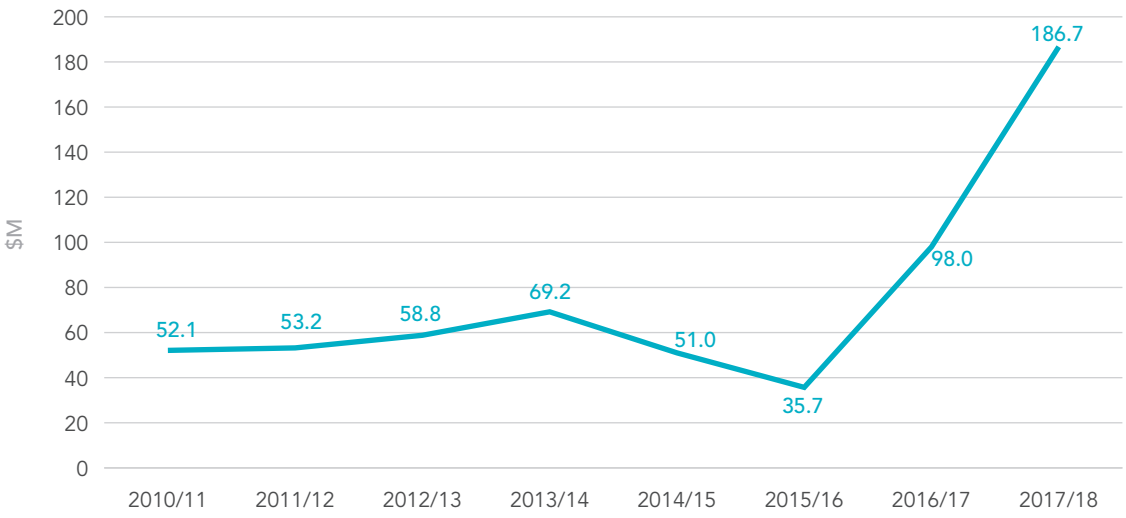


Figure 3.18: Queensland royalty payment contribution by the oil and gas sector.[19]

CSG contributed $170.8 million or 91 percent of the total oil and gas royalty payments made in the 2017/18 financial year (Figure 3.19). The remaining royalty payments made that year were from the production of oil, condensate, LPG and conventional gas.

Breakdown of petroleum royalties

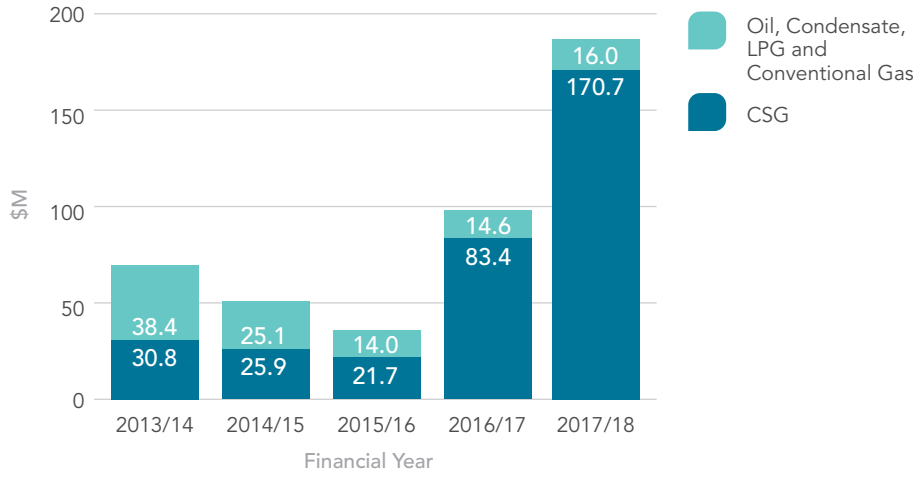


Figure 3.19: Breakdown of petroleum royalty payments over the last five financial years.[19]

INSIGHTS

LPG (liquefied petroleum gas) is used by Queenslanders to fuel vehicles, barbeques, hot water tanks and gas stoves in their kitchens.

19 Queensland Treasury, Office of State Revenue, Royalty Statistics, May 2019

LAND ACCESS AND COMPENSATION

INSIGHTS

Under Queensland's land access laws, resource companies have the right to access and undertake petroleum and gas activities on a landholder's property provided that all legal requirements under the land access laws are complied with.

The legal requirement depends on the type of activities that are to be carried out on the landholder's property:

Preliminary activities, such as walking the area, taking soil samples or survey pegging (minimal impact on landholders)	**Advanced activities**, such as infrastructure construction (longer term and/or extensive impacts on landholders)	**Decommisioning activities**, such as rehabilitation for wells or pipelines

A Conduct and Compensation Agreement (CCA) is required for any advanced activities. This is a legally binding document that specifies the company's activities and behaviours, respective obligations and protections. A CCA also ensures the landholder is compensated for the effects and impacts of the advanced activities.

All CCAs are registered on the property's land title. If a property is sold, any registered CCAs are transferred with it.

Conduct and Compensation Agreements

As at 31 March 2019, the number of CCAs recorded on Queensland land titles was **4,746**.[20]

Of these 4,746 CCAs, over **70 percent** of them exist within a production lease (see Chapter 1: Land Use for a description of the types of resource authorities).

The Surat Cumulative Management Area comprises **70 percent** of all current CCAs (see Chapter 5: Groundwater to find out more about this area).

Landholders living in the the **Maranoa** and **Western Downs Regional Council** areas account for **72 percent** of all CCAs.

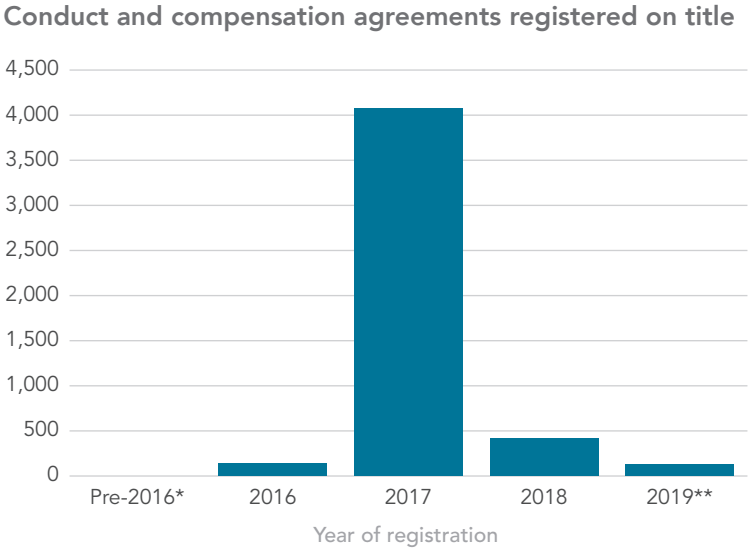


Figure 3.20: Number of Conduct and Compensation Agreements (CCAs) registered to land titles in Queensland each year.[20]

* no requirement to register pre–2016 CCAs on land title
** data as at 31 March 2019

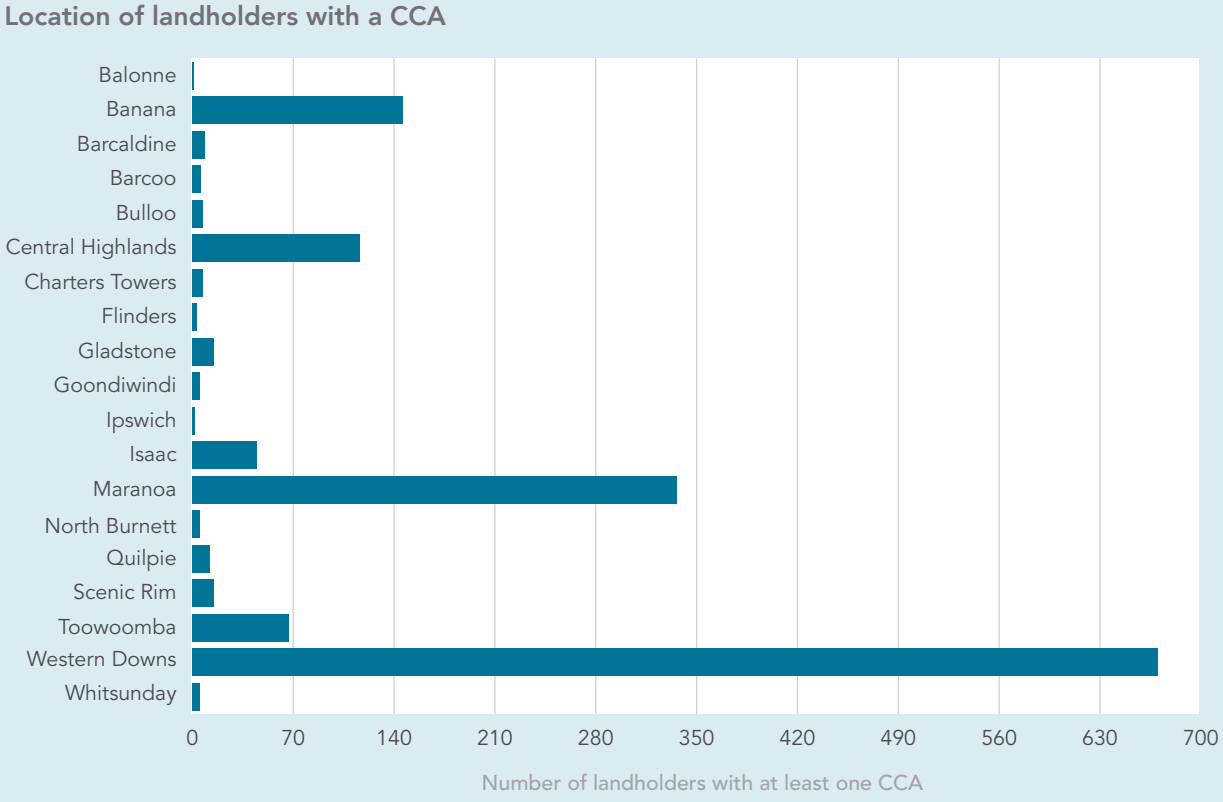


Figure 3.21: Landholders with Conduct and Compensation Agreements (CCAs) by local government areas. Where a CCA applies to a group of properties located across more than one local government area, the CCA was assigned to only one of the areas to avoid being double counted.[20]

20 Queensland Title Registry, Department of Natural Resources, Mines and Energy, personal communication, April 2019

Conduct and compensation agreements by local government area

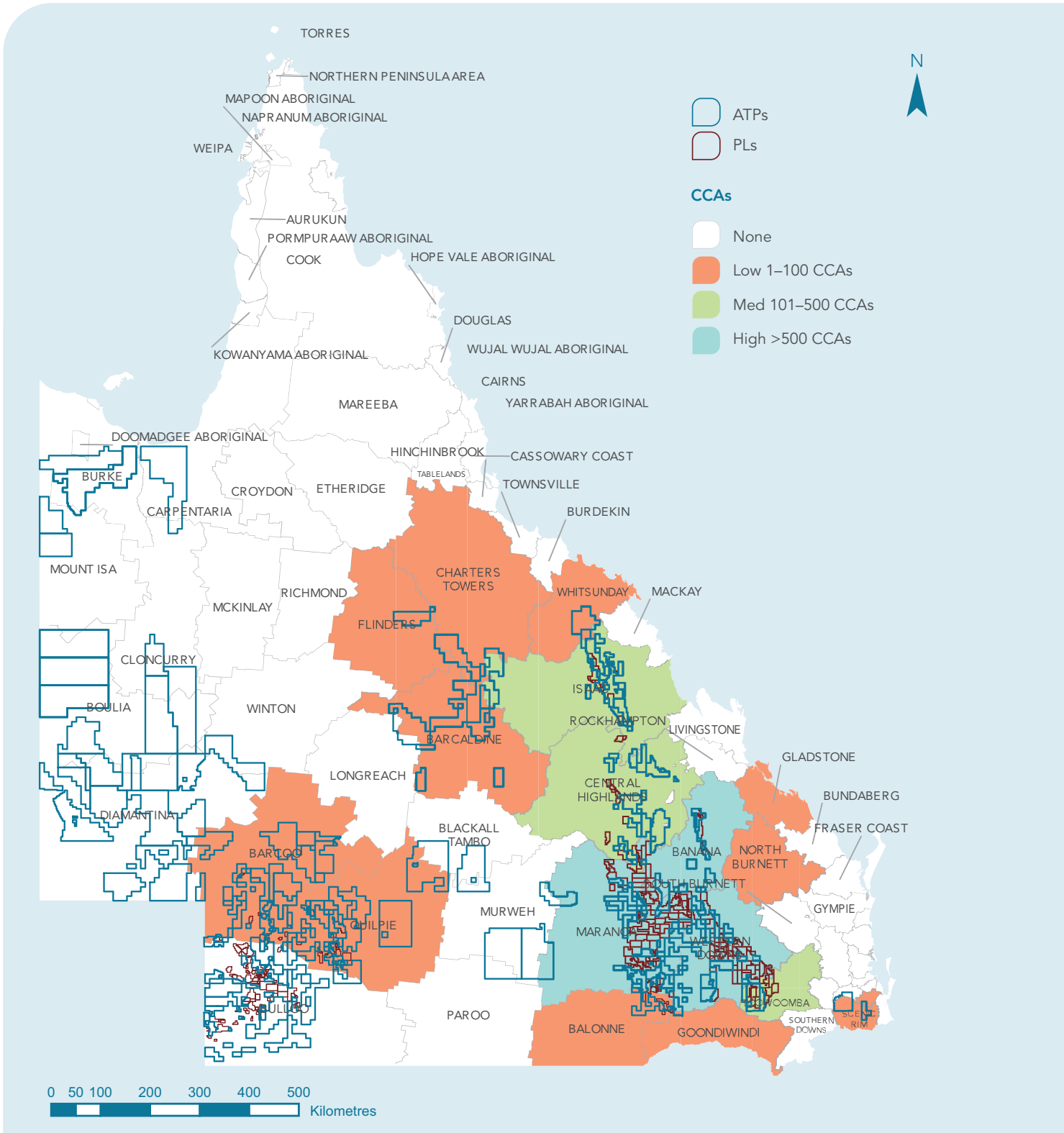


Figure 3.22: Map of Queensland showing the local government areas, number of Conduct and Compensation Agreements in each of these areas and petroleum/gas authorities. Where a Conduct and Compensation Agreement (CCA) applies to a group of properties located across more than one local government area, the CCA was assigned to only one of the areas to avoid being double counted.[21]

21 Map generated using data from Department of Natural Resources, Mines & Energy Queensland Spatial Catalogue, retrieved April 2019 and Queensland Title Registry, Department of Natural Resources, Mines and Energy, personal communication, April 2019

The **4,746** total CCAs are held by **1,472** different landholders.

In cases where there is more than one resource company operating on a property, this property will have more than one CCA registered to it. Table 3.3 shows that **45 percent** of landholders with CCAs hold more than one.

Table 3.3: Number of landholders with Conduct and Compensation Agreements as at 31 March 2019[22]

Number of CCAs held by an individual landholder	Number of landholders
1	812
2	281
3–10	322
>10	57
Total	**1,472**

89 percent of the CCAs are held on **freehold land**.

Table 3.4: Number of Conduct and Compensation Agreements on freehold and leasehold properties[22]

Property type	Number of CCAs
Freehold	4,207
Leasehold	539
Total	**4,746**

22 Queensland Title Registry, Department of Natural Resources, Mines and Energy, personal communication, April 2019

Compensation paid

In the 2018/19 financial year, **$78 million** in compensation was paid to landholders for the impacts resulting from petroleum and gas development activities on their properties.

Figure 3.23 shows the cumulative compensation that has been paid to date is more than **$505 million**.

Cumulative compensation paid to landholders

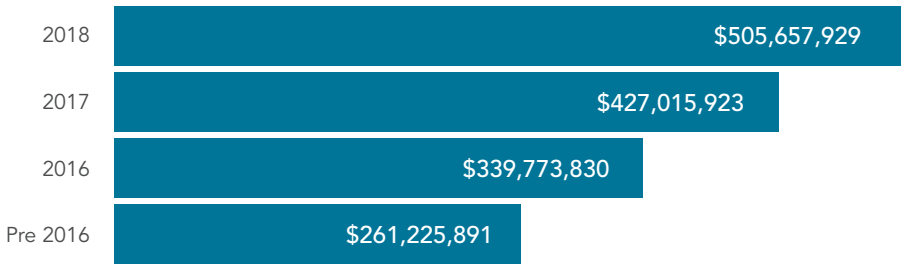
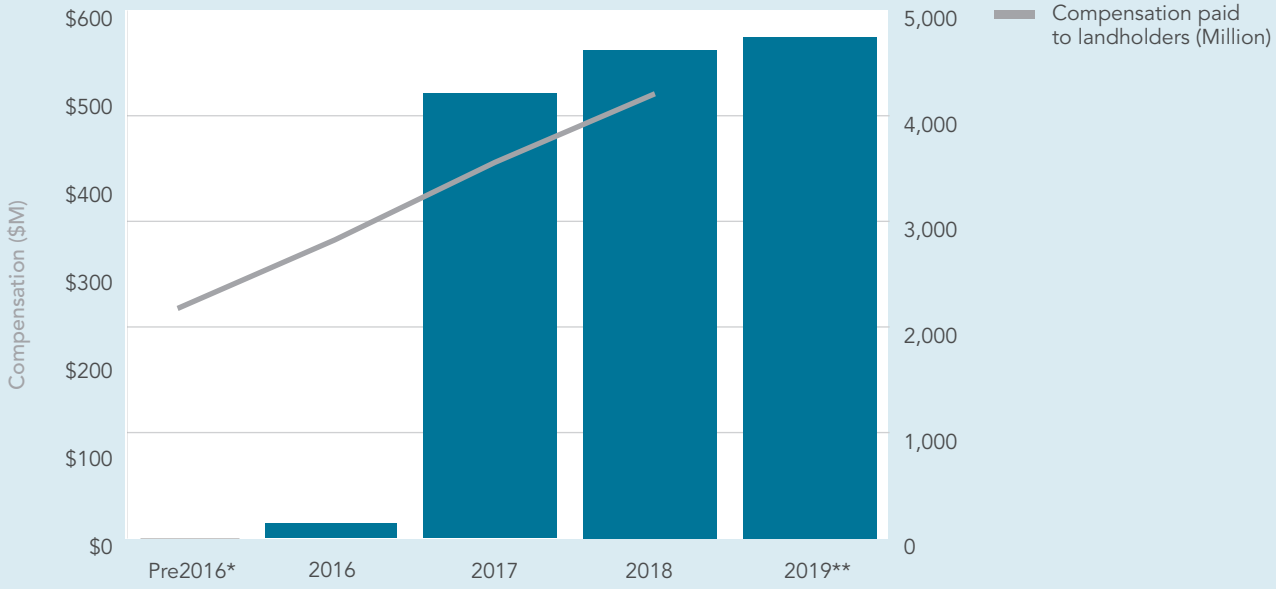


Figure 3.23: Cumulative compensation paid to landholders for petroleum and gas development on private land.[23]

Conduct and compensation agreements registered on title and compensation paid



* no requirement to register pre–2016 CCAs on land title

** data as at 31 March 2019

Figure 3.24: Cumulative number of Conduct and Compensation Agreements with compensation paid to landholders for petroleum and gas development on private land.[23]

23 Australian Petroleum Production & Exploration Association, personal communication, 2018

INSIGHTS

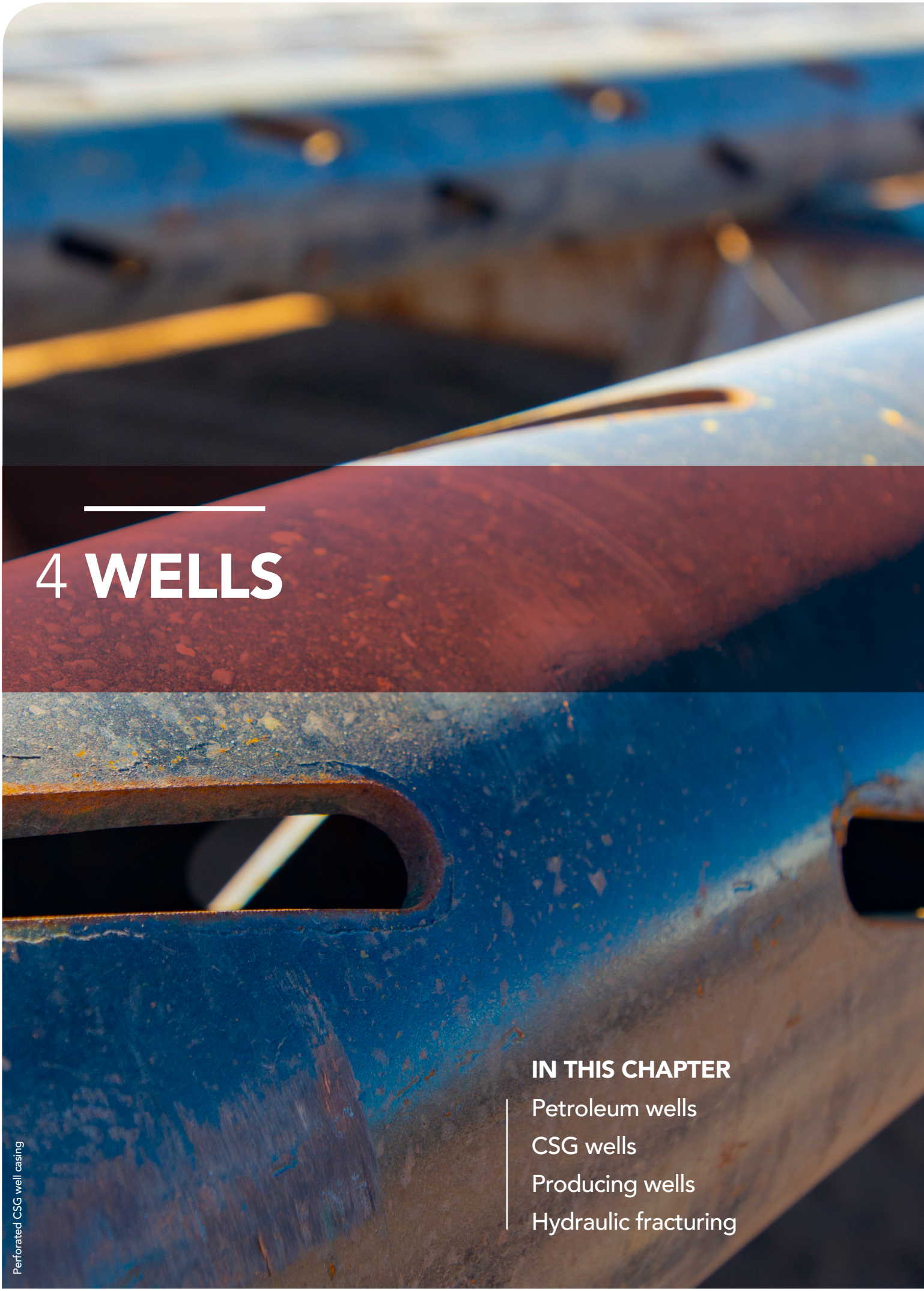
It is not possible to calculate an indicative individual CCA value based on this data as:

- every property, land value, business operation and profitability is different.
- the type and extent of company activity on each property and impact to a landholder's operations is different.
- the total number of CCAs include agreements that are signed before the commencement of company activities, and payments are not yet due.
- apportionment of payments vary significantly between agreements, from a large proportion of total compensation paid up front to annual compensation payments over the life of the agreement.

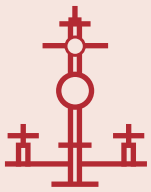
4 WELLS

IN THIS CHAPTER

Petroleum wells
CSG wells
Producing wells
Hydraulic fracturing



Perforated CSG well casing



14,034
total oil and gas wells have been drilled in Queensland as at the end of 2017/18

5,750
of the wells are **exploration** and **appraisal** wells

10,664
of the wells are **targeting CSG**

82%
of producing CSG wells are located in the **Surat Basin**

7.5%
of all oil and gas wells in Queensland have been **hydraulically fractured**

96.5%
of hydraulic fracturing fluid is **water**

TYPES OF WELLS

A total of 14,034 oil and gas wells had been drilled in Queensland at the end of the 2017/18 financial year.

This includes:

- conventional oil and gas wells
- unconventional tight gas, shale gas and coal seam gas (CSG) wells.[1]

Of the total wells drilled, 5,750 were exploration and appraisal wells.[1]

For this chapter, '**petroleum wells**' refers to conventional oil and gas, tight gas and shale gas wells.

Gas typically flows through the perforation in the well casing into the production tubing and up to the surface.

1 Department of Natural Resources, Mines and Energy 2018, personal communication

Conventional versus unconventional (CSG) wells

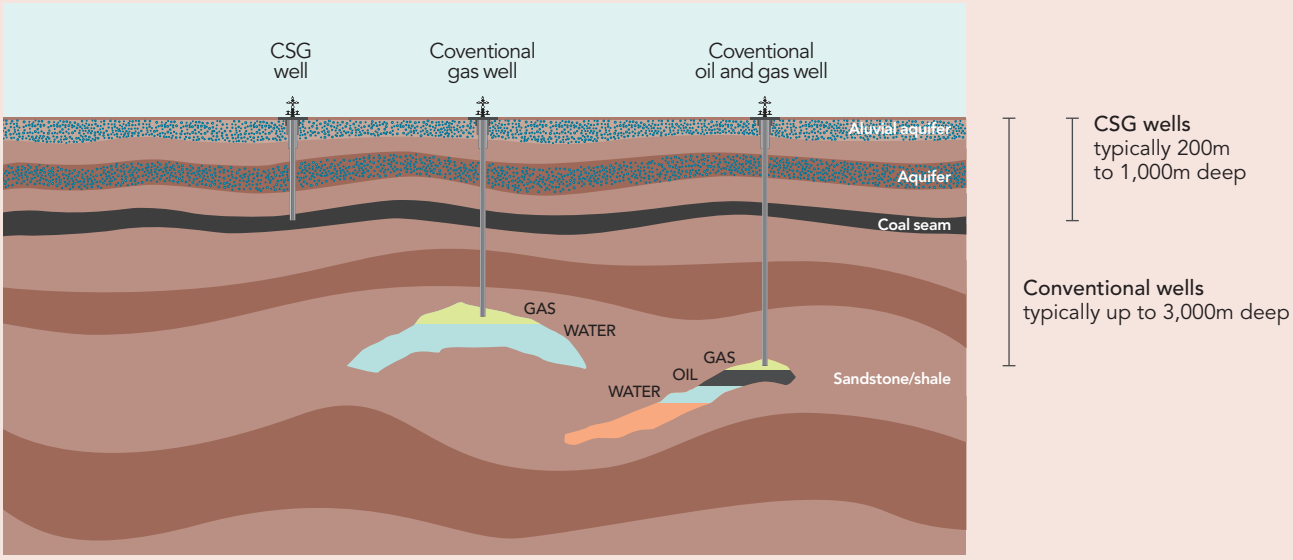


Figure 4.1: Drilling diagram comparing unconventional (CSG) and conventional oil and gas wells.

PETROLEUM WELLS

A total of 3,370 petroleum wells had been drilled in Queensland at the end of the 2017/18 financial year, across five geological Basins: the Cooper, Eromanga, Bowen, Surat and Galilee Basins (Figure 4.2).

Around half of those petroleum wells are in the Cooper and Eromanga Basins.[1]

No. of petroleum wells drilled as at 30 June 2018

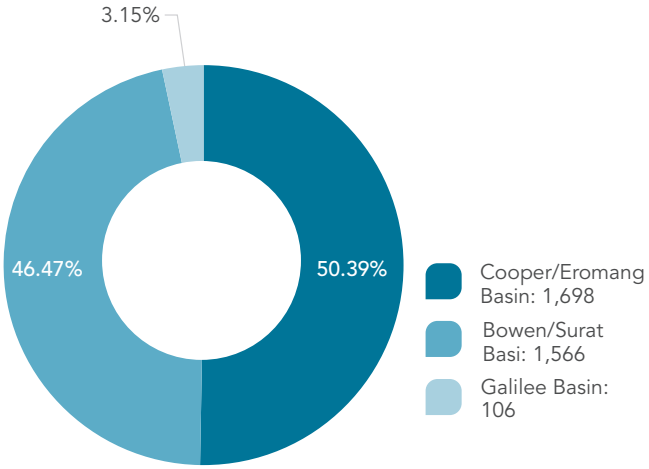


Figure 4.2: Total number of petroleum wells drilled in each basin. This includes conventional oil and gas, tight gas and shale gas wells.[1]

COAL SEAM GAS WELLS

A total of 10,664 CSG wells had been drilled in Queensland at the end of the 2017/18 financial year.

Two thirds of those were drilled in the Surat Basin and almost a third drilled in the Bowen Basin (Figure 4.3).

While CSG wells have been drilled across four Basins, all current CSG production is from the Surat and Bowen Basins.[1]

No. of CSG wells drilled as at 30 June 2018

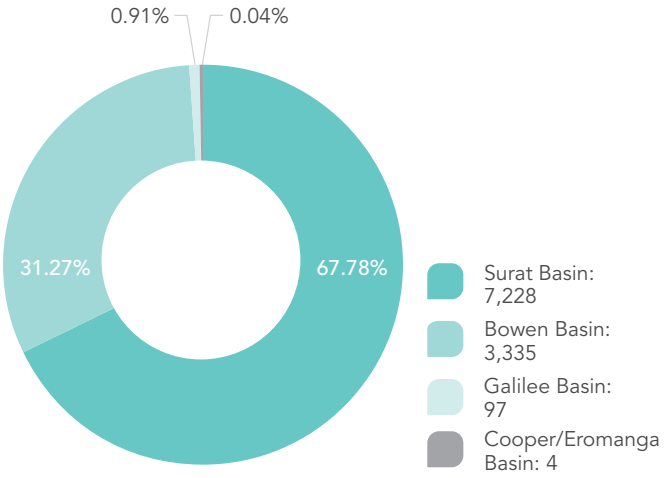


Figure 4.3: Number of CSG wells drilled in each basin as at 30 June 2018.[1]

1 Department of Natural Resources, Mines and Energy 2018, personal communication

PRODUCING WELLS

The number of CSG wells in Queensland has grown rapidly since 2010 to support Queensland's LNG export industry.

As at 30 June 2018 there was a total of 6,656 producing CSG wells in Queensland – 18 percent in the Bowen Basin and 82 percent in the Surat Basin.[1]

Total producing wells in Queensland

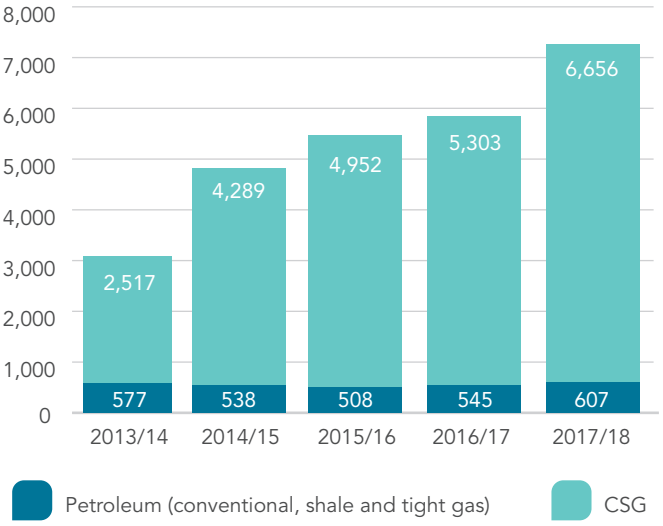


Figure 4.4: Total number of producing wells in Queensland.[2]

HYDRAULIC FRACTURING

7.5 percent of all oil and gas wells drilled in Queensland to the end of the 2017/18 financial year have been hydraulically fractured.

Of the 10,664 CSG wells drilled in Queensland, 8.8 percent have been hydraulically fractured within the Surat and Bowen Basins only.

CSG wells hydraulically fractured to June 2018

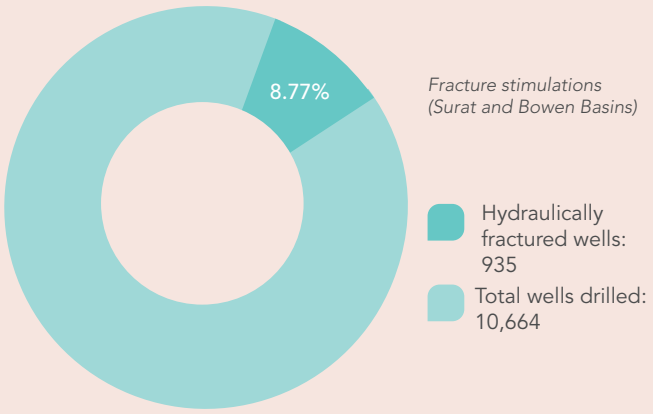


Figure 4.5: Hydraulically fractured CSG wells as a proportion of total CSG wells drilled.[1]

Of the other 3,370 petroleum wells drilled in Queensland, 3.5 percent have been hydraulically fractured mostly in the Cooper and Eromanga Basins with some in the Bowen and Surat Basins.[1]

Petroleum wells hydraulically fractured to June 2018 (conventional oil and gas, tight gas and shale gas)

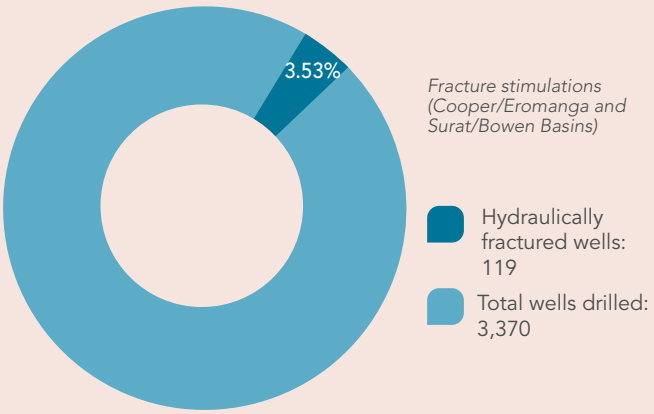


Figure 4.6: Hydraulically fractured petroleum wells as a proportion of total petroleum wells drilled. These figures include conventional oil and gas wells, tight gas wells and shale gas wells.[1]

1 Department of Natural Resources, Mines and Energy 2018, personal communication
2 Department of Natural Resources, Mines and Energy presentation to the APPEA 2019 Conference and Exhibition, Brisbane

INSIGHTS

What is hydraulic fracturing?

Hydraulic fracturing is a process used to increase the flow of oil or gas from a well.

The process has been part of the Australian oil and gas industry for over 40 years and has been used in 7.5 percent of petroleum and gas wells in Queensland.

Many coal formations (i.e. where CSG comes from) naturally have a lot of fractures, which allow water and gas to flow easily. Other coals have fewer natural fractures that can contain significant amounts of gas making it more difficult to extract. Hydraulic fracturing is a technique used to enhance the flow of gas.

The process involves using an explosive charge to perforate the well casing and to penetrate the geological formation and then pumping fluid at high pressure to force proppant into the fractures – usually sand – to prop open the cracks.

This creates pathways for oil and gas to flow more easily through the geological formation into the well and increase its productivity.[3]

Comparatively small volumes of other additives are also used.

An analysis undertaken for this report shows that chemical additives account for less than one percent of fracturing fluid volume.[4]

Fluids are used in hydraulic fracturing to both create cracks and to carry proppant materials that prop open the cracks.

The composition of hydraulic fracturing fluids varies depending on site specific conditions.

The use of benzene, toluene, ethyl-benzene and xylenes (BTEX) is banned in Queensland.

Table 4.1 shows the main components of a hydraulic fracture and Figure 4.8 shows the average breakdown of chemical components used in 21 sample case studies.[4]

A comprehensive list of the most commonly used additives for hydraulic fracturing fluid can be found in Appendix A.

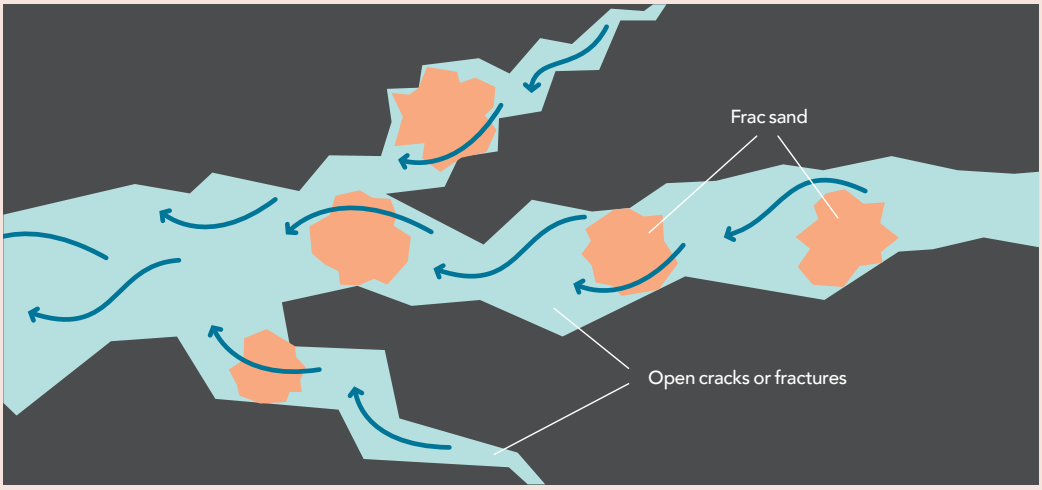


Figure 4.7: Small cracks in the geological formation held open by proppant as part of a hydraulic fracturing process.

3 Santos, What is hydraulic fracturing, retrieved 2019
4 Witt, et al., University of Queensland, Centre for Coal Seam Gas, personal communication, 2018

Hydraulic fracturing adds to the expense of gas production so it is generally only conducted if gas production from a well is too low to be economic.[5]

CASE STUDY[4]

Researchers at the University of Queensland's Centre for Coal Seam Gas reviewed a selection of 21 *Hydraulic Fracturing Activities Completion Reports* for wells drilled for exploration and production purposes in the Bowen and Surat Basins to generate a 'typology' of hydraulic fracturing activities in these (mainly CSG) basins.

The data was extracted from publicly available Queensland Government QDEX data.[6]

Water is the primary component of a hydraulic fracturing fluid averaging around 96.5 percent of the total volume.

Sand was used as proppant in all cases – three percent.

Chemical additives accounted for less than one percent of a hydraulic fracturing fluid with an average of seven different types of additives used in each fracture.

4 Witt, et al., University of Queensland, Centre for Coal Seam Gas, personal communication, 2018
5 Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC), Hydraulic fracturing ('fraccing') techniques, including reporting requirements and governance arrangements, June 2014
6 Department of Natural Resources, Mines and Energy, Geological Survey of Queensland, Queensland Digital Exploration Reports, retrieved 2018

Table 4.1: Main components of hydraulic fracturing[7]

Components	Purpose in fracture stimulations	Examples component type	Example of other uses
Water	Fractures the coal when injected under high pressure	Bore water, farm pond water or treated produced water	
Proppant	Props fractures open once hydraulic pressure is released	• Sand • Resin-coated sand • Ceramics • Bauxite (aluminium ore)	Drinking water filtration, play sand, concrete, brick mortar

Appendix B provides an outline of how hydraulic fracturing is regulated by government in Queensland.

The composition of the hydraulic fracturing fluid varies across sites due depending on the geology, the existing groundwater quality and the extent of fracturing needed.

No. of cases	Base Water	Proppant – sand	Chemical additives	Average no. of additives
21	96.5%	2.9%	0.6%	7

General composition of hydraulic fracturing fluid

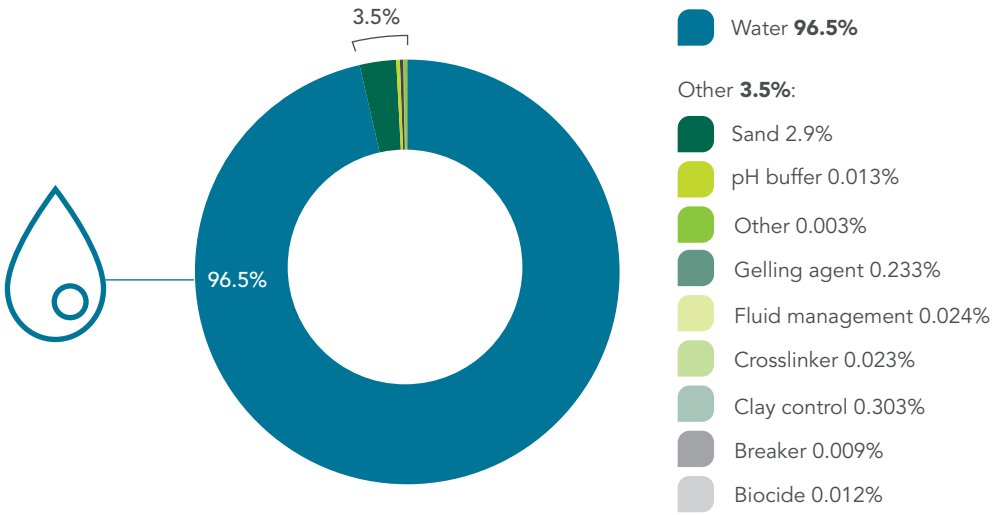


Figure 4.8: Average hydraulic fracturing fluid composition based on 21 sample case studies in the Bowen and Surat Basins.[8]

7 Witt, et al., University of Queensland, Centre for Coal Seam Gas, personal communication, 2018, adapted from Independent Expert Scientific Committee (IESC), Hydraulic fracturing ('fraccing') techniques, including reporting requirements and governance arrangements, June 2014

8 Witt, et al., University of Queensland, Centre for Coal Seam Gas, personal communication, 2018

Gas companies are required to demonstrate that the volume of flow back water extracted from the well must be 1.5 times the volume of fluid used to hydraulically fracture the well, to ensure that all water used for hydraulic fracturing is recovered.[9]

The exact amount of water used in a single fracture depends on the type of well stimulated.

Based on the 21 cases studied the average amount of water used in a single Bowen/Surat fracture is 973,000 litres (approximately 1ML) or about 40 percent of the volume needed to fill an olympic swimming pool (approximately 2.5ML) (Figure 4.9).

This flow back water is contained and can be re-used in another hydraulic fracturing operation or treated and disposed in accordance with government regulations.

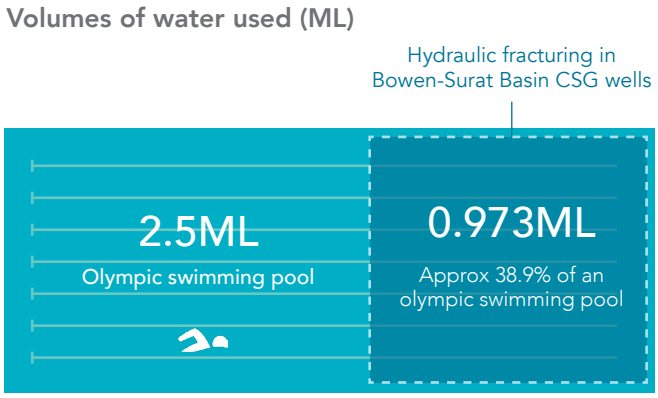
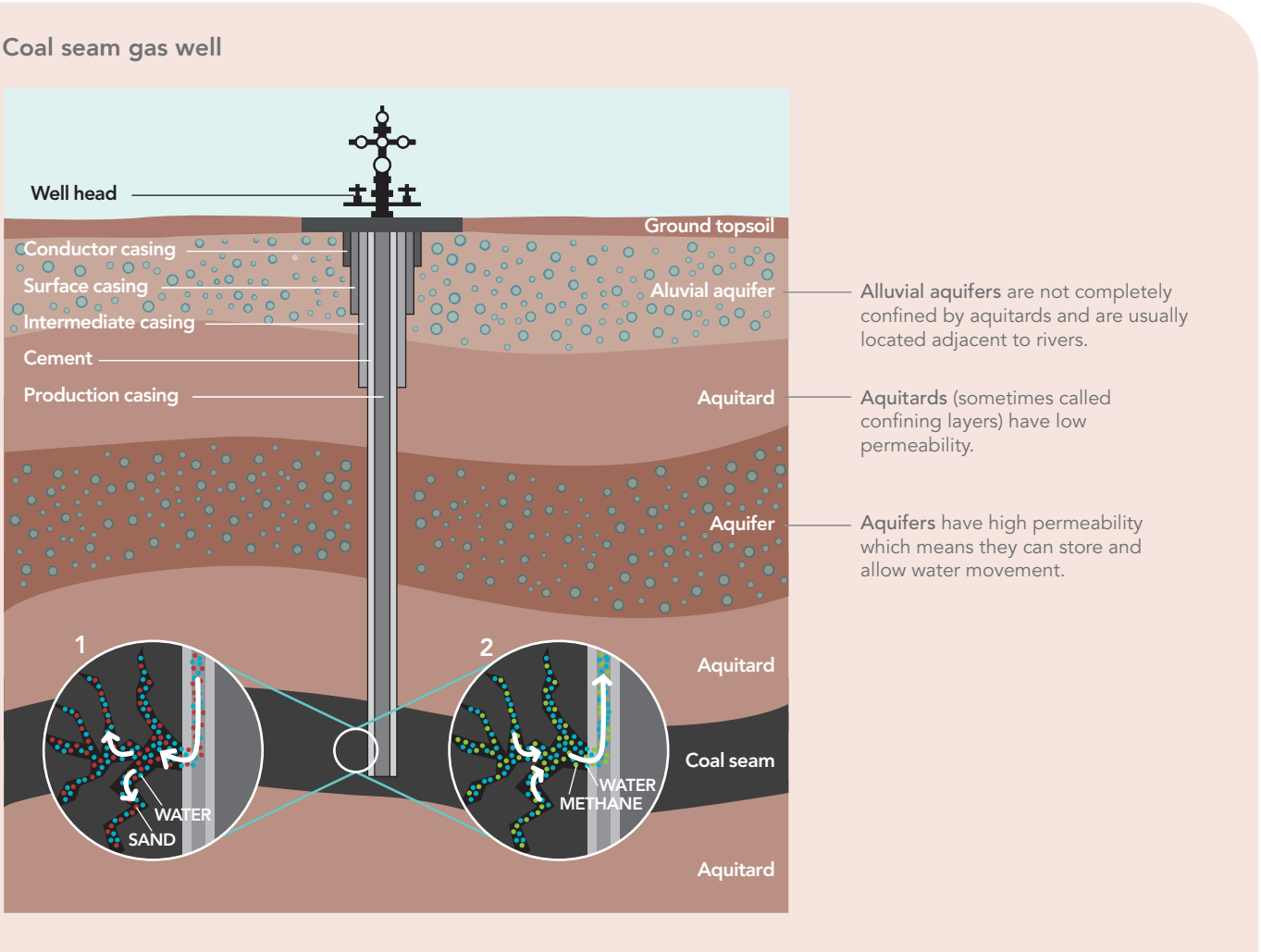


Figure 4.9: Average volume of water used to hydraulically fracture a Bowen-Surat CSG well compared with an olympic swimming pool.[10]



9 Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC), Hydraulic fracturing ('fraccing') techniques, including reporting requirements and governance arrangements, June 2014

10 Witt, et al., University of Queensland, Centre for Coal Seam Gas, personal communication, 2018

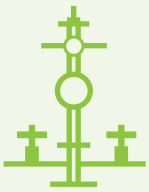
5 GROUNDWATER

IN THIS CHAPTER

Beneficial use of associated water

324,058ML

of groundwater is taken for non-gas related activities each year

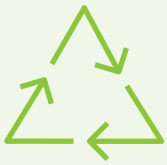


66,000ML

of groundwater is taken for petroleum and gas activities each year

>1,500

groundwater monitoring points exist in Queensland



145,000ML

of treated associated water has been beneficially used for other purposes

≈2%

of Surat CMA water bores are predicted to be impacted by petroleum and gas development in the long term

>56

make good agreements have been signed between bore owners and resource companies

INSIGHTS

Formations containing coal seams can be aquifers that:

- provide water for many landholders
- contain gas that is at least 99 percent methane.

Gas is released when the coal formation is depressurised when groundwater is extracted for agriculture or gas production.

Water produced from aquifers containing coal seams:

- varies in composition
- has salinity ranging from 300 to 10,000 mg/L
- is a resource for landholders, mostly used for stock and domestic purposes
- as a by-product during gas production is called 'associated water' and is regulated as a waste product and requires a number of approvals to be used beneficially.

Historical evidence from coal rich areas in Queensland, such as the Surat and Bowen Basins, shows that natural gas seepage from the landscape existed prior to the development of the current coal seam gas industry.

GROUNDWATER TAKE

The estimated total groundwater take from all aquifers across the petroleum and gas producing areas of Queensland for all purposes is approximately 390,000 ML/year.[1,2,3]

Most of this is used for agricultural (includes stock intensive and irrigation use) and stock and domestic purposes (Figure 5.1).

Of the total water take, approximately 134,000 ML/year (34 percent) is drawn from the upper alluvial and volcanic aquifers that overlie the Bowen and Surat Basins for non-petroleum and gas activities (Figure 5.2).

Approximately 66,000 ML/year or 17 percent of the total water take is for petroleum and gas purposes.

Groundwater take across the petroleum and gas producing areas of Queensland in 2018

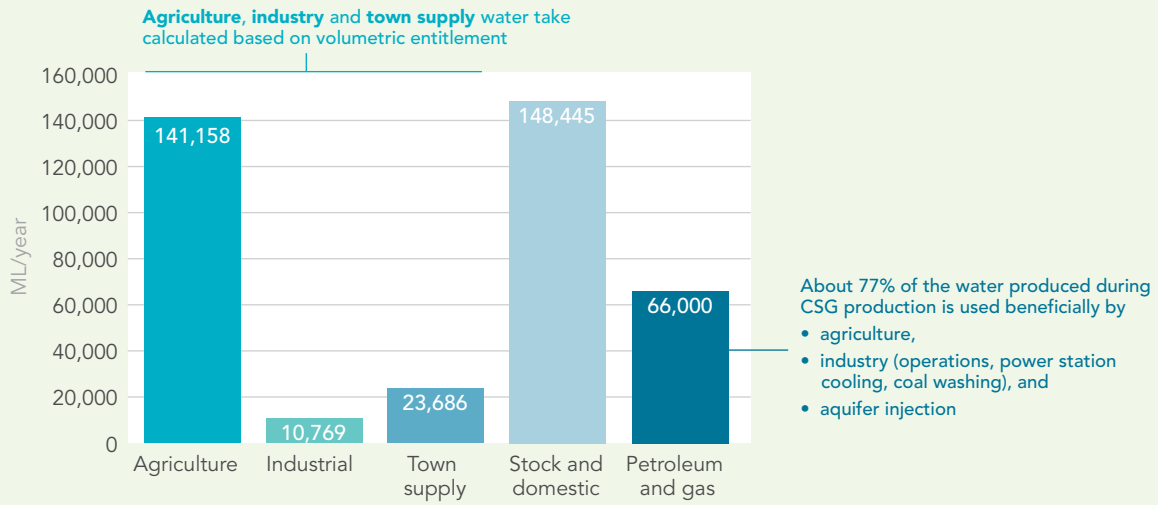


Figure 5.1: Estimated total groundwater take in the petroleum and gas producing areas of Queensland by sector.[1,2,3]

Total groundwater take across the petroleum and gas producing areas of Queensland in 2018 (ML/year)

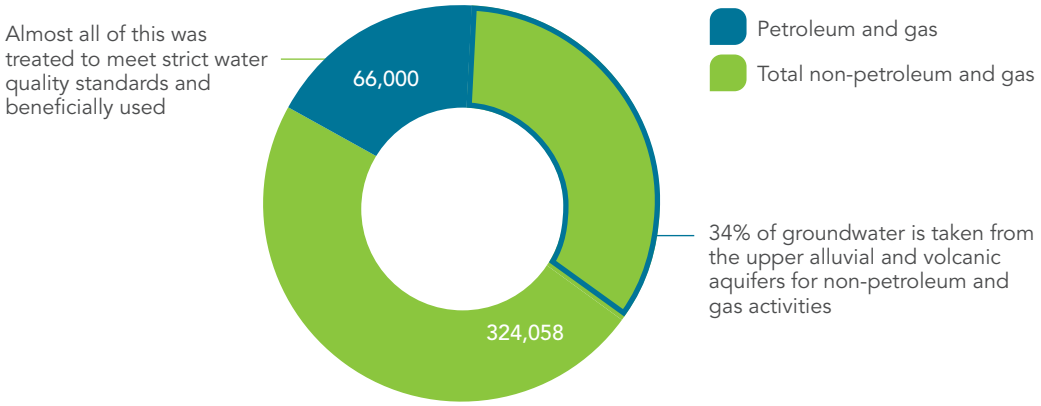


Figure 5.2: Total groundwater take across the petroleum and gas producing areas of Queensland by petroleum and gas activities and by non-petroleum and gas activities.[1,2,3]

1 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019
2 Department of Natural Resources, Mines and Energy, Groundwater Database Queensland, retrieved 2019
3 Queensland Government Water Licence Dataset, accessed 2019

Associated water take in 2018 from the Surat and Bowen formations is approximately 61,000 ML/year (Figure 5.3).

Non-petroleum and gas groundwater take from these formations is comparable to petroleum and gas take at approximately 59,700 ML/year and does not include the shallow alluvium and volcanic formations.

No CSG is produced from the Eromanga formations or the underlying Galilee and Cooper Basins although exploration has been carried out.

For detailed information on groundwater and the effects of extracting groundwater, refer to Appendix C: Groundwater explained.

Groundwater take from Surat and Bowen formations

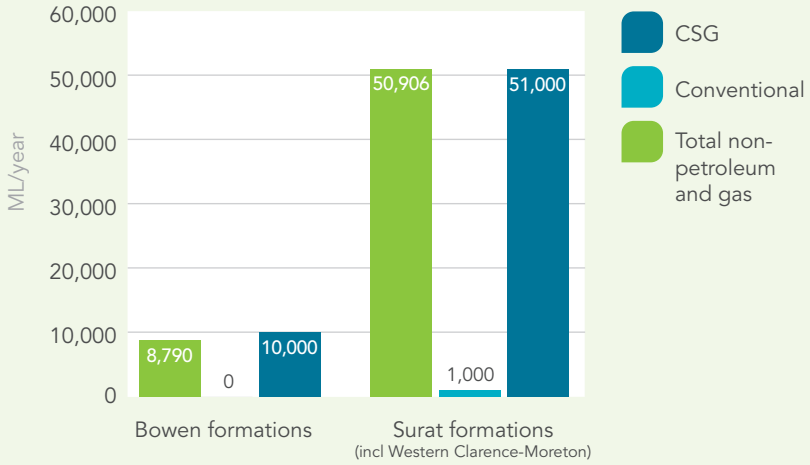
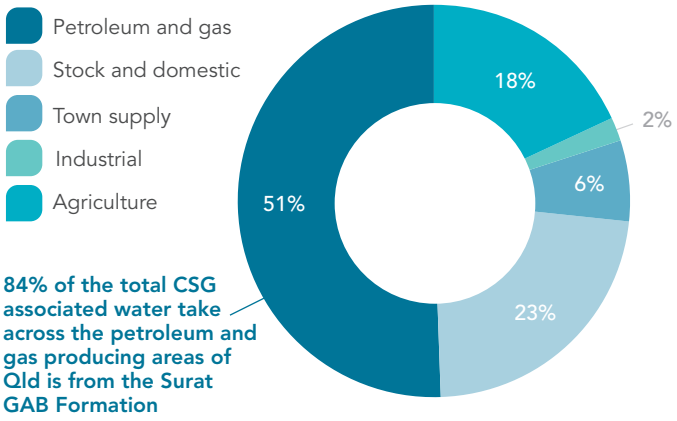


Figure 5.3: Estimated water take from the Surat and Bowen formations in 2018.[1,2]

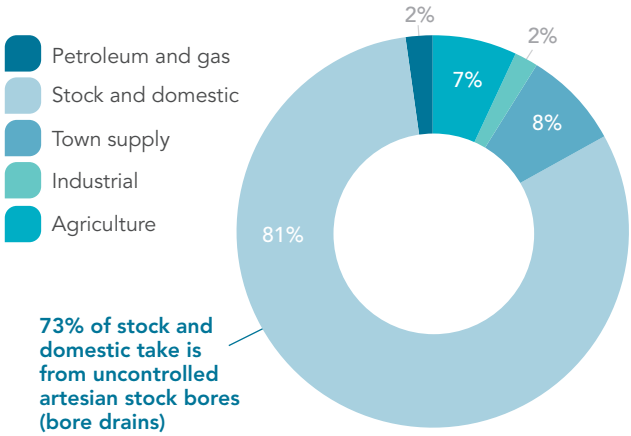
Groundwater take from Surat* GAB formations



84% of the total CSG associated water take across the petroleum and gas producing areas of Qld is from the Surat GAB Formation

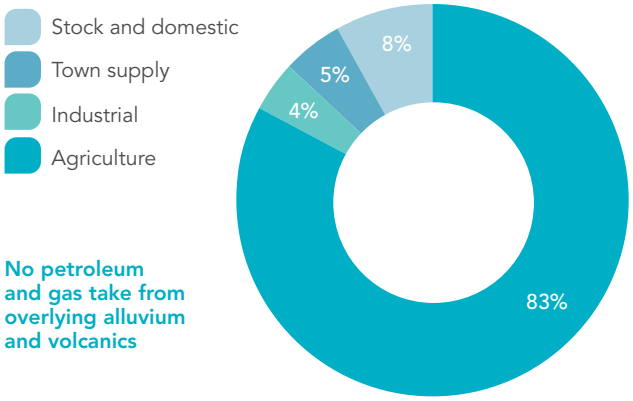
*including Western Clarence-Moreton Basin

Groundwater take from Eromanga GAB formations



73% of stock and domestic take is from uncontrolled artesian stock bores (bore drains)

Groundwater take from overlying alluvium and volcanics



No petroleum and gas take from overlying alluvium and volcanics

Figure 5.4: Estimated groundwater take from the Great Artesian Basin (GAB) and overlying shallow aquifers in 2018.[1,2]

1 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019
2 Department of Natural Resources, Mines and Energy, Groundwater Database Queensland, retrieved 2019

As an overview, Figure 5.5 below shows the estimated groundwater take from the respective basin formations within the petroleum and gas producing areas of Queensland by the various sectors.

Groundwater take by sector

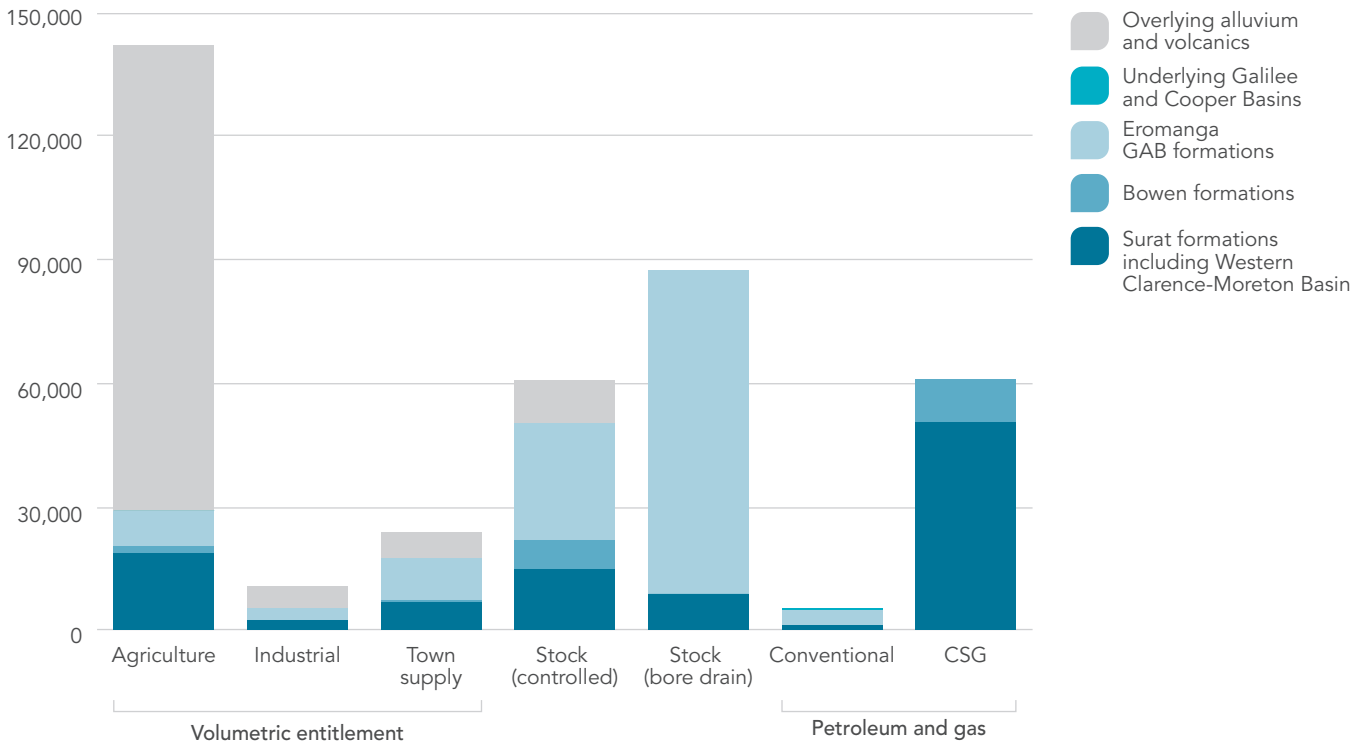


Figure 5.5: Estimated groundwater take from the respective basin formations in 2018 by sector (ML/year).[1,2]

MONITORING POINTS

INSIGHTS

Chapter 3 of the *Water Act 2000* requires that:

- petroleum and gas companies monitor and assess the impact of their operations on groundwater
- companies publish a report which outlines their obligations, including monitoring obligations for aquifers and springs
- companies comply with legally binding make good obligations, including the requirement to undertake a bore assessment and negotiate a make good agreement
- the independent Office of Groundwater Impact Assessment (OGIA) assess and predict the impact of CSG water extraction on groundwater resources in cumulative management areas (CMAs).

1 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019
2 Department of Natural Resources, Mines and Energy, Groundwater Database Queensland, retrieved 2019

There are a number of groundwater monitoring networks across the petroleum and gas producing areas of Queensland that serve different functions (Table 5.1).

The spatial distribution for the first four monitoring networks is shown in Figure 5.6.

Table 5.1: Groundwater monitoring network in the petroleum and gas producing areas of Queensland and their functions[4]

Monitoring network	Network function	Number of monitoring points	Total number of points per basin[5]
Groundwater Net	• Designed and maintained by the Department of Natural Resources, Mines and Energy (DNRME) as a community-based monitoring group to help landholders in resource development areas monitor groundwater levels in their own bores and better understand the groundwater resource.	108	72 – Bowen 5 – Clarence-Moreton 10 – Eromanga 21 – Surat
Groundwater Online	• Community focused network of strategically located artesian and subartesian bores designed and maintained by DNRME. • Complements the Groundwater Net Network, to monitor key formations in and around the CSG footprint using continuous monitoring loggers and telemetry. Loggers measure water levels every 15 minutes and telemetry to send the data directly to the DNRME Groundwater Database.	83**	4 – Bowen 12 – Clarence-Moreton 10 – Galilee 57 – Surat
Underground Water Impact Report (UWIR) Groundwater Monitoring Network	• Designed by OGIA and implemented (constructed, operated and maintained) by CSG companies to establish background groundwater level trends, understand how the groundwater system works and how it is responding to current and will respond to future CSG development.	643***	See Table 5.2
Queensland Groundwater Monitoring Network	• Designed and maintained by DNRME to provide a broad picture of the condition and trend of groundwater resources across Queensland.	702*	68 – North Bowen Basin 145 – Eromanga 489 – Surat
Monitoring Programs Under Environmental Authorities	• A network of groundwater monitoring bores is installed in locations around relevant site infrastructure that poses a risk to groundwater (e.g. dams and other containment structures) in accordance with the Environmental Authority (EA). • Resource companies are required to monitor significant changes to groundwater quality (e.g. as a result of seepage from containment structures) to meet the conditions of an EA. • If hydraulic fracturing or aquifer injection are approved, prescriptive conditions require both groundwater water level and water chemistry to be monitored in active landholder bores during the testing and development stage as part of their stimulation impact monitoring program.	NA	NA
Water Monitoring and Management Plans (WMMP) under the Environmental Protection and Biodiversity Act 1999	• Major coal seam gas projects are closely monitored by the federal and the Queensland Government. • A WMMP addresses the Australian Government approval conditions relating to the assessment, management, and mitigation of surface and groundwater impacts as a result of project development, and also addresses relevant commitments in the environmental impact statement (EIS) for the project. • The monitoring systems put in place federally are designed to complement the management arrangements set up by the OGIA.	NA	NA

NA: Information on the Environmental Authority and Environmental Protection and Biodiversity Act monitoring networks is not available at time of reporting.
* Monitoring points include 2 Groundwater Net bores and 10 Groundwater Online bores
** Monitoring points include 4 Groundwater Net bores
*** Monitoring points include 5 Groundwater Online monitoring bores

4 Department of Natural Resources, Mines and Energy, personal communication, December 2018 and Department of Natural Resources, Mines and Energy, Groundwater Database Queensland, retrieved 2019
5 Department of Natural Resources, Mines and Energy, personal communication, December 2018

INSIGHTS

Groundwater monitoring data is available from:

- Water Monitoring Information Portal
  https://water-monitoring.information.qld.gov.au/
- Queensland Globe
  https://qldglobe.information.qld.gov.au/
- Groundwater Net Digital Report 2018
  http://qldspatial.information.qld.gov.au/GroundwaterNetReport/index.html

Groundwater monitoring points in petroleum and gas producing areas of Queensland

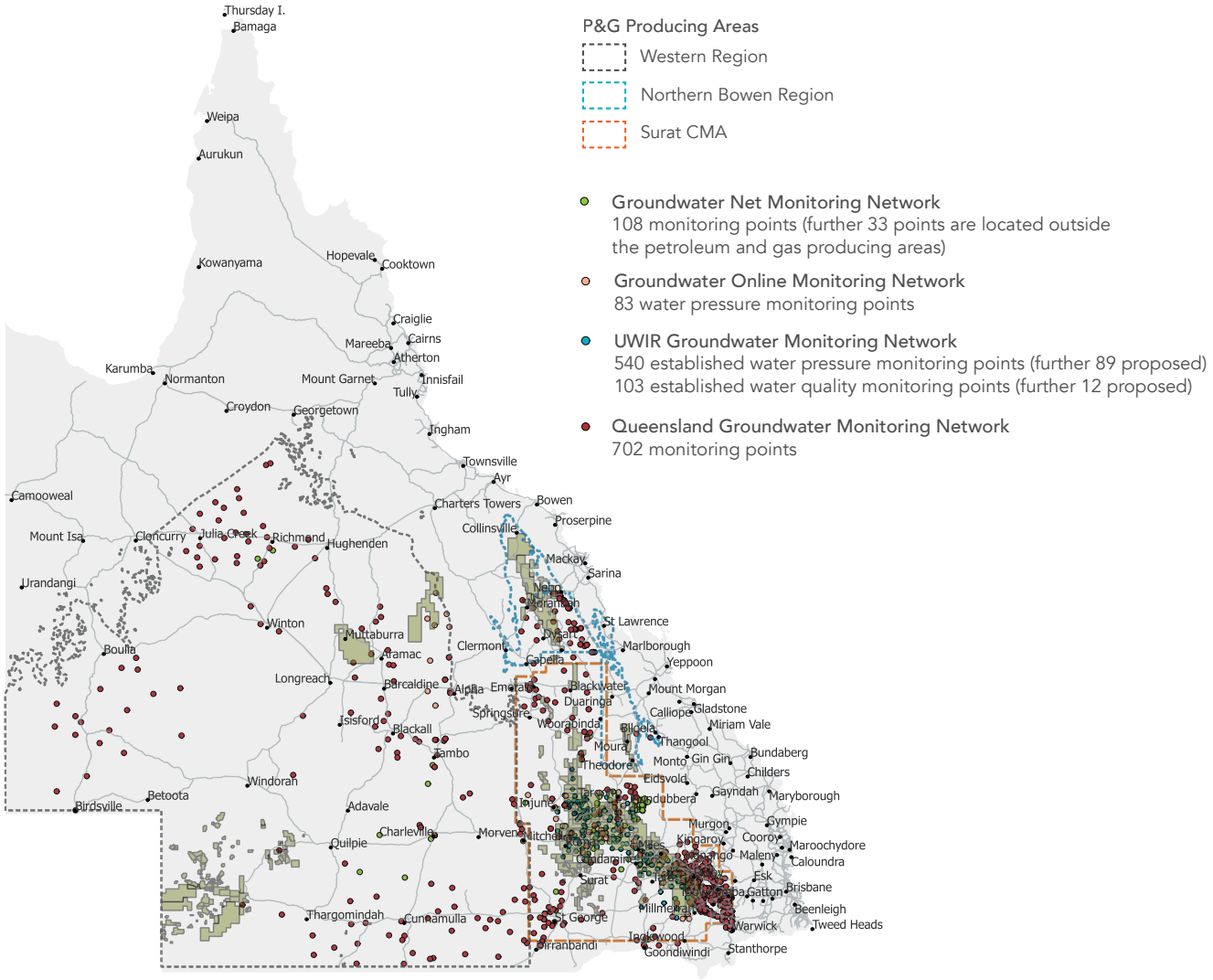


Figure 5.6: Distribution of monitoring points that make up the groundwater monitoring networks in the petroleum and gas producing areas of Queensland.

Figure 5.7 is a generalised diagram that shows the various groundwater systems and their movement in the Surat and Bowen Basins. For more information about groundwater systems and storage, refer to Appendix C: Groundwater explained.

Groundwater systems in the Surat and Bowen Basins

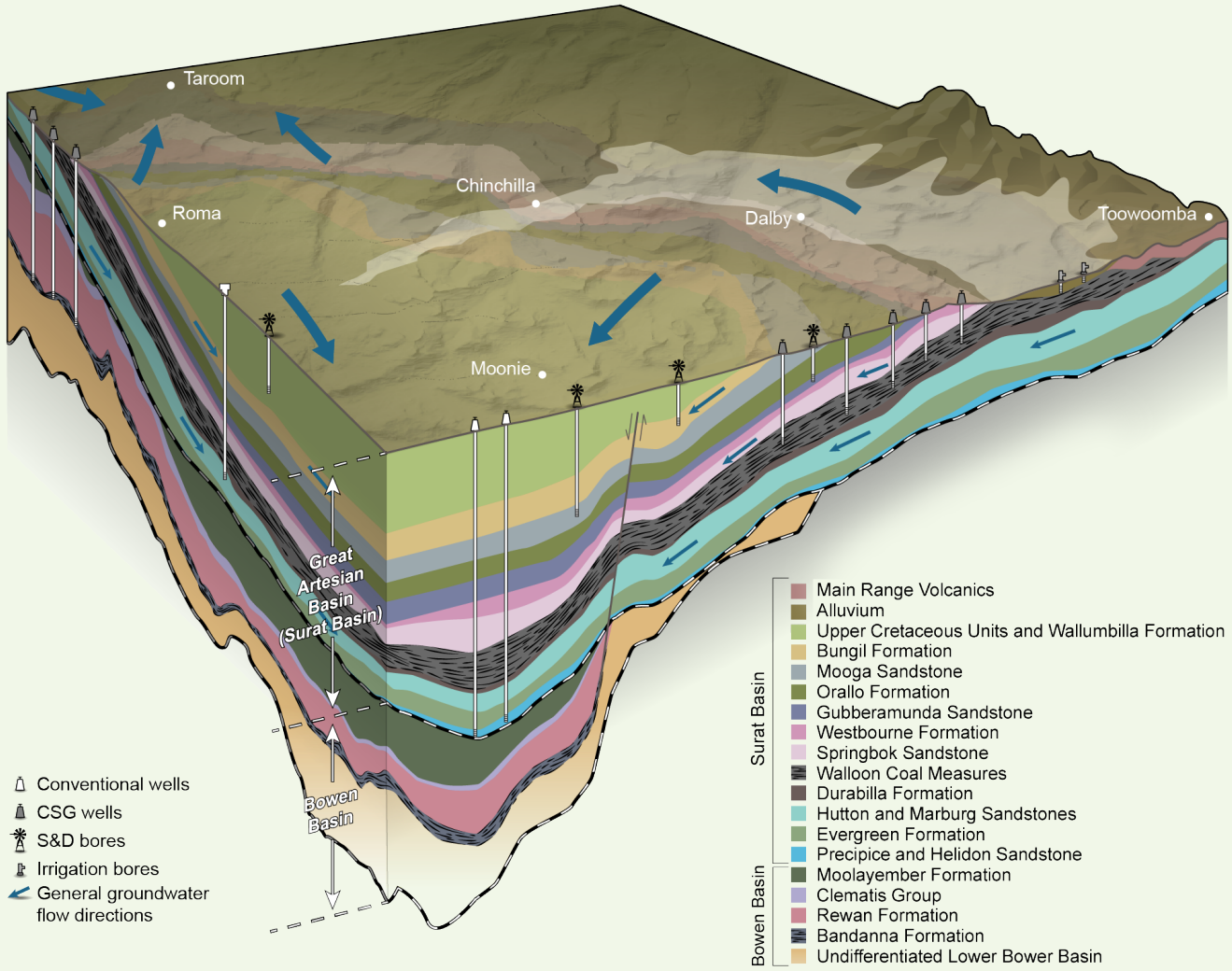


Figure 5.7: Representation cross section showing the main groundwater systems in the Surat Cumulative Management Area.[6]

The number of groundwater monitoring points within this Surat, lower Bowen and Clarence-Moreton Basins and their respective aquifer are shown in Figure 5.8. These monitoring points are from the Underground Water Impact Report, Groundwater Online and Groundwater Net Networks and focuses on monitoring groundwater around resource development areas. A breakdown of these monitoring points by formation is shown in Table 5.2.

6 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019

Groundwater monitoring points by geological formation

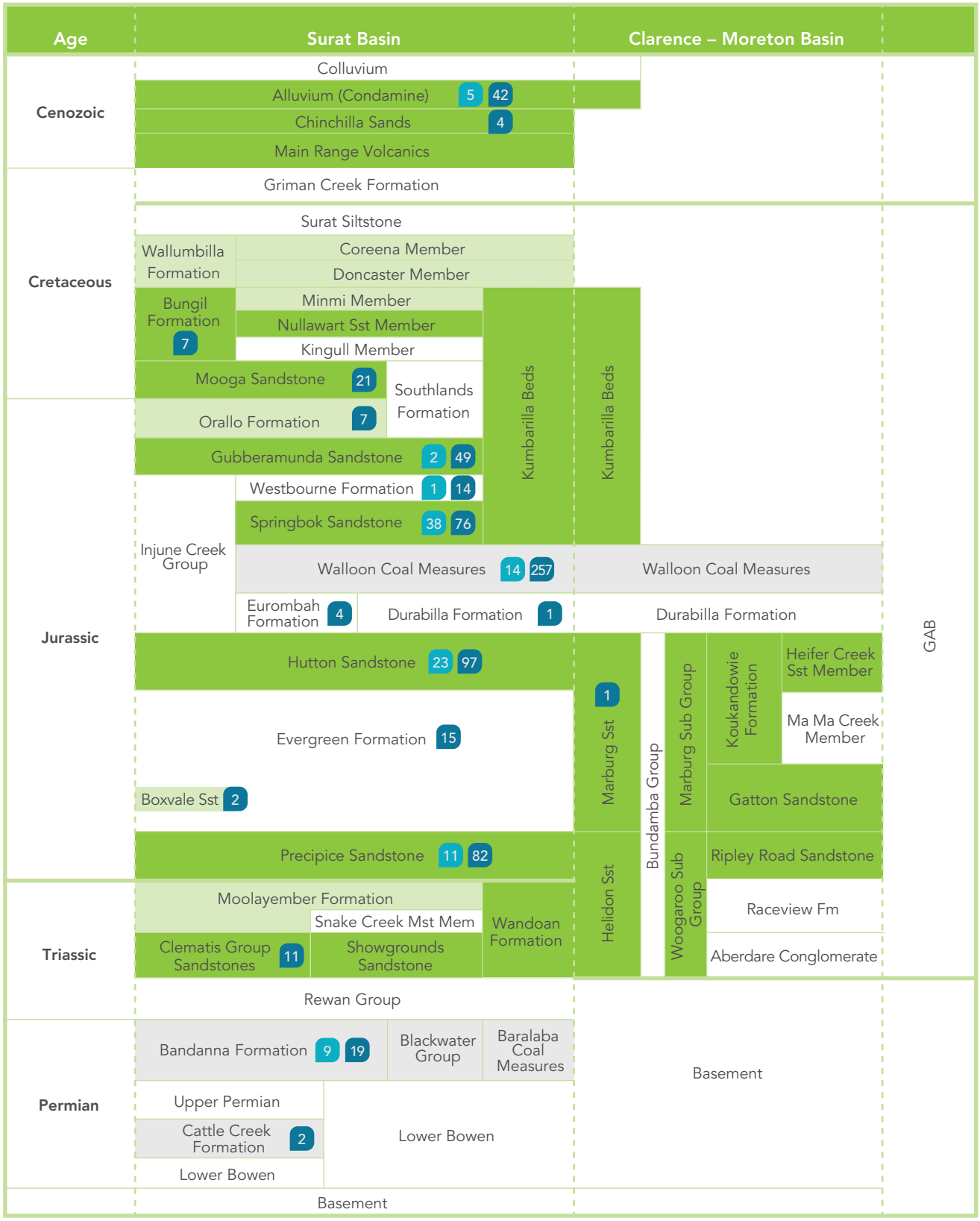


Figure 5.8: Generalised breakdown of geological formations for the Surat, lower Bowen and Clarence-Moreton Basins and the number of operating groundwater monitoring points from the UWIR, Groundwater Online and Groundwater Net Networks in each formation.[7]

7 Department of Natural Resources, Mines and Energy, Groundwater Database Queensland, retrieved 2019

Table 5.2: Number of monitoring points by geological formation

		UWIR Groundwater Monitoring Network (operating)		Groundwater Online	Groundwater Net	Total by formation
Basin	Formation	Water pressure	Water quality			
Alluvium and Basalt (including Clarence-Moreton)	Condamine Alluvium	27	5	7	8	47
	Main Range Volcanics	2		2		4
Clarence-Moreton Basin	Marburg Sandstone			1		1
Surat Basin (GAB)	Bungil Formation				7	7
	Mooga Formation	3		7	11	21
	Orallo Formation	1			6	7
	Gubberamunda Sandstone	33	2	12	4	51
	Westbourne Formation	9	1		5	15
	Springbok Sandstone	70	38	6		114
	Walloon Coal Measures	247	14	6	4	271
	Eurombah Formation	4				4
	Durabilla Formation				1	1
	Hutton Sandstone	66	23	16	15	120
	Evergreen Formation	2		1	12	15
	Boxvale Sandstone	1		1		2
	Precipice Sandstone	48	11	10	24	93
Bowen Basin	Clematis Group	6		4	1	11
	Bandanna Formation	19	9			28
	Cattle Creek Formation	2				2
Eromanga Basin	Hooray Sandstone				5	5
	Hutton Sandstone				3	3
	Injune Creek Group				1	1
	Precipice Sandstone				1	1
Galilee Basin	Tertiary Sediments			5		5
	Clematis Group			5		5
	TOTAL	**540**	**103**	**83**	**108**	**834**

INSIGHTS

Groundwater monitoring data provides important information for impact models and predictions as part of Underground Water Impact Reports (UWIRs).

Gas companies must prepare a UWIR every three years (for applicable tenures they hold) which includes an assessment of the water pressure reductions in aquifers and impacts to springs in the long and short-term. The UWIRs provide predictions as to which water supply bores are likely to be affected by gas operations.

The Surat Cumulative Management Area (Surat CMA) UWIR is prepared independently by OGIA because this is an area of intense resource development involving many different gas companies.

As at June 2019, 18 UWIRs have been prepared by individual resource tenure holders (gas companies) and approved by the Department of Environment and Science (DES).

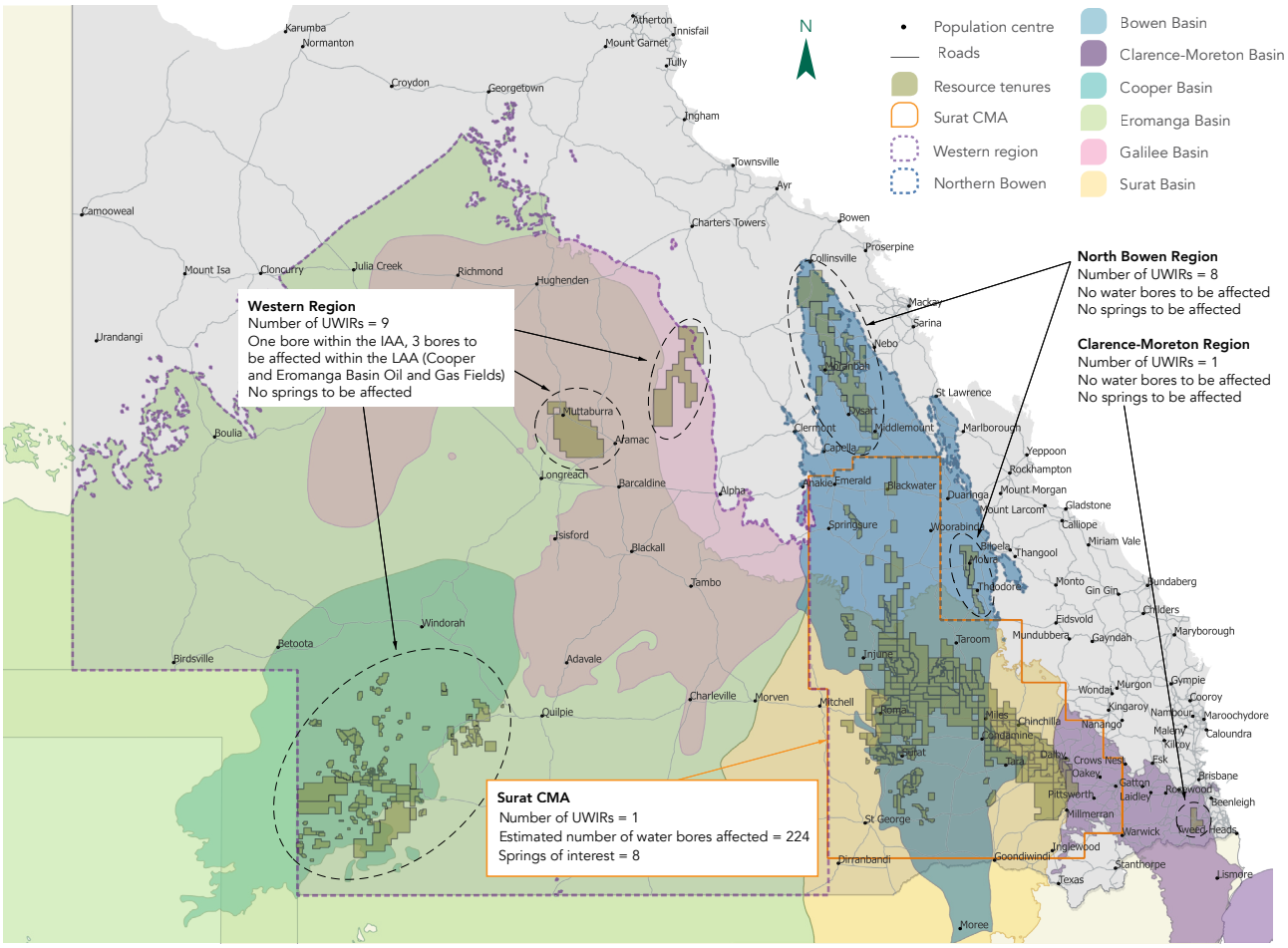


Figure 5.9: Location of Underground Water Impact Reports (UWIRs) and their summary findings.

OGIA's 2019 draft UWIR for the Surat CMA area states:

- There are approximately 22,500 water bores in the Surat CMA.
- A total of 574 water bores (approximately 2.5 percent) are predicted to be impacted in the long term – an increase of about 10 percent compared to 2016 predictions. About 80 percent of those bores are in the CSG target formations and the remainder are in the surrounding aquifers.
- In the next three years, 101 water bores are predicted to be impacted by gas industry activity, in addition to the 123 Immediately Affected Area (IAA) bores identified through predictions in the two previous UWIRs (just under one percent of all Surat CMA bores are in the IAA).

WATER QUALITY

Water quality varies within the major aquifers. Primary factors which influence water quality include formation mineralogy, proximity to areas where the formation is recharged and groundwater flow within the formation.

A summary of the water chemistry for the major water supply formations across the Surat CMA is provided in Table 5.3 and Figure 5.10. A complete analysis can be found in Appendix C: Groundwater explained.

These key formations are more suitable for drinking and/or irrigation purposes and account for more than 90 percent of non-stock and domestic water use in these units.[8]

Table 5.3: Median values of key analytes for major aquifers in the Surat Cumulative Management Area.[8]

	CONCENTRATION (mg/L)							
Formation	Calcium	Sodium	Magnesium	Chloride	Fluoride	TDS*	pH	SAR**
Alluvium	46.0	205.0	40.0	250.0	0.2	1,064.0	7.9	5.4
Basalt	46.0	106.0	52.0	170.0	0.2	825.0	7.9	2.7
Mooga Sandstone	3.0	462.0	1.0	210.0	0.9	1,558.0	8.4	57.8
Gubberamunda Sandstone	2.6	350.0	1.0	150.0	0.3	1,126.0	8.4	46.3
Springbok Sandstone	11.5	653.5	1.2	844.5	0.7	1,970.0	8.3	64.1
Walloon Coal Measures (Non-CSG)	34.2	550.0	19.0	597.5	0.37	1,877.0	8.0	18.6
Walloon Coal Measures (CSG)	6.0	1160.0	1.2	930.5	2.4	3,466.4	8.3	112.1
Hutton Sandstone	29.0	321.0	10.0	310.0	0.3	1,297.0	8.0	12.8
Precipice Sandstone	2.7	45.0	1.0	16.0	0.2	184.0	7.3	7.8
Clematis Sandstone	23.5	76.0	14.0	50.0	0.17	522.0	7.8	2.3
Bandanna Formation	5.5	498.0	1.0	177.0	1.45	1,576.0	8.1	44.5

* For human drinking purposes, a TDS of less than 1,000 mg/L is required, whereas up to 4,000 mg/L TDS is acceptable for stock purposes without dilution from other sources. ANZECC Water Quality Guidelines also state that cattle can tolerate up to 10,000 TDS for short periods of consumption.

** SAR – Sodium Absorption Ratio.

8 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019

Groundwater chemistry in the Surat Cumulative Management Area

Figure 5.10: Median values of analytes for major aquifers in the Surat Cumulative Management Area.[8]

8 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019

BENEFICIAL USE

An estimated total of more than 145,000ML of treated associated water has been beneficially used between July 2015 and June 2018.[9]

Figure 5.11 below shows the distribution of use of treated water over the last three financial years, with the dominant beneficial use being irrigation.

A small portion of treated water is used for purposes such as discharge into watercourses or used in petroleum and gas operational activities.

More than 20,000 ML (averaging around 5,000 ML/year) of treated water has also been injected into the Precipice Sandstone aquifer, since January 2015, in accordance with environmental approvals.

Information about the legal requirements for how associated water can be beneficially used can be found in Appendix C: Groundwater explained.

INSIGHTS

For associated water to be used for beneficial purposes it must meet strict conditions regarding water quality, including salinity and pH levels. All associated water requires some treatment or amendment.

Almost all associated water is treated in reverse osmosis plants prior to use.

The water quality after treatment in a reverse osmosis plant is equivalent to distilled water, so water is either blended with another source or amended by adding minerals such as magnesium, calcium, sodium, sulfate etc.

Beneficial use of associated water

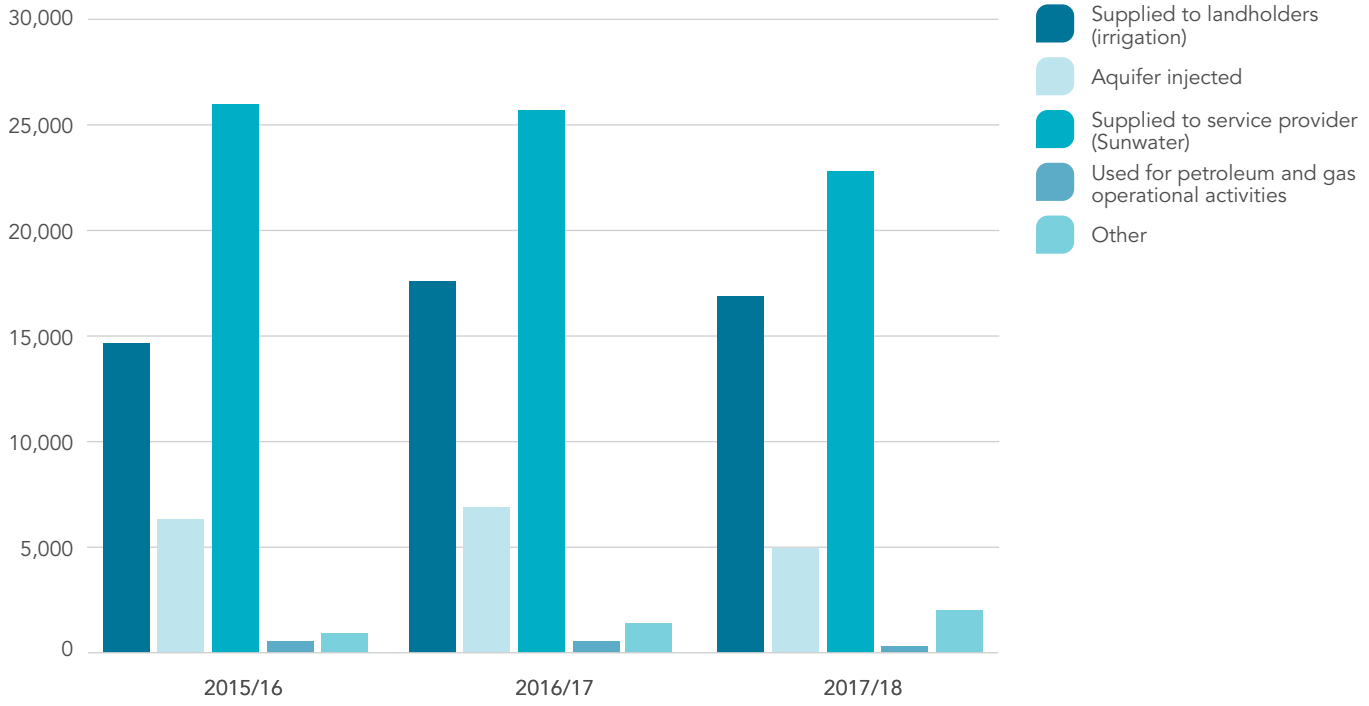


Figure 5.11: Volume of associated water used beneficially for various purposes from 2015/16 to 2017/18.[9]

9 Australian Petroleum Production & Exploration Association, personal communication, 2019

BASELINE ASSESSMENT

Queensland-wide there are over 120,000 bores recorded in the Queensland Groundwater Database, of which 66,000 bores are recorded as water supply bores. However, not all of these bores are existing or in useable condition.[10]

Under the Water Act, resource tenure holders are required to conduct a baseline assessment of all water bores within their tenure. A baseline assessment collects information about bores including water levels, water quality, bore construction and associated infrastructure to benchmark bores prior to petroleum and gas development. OGIA indicated that there were 4,242 records of baseline assessments as at August 2019.[11]

In some cases, more than one assessment had been completed for an individual bore.

BORE ASSESSMENT

A bore assessment is undertaken to assess the capacity of a water bore and to establish whether or not a water bore has, or is likely to have, an impaired capacity due to resource company activities. The outcome of a bore assessment assists in identifying options for make good measures. OGIA indicated that 148 bore assessments had been conducted as at August 2019.[11]

MAKE GOOD AGREEMENTS

The GasFields Commission carried out a survey of companies with make good obligations during the first quarter of 2018, with an update requested in July 2019. Three out of the four major gas companies confirmed that as of 8 July 2019, 56 make good agreements are in place. One of the companies confirmed they had no make good obligations during the reporting period.

Arrow, Santos, Senex and QGC contributed to the survey.

Number of make good agreements in place per year are shown in Figure 5.12.

Table 5.4: Number of baseline and bore assessments undertaken on groundwater bores[11]

Basin	Number of baseline assessments	Number of bore assessments
Bowen	516	0
Cooper/Eromanga	258	1
Galilee	18	0
Surat	3,450	147
Total	**4,242**	**148**

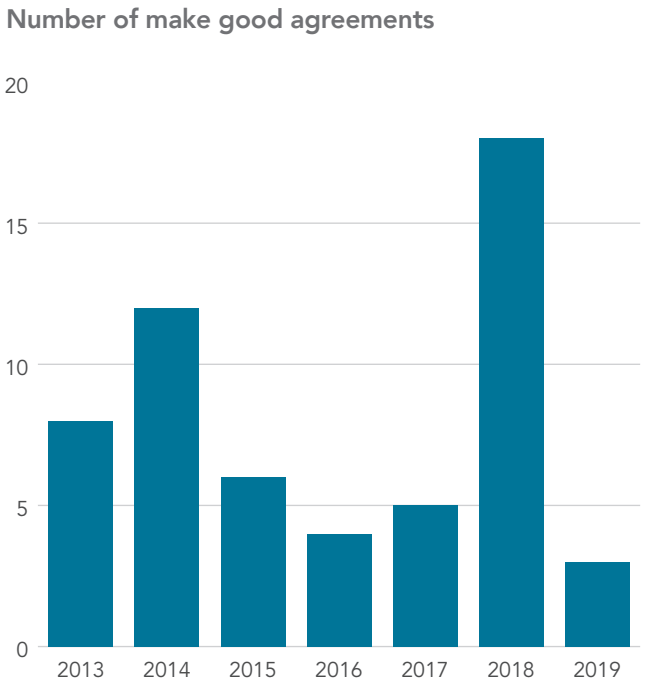


Figure 5.12: Number of make good agreements from three out of the four major gas companies operating in Queensland (as at July 2019).

10 Department of Natural Resources, Mines and Energy, Groundwater Database Queensland, retrieved 2019
11 Office of Groundwater Impact Assessment, personal communication, August 2019

Fifty (89 percent) of the 56 make good agreements are for bores extracting water from the Walloon Coal Measures, where the majority of CSG extraction occurs, while the remainder are for bores installed in other formations.

Of the 56 agreements, 38 bore assessments were mandatory while five were directed by the regulators (DES) and a further 13 were undertaken voluntarily by the resource company (Figure 5.14).

Number of make good bores by formation

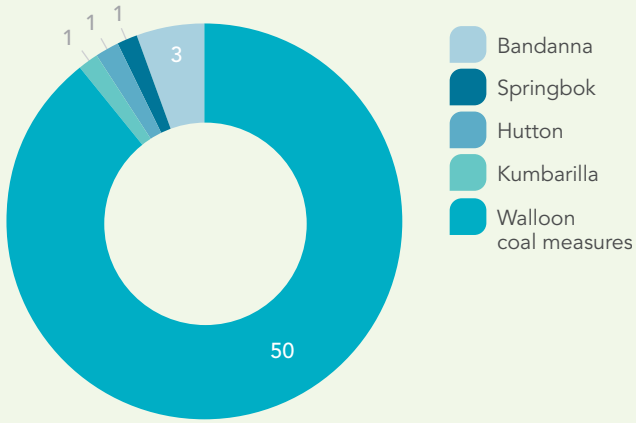


Figure 5.13: Number of bores subject to make good agreement and the geological formations they sourced water from.

Bore assessments conducted by reason

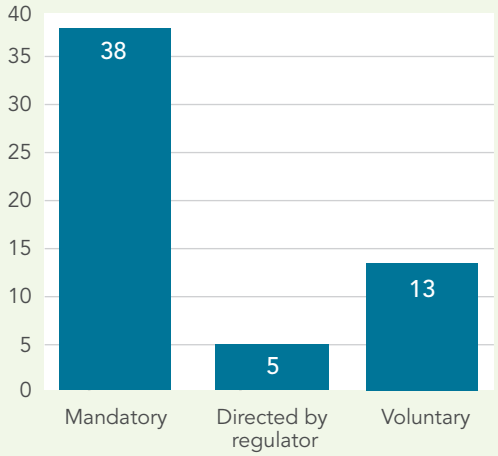


Figure 5.14: Reasons for make good agreements.

There are three preferred types of make good measures based on the 56 make good agreements that have been signed to date:

1

Monetary compensation, where the bore owner is given an agreed sum of money to compensate for the impaired capacity. This may be used to install a new bore (or bores) capable of supplying water at the same or higher capacity (collectively, if multiple new bores) as the impaired bore.

2

Monitoring of affected water bore, where the resource company carries out groundwater monitoring of the water bore(s), to ensure that any potential effects of their activities on the water supply is captured. If the bore is determined to be or likely to become impaired, further make good measures should be agreed between the parties.

3

Replacement bore, where the resource company drills and installs a new water bore (or bores) capable of supplying water at the same or higher capacity (collectively, if multiple new bores) as the impaired bore.

Based on the information received for 56 make good agreements, monetary compensation is shown to be the main form of make good measure at 77 percent, followed by monitoring (5 percent). There is one case of combined measure of monetary compensation and monitoring.

A total of five bores were found to not be impaired after a bore assessment (four mandatory and one voluntary). Four of these bores were damaged and non-functioning. A non-functioning bore is considered not able to be impaired as it has no capacity to supply water. Therefore, no impairment to capacity was deemed possible in this case. In cases where there is no impairment, a make good agreement is still required under the Water Act, however no make good measure is necessary.

Under the Water Act, there is no obligation to decommission a water bore. This can be agreed as part of a make good agreement if there are unacceptable risks associated with the existence of that water bore, for example:

- If the impaired water bore is found to be constructed in a manner where the bore screens across multiple aquifers (the bore extracts water from more than one aquifer), this increases or creates connectivity facilitating water movement between aquifers.
- If free gas is present in the bore and presents a health or safety risk.

Make good measure by type

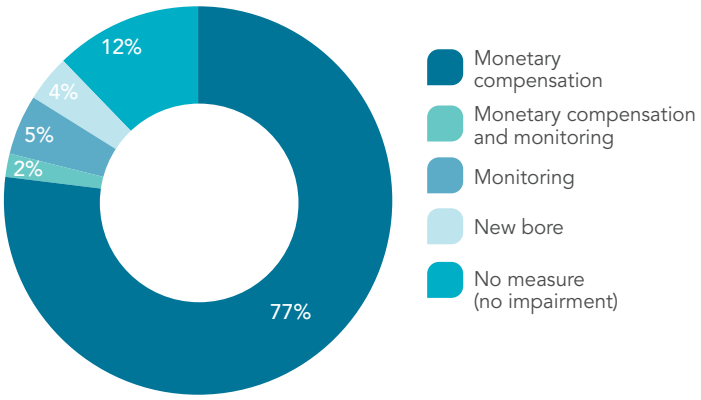


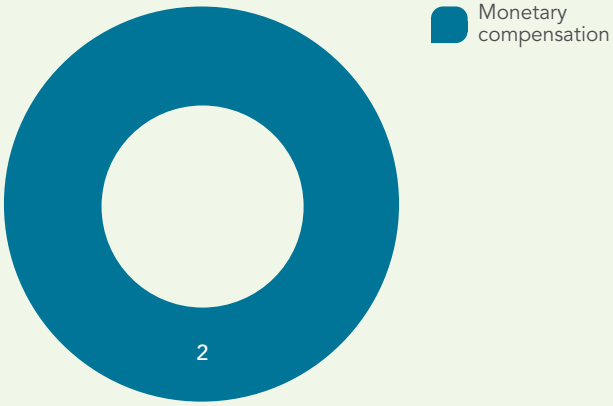
Figure 5.15: Breakdown percentages of the types of make good measures.

The following figures show the 52 bores that were determined to either be impaired, likely to be impaired, unlikely to be impaired and not impaired.

Bore assessment outcomes and make good measures

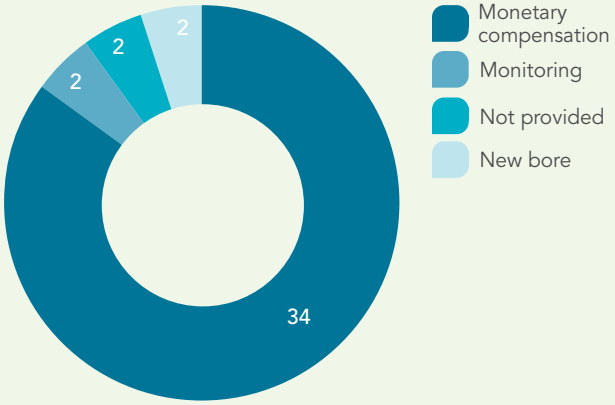
Two bores were determined to be impaired. Bore owners were given monetary compensation, and both bores were decommissioned

Impaired – 100% decommissioned



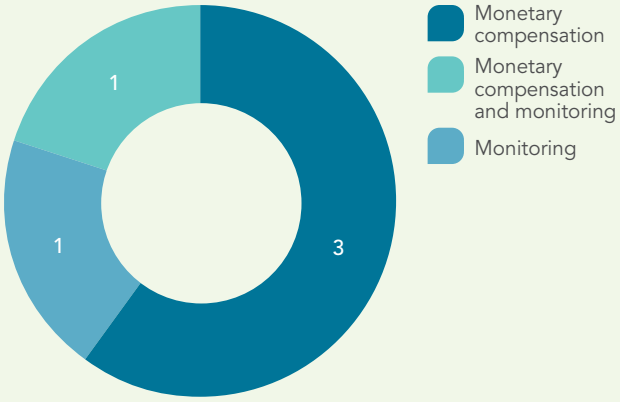
Of the 40 bores that will likely become impaired, the majority of bore owners were given monetary compensation. Not all bores were decommissioned. Two of the bores are being monitored.

Impairment likely – 77.5% decommisioned



Five bores were unlikely to become impaired. Of those, three were given monetary compensation, and three were decommissioned. One of the bores is being monitored, and monetary compensation was also given.

Impairment unlikely – 60% decommissioned



Five bores were not impaired, and no make good measures were necessary although one received monetary compensation. Two of those bores were decommissioned.

Not impaired – 40% decommissioned

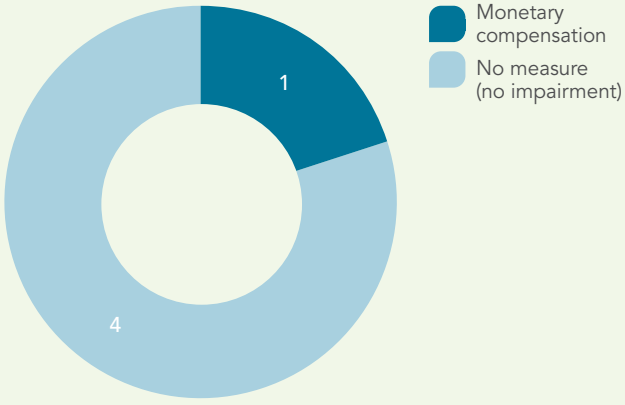


Figure 5.16: Make good measures for various bore assessment outcomes and percentage of bores decommissioned.

Of the remaining four bores:

- Two bores were already decommissioned prior to assessment and were unable to be assessed.
- One bore did not have a bore assessment undertaken and no further information was provided regarding its outcome (however monetary compensation was provided).
- One bore was listed as already abandoned and destroyed, and no make good measure was necessary.

Table 5.5 lists the number of agreed make good measures provided by the responsible tenure holder to the bore owner based on the outcome of a bore assessment.

Table 5.5: Make good measures provided against bore assessment outcome

BORE STATUS	MAKE GOOD MEASURE				
Bore assessment outcome	**Monetary compensation**	**Monetary compensation and monitoring**	**Monitoring**	**No measure** (no impairment)	**New bore**
Impaired	4	0	0	0	0
Impairment likely	35	0	2	2	2
Impairment unlikely	3	1	1	0	0
Not impaired	1	0	0	5	0
Total	**43**	**1**	**3**	**7**	**2**

* This bore was listed as a long-term affected area (LAA) bore in the survey. A formal bore assessment was not conducted. The bore was reported as being usable but not in use. It was recorded as having no impairment but received monetary compensation

Figure 5.17 shows the time taken to reach an agreement post bore assessment. The Water Act stipulates that best endeavours should be made to reach an agreement within 40 business days after a bore assessment, however this may not always occur. There may be several factors that influence the length of time taken to negotiate an agreement including relationship between parties and varying or unreasonable expectations. There may be some reluctance for bore owners to sign an agreement, particularly for a bore not impaired as the need to make good the bore is redundant/unwarranted.

Timeframe from bore assessment to agreement

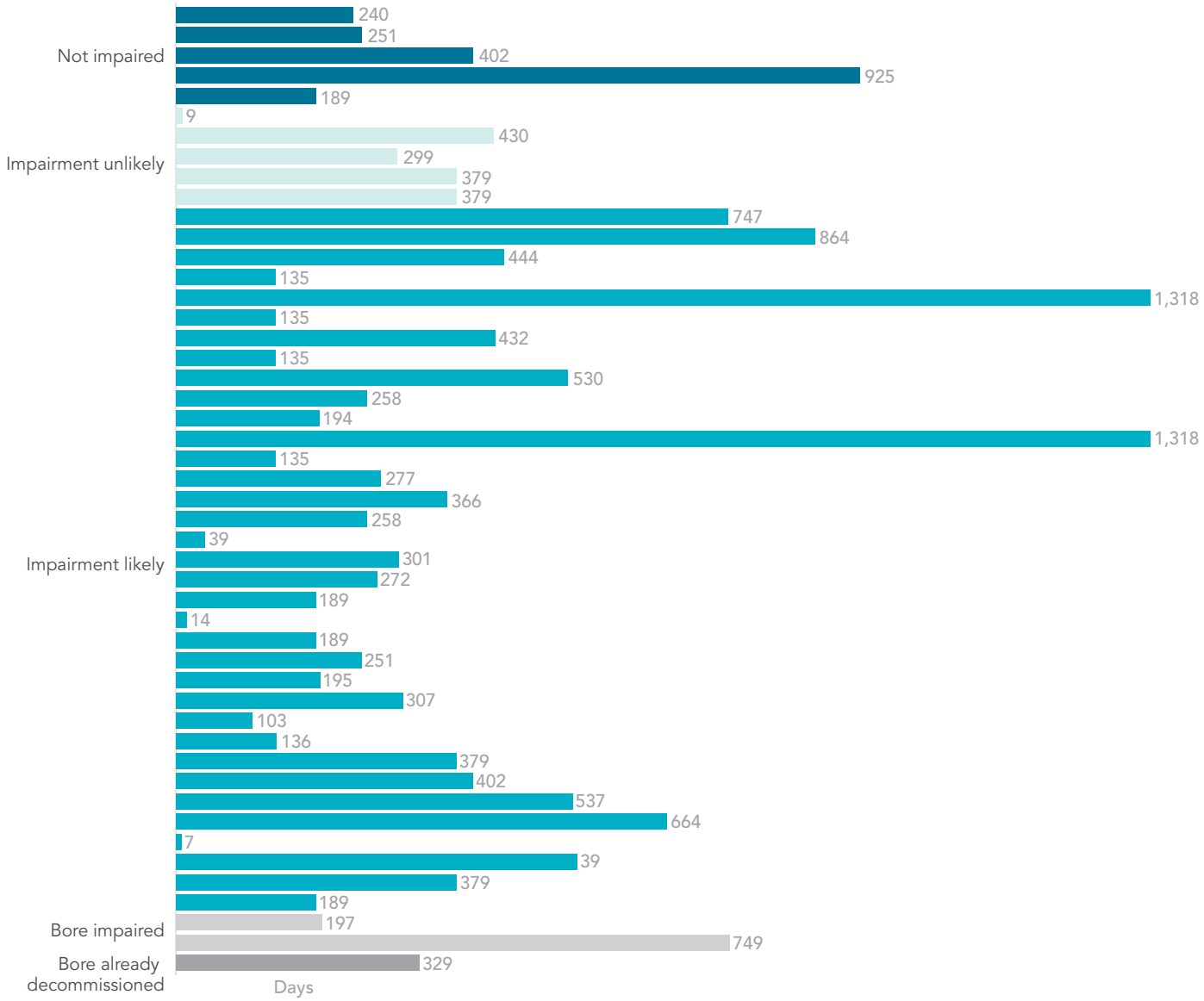


Figure 5.17: Number of days taken to reach a make good agreement (since bore assessment date).

Figure 5.18 shows the general time taken to implement a make good measure after a make good agreement is signed. The timing varies for different agreements and will be based on the negotiation and/or timeframes agreed between the gas company and bore owner.

Timeframe from bore assessment to implementation

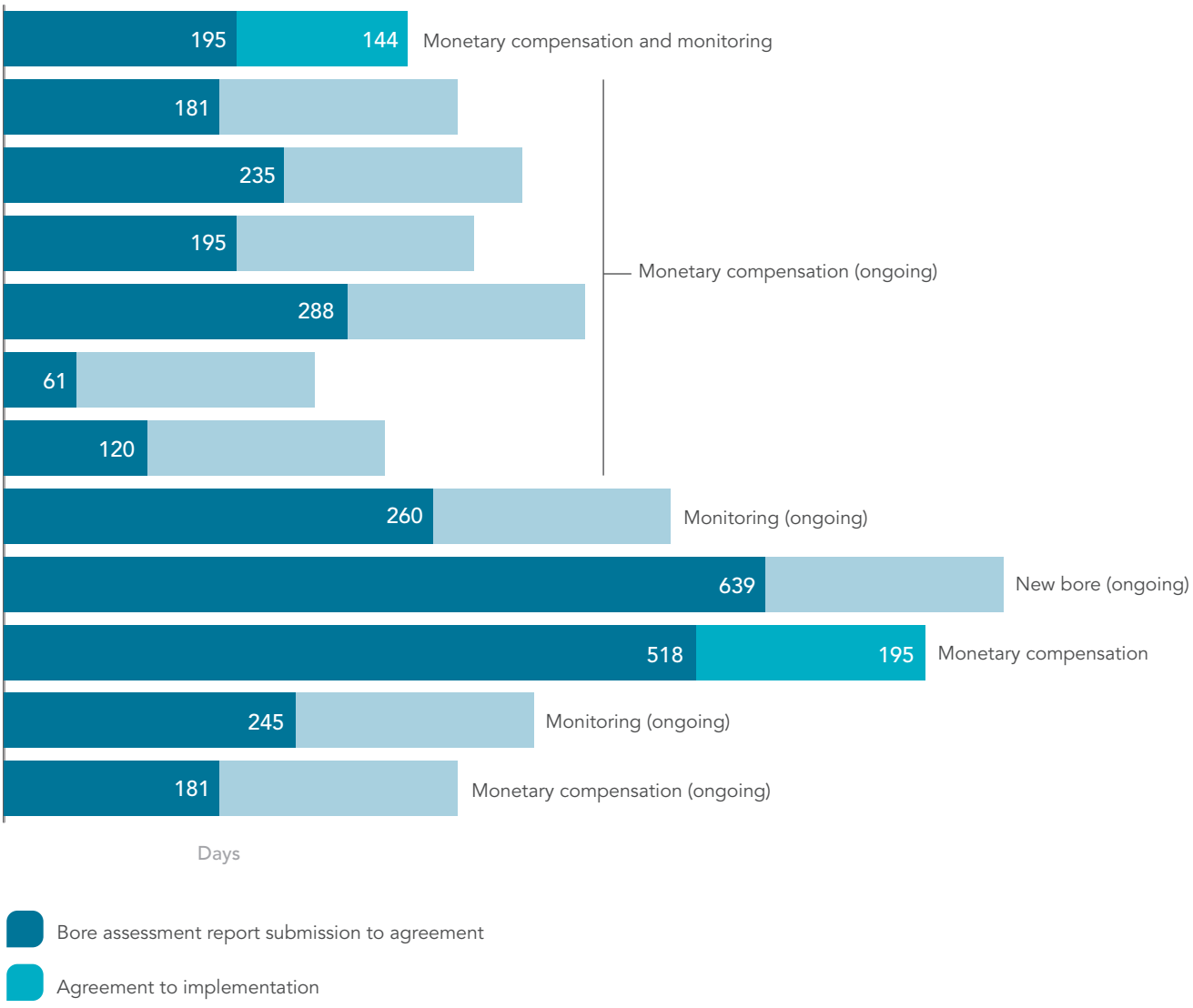


Figure 5.18: Time taken to reach a make good agreement and time taken to implement make good measure.

Location of water bores under make good agreement

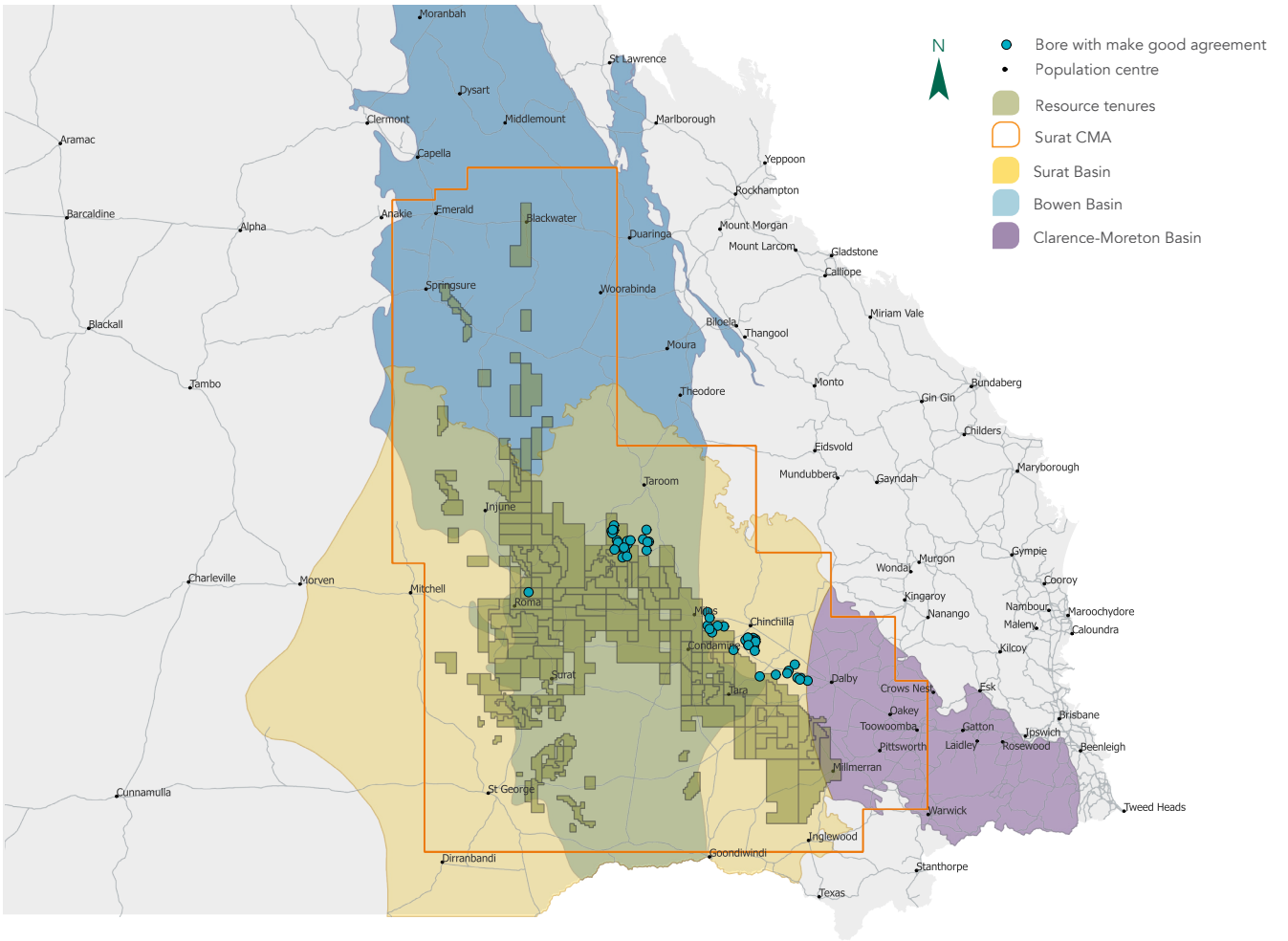


Figure 5.19: Distribution of water bores under a make good agreement in Queensland.

There are over 66,000 water supply bores in Queensland, 22,500 of these bores are in the Surat CMA.

Less than one percent of water bores in the Surat CMA are identified as Immediately Affected Area bores.

2.5 percent of water bores in the Surat CMA are predicted to be impacted in the long term.

Bores predicted to be impacted by resource company activities are in basins that contain significant groundwater resources suitable for agricultural use or town supplies – this is why make good obligations occur in the Surat Basin.

6 SUPPLY AND DEMAND

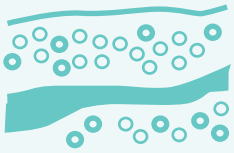
IN THIS CHAPTER

- Petroleum and gas production
- Interstate gas sales
- Energy generation and consumption
- Exports

Gas supply hub at Wallumbilla, Queensland

1,584

petajoules of natural gas was produced in Queensland in **2017/18**



96.5%

of all gas produced in Queensland in 2017/18 was **CSG**

7,145

tonnes of LPG was imported to meet Queensland's domestic demand in 2017/18

33.6PJ

petajoules of gas was exported from Queensland to other Australian states in 2018

97%

of Queensland's **gas consumption** is for electricity generation, fertiliser production and mineral processing

93%

of the **agricultural commodities** consumed in Queensland are produced in Queensland

PETROLEUM AND GAS PRODUCTION

The total amount of gas produced in Queensland increased by 12% in the 2017/18 financial year compared to the previous financial year (Figure 6.1)[1]. This represents both conventional gas and unconventional gas, including CSG.

Queensland was the first in the world to develop a CSG to LNG export industry.

1 Queensland Government Petroleum and gas production and reserve statistics, retrieved June 2018

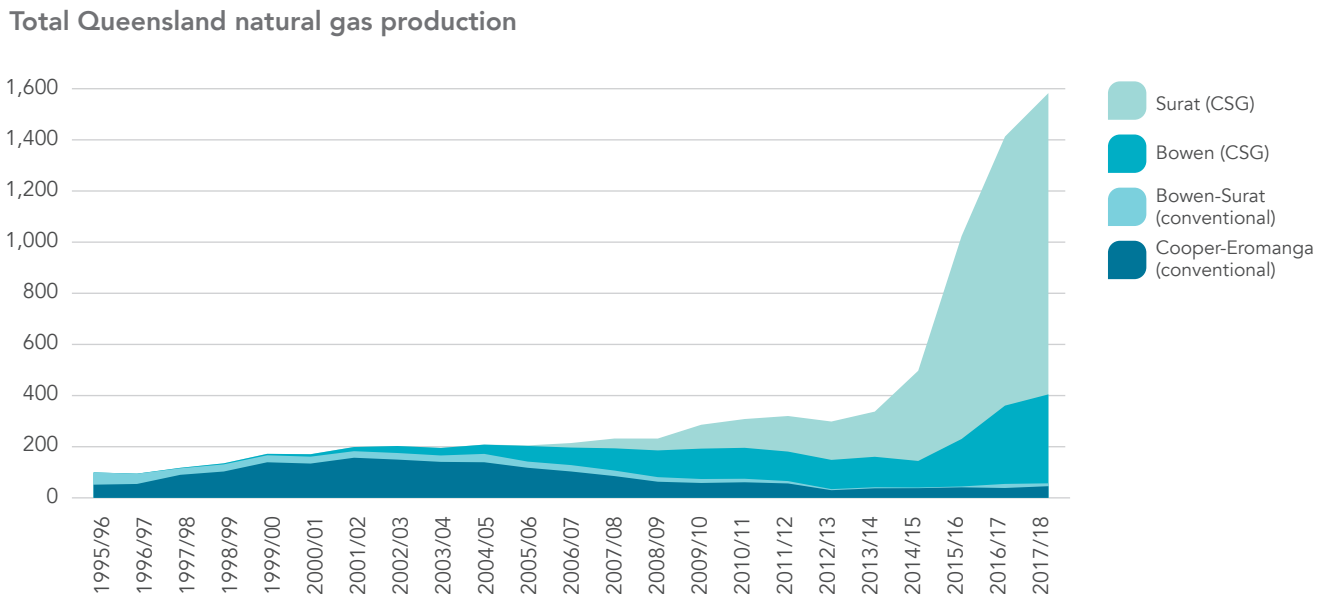


Figure 6.1: Total production of natural gas by basin in Queensland from 1995/96 – 2017/18.[4]

1 petajoule (PJ) is enough energy to power 42,000 average Australian households for 1 year[2]

CSG production

A cumulative total of 6,120 PJ of CSG has been produced in Queensland since the first commercial CSG wells began operations at Moura in 1996.[3] In 2017/18, a total of 1,526 PJ of CSG was produced – 77 percent from the Surat Basin and the remaining 23 percent from the Bowen Basin (refer to Figure 6.2).

CSG production made up 96.5% of all gas that was produced in Queensland in 2017/18[4]

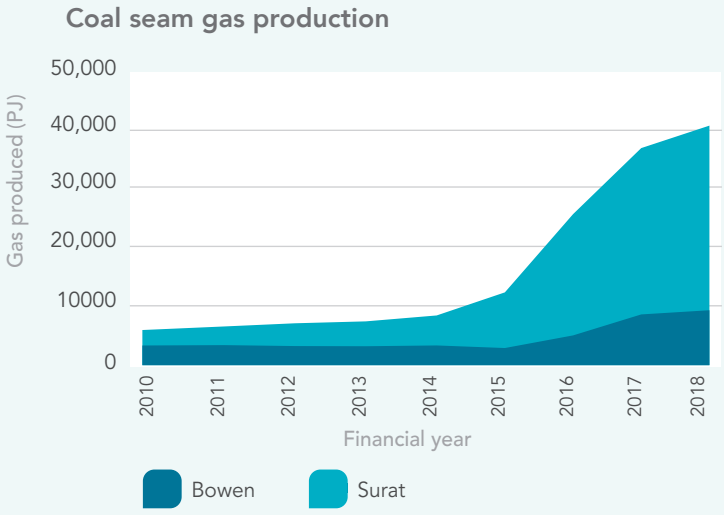


Figure 6.2: Volume of CSG produced in the Surat and Bowen Basins between 2010–2018.[4]

2 Department of Environment and Energy, Australian Energy Update 2018
3 Department of Natural Resources, Mines & Energy, Queensland is a Resource Powerhouse, 2019
4 Queensland Government Petroleum and Gas Production and Reserve Statistics, retrieved June 2018

Conventional petroleum and gas production

Conventional petroleum and gas produced in Queensland includes:

- natural gas
- condensate
- crude oil
- liquefied petroleum gas (LPG).

Conventional natural gas production made up 3.5 percent of the total gas production in Queensland in 2017/18 (Figure 6.3).

Queensland produced 57,149 tonnes of LPG in 2017/18, the highest it had been since 2010/11 (Figure 6.4).

The total Queensland domestic demand for LPG in 2017/18 however was 64,294 tonnes.

Conventional natural gas production in Queensland

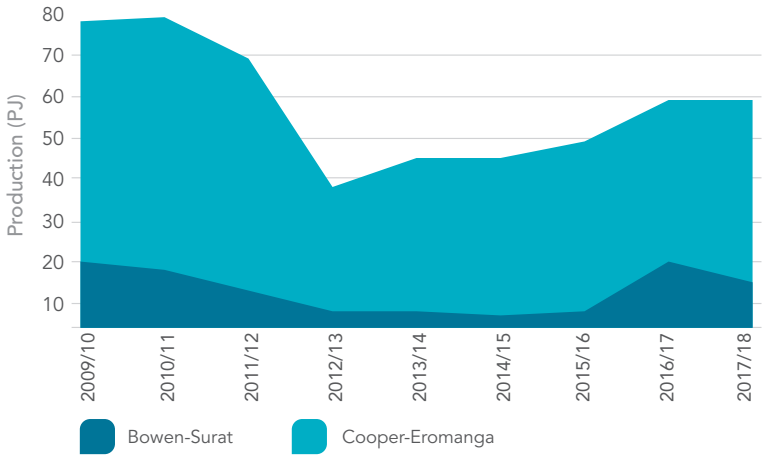


Figure 6.3: Conventional natural gas production in the Bowen-Surat and Cooper-Eromanga Basins within Queensland. (Data. Qld. Gov.)[4]

INSIGHTS

LPG is used by Queenslanders to fuel vehicles, barbeques, hot water tanks and gas stoves in their kitchens.

LPG production in Queensland

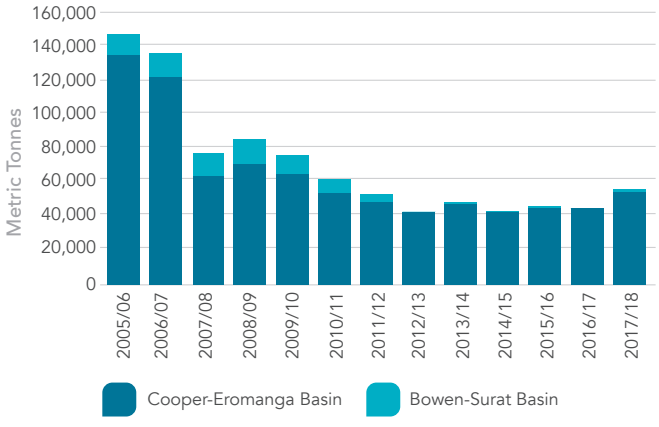
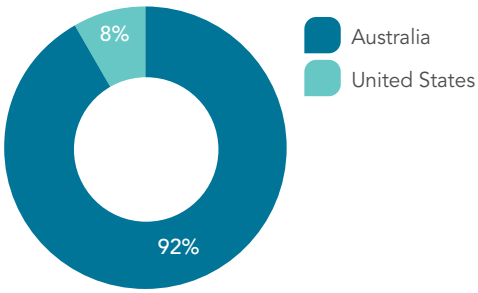


Figure 6.4: LPG production in Queensland.[4]

The additional 7,145 tonnes of LPG needed to meet Queensland's domestic demand was imported from outside the state (Figure 6.5) with 92 percent imported from other Australian states and the remaining 8 percent imported from the United States of America.[5]

Queensland LPG imports 2018[5]



Queensland LPG imports

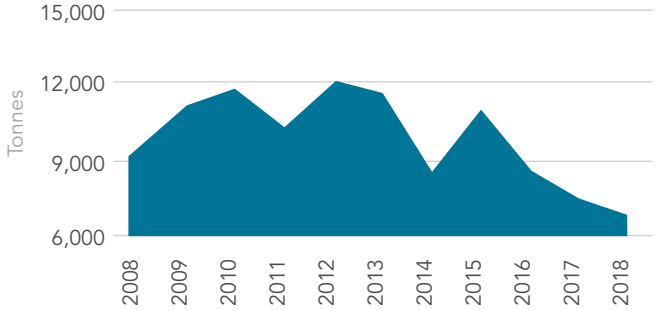


Figure 6.5: Queensland LPG imports.[5]

4 Queensland Government Petroleum and Gas Production and Reserve Statistics, retrieved June 2018
5 Gladstone Ports Corporation, Cargo Statistics Selections, retrieved 2019

Figure 6.6 shows the production of crude oil and condensate in Queensland increased in 2017/18 from the previous financial year, although it remains within the 10–year average.

Production of oil and condensate in Queensland

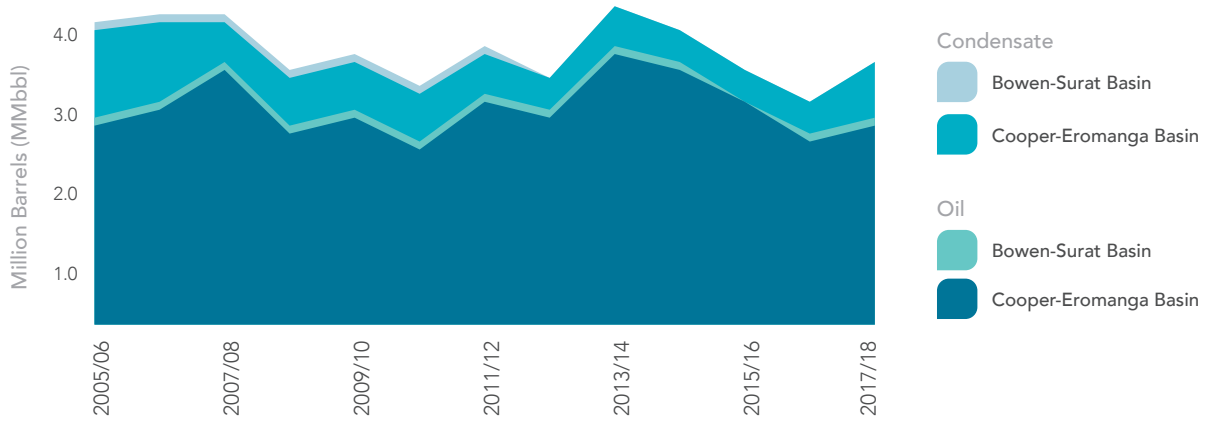


Figure 6.6: Production of crude oil and condensate in Queensland.[4]

Interstate gas sales

The network of pipelines across the east coast of Australia (and recently into the Northern Territory) allows for the transmission and trade of gas between states.

During the 2018 calendar year, Queensland exported a net total of 33.6 petajoules of gas domestically to Australia's southern states (see Figure 6.8). This is a reversal of the historical trend where Queensland imported more gas from the southern states than it exported to them.

Figure 6.8 shows that gas flows tend to vary considerably throughout the year. These normal fluctuations reflect the changes in gas demand between winter and summer months as gas is used in different ways at different times across the east coast of Australia.

For example, in Victoria, gas consumption during the winter is dominated by the residential/ commercial sector with heating representing a significant proportion of usage. In Queensland however, this sector represents a very small proportion of regional gas consumption.[6]

Figure 6.7: East coast gas distribution pipeline network.[6]

4 Queensland Government Petroleum and Gas Production and Reserve Statistics, retrieved June 2018
6 Australian Energy Market Operator Quarterly Energy Dynamics Q1 2019

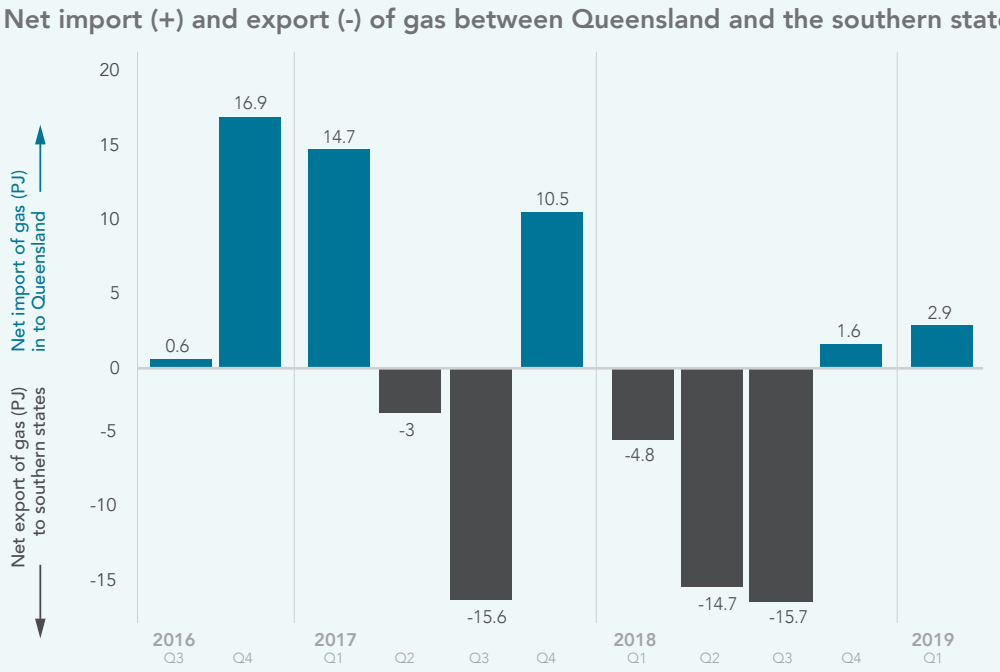


Figure 6.8: Interstate gas trading between Queensland and southern states.[6]

Energy generation and consumption

Queensland has increased its total energy generation since 2014–2015 as shown in Figure 6.9 which can mostly be attributed to the state's continued reliance on black coal for energy production.

The use of natural gas for energy generation in Queensland has been decreasing since 2015, however the national trend is showing an overall increase in the use of gas for energy in Australia.[7]

Renewables continue to make up a small percentage of total energy production in Queensland with this contribution showing a 30 percent increase from 2016–17 to 2017–18.[7]

The Queensland trends in black coal and renewable fuel sources are consistent with those for Australia as a whole.

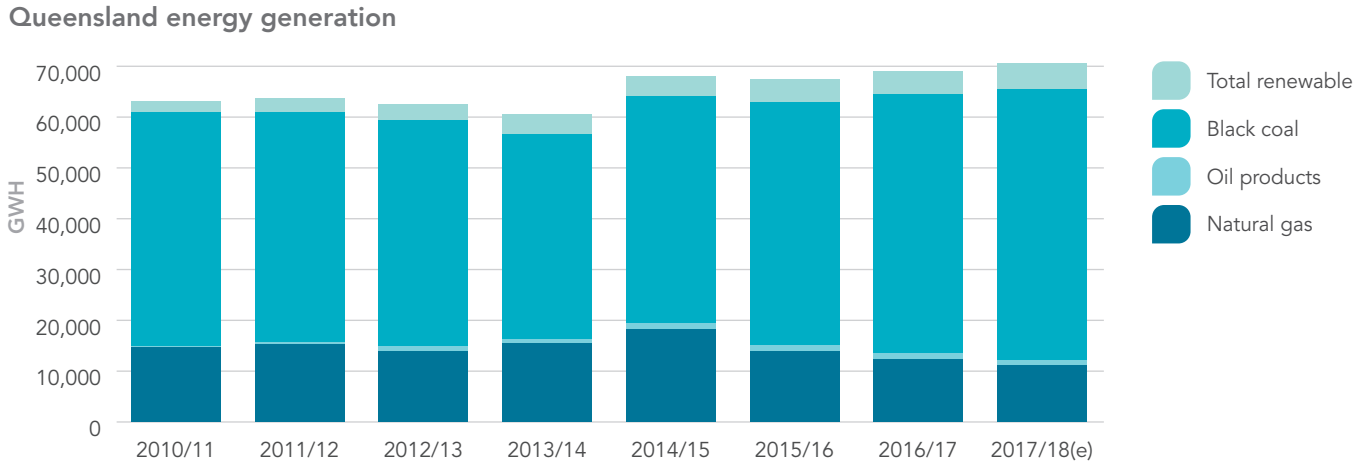
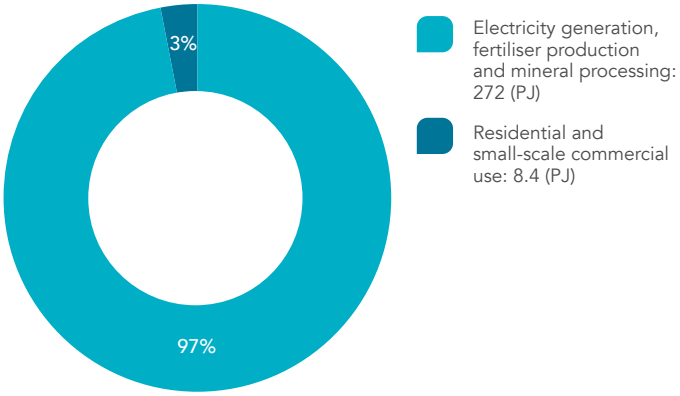


Figure 6.9: Queensland energy generation – 2010/2011 – 2017/2018(e). Figures for 2017–18 were published as estimates in August 2018.[7]

6 Australian Energy Market Operator Quarterly Energy Dynamics Q1 2019

7 Department of the Environment and Energy, Australia Energy Statistics, Table O, retrieved March 2019

Queensland domestic gas consumption 2018



Electricity generation, fertiliser production and mineral processing accounts for just over 97 percent of Queensland's gas consumption. Large industrial customers are located in regional centres such as Gladstone, Townsville and Mount Isa as well as Brisbane.

Residential and small-scale commercial use of gas accounts for nearly three percent of consumption. This is significantly lower than in the southern states due to Queensland's warmer climate and resulting lack of gas use for heating purposes.

Figure 6.10: Queensland natural gas consumption distribution 2018.[8]

EXPORTS

Queensland's LNG exports

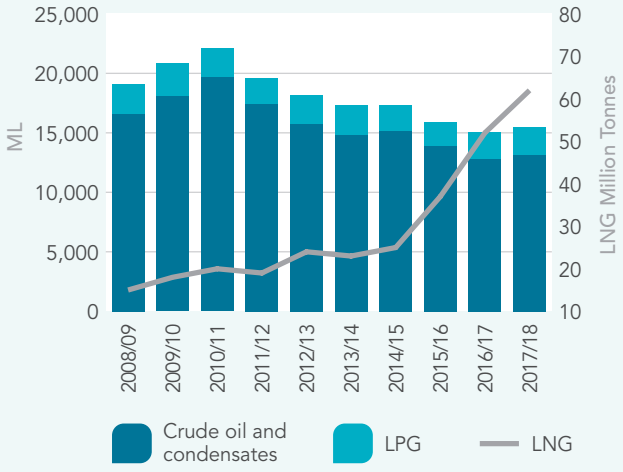
For long distance export, gas is chilled to -161°C, at which temperature it becomes a liquid. Liquefied natural gas (LNG) occupies 1/600th of the space it does as a gas, making it economical to export. LNG is exported in purpose-built tanker ships and then re-gasified on delivery.

The commencement of three LNG projects in Gladstone, Queensland has driven significant increases in Australian LNG exports.

Australia exported 62 million tonnes of LNG in the 2017/18 financial year, 33 percent of which was produced in Queensland.[9]

Australia delivered 22 percent of the world's LNG exports in the 2018 calendar year, making it the second largest LNG exporter in the world behind Qatar which delivered 25 percent.[9]

Australian energy commodity exports



Australian energy commodity export value

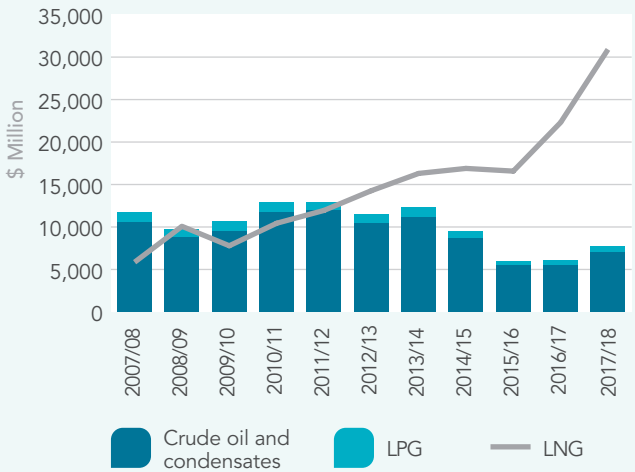


Figure 6.11: Australian Energy Commodity Exports and Export Value 2009/10–2017/18.[9]

8 Business Queensland (2018). Gas Retail and Competition
9 Office of the Chief Economist. (2018). Resources and Energy Quarterly

Table 6.1: Queensland LNG exports from the port of Gladstone[10]

Calendar year	Tonnes of LNG*	No. of shiploads	% nameplate capacity**	Nominal export value***
2015	5,820,960	90	23%	
2016	17,471,251	269	69%	
2017	20,234,542	310	80%	$9.6B
2018	20,578,226	310	81%	$13.5B

* Gladstone Port Authority
** The combined nameplate capacity of the three LNG facilities in Gladstone is 25,300,000 tonnes of LNG per year
***Australian Bureau of Statistics merchandise export data (Queensland Treasury)

Destination of Queensland gas in the 2018 calendar year

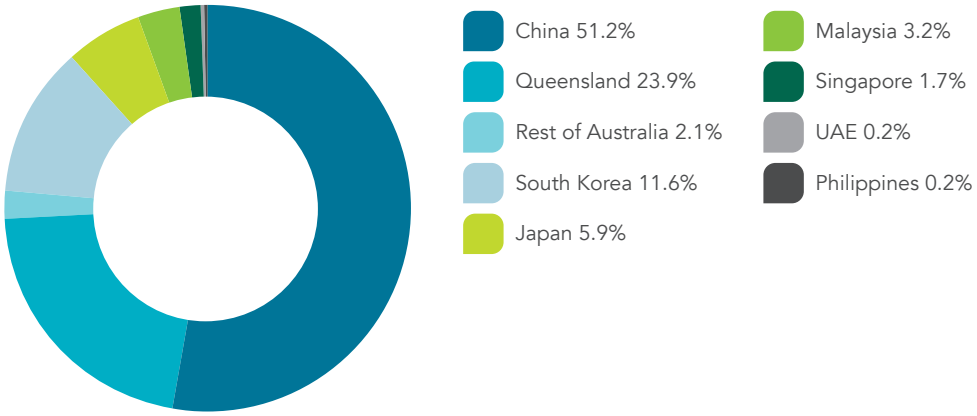


Figure 6.12: Destination of Queensland's gas in the 2018 calendar year.[11]

*includes gas used in the production of LNG

The production of LNG in Queensland reached a record level of 20,578,226 tonnes (1,176 PJ*) in the 2018 calendar year, with an estimated nominal export value of $13.48 billion.

This represents only a one percent increase in production volumes from 2017, but a 40 percent increase in export value. The rise in export value was primarily because LNG export contracts are linked to the price of crude oil, which on average was significantly higher in 2018 than in 2017.

The rate of LNG production levelled off in 2017 and 2018 at approximately 80 percent of the nameplate capacity of the three LNG facilities.

The largest purchaser of Queensland LNG in the 2018 calendar year was China, which bought four and a half times more LNG than the next largest importer, South Korea.

The export of Queensland LNG to China increased 23 percent over the last calendar year, from 11.6 million tonnes in 2017 to 14.3 million tonnes in 2018.

10 Gladstone Ports Corporation, Cargo Statistics Selections, retrieved 2019
11 Australian Energy Market Operator Quarterly Energy Dynamics Q1 2019

Queensland's agricultural production and exports

Queensland's agricultural producers supply 93 percent of the agricultural, forestry and fishing products consumed in the State of Queensland.[12]

Of Queensland's total agriculture and food production in 2016/17, 58 percent was exported overseas, 24 percent was consumed in Queensland and 18 percent was exported to other states and territories in Australia.

Queensland exported around $10.3 billion of agricultural commodities in 2016/17. This included meat and meat products (including live animals), fruits and vegetables, sugar, grains and grain products, cotton and wool, and seafood as shown in Table 6.2.

Table 6.2: Queensland's agriculture production outputs for 2016/17[12]

Agriculture products	Value sold in Queensland ($M)	Export value ($M)	Total ($M)
Meat and meat products	4,661	4,661	9,322
Fruit and vegetables	2,660	507	3,167
Sugar	394	1,926	2,320
Grains and grain products	142	1,890	2,032
Cotton and wool	302	861	1,163
Live animal exports	–	278	278
Seafood	204	180	384
Total	**8,363**	**10,303**	**18,666**

12 Queensland Agriculture Snapshot 2018, Department of Agriculture and Fisheries

Major destinations of Queensland's agriculture exports for the 2016/17 financial year

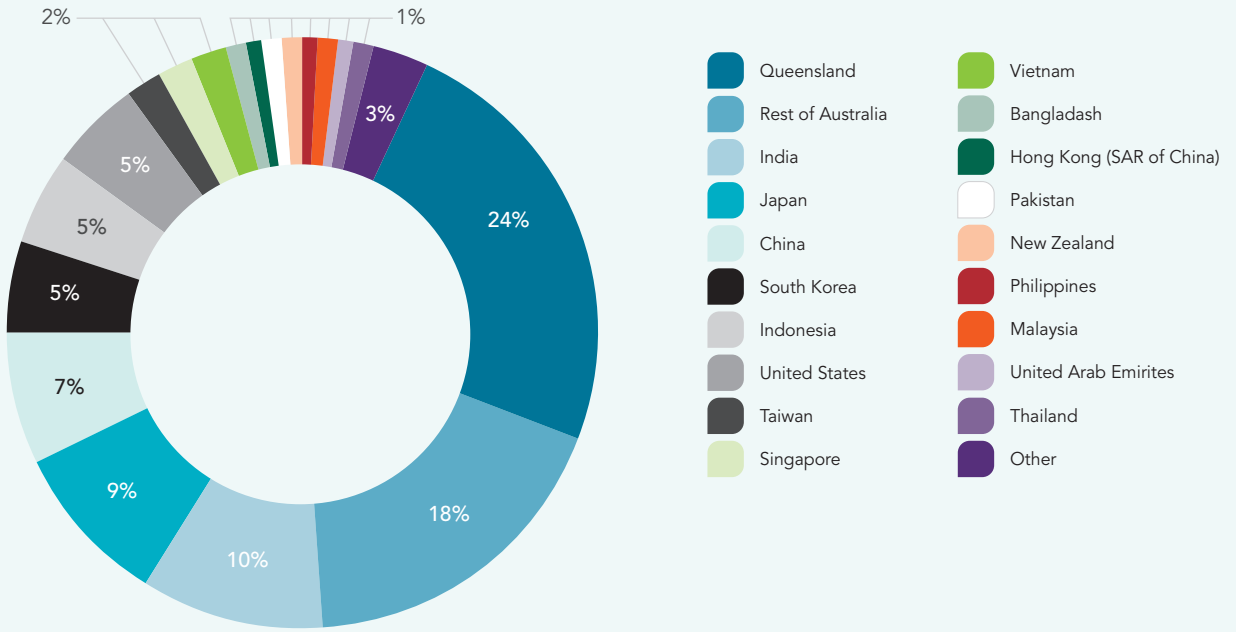


Figure 6.13: Destinations of Queensland's agriculture and food production, 2016/17.[12]

12 Queensland Agriculture Snapshot 2018, Department of Agriculture and Fisheries

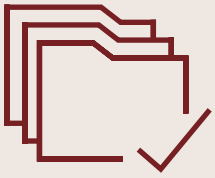
7 COMPLIANCE

IN THIS CHAPTER

Gas wells are closely monitored

1,800

enquiries and **complaints** have been received by DNRME since 2012/13

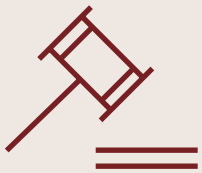


97%

of all enquiries and complaints received by DNRME have been **closed** as at 30 June 2018

2,002

community reports and company self-reporting of incidents were received by DES between 2010 and July 2018



429

enforcement measures have been implemented by DES since 2010

2 DISPUTES

have been **opened for investigation** by the Office of the Land Access Ombudsman since it opened in 2018

148

inspections were completed by the Petroleum and Gas Inspectorate in 2018

INSIGHTS

Petroleum and gas activities in Queensland are regulated by the Department of Natural Resources, Mines and Energy (DNRME) and Department of Environment and Science (DES).

The departments regulate the industry through planned audits, complaint management and investigation of alleged non-compliance.

Certain approvals require the companies to report breaches of conditions or environment and safety incidents within a stated time period to ensure prompt attention and response. In many cases that timeframe for notification is 24 hours.

While DNRME and DES work closely together, they are responsible for enforcing different legislation and therefore have different procedures for dealing with complaints, different reporting requirements and varied methods of data collection.

COMPLAINTS AND ENQUIRIES

Figures 7.1 and 7.2 summarise the volume of information requests and complaints that DNRME's engagement and compliance unit has received since 2012/13 in relation to gas activities.

Complaints are defined as matters that have been reported to DNRME's engagement and compliance unit and require investigation.

DNRME uses the following categories for incoming cases:

- Bores (e.g. bore impacts, make good agreements)
- CSG operations (e.g. rehabilitation, dam management, safety)
- Environmental services (e.g. environmental authorities – dust, noise, odour, pests)
- Field and land access (e.g. entry and access issues, land access code)
- Governance (e.g. legislation and policy communications)
- Land (e.g. cultural heritage, erosion, mapping)
- Water (e.g. baseline monitoring, general water quality issues).

The most common requests for information received by DNRME's engagement and compliance unit about the gas industry since 2012/13 have been regarding:

- **Bores**
- **Water**
- **Governance**
- **CSG operations.**

Information requests received by DNRME's engagement and compliance unit

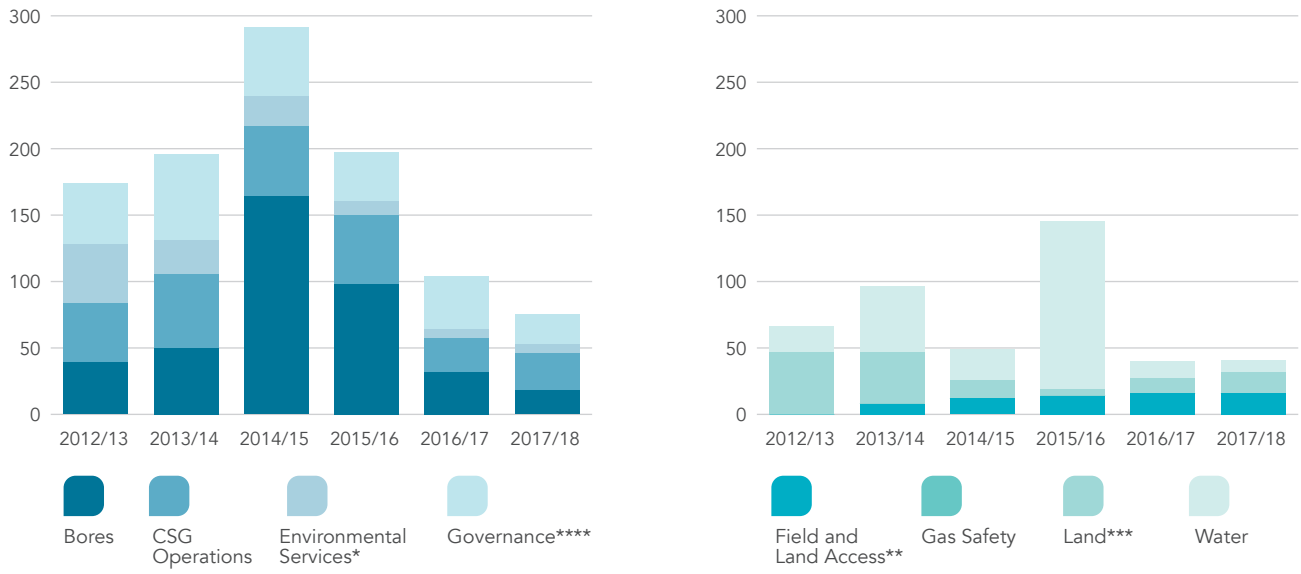


Figure 7.1: Number of information requests related to petroleum and gas submitted to the Department of Natural Resources, Mines and Energy's engagement and compliance unit: 2012/2013 – 2017/2018.[1]

* Environmental Services: referrals to Department of Environment and Science
** Field and Land Access: includes property entry and access issues and the land access code
*** Land: includes cultural heritage, erosion and vegetation clearing
**** Governance: includes, but is not limited to, matters concerning legislation, regulatory framework, government initiatives, public reports and communications.

1 Department of Natural Resources, Mines and Energy, personal communication, 2018

Complaints received by DNRME's engagement and compliance unit

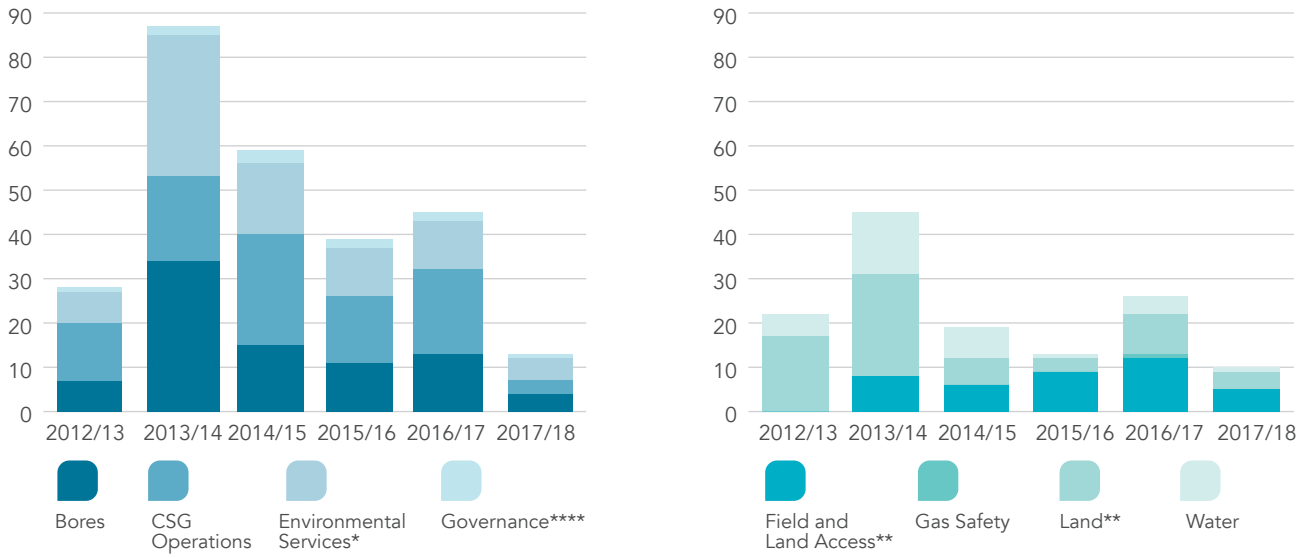


Figure 7.2: Complaints and cases regarding petroleum and gas that have responded to by the Department of Natural Resources, Mines and Energy's engagement and compliance unit: 2012/13 – 2017/18.[1]

* Environmental Services: referrals to Department of Environment and Science
** Field and Land Access: includes property entry and access issues and the land access code
*** Land: includes cultural heritage, erosion and vegetation clearing
**** Governance: includes, but is not limited to, matters concerning legislation, regulatory framework, government initiatives, public reports and communications.

The most common complaints received by DNRME's engagement and compliance unit about the gas industry since 2012/13 have been regarding:

- Bores
- Environmental services (complaints referred to DES for action – see Figure 6.3)
- CSG operations.

DNRME records show that that 97 percent of all information requests and complaints received over the total reporting period had been closed as at 30 June 2018, with the remainder being resolved in the subsequent financial year.

INSIGHTS

Government and industry believe that the reduction in information requests received in the last two financial years is likely to be due to increased community knowledge and understanding of the gas industry.

Some of this reduction may also be associated with enquiries now being directed to other agencies such as the GasFields Commission Queensland and the Office of the Land Access Ombudsman.

1 Department of Natural Resources, Mines and Energy, personal communication, 2018

DES investigates community reports received from sources including landholders, members of the community, interest groups, government agencies and media.

Most investigation activities are initiated in response to company self-reporting when notifying the regulator of a breach of conditions or an environment or safety incident (see Figure 7.3).

The overall level of both community reports and company self-reporting has consistently reduced since the peak level of drilling activity in 2013.

Reports received by DES and total number of wells drilled

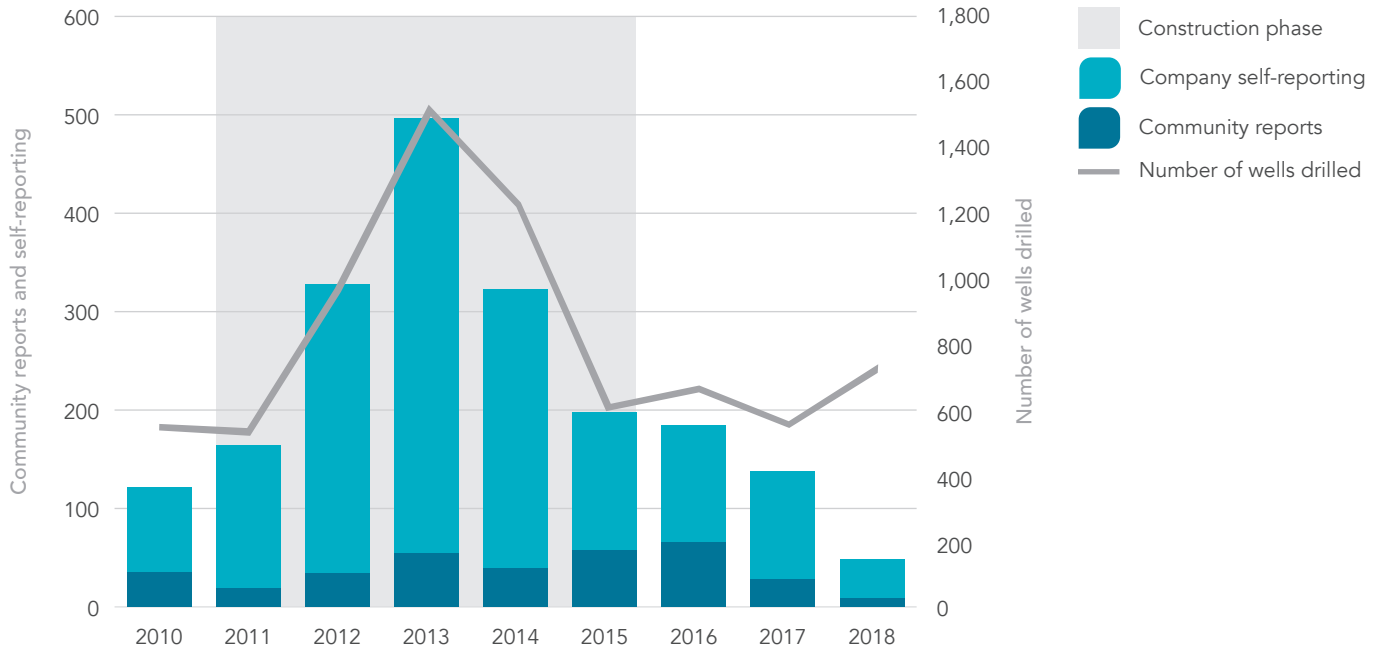


Figure 7.3: Community reports and company self-reporting of incidents 2010–July 2018, compared with wells drilled as an indicator of gas industry activity. Note: DES has made improvements to its reporting and data capture systems over the years. Therefore, the older the data is, the less accurate it may be.[2]

2 Department of Environment and Science, personal communication, 2018

Investigations

Both DNRME and DES undertake investigations in response to information requests, complaints, community reports and company self-reporting.

These departments also have proactive compliance programs of planned inspections and audits (both desk-based and field-based) to review higher risk activities in accordance with the legislative framework.

DNRME engages with industry through workshops, seminars, conferences and other forums to inform and guide improved compliance standards.[1]

DNRME uses a risk-based approach to target and prioritise areas where compliance and engagement efforts are most needed and will prove most effective for the industry and communities.

For DES, each year the focus and number of audits/ reviews of specific activities changes in response to factors such as the introduction of new legislation, analysis of complaints data, or understanding of changing activity levels.

Table 7.1: Focus of DES compliance each year[2]

Year	Compliance plan focus area
2012/13	Pipeline construction Water management
2013/14	Construction footprint Waste management Hydraulic fracturing
2016/17	Bore assessments Make good agreements
2017/18	Pipeline rehabilitation

DES inspections and desktop reviews

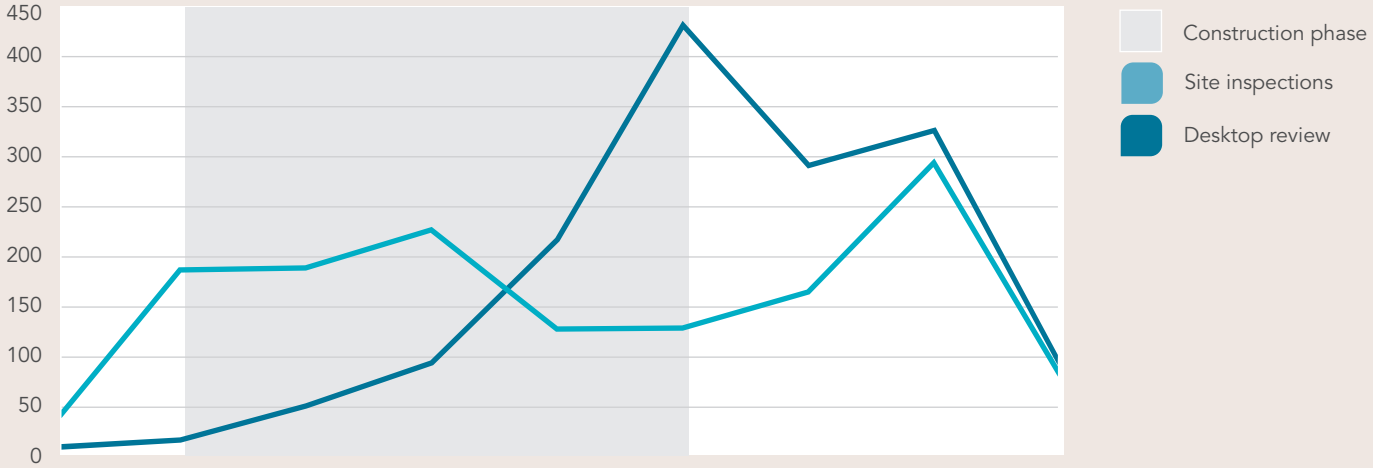


Figure 7.4: Trend and profile of inspections, audits and reviews performed by the Department of Environment and Science from 2010 to July 2018. Note: DES has made improvements to its reporting and data capture systems over the years. Therefore, the older the data is, the less accurate it may be.[2]

1 Department of Natural Resources, Mines and Energy, personal communication, 2018
2 Department of Environment and Science, personal communication, 2018

Land Access Ombudsman

The Office of the Land Access Ombudsman (LAO) opened in September 2018 with specific functions to investigate breaches of Conduct and Compensation Agreements and Make Good Agreements, and make practical recommendations to resolve disputes.

As of 17 June 2019, the LAO had opened two investigations. Of these, one had been resolved after recommendations were made and complied with. The other case was still current with a possible upcoming conference and subsequent LAO recommendations pending.

In addition to the two investigation cases opened, the LAO had received a further 15 enquiries that were either outside of the LAO's scope (subsequently referred to other bodies to resolve) or were already being dealt with by a government department.

Of the total 17 referrals received by the LAO, one had been referred by a resource company and the other 16 were referred by landholders.[3]

LAO incoming referrals by subject

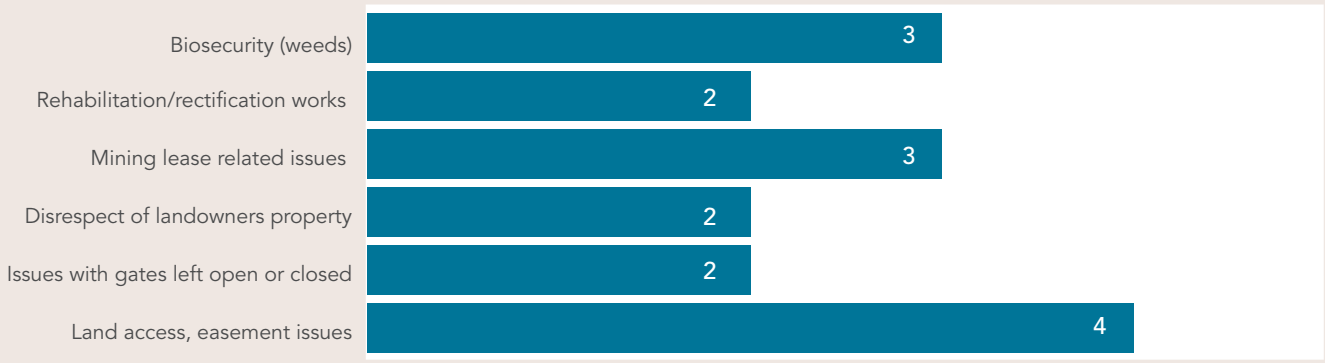


Figure 7.5: Office of the Land Access Ombudsman referrals received by subject as at 17 June 2019. These numbers are related to all resource activity, not limited to petroleum and gas activity. Some incoming referrals cover multiple subjects while some are responded to without the need for formal investigation or categorisation.[3]

Complaints referred on by LAO

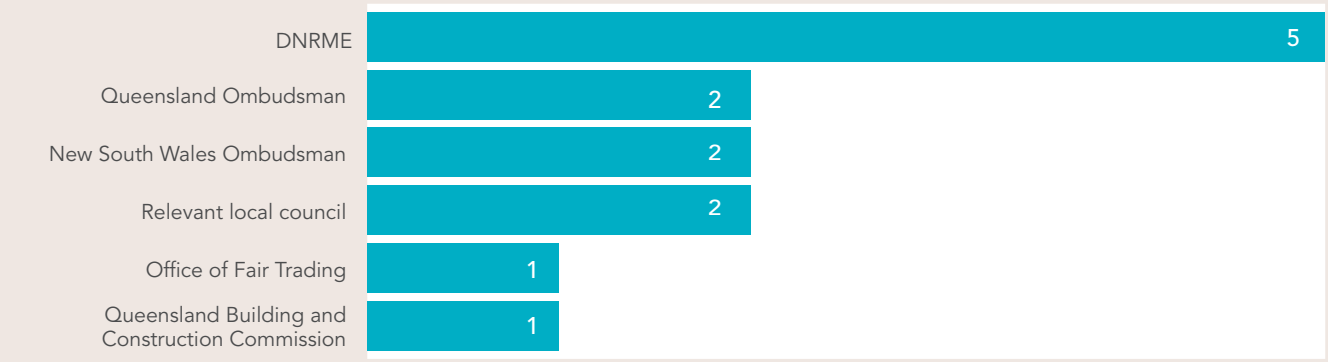


Figure 7.6: Complaints referred on by the Office of the Land Access Ombudsman to other organisations at 17 June 2019. These numbers are related to all resource activity, not limited to petroleum and gas activity. Some cases are responded to by LAO without the need for formal investigation or referral to a government agency.[3]

3 Office of the Land Access Ombudsman, personal communication, June 2019

Enforcement

Enforcement activities range from education, working with the company to rectify potential non-compliance and issuing of warnings through to prosecution. These measures can be used in isolation or in combination, depending on the outcome sought.

Type of enforcement measures taken by DES

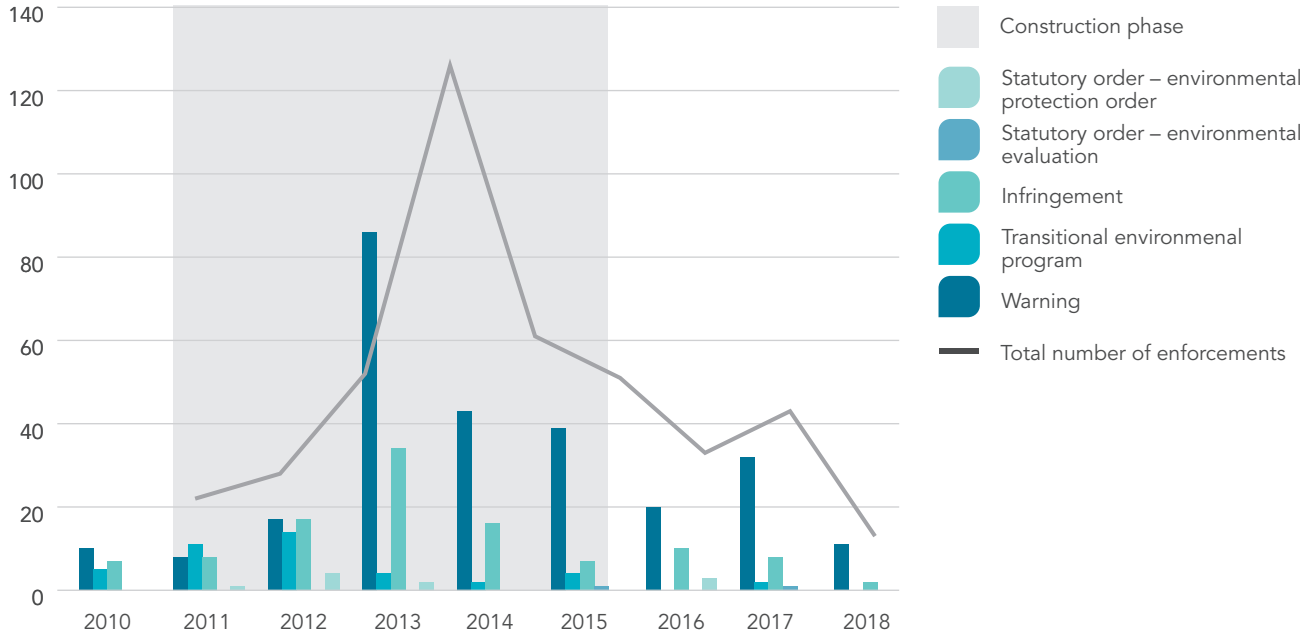


Figure 7.7: Distribution of enforcement measures applied by the Department of Environment and Science, 2010 – July 2018. This data does not reflect the severity of the incidents reported. Note: DES has made improvements to its reporting and data capture systems over the years. Therefore, the older the data is, the less accurate it may be.[4]

The highest number of enforcement measures applied by DES were in 2013. This coincides with the peak period of complaints and self-reporting, and peak industry construction activity. Since this time, the overall number of enforcement measures has declined from 126 in 2013 to a low of 13 in the first half of 2018.

From 2010–July 2018, warnings (266) and infringement notices (109) accounted for 87 percent of enforcement measures. These types of measures are generally associated with low or minor breaches of conditions.

Statutory orders (an administrative enforcement tool), have rarely been imposed accounting for 12 cases since 2010 (2.8 percent).

From 2010–2018, the common types of incidents reported and acted on included but were not limited to:

- Erosion and sediment control
- Damage to vegetation or animals
- Administrative breaches
- Noise
- Waste water discharge.

4 Department of Environment and Science, personal communication, 2018

Well integrity

Well integrity is regulated by DNRME's Petroleum and Gas Inspectorate (the Inspectorate).[5]

The petroleum and gas industry must comply with a code of practice for the construction, operation and decommissioning of wells.

A key requirement is to ensure that fluids produced by the wells – petroleum, gas and water – are isolated from geological formations above and below and contained to protect the environment and ensure the safe flow of gas to the surface.[6]

The primary control for well integrity is ensuring that wells are constructed properly.

Petroleum and gas companies are required to notify the Inspectorate within 24 hours if a well fails to meet the standards outlined in the Code of Practice (the Code).

Well compliance under the construction code 2018

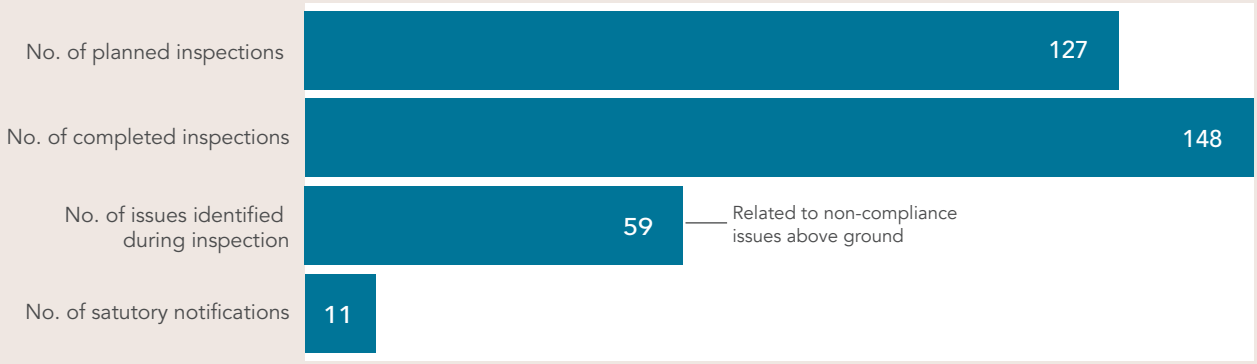


Figure 7.8: Petroleum and Gas Inspectorate inspections and statutory notifications: 2018.[7]

All non-compliance issues were resolved after testing and remediation

5 Provisions of the Petroleum and Gas (Production and Safety) Act 2004, the Petroleum and Gas (Production and Safety) Regulation 2004, the Code of Practice for the construction and abandonment of coal seam gas and petroleum wells and associated bores in Queensland, and associated industry standards.
6 GasFields Commission Queensland. Onshore Gas Well Integrity in Queensland, Australia. July 2015 Pg. 4
7 Department of Natural Resources, Mines and Energy, personal communication, 2018

CASE STUDY

A review undertaken at the request of the GasFields Commission Queensland in July 2015[8] found that 21 statutory notifications had been issued in respect of the 6,734 CSG exploration, appraisal and production wells drilled between 2010 and March 2015 (a rate of 0.3 percent).

No breaches were identified after testing, remediation and follow-up action under the Code of Practice.

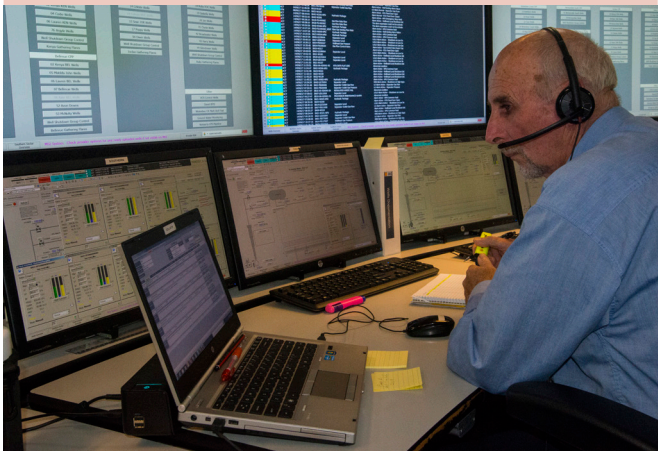
Petroleum well assurance program: design and construction review[9]

During 2017/18 the Petroleum and Gas Inspectorate conducted a proactive well integrity compliance review that involved seven oil and gas companies which operate conventional and unconventional (CSG) wells. The review assessed compliance against internal company standards, mandatory well design requirements and good industry practice.

The program included:

- Review of the operator's well design protocols and standards
- Providing input to the well design and planning processes for eight wells
- Review of well construction practices against the operator's plans in the well execution stage, including carrying out well barrier monitoring and validation.

The Inspectorate advised there was 97–98 percent compliance with operator and mandatory standards and good industry practice, and that design processes in participating companies have improved as a result of the review.



6 GasFields Commission Queensland. Onshore Gas Well Integrity in Queensland, Australia. July 2015 Pg. 4
9 Scott, Michael P., Department of Natural Resources, Mines and Energy, Managing Well Integrity in Queensland, The APPEA Journal 2019, 59, 810–813

APPENDIX

APPENDICES

Good communication is critical to the business relationship

APPENDIX A:

MAIN ADDITIVES IN HYDRAULIC FRACTURING FLUID

These additives account for less than one percent of fracturing fluid volume. In a sample of 21 hydraulic fracturing case studies[1], an average of seven types of chemical additives were used in a single frac. Refer to Chapter 4 – Wells for more details.

Additive type	Purpose in fracture stimulations[2,3]	Examples of compound type[3]	Common use of main compound[2]	Notes[3]
Biocide	Limits or prevents growth of bacteria that could damage the gelling agent	Glutaraldehyde	Used in tanning and as disinfectant sterilise medical/dental equipment	The natural polymer gelling agents are good food for bacteria, so they encourage bacterial growth – biocides kill these bacteria
Breaker	Chemically break the bonds of the gel in order to reduce the viscosity back to that of water.	Hydrogen peroxides, sodium persulfate, Diammonium peroxidisulphate	Bleaching agent in detergent and hair cosmetics, manufacture of household plastics	Only required if a gel is used
Clay stabilisers	Prevents clays from swelling or shifting	Polydimethyldiallylammonium chloride (PolyDADMAC)/ Tetramethyl ammonium chloride	Waste water treatment/ water purification, pulp and paper industry	
Crosslinker	Increases the viscosity of gelling agents	Borate salts	Used in laundry detergents, cosmetics and hand soaps	There are different crosslinkers for different gelling agents
Acid	Dissolves calcite in the coal prior to fracturing	Hydrochloric acid/Muriatic acid	Manufacturing and treatment processes including the production of drinking water, pharmaceuticals, beverages and foods. Swimming pool water cleaner/neutraliser	Not all wells require this treatment because coal seams do not always contain calcite
Gelling agent	Thickens the water to allow more proppant to be carried into fractures	Guar gum and hydroxyethyl cellulose	Thickening and stabilizing properties useful in food products (e.g. sauces, baked goods, ice cream), feed and industrial applications	Not all hydraulic fracturing uses a gel; gel-free fracturing is termed 'slickwater'
pH buffer	Keeps the pH of the fluid in a specified range to maintain the effectiveness of other components, such as crosslinkers	Potassium or sodium carbonate, potassium or sodium hydroxide	Used in laundry detergents, soap, water softener and dish washing detergents	Required for the stability of crosslinked polymers
Corrosion inhibitors	Prevents the corrosion of the pipe Bonds to metal surfaces (pipe) downhole. Any remaining product not bonded is broken down by micro-organisms and consumed or returned in produced water	n,n-dimenthyl formamide	Used in pharmaceuticals, acrylic fibres, plastics	
Other additives	**Operators in Queensland are required to disclose a full list of additives prior to hydraulic fracturing[3]**			

1 Witt, et al., University of Queensland Centre for Coal Seam Gas, personal communication, 2018
2 BC Oil and Gas Commission, Frac Focus Chemical Disclosure Registry, retrieved 2018
3 Independent Expert Scientific Committee (IESC), Hydraulic fracturing ('fraccing') techniques, including reporting requirements and governance arrangements, June 2014

APPENDIX B:

HOW IS HYDRAULIC FRACTURING REGULATED?

Hydraulic fracturing is a long established process with significant international and Australian regulations, including the restriction and management of chemicals, drilling and well construction processes.[1]

Each fracturing process is tailored to suit the geological and environmental conditions present.

Companies monitor the hydraulic fracturing operations both from the surface (e.g. micro-seismic techniques) and with pressure measurements at the bottom of the well.

Pressure changes in the subsurface are watched very closely during the fracturing process along with the surface measurements to ensure that the fracture grows to the required distance and remains within the target zone.

The surrounding groundwater is tested before the hydraulic fracturing takes place and afterwards — monthly for the first six months and then annually for at least five years to monitor if any changes in water chemistry occur.[2]

The gas company's Environmental Authority has project-specific conditions which must be met before operations can begin.

The Environmental Protection Act 1994

- BTEX chemicals are prohibited from being added to hydraulic fracturing fluids in Queensland.
- Affected landholders must be notified of incidents that may cause serious or material environmental harm.

Industrial Chemicals (Notification and Assessment) Act 1989

- Chemical additives used in hydraulic fracturing fluids are required to be notified to, and assessed by, the National Industrial Chemicals Notification and Assessment Scheme.
- Chemical additives used in hydraulic fracturing fluids must be listed on the Australian Inventory of Chemical Substances.

Source: Independent Export Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Hydraulic fracturing ('fraccing') techniques, including reporting requirements and governance arrangements 2014.

Petroleum Regulation 2004 and Petroleum and Gas (Production and Safety) Act 2004

- Coal seam gas companies are required to notify the government and landholders
  - when carrying out hydraulic fracturing activities at least 10 business days before commencement, and
  - when completing hydraulic fracturing by submitting a notice of completion within 10 days of completion. [1]
- Companies must lodge a report with the Queensland Government, within two months of any hydraulic fracturing activity, detailing the composition of the fracturing fluid used at each well and its potential impact. These detailed completion reports are made available to the public after five years.

1 Independent Export Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Hydraulic fracturing ('fraccing') techniques, including reporting requirements and governance arrangements. 2014

2 Department of Environment and Science, ESR/2016/1989 Streamlined Model Conditions for Petroleum Activities

Department of Environment and Science (DES) has established model conditions for an Environment Authority that specify the management requirements for hydraulic fracturing activities in coal seam gas wells.[2]

DES Guideline

Streamlined model conditions for petroleum activities

Hydraulic fracturing activities

- Polycyclic aromatic hydrocarbons or products that contain polycyclic aromatic hydrocarbons **must not be used** in hydraulic fracturing fluids in concentrations above the reporting limit (ranging between 0.005 ug/L–0.02 ug/L).
- Hydraulic fracturing activities **must not**
  - negatively affect water quality, other than that within the stimulation impact zone of the target gas producing formation.
  - cause the connection of the target gas producing formation and another aquifer.
- The internal and external mechanical integrity of the well system prior to and during hydraulic fracturing must be ensured such that there is:
  - **no significant leakage** in the casing, tubing, or packer; and
  - **no significant fluid movement** into another aquifer through vertical channels adjacent to the well bore hole.
- Practices and procedures must be in place to detect, as soon as practicable, any fractures that cause the connection of a target gas producing formation and another aquifer.

Stimulation impact monitoring program

- Development of a stimulation (hydraulic fracturing) impact monitoring program to monitor the production of flow back water and any changes in groundwater quality – minimum timeframes are specified.
- Companies are required to demonstrate that the volume of flow back water extracted from the stimulated well must be 1.5 times the volume of fluid used.

Water quality baseline monitoring

- Preparation of a baseline bore assessment of the water quality of landholder groundwater bores within a 2km radius of the well to be hydraulically fractured if the bore is located:
  - within that target gas producing formation; or
  - within 200m above or below the target gas producing formation.

Stimulation risk assessment

- A stimulation (hydraulic fracturing) risk assessment **must be developed and carried out for every well** to be hydraulically fractured to ensure that hydraulic fracturing activities are managed to prevent environmental harm.
- The conditions must address issues that include (but are not limited to) 27 elements relating to the proposed hydraulic fracturing process, geological conditions, proximity to other groundwater users and potential impacts to landholder bores, hydrogeological conditions, well integrity testing, fracturing control mechanisms, hydraulic fracturing fluid composition, and environment hazard assessments (environmental and human health).

2 Department of Environment and Science, ESR/2016/1989 Streamlined Model Conditions for Petroleum Activities

APPENDIX C:

GROUNDWATER EXPLAINED

Sedimentary basins

Petroleum and gas, and much of our groundwater resources are found in sedimentary rocks, such as sandstone and shales, that are layers within sedimentary basins.

Basins are formed over different geological periods through stresses in the earth such as the movement of tectonic plates that result in areas of subsidence.

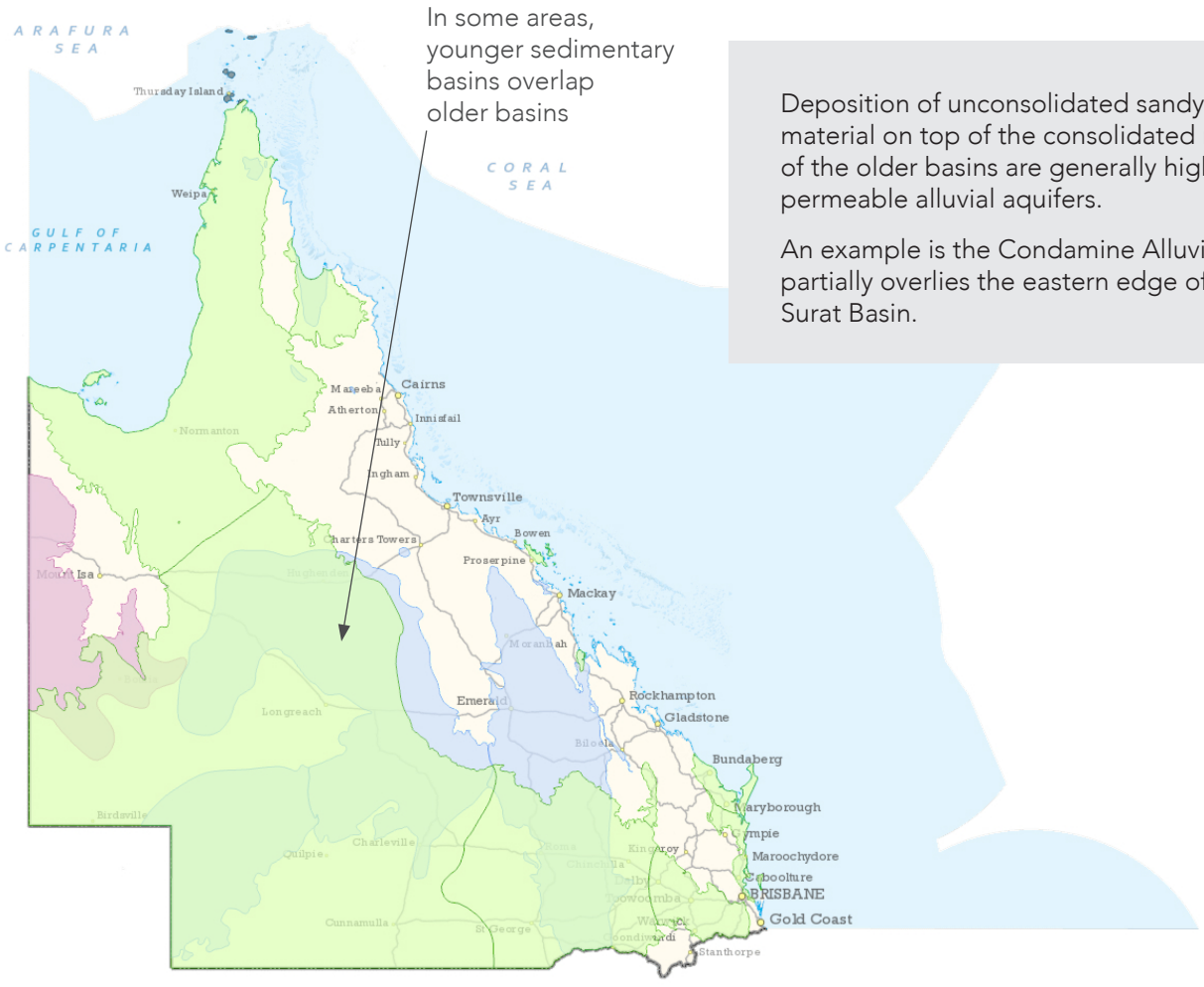
Subsidence creates low-lying areas in the earths crust where different types of sediments are deposited and accumulate over time.

Changing condition such as uplift in the Earth's surface, sea level change and climate change results in the deposition of different types of material. The accumulation of varying deposits over time eventually results in the formation of layers of consolidated deposits or geological formations. One formation may be rich in sandstone, another rich in mudstone and some formations are rich in gas bearing coal seams.

Petroleum and gas can move over geologic time from deep in a basin or underlying basin, upward into shallower rock layers where it may be trapped to form a commercial resource.

Deposition of unconsolidated sandy alluvial material on top of the consolidated rocks of the older basins are generally highly permeable alluvial aquifers.

An example is the Condamine Alluvium that partially overlies the eastern edge of the Surat Basin.



Groundwater does not move through major channels or 'underground rivers'.

Groundwater moves slowly through sandstone rich geological formations because there is usually enough room between sand grains to allow water movement caused by pressure differences. The nature of groundwater movement is shown diagrammatically in Figure 1.

Figure 2 shows how water can travel along different flow paths at different rates. Over very long timeframes, some of the water in an aquifer can move through low permeability geological formations separating the aquifers, resulting in some hydraulic connectivity between these aquifers.

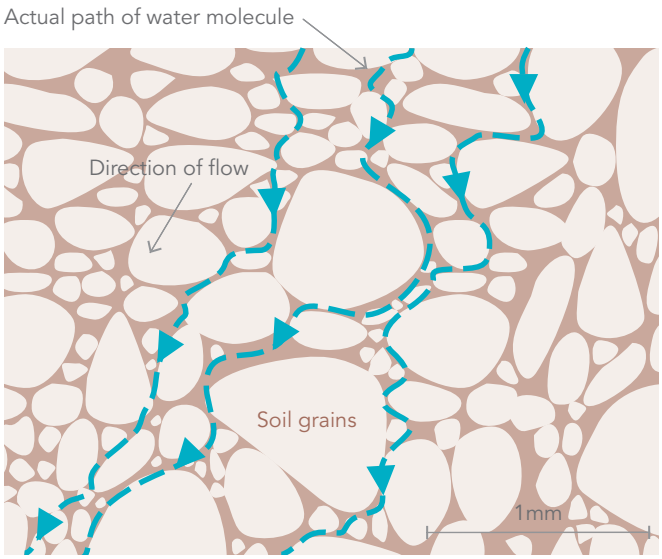


Figure 1: Groundwater movement and direction of flow.

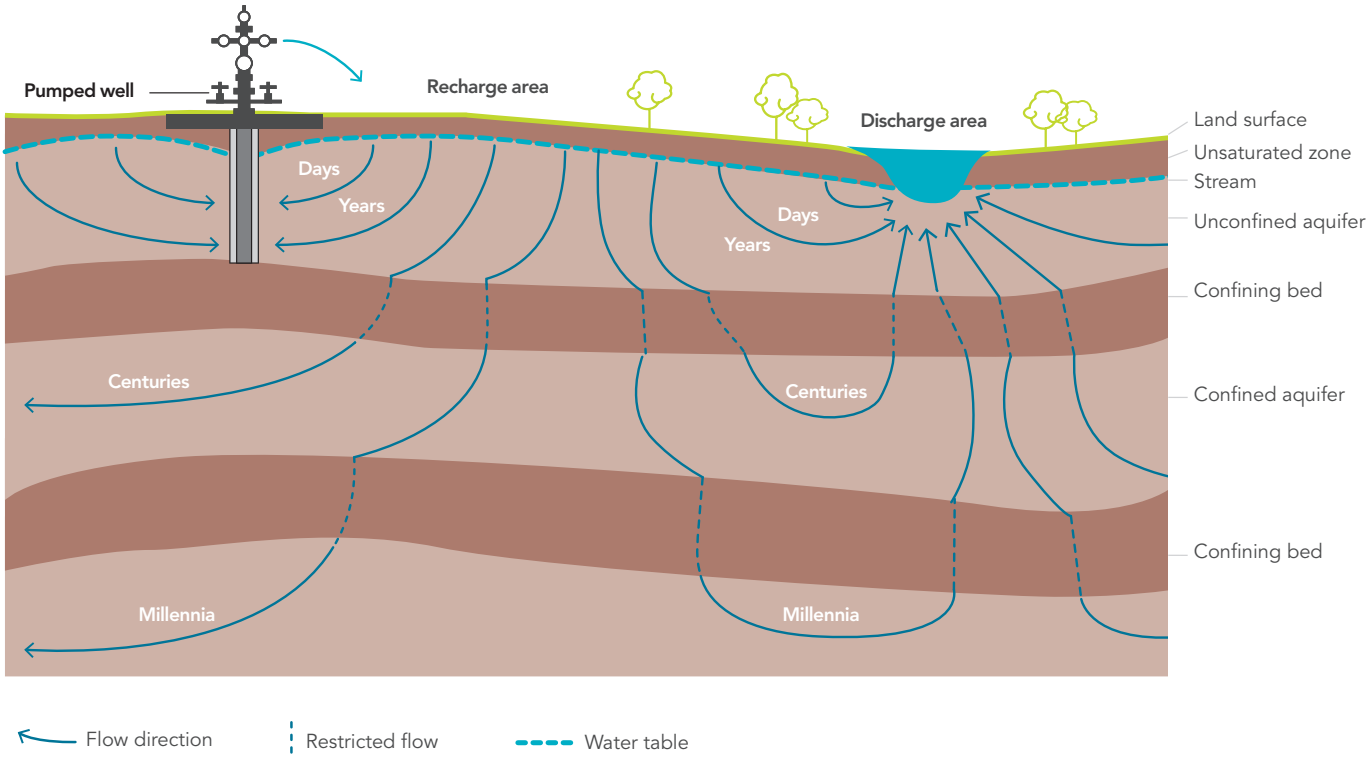


Figure 2: Diagrammatic cross section showing groundwater flow paths from recharge to discharge areas.

Petroleum and gas basins

Sedimentary basins vary in thickness from a few hundred to thousands of metres thick.

After a period of stability, new conditions can cause subsidence to recommence resulting in a new overlying basin. Figure 3 shows the Eromanga Basin developed over the top of the older Cooper and Galilee Basins. Figure 4 shows how the Surat Basin developed over the southern part of the older Bowen Basin.

The Great Artesian Basin (GAB) contains a major water resource that has provided water for regional and remote communities for more than a century.[1]

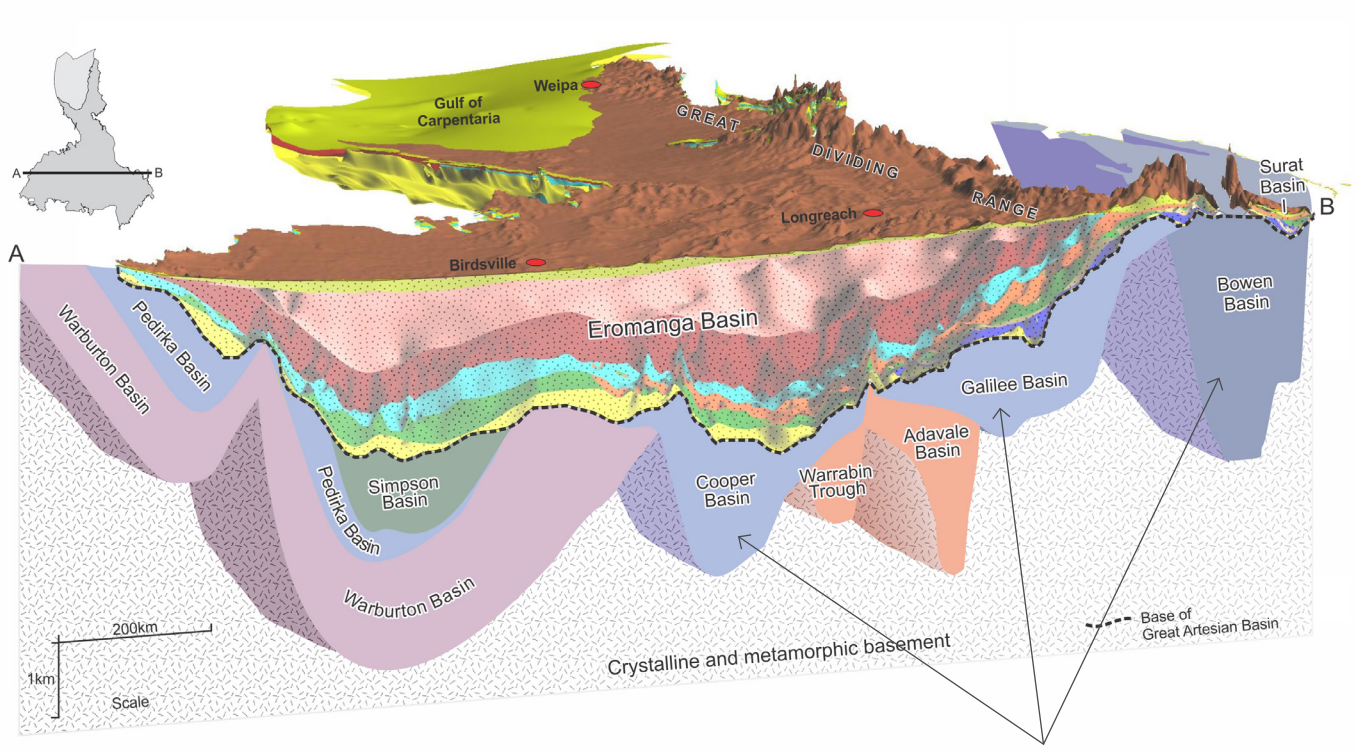


Figure 3: Eromanga and underlying basins [2]

The older basins that largely underly the GAB are the Bowen, Galilee and Cooper Basins, which do not contain major aquifer systems.

The GAB is essentially three separate basins, the Eromanga, Surat, and Carpentaria Basins, which generally have equivalent rock formations, somewhat separated by highs in the basement rocks.

Coal seam gas is mainly sourced from the coal rich formations of the Surat and Bowen Basins.

Concentrations of conventional petroleum and gas that have migrated through strata to collect in traps are found mainly in the Eromanga and Cooper Basins.

1, 2 Smerdon, Brian & TR, Ransley & Radke, Bruce & JR, Kellet. (2012). Water resource assessment for the Great Artesian Basin. A report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment.

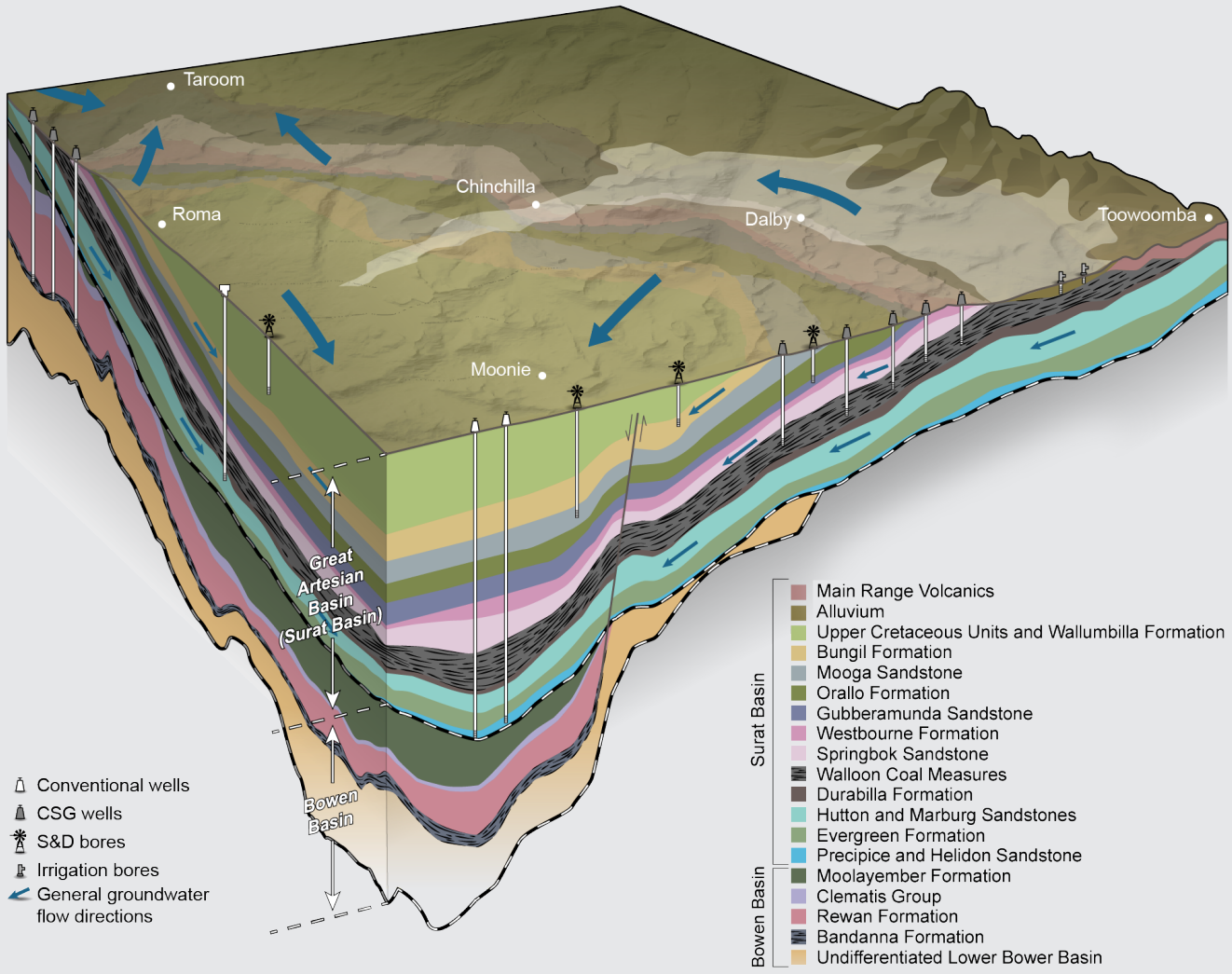


Figure 4: Representative cross-section showing the main groundwater systems in the Surat Cumulative Management Area.[3]

When petroleum and/or gas is produced, there is generally a component of groundwater mixed with the resource.

The groundwater component, extracted as a by-product, is known as 'associated water'.

In the case of conventional gas, the amount of associated water extracted is relatively small, however the production of CSG requires the extraction of larger volumes of water from coal seams to reduce the pressure in the coal seam and allow gas to flow into the gas well.

The difference between the ratio of water to gas over time during conventional and unconventional gas production is shown in Figure 5.

For conventional oil and gas, water volumes increase towards the end of the life of the well, while for unconventional gas, such as CSG, water production is at its peak at the beginning of production and declines with time.

3 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019

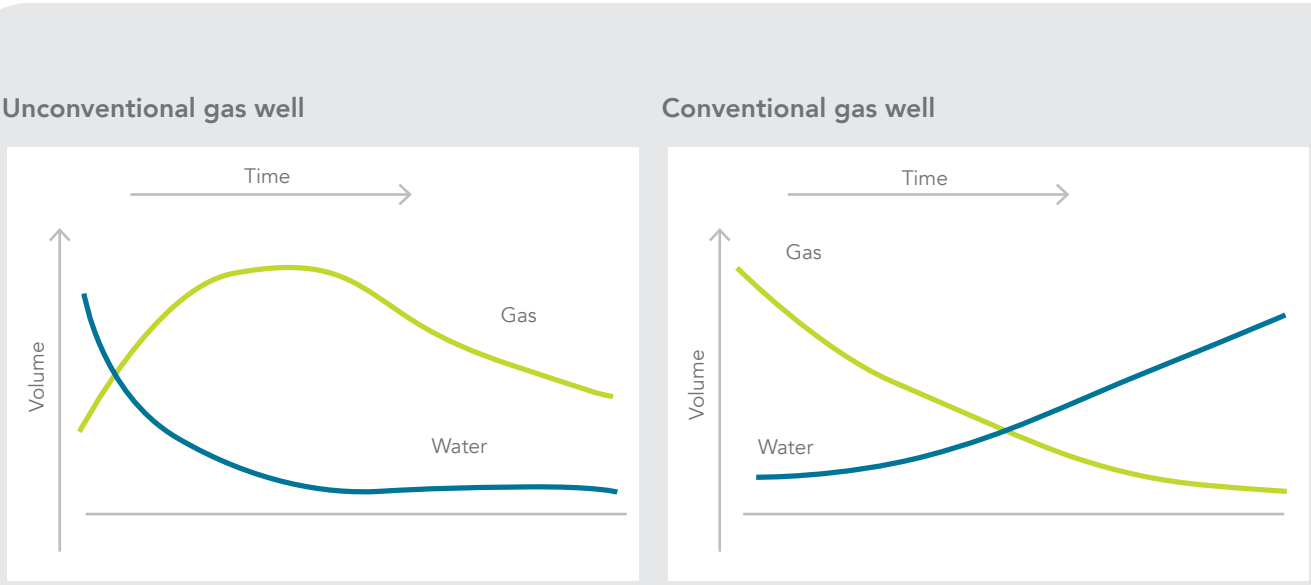


Figure 5: The general differnce between the volume of gas and water produced over time for unconventional and conventional gas wells.

Effects of groundwater take

When water is extracted for agricultural, industrial or community use from an aquifer containing coal formations:

- Depressurisation releases gas from the coals and the water bore may begin to produce gas
- Depressurisation can cause water level decline in the aquifer and impact nearby water bores taking water from the same aquifer.
- In areas where higher connectivity exists between the coal formation and surrounding aquifers, bores taking water from aquifers above or below the coal seam formations may be affected in areas where groundwater take is high.
- The number of water supply bores that become affected depends on the degree of hydraulic connectivity between a target coal formation and the overlying or underlying aquifers.

Free gas (mainly methane) can also potentially impact nearby water bores by adversely affecting the quantity or quality of water provided. This can occur if a portion of the gas released by depressurisation of the coal seam moves under buoyancy effects into a nearby bore. The gas can reduce the efficiency of a pump or create a health or safety risk. Methane is not considered toxic, but it is an asphyxiant at a concentration of over 50 percent (500,000 ppm) in air. Methane is flammable and can be ignited by heat, sparks or flames.

Artesian bore capping program

Considerable progress is being made to repair uncontrolled artesian bores used for stock watering and replacing open bore drains with piped distribution systems. See https://www.business.qld.gov.au/industries/mining-energy-water/water/rural-assistance/igabiip for more details.

This is a major initiative to improve water take from significant groundwater systems.

The *Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017* requires that uncontrolled bores used for stock watering be capped and bore drains replaced with pipes by September 2027.

Example of an uncontrolled artesian stock bore.

Groundwater management in Queensland

The petroleum and gas industry's environmental and water management obligations are governed by a regulatory framework that includes elements of the:

- *Environmental Protection Act 1994*
- *Water Act 2000*
- *Waste Reduction & Recycling Act 2011*
- *Petroleum and Gas (Production and Safety) Act 2004*
- *Water Supply (Safety & Reliability) Act 2008*

Petroleum and gas operators require a range of approvals from the Queensland Government before they can start construction and/or activities.

Resource companies have the right to take associated water under the *Petroleum and Gas (Production and Safety) Act 2004* and the *Petroleum Act 1923* as water is a by-product in the process of extracting gas.

In addition, resource companies have an obligation to comply with the groundwater management framework under the *Water Act*.

The regulatory framework requires resource companies to:

- Submit a baseline assessment plan (BAP) to the Department of Environment and Science (DES) for approval before any water extraction commences.
- Carry out a baseline assessment of landholder water bores near planned gas wells before any water extraction can commence.
- Prepare an Underground Water Impact Report (UWIR) every three years which includes an assessment of the water level decline in aquifers and impacts to springs in the long and short-term. The UWIR must identify environmental values that could be impacted through the exercise of underground water rights as well as any landholder bores and / or springs that are predicted to be affected by the existing and forecast associated water take. A water monitoring strategy and spring impact management strategy must be prepared and implemented.
- Carry out a detailed bore assessment of each water bore predicted in the UWIR to experience impact within three years and enter into an agreement with the bore owner about the outcome and measures to make good if the capacity of the bore is or is likely to be impaired.

The same regulatory framework operates across Queensland, however in areas of intense development where multiple projects are involved, a Cumulative Management Area (CMA) can be declared by DES within which the framework varies slightly.

In a CMA the water level decline in an aquifer may be due to impacts from two or more individual resource projects resulting in unclear make good responsibilities.

Also, the construction of groundwater flow models by individual resource companies to assess future water level decline becomes difficult as data would be needed for the adjacent projects. Similar issues would arise for the development of monitoring networks. Therefore, the independent Office of Groundwater Impact Assessment (OGIA) is responsible for preparing the UWIR for the CMA and will assign make good responsibilities to individual resource companies.

The Surat CMA, declared in 2011, is currently the only CMA in Queensland and it encompasses multiple CSG developments in the Surat Basin.

Separate to the management of the impacts of the extraction of water by petroleum and gas operations, DES regulates the disposal or treatment and beneficial use of the water taken under the *Waste Reduction and Recycling Act 2011*.

DES also regulates activities to avoid the potential contamination of groundwater through specific authorised activities. Companies need to provide an assessment of the potential environmental impacts of the activity and outline strategies to avoid or mitigate those impacts.

Further protection is provided by the *Regional Planning Interest Act 2014*. Under this legislation, water extraction by any new petroleum and gas project would need to avoid having a net impact on a water resource specified as a 'regionally significant water source'.

In addition to the Queensland government regulatory framework, the Australian government also provides approval conditions for large scale CSG projects.

A water monitoring and management plan (WMMP) is required to address the Australian government approval conditions relating to the assessment, management, and mitigation of surface and groundwater impacts as a result of project development, and also addresses relevant commitments in the environmental impact statement (EIS) for the project.

The monitoring systems put in place federally are designed to complement the management arrangements set up by the Queensland Government's Office of Groundwater Impact Assessment.

Make good framework

Water bores identified in a UWIR that are predicted to experience a water level decline of more than two metres for an unconsolidated aquifer or five metres for a consolidated aquifer within three years are listed as Immediately Affected Area (IAA) bores. These bores automatically trigger the resource company's make good obligations, which include:

- undertaking a bore assessment
- entering into a make good agreement
- complying with the make good agreement, and
- negotiating a variation of the make good agreement (as required).

Resource companies have the obligation to make good impairment to the adequacy of water supply from bores resulting from their gas production activities.

Make good measures are required when it has been determined that the water bore has or will likely have impaired capacity. If a bore assessment finds that the bore is not or is unlikely to become impaired, then no make good measure is required but a make good agreement must still be signed.

Table 1: Details of water bores and estimated groundwater use in the Surat CMA[4]

	Number of bores			Estimated groundwater extraction (ML/y)							
Formation	Non-S&D*	S&D*	Total	Stock intensive	Town water	Agriculture	Industrial	Irrigation	Non-associated	S&D*	Total
Condamine Alluvium	1,366	3,278	**4,644**	6,060	2,078	1,305	54	57,826	-	2,436	**69,760**
Other Alluvium and Basalts	1,524	7,451	**8,975**	8,129	3,933	909	701	28,945	-	7,253	**49,870**
Upper Cretaceous	9	123	**132**	133	-	-	-	392	-	414	**940**
Non-GAB upper subtotal	2,899	10,852	**13,751**	14,322	6,012	2,214	755	87,163	-	10,103	**120,570**
Wallumbilla Formation (Coreena)	2	122	**124**	3	-	-	-	14	-	339	**357**
Bungil Formation	1	235	**236**	2	1	-	-	-	-	634	**638**
Mooga Sandstone	13	625	**638**	130	120	7	1	-	-	1,713	**1,971**
Orallo Formation	33	736	**769**	980	425	61	203	-	-	1,861	**3,530**
Gubberamunda Sandstone	78	685	**763**	2,022	1,672	62	288	21	240	1,858	**6,162**
Westbourne Formation	2	59	**61**	546	1	-	-	-	-	122	**669**
Springbok Sandstone	13	194	**207**	58	3	-	1	59	30	364	**515**
Walloon Coal Measures	124	1,008	**1,132**	1,534	314	66	63	1,421	-	1,215	**4,614**
Durabilla Formation	10	101	**111**	115	-	4	5	58	-	162	**345**
Hutton Sandstone	348	2,697	**3,045**	5,169	907	540	895	2,635	13	3,596	**13,755**
Boxvale Formation		44	**44**	-	-	-	-	-	-	143	**143**
Evergreen Formation	21	443	**464**	140	14	83	314	83	12	802	**1,448**
Precipice Sandstone	45	289	**334**	2,112	2,397	65	441	355	207	547	**6,125**
Moolayember Formation	2	156	**158**	-	17	-	-	42	1	450	**510**
GAB subtotal	*692*	*7,394*	***8,086***	*12,811*	*5,871*	*888*	*2,212*	*4,687*	*503*	*13,808*	***40,781***
Clematis Sandstone	6	126	**132**	-	232	-	-	-	-	319	**551**
Rewan Group	3	60	**63**	-	-	-	19	-	1	111	**131**
Bandanna Formation	4	62	**66**	18	3	-	-	148	-	112	**280**
Bowen Basin Sediments	27	336	**363**	37	99	-	-	858	-	447	**1,440**
Cattle Creek Formation	-	10	**10**	-	-	-	-	-	-	10	**10**
Non-GAB lower subtotal	*40*	*594*	***634***	*55*	*334*	-	*19*	*1,006*	*1*	*999*	***2,413***
TOTAL	**3,631**	**18,840**	**22,471**	**27,188**	**12,216**	**3,103**	**2,986**	**92,857**	**505**	**24,910**	**163,764**

*Stock and domestic

4 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019

Table 2: Water chemistry summary for the major formations in the Surat Cumulative Management Area[5]

Formation	Ca			Mg			Na			K			Alkalinity		
	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th
Alluvium	30.00	46.00	76.80	22.00	40.00	80.00	100.00	205.00	500.00	0.05	1.00	3.00	308.00	403.00	511.70
Basalt	22.00	46.00	80.00	15.00	52.00	98.00	75.00	106.00	155.00	0.05	1.00	3.00	244.00	393.00	537.00
Upper Cretaceous Formations	43.40	305.00	819.10	29.00	215.00	620.90	771.50	2260.00	4556.00	2.00	10.00	42.50	143.50	200.00	431.50
Cenozoic	15.40	44.00	107.00	16.40	54.00	175.80	397.50	563.00	1503.50	0.05	4.00	9.50	275.50	470.00	640.50
Wallumbilla Formation	2.80	11.00	502.80	1.00	6.00	363.90	435.00	500.00	3451.50	0.05	2.00	15.50	229.00	486.00	855.00
Bungil Formation	2.00	4.00	27.80	0.30	1.90	6.80	440.00	526.50	805.00	0.05	2.00	3.00	348.00	715.00	929.50
Mooga Sandstone	2.00	3.00	8.00	0.20	1.00	3.00	396.00	462.00	567.00	0.05	1.00	2.00	460.00	700.00	888.00
Orallo Formation	2.00	3.00	12.30	0.10	1.00	4.00	320.00	435.00	534.50	0.05	1.00	2.00	338.50	598.00	884.50
Gubberamunda Sandstone	1.90	2.60	8.20	1.00	1.00	3.00	274.00	350.00	424.00	1.00	1.00	3.00	350.00	527.00	664.00
Westbourne Formation	3.30	11.50	320.30	1.00	7.80	256.30	201.30	646.50	4405.00	1.00	3.00	24.50	238.00	417.00	448.80
Springbok Sandstone	2.90	11.50	43.80	1.00	1.20	17.90	470.80	653.50	1207.50	1.63	3.00	6.00	240.00	364.50	620.00
Walloon Coal Measures-Non-CSG	11.60	34.20	80.00	4.00	19.00	63.90	250.00	550.00	1350.00	0.05	2.00	5.00	282.00	427.00	644.80
Walloon Coal Measures-CSG	4.00	6.00	11.00	0.70	1.20	3.50	912.00	1160.00	1770.00	4.00	6.70	13.00	880.80	1230.00	1561.60
Durabilla Formation	3.10	11.00	68.50	1.00	3.90	42.00	244.80	425.00	778.00	0.05	1.00	2.00	254.80	316.00	491.30
Hutton Sandstone	4.00	29.00	72.00	1.00	10.00	59.40	196.00	321.00	623.00	0.05	2.00	5.00	244.00	399.00	604.00
Evergreen Formation	5.00	20.00	52.00	1.00	8.70	22.00	33.00	87.00	356.00	0.05	2.00	5.00	122.00	195.00	478.00
Precipice Sandstone	1.10	2.70	7.00	0.30	1.00	1.70	31.00	45.00	75.30	2.00	2.00	3.00	73.80	112.00	172.00
Moolayember Formation	13.50	27.00	89.30	4.90	21.50	81.30	118.80	384.00	1123.80	0.05	1.03	5.75	150.00	282.00	460.80
Clematis Sandstone	9.40	23.50	39.00	5.30	14.00	39.00	31.50	76.00	120.00	8.00	12.00	16.00	120.00	322.50	465.00
Rewan Group	27.40	80.60	281.00	51.30	71.80	200.90	252.00	706.00	2326.30	0.05	1.00	8.25	143.30	342.00	381.80
Bandanna Formation	2.10	5.50	31.70	1.00	1.00	36.20	271.50	498.00	934.90	0.05	1.00	2.00	549.30	675.50	993.00
Bandanna Formation-CSG	7.00	11.00	13.00	5.00	6.00	8.50	1210.00	1470.00	1715.00	23.00	39.00	61.50	967.00	1150.00	1520.00
Undivided lower Bowen Basin	28.30	38.30	58.10	33.50	49.00	76.00	79.50	163.50	1096.80	1.25	4.00	8.00	316.50	533.50	742.50
Undivided Permian Upper	31.50	61.80	84.30	36.30	52.20	85.10	143.30	372.00	628.00	1.25	2.50	5.50	474.30	722.00	890.80
Metamorphic/ igneous/ old basement rocks	42.40	115.10	159.50	35.00	51.40	166.80	260.50	512.00	806.00	2.00	3.00	13.75	200.30	261.00	382.30

5 Office of Groundwater Impact Assessment (OGIA), Underground Water Impact Report for the Surat Cumulative Management Area, Consultation Draft, May 2019

Cl			SO_4			F			TDS			pH			SAR		
25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th	25th	50th	75th
84.00	250.00	780.00	5.00	15.00	70.00	0.10	0.20	0.30	649.00	1064.00	2016.00	7.60	7.90	8.20	2.90	5.40	11.90
86.40	170.00	310.00	3.20	9.40	19.00	0.10	0.20	0.30	536.70	825.90	1179.00	7.70	7.90	8.20	1.60	2.70	5.80
861.20	4150.00	9105.50	45.50	470.80	1225.00	0.12	0.20	0.33	2366.40	7915.40	17205.90	7.20	7.40	8.00	19.90	25.60	29.90
370.00	630.00	2320.00	9.40	38.00	135.00	0.04	0.20	0.40	1405.90	1901.90	5018.30	7.60	8.00	8.20	9.10	16.90	27.80
160.00	376.00	6735.90	1.00	26.00	613.40	0.20	0.80	1.40	1447.00	1664.50	12408.30	7.20	8.00	8.50	23.20	32.50	68.60
140.80	302.50	1046.50	0.10	2.00	11.50	0.30	0.98	1.84	1468.10	1757.00	2328.40	8.10	8.20	8.50	42.90	57.60	72.40
140.00	210.00	457.00	0.10	2.00	48.00	0.30	0.90	2.03	1272.80	1558.30	1857.60	8.10	8.40	8.60	41.00	57.80	73.70
110.00	164.00	422.50	1.00	6.00	51.20	0.10	0.50	2.18	1080.40	1388.40	1792.20	8.10	8.40	8.50	31.00	48.90	66.90
104.00	150.00	257.00	1.00	3.00	22.00	0.20	0.30	0.50	894.90	1126.40	1320.60	7.90	8.40	8.70	26.10	46.30	56.70
69.50	686.50	7350.00	3.80	21.80	190.80	0.10	0.28	1.23	706.60	1756.40	13062.10	7.40	8.20	8.60	31.70	42.40	56.80
364.80	844.50	1780.00	1.00	1.30	18.50	0.20	0.70	2.00	1442.20	1970.10	3408.70	7.80	8.30	8.80	24.20	64.10	88.30
245.00	597.50	1988.50	1.00	10.00	40.00	0.20	0.37	0.80	1052.00	1877.40	4101.10	7.70	8.00	8.30	8.60	18.60	54.40
503.50	930.50	1932.50	0.10	0.10	2.00	1.50	2.40	3.60	2817.90	3466.40	5054.60	8.20	8.30	8.40	97.30	112.10	130.30
252.50	477.70	1117.50	0.10	3.90	23.50	0.20	0.35	0.78	906.40	1437.30	2601.20	7.70	8.10	8.40	13.40	34.50	55.50
152.00	310.00	790.00	2.00	13.00	37.00	0.13	0.30	0.70	775.70	1297.70	2252.70	7.70	8.00	8.30	5.90	12.80	38.10
25.00	54.00	310.00	0.10	8.10	24.50	0.10	0.20	0.42	223.10	411.10	1458.10	7.20	7.60	8.20	1.70	6.40	12.50
10.00	16.00	44.40	0.10	1.00	2.00	0.10	0.20	0.50	128.40	184.10	302.90	7.00	7.30	8.00	3.00	7.80	10.70
98.50	444.50	1654.80	0.10	4.90	24.00	0.10	0.30	0.59	537.50	1401.50	3657.10	7.50	7.90	8.20	5.00	13.20	26.10
34.30	50.00	68.50	2.00	5.50	16.80	0.10	0.17	0.23	227.10	522.40	745.40	7.10	7.80	8.00	1.70	2.30	3.90
272.50	1141.00	4215.00	1.00	25.90	164.90	0.16	0.30	0.45	1138.70	2648.00	7009.00	7.40	7.40	7.60	5.80	17.00	28.50
51.30	177.00	865.70	1.00	1.00	11.50	0.33	1.45	2.30	946.30	1576.80	2768.10	7.80	8.10	8.20	14.50	44.50	96.90
1230.00	1420.00	1975.00	0.10	0.10	4.00	0.25	0.40	0.50	3538.80	4437.30	5025.50	8.00	8.20	8.40	70.90	85.50	102.10
57.50	164.00	1609.80	14.30	25.30	84.30	0.20	0.30	0.50	731.30	991.90	3762.20	7.90	8.10	8.30	2.40	8.10	19.70
137.30	342.50	595.30	0.10	16.00	85.00	0.22	0.35	0.62	1244.20	1770.10	2342.40	7.90	8.00	8.10	3.40	7.90	14.90
420.00	1054.50	1665.00	11.80	74.00	154.50	0.22	0.37	0.60	1138.50	2338.60	3491.70	7.30	7.90	8.10	4.60	8.10	17.10

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